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Paluel nuclear power plant (France).
During the last few years, radiation protection has gone through a period of significant developments and achievements*. The major event in this period was the conclusion of the three-year process of revision of the basic recommendations of the International Commission on Radiological Protection (ICRP), whose last edition goes back to 1977. The ICRP is an independent international group of senior experts in the scientific, regulatory and operational aspects of radiation protection, which was established in 1928 as an emanation of the International Congress of Radiology. The Commission keeps under review the scientific information on the biological effects of radiation and the associated protection techniques, develops a radiation protection doctrine, and issues recommendations on policies and techniques for the protection of workers and members of the public against the harmful effects of radiation. The recommendations of the Commission are not binding, but, in view of the high scientific and conceptual prestige of the Commission, are utilised in all countries as a basis for their own radiation protection regulations and practices.

The recent revision of the ICRP recommendations was required in order to take into account the new scientific and epidemiological evidence on the effects of the Hiroshima and Nagasaki nuclear explosions in 1945, as well as to incorporate in an organised form the results of the evolution of radiation protection concepts and methods during the last decade. This new version of the recommendations confirms the fundamental philosophy of the system of protection proposed by the Commission in 1977, based on the three principles of justification of practices and interventions, optimisation of protection, and limitation of individual risks. The revision, therefore, represents an evolution more than a revolution with respect to the 1977 recommendations. However, some important developments and significant new elements have been introduced, and the guidance has been given a more rationalised and streamlined presentation than in the previous recommendations.

A principal new element, which has given rise to heated debate in the past few years, is the revision of the radiation risk factors for workers and members of the public. These risk factors represent the probability that severe health effects (cancers, detrimental genetic effects) will occur in a population as the result of radiation exposure. The revision of the risk factors was based on a revised assessment of the doses received by the Hiroshima and Nagasaki survivors and on expanded epidemiological information on the incidence of cancers and other effects among these survivors and their progeny. This new information has led to the introduction in the latest recommendations of more stringent individual dose limits. These lower limits are not expected to have any significant impact on the requirements and costs of protection for members of the public, but they may have a significant impact on some segments of the nuclear industry, where more efforts and costs will be needed to ensure that the exposures of certain critical groups of workers are kept well below the new limits.

Another important novel aspect of the new recommendations is the attempt to introduce an integrated approach to the management of risks. This approach suggests that the general radiation protection philosophy, which has been so far applied only to the control of exposures that are expected to happen, as in normal operating conditions, and to the protection of persons once an accident has happened, should apply to the prevention of all risks, irrespective of the probability of the events leading to an exposure. In other words, the ICRP now suggests that the general principles of the system of protection should be applied, in the design and operation of facilities, not only to limit doses to persons but also to the prevention of risks associated with so-called probabilistic events, namely accidental events which might or might not occur, but for which a probability of occurrence can be assigned. This development

* This article is based on a more comprehensive paper prepared by O. Ilari (NEA), A. Gonzalez (IAEA), G. Hanson (WHO), E. Boutrif (FAO) and C. Borras (PAHO) for the International Conference on Implications of the New ICRP Recommendations on Radiation Protection Practices and Interventions, Salamanca, 26-29 November 1991.

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in the ICRP thinking and guidance appears beneficial and relatively easy to apply in the case of small installations, but it may result in severe difficulties of application, at least at this stage, in the case of large and complex nuclear installations.

The new recommendations have also created the potential for other significant problems of application in so-called "de-facto" situations, namely those where the only available protection action can be an "intervention" to decrease existing exposures by removing existing sources, modifying exposure pathways or reducing the number of exposed individuals. This can be the case where members of the public and workers are subject to exposures from natural radioactivity or from the consequences of a nuclear or radiological accident.

TRANSLATING THE ICRP RECOMMENDATIONS INTO PRACTICAL GUIDANCE

The new ICRP recommendations have been deliberately drafted in general and scientific terms so that sufficient scope for interpretation and application is left to the users of the recommendations, particularly the national authorities. There is now a need to convert the ICRP guidance into terms that are sufficiently practical and straightforward to facilitate their translation into regulatory and operational practices at the national level.

Traditionally, this has generally been the task of the international intergovernmental organisations, in particular through the Basic Safety Standards for Radiation Protection (BSS), jointly issued by the IAEA, NEA, World Health Organisation (WHO) and International Labour Organisation (ILO), and the Euratom Radiation Protection Directives, issued by the Commission of the European Communities (CEC). In view of the forthcoming issuance of the revised ICRP recommendations, the four organisations responsible for preparing the BSS, which were later joined by the Food and Agriculture Organisation (FAO) and the Pan-American Health Organisation (PAHO), agreed in 1990 on the need to revise the BSS to take account of the recent developments in scientific knowledge and the recent orientations in radiation protection principles and concepts as expressed in the new ICRP recommendations.

The main purpose of the BSS is to offer a base for and give guidance on the transfer of the conceptual and scientific recommendations of the ICRP into applicative requirements and guidelines that could be used at the national level for the establishment of regulations and operational criteria. For this purpose, the BSS are given the character of "standards" that national authorities can directly use as a regulatory basis for the protection of workers and members of the public. Moreover, it is expected that this document should also be of use for the management bodies with responsibilities for radiation protection in their own operations as well as for the professional operators in radiation protection.

ISSUES TO BE ADDRESSED IN THE NEW BASIC STANDARDS

The guidance given by the previous ICRP recommendations and, subsequently, by the previous BSS was essentially focused on the control of "normal" exposures, namely exposures that are virtually certain to result from planned operations in normal conditions. The merit of the new ICRP recommendations is to generalise this guidance to cover the whole network of possible exposure situations, including not only "normal" but also "potential" exposures, not only from artificial but also from natural sources, not only controllable by prior planning but also pre-existing or unplanned and only liable to be decreased by intervention and remedial measures. This network is further complicated by the existence of different types of exposure, such as "occupational", "medical" and "public".

It is obvious that this scheme, in itself highly rational, creates problems of application due to the different degrees of controllability of the exposures which characterise the various situations. The new BSS will have to address all aspects of application of the radiation protection principles to this complex network, both from the technical and the regulatory viewpoints, as summarised in the following diagram:
Individual Dose Limitation

Although optimisation of protection is confirmed by the ICRP as the main principle of a correct management of radiation exposures, the limitation of individual doses to workers continues to be the principal issue of concern to those who have the responsibility to implement radiation protection requirements in practice.

In fact, several industrial and radiation protection operators have expressed perplexities on the feasibility of coping, at reasonable costs, with the new reduced dose limits recommended by the ICRP. According to these critics, parts of the nuclear industry, and perhaps also other activities involving radiation, might face major facility redesign and reorganisation of work practices, involving significant labour and cost increases, if this increase in the rigour of the international recommendations is followed by a similar stiffening of national regulatory requirements. Cases where these difficulties may arise include the maintenance of nuclear facilities, the operation of some underground uranium and other mines, and some operations involving uranium and plutonium oxides.

There are, perhaps, other fields where the new dose limits for workers may create problems of compliance. This may be the case for some industrial applications, such as industrial radiography, and some medical practices. This may be particularly true for certain diagnostic and surgical techniques, such as cardiac catheterization and angioplasty, which involve prolonged exposures of the medical personnel. These cases will have to be carefully examined to make sure that the requirements of the new BSS can be actually implemented.

One potential problem that could emerge with the introduction of a lower dose limit concerns those workers who have already received doses in excess of the proposed new dose limit of 20 millisieverts (mSv) per year. These workers and the trade unions might argue that they should now be guaranteed an annual dose limit lower than 20 mSv to compensate for what they could consider an unjustified past
detriment. This is not a conceptual issue, nor is it of direct relevance to the text of the BSS, but its implications for the ensuing national regulations should not be overlooked.

An interesting concept introduced by the new ICRP recommendations is that of source-related dose constraints. A dose constraint is a value of individual dose to be established to restrict the range of options considered in the process of optimisation of protection for a given source or installation. In other words, the optimisation analysis for a given source would be subject to a pre-established ceiling on the levels of individual dose that could be considered. The aim in imposing a constraint is to avoid an inequitable distribution of the doses to the individuals involved and to make sure that no individual receives a combined dose from several sources that exceeds the regulatory dose limit. According to the ICRP, the dose constraints, to be fixed by national or local authorities, are not to be seen as “limits” in the sense indicated by the Commission and by the national regulations for the individual dose limits. They have, however, a regulatory meaning for the design and operation of a given practice and, therefore, those responsible for the preparation of the new BSS shall pay particular attention to the definition of criteria for the establishment of dose constraints and their relationship with the dose limits.

**Exposure Situations**

Historically, the ICRP recommendations mainly focused on the control of “normal” exposures from “practices”, i.e. exposures that can be anticipated in advance and assumed to be delivered with virtual certainty and predictable magnitude. The new ICRP recommendations address two types of radiation-related activities not fully covered by previous recommendations, namely:

i) practices that may give rise to accidental, or “potential” exposures; and

ii) “interventions”.

Not surprisingly, the available international guidance on radiation protection mainly concentrates on normal exposures. Apart from
international standards for nuclear reactor safety, virtually no guidance exists for potential exposure situations and only general guidance is given internationally for intervention situations. Clarification is therefore required regarding the application of the current principles of justification, optimisation and individual risk limitation in such situations.

Potential Exposures

Potential exposure situations may arise from a wide spectrum of sources and involve a large variety of potential consequences. At one extreme there are simple sources, such as those used in industrial radiography, which may deliver potential exposures with fairly predictable and limited consequences, such as the overexposure of one or a few individuals. At the other extreme there are complex sources, such as nuclear installations, where potential exposure situations can lead to more diverse and less predictable consequences, such as economic and social disruptions that might override the individual radiation risk. There are also potential exposure situations, such as those associated with radioactive waste disposal, which can arise in the far future where consequences become very difficult to predict.

Radiation safety for this wide spectrum of situations should be governed by coherent and consistent principles. The new ICRP recommendations on potential exposures are not very explicit, although an ICRP Task Group is expected to produce more comprehensive recommendations. In any case, practical guidance will be needed in the new BSS, which will have to address a wide spectrum of issues, encompassing basic principles as well as practical problems, such as the identification of universally agreed individual risk limits, and the establishment of criteria for optimising safety when potential exposures are involved.

Intervention

The need for a radiation protection policy for intervention was highlighted by the discovery of high levels of radon (a radioactive gas of...
natural origin) in homes and by the post-Chernobyl contamination. These are extreme but by no means unique examples of situations requiring intervention. Situations in which intervention may be considered can be long-standing, which do not call for urgent action, or situations which call for prompt action in order to avoid serious exposures; the Chernobyl accident gave rise to both types of situation. The long-standing situations are typical of exposure to high natural background radiation in general (radon in dwellings in particular) and to radioactive residues from previous events (as the current contamination due to Chernobyl).

The new ICRP recommendations provide two basic principles for intervention, namely:

i) the proposed intervention should do more good than harm (Justification of the intervention); and

ii) the net benefit provided by the intervention should be maximised (Optimisation of the intervention).

The concept of dose limits is not applicable to these kinds of situations and the protection of individuals should be sought by introducing “intervention levels” established on the basis of the above two basic principles.

These concepts are currently being addressed by various international organisations, but several problems still remain. For example, the new ICRP recommendations highlight the problem of high levels of radon in buildings, but do not indicate how this problem can be regulated, nor give numerical guidance on acceptable levels in the various circumstances, although an ICRP Task Group is currently working on this question. Analogously, in spite of attempts by several international organisations after the Chernobyl accident, there is not yet unified international guidance on criteria and levels for intervention in case of an accident. There is, therefore, a need for interpretation of the ICRP concepts and choice of options by those in charge of the preparation of the revised BSS.

CONCLUSION

The issues highlighted in this article are only some of the most important questions to be addressed in the implementation of the new ICRP recommendations. Several other problems of a more detailed nature can be raised by a reading of these recommendations, and a significant effort of interpretation and choice of options will have to be made in the transformation of the ICRP guidance into international recommendations for concrete application. The new BSS will have to solve these questions in order to make an effective contribution to practical radiation protection in OECD countries.
NUCLEAR ENERGY AND WOMEN: 
IS A DIFFERENT FORM OF COMMUNICATION NEEDED?
F. Galliot

Public participation in debates and decisions concerning energy policy — especially nuclear energy — is a characteristic of industrial societies. This implies that the public has the means to understand the terms of policy options and their underlying technical, regulatory and ethical aspects.

Communication in this field must therefore take account of the need to make the different components of such information readily understandable by a public largely unfamiliar with the concepts proposed or with scientific language in general.

Against this background, the OECD Nuclear Energy Agency (OECD/NEA) organised an international seminar* on communicating complex technical issues such as nuclear power to those sections of the public, including women, which are least familiar with scientific concepts.

This seminar helped to identify more clearly the characteristics of such groups, and to determine their needs as well as the special problems of providing information regarding nuclear matters, for example concerning the language used and the terms of the message. Following discussion of the experience of OECD countries in communicating with nontechnical publics, the participants endeavoured to reach agreement on the best communication techniques to use in presenting subjects such as electricity needs and the role of nuclear power, radioactivity, the perception of risks, and safety. Numerous interesting conclusions were reached at this seminar, both as regards the similarity of the problems relating to informing women about nuclear issues within OECD countries, and the communication techniques to be used.

WOMEN'S ATTITUDES TO NUCLEAR POWER

Opinion polls conducted in several OECD countries all share a common finding: women are much less in favour of nuclear energy than are men. They also feel poorly informed about nuclear energy, and they are in fact much less informed than the opposite sex. They are unfamiliar with the benefits of nuclear energy and have no confidence in the safety of power stations. The gap between men and women is, however, less pronounced with regard to opinions as to the use of nuclear power as a source of electricity in the future. According to a 1990 poll in Japan, for example, 51 per cent of men and 44 per cent of women consider that nuclear power will constitute a valuable source of energy for their country. Indeed, 79 per cent of men and 75 per cent of women even hold the opinion that nuclear power will play a major future role in meeting electricity needs. While recognising the need for nuclear energy, women nevertheless would like to be better informed and claim to want information better tailored to their needs. In France, for example, 42 per cent of women and 31 per cent of men admit to understanding nothing at all about nuclear energy in spite of the information provided. However, care must be taken to identify precisely the type of information desired by women and to ensure that this information contributes to a better understanding. In other words, attention must first be paid to the specific needs of one's audience in order to impart information in a suitable and comprehensible form.

In most OECD countries, women's attitude to nuclear energy differs significantly from that of men. More women tend to object to the use of nuclear power, and they are more inclined (20 per cent more so than men) to refer to its drawbacks rather than its advantages. Several factors explain this phenomenon, in particular the fact that nuclear energy is essentially a man's world, with women finding it difficult to identify with the experts in this field. Among...

* This NEA seminar was held in Tokyo on 21 and 22 October 1991. It was organised in conjunction with Japan's MITI (Ministry of International Trade and Industry), STA (Science and Technology Agency), JAIF (Japan Atomic Industrial Forum) and JAERO (Japan Atomic Energy Relations Organisation), and brought together some 170 participants, including representatives from Japanese governmental bodies, electricity company directors of information and communication, and journalists.

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the other reasons giving rise to this difference in perception, it would appear that:

- women are less knowledgeable about technical matters, and are still not much interested in technological issues;
- they are less influenced by economic considerations;
- they show little interest in energy questions;
- they are more sensitive to the hazards of nuclear energy described by the media, in particular those relating to radiation;
- they feel more concerned by the environment and the fate of future generations;
- they seem less prepared to accept risks in general;
- they make less of a distinction between the use of uranium for peaceful as opposed to military purposes;
- they are less well disposed to the use of technology in society, even if they benefit as much as men.

While women, especially in Japan, are more inclined than men to hold negative opinions about nuclear energy, they nevertheless remain ready to qualify their position, and most women claim still to have an open mind. In general terms, a study carried out in the United States showed clearly that 5 per cent of the public are strongly in favour of nuclear energy, 5 per cent strongly against, but that the great majority have mixed feelings, with replies varying widely over time.

SPECIAL CONSIDERATIONS APPLYING TO JAPANESE WOMEN

The weight of history

Generally speaking, the Japanese people remain deeply affected by the events at Hiroshima and Nagasaki. This trauma, handed down from generation to generation, perpetuates an a priori distrust of nuclear power. The military use of atomic power continues to be associated with the production of nuclear energy for peaceful purposes despite numerous information campaigns, and the adoption of a national Energy Day on 26 October, in the
NUCLEAR ENERGY AND WOMEN

A seminar on women and nuclear energy attracted some 250 participants in the city of Aomori in Japan.

hope of drawing a distinction from the 8 August commemoration, has not altogether succeeded in preventing this association.

Two major concerns

One of the consequences of this shared trauma in Japan is the very marked preoccupation of the Japanese people, and in particular women, with issues related to environmental protection and with questions relating to health. Several polls in Japan have confirmed that these two subjects top the list of public concerns.

The political factor

Another special feature in Japan is the very strong public perception of the need to reach national autonomy in energy, and this is true at all levels of the population. This results in a certain ambiguity in public attitudes to nuclear energy, which, while giving rise to general public distrust, is nevertheless recognised as having a major role in guaranteeing the country’s energy independence. The same situation prevails, moreover, in certain OECD countries, in particular the United States. For example, more than 70 per cent of Americans consider that nuclear power is of major importance to electricity production, particularly because of its contribution to achieving energy independence, and also because of its economic profitability and for environmental reasons.

Social factors

As a rule, and more specifically when considering issues relating to technology or to society, there is a tendency in Japan for individuals to join special groups or associations and to express themselves exclusively through such organisations, avoiding any individual pronouncement. Issues related to energy and the environment in particular are discussed within such organisations. There are many women who belong to essentially female groups on energy, the environment or other topics and who, as members of such groups, are able to attend conferences or participate in organised visits to sites.

Feminine attitudes

Such interest groups, which are rarely mixed, highlight a particular trait of Japanese women, namely that they are relatively suspicious of the masculine world in general, and in particular of experts, scientists and even doctors when it comes to nuclear energy. This distrust must be taken into account when
explaining nuclear issues. One approach would be to promote the role of women in communication so that the female public can more easily identify with the communicator.

The demand for information

In spite of these different factors, most Japanese women do not necessarily have a fixed opinion on nuclear energy, and are open to targeted information and explanations that might lead them to change their views. It is not so much a question of playing on the changeability of opinions as to replying to concerns that are often simple, but which reveal feelings of deep anxiety about nuclear power in general and the consequences of radioactivity in particular. Japanese women want information about nuclear power that will enable them to grasp the basic concepts and understand the general mechanisms involved in producing nuclear energy. They expect simple answers that are easily understandable and directly relevant to their daily lives. It is therefore particularly important to make use of examples, comparisons and past experience when providing information to a female public.

THE DIFFICULTIES OF COMMUNICATION: A PROBLEM COMMON TO OECD COUNTRIES

Several measures have been undertaken in OECD countries to improve the dialogue with the public about nuclear issues, and in particular to involve women to a greater extent in the discussion about energy.

Meeting electricity needs

Technology today is no longer understood, it is merely “consumed”, as is the case with electricity for example, by performing simple actions which no longer require any knowledge of the processes involved “upstream” or even of the consequences of the action in question. The only thing that matters in using technology is the result obtained. The simple touch of a button can turn day into night, heat into cold, or give access to information, silence or music. Our daily activities are obviously highly dependent on electricity. Despite this fact, the general understanding of how electricity works remains very superficial, and most people never consider the link between the lamp switch and the process which makes it possible to have light. In fact, this dependency “comes to light” only when there is a breakdown in the electricity supply.

That is why there is a real need today to make women aware of their own energy needs in such a way that they realise the extent to which they themselves are major consumers of electricity in their daily working lives. They will thus more readily admit that decisions have to be taken to guarantee that these needs are met and to find energy sources adapted to the political and economic requirements of their country. Such an exercise can be undertaken using various aids to review different household tasks and the electric appliances used to perform them, without forgetting Hi-Fi systems, electronic gadgets and the whole range of leisure activities enjoyed by their children.

Comparing advantages and drawbacks

The advantages and drawbacks of nuclear power should be compared with those of other sources of electricity. This comparison should be made in precise but sufficiently simple terms, and should be founded on considerations of risks, energy resources, cost and the environment. Experience shows, on the other hand, that there is no point in describing risks in terms of probabilities, since this systematically excludes the lay public from the world of the experts by cutting short any attempt at constructive dialogue. It can even be perceived as a subterfuge deliberately used to conceal the real position regarding risks. Furthermore, each person should be allowed to draw his own conclusions from the list of comparative arguments. A good communicator seeks above all to establish dialogue, not to promote his product.

Trusting the communicator

The objective in proceeding in this way is to raise the level of public understanding about energy issues while avoiding any attempt to
influence opinion. On the other hand, it is important for the communicator to gain the complete confidence of his public. In order to do this, he must not play the role of a technical expert and must avoid detailed scientific explanations, unless of course the public requests this. When speaking to an audience of women, the communicator’s first concern should be that his audience identifies with him and comes to trust him as a person, an essential stage in establishing confidence in the technology being discussed. In any event, the communicator should always make a distinction between public understanding, confidence and acceptance in relation to nuclear questions.

Adapting the message

So far, nuclear experts have tended to target information at a male audience. When a female audience—less susceptible to technical and economic arguments—is being addressed, the information should be reformulated, though without changing its basic content.

However, public perception of the message involved does not always differ according to the sex of the audience. In the United States for example, both men and women are reassured by information about the benefits of nuclear energy in the medical field and by the message that power plant radioactivity is carefully controlled. Information based on quantitative comparisons, on the other hand, is not easily understood, especially by women. Thus, it is no doubt possible to use the same messages for male and female audiences, provided that the characteristics of each of them are taken into account in the presentation adopted.

Using appropriate language

When attempting to establish dialogue between experts and non-experts on a
technical subject, it is first of all important to ensure that the terms used are chosen carefully and understood properly by everyone. The subject of nuclear energy lends itself particularly to the over-use of technical terms and to misunderstandings by the public, for example, with regard to the “criticality” of a power station, the concept of “passive safety”, “fission poisons”, etc. To avoid emotional reactions and associations with the sensational images present in the subconscious, the language used in communication about nuclear issues, far from being designed to impress an already suspicious public, must aim for clarity and simplicity.

Promotion of scientific careers

Women are less susceptible as a rule to scientific and technical arguments simply because they rarely pursue scientific studies to the same extent as men. No matter how logical and rational the arguments used, they should therefore not be presented using technical terms alone.

Another way of making women more aware both of nuclear issues and especially of scientific careers is to mention the examples, still too few in number, of women who work in the nuclear industry, in particular in positions of authority. The impact, moreover, is all the greater if such women themselves come to talk about their experience and explain that their scientific career and resulting responsibilities are compatible with their family life.

The ultimate, though not always acknowledged goal of this type of demonstration is to incite women to take up scientific careers, or at least to encourage any aspirations of the sort on the part of their daughters. There is still too much of a tendency in OECD countries for women to choose non-scientific careers, often for social reasons. Encouragements to choose such careers must come from parents, educators and above all captains of industry, still little inclined to recruit female engineers. It is clear that the lack of professional openings for women in scientific and technical careers and the inadequate recognition of their skills constitute the major obstacle for young women hoping to fill senior posts in industry.

The role of women in communication

Women identify more easily with other women. They understand better their fears, using, moreover, their own way of speaking, with terms different from those used by men talking about the same subjects, something which appears very clearly in the Japanese language. Communication between men and women must therefore take account of these almost cultural differences.

All women working in the nuclear field are potential ambassadors inasmuch as they themselves are well informed. They could, in addition, participate in different social or professional groups or clubs, and communicate information about the role and uses of nuclear energy. Moreover, primary school teachers should be given the opportunity to participate in seminars on energy, so as to be able to encourage an interest in their pupils, from the earliest age, in matters related to the production of energy and in science in general. The wives of power plant workers should also be given comprehensive information so that they can participate in local information programmes.

Thus, communicating information to a female audience about a complex topic such as nuclear power comes down to finding the link between an essentially technical world, in which logic and demonstration reign supreme, and a world in which reactions are of a more emotional nature. While the message itself must remain fundamentally technical, perhaps the way in which it is delivered should at least appear more human, using dialogue rather than monologue. At the end of the day, the objective of communication is less that of “proving” technology than of encouraging an awareness, or an enlarged debate on the purpose of nuclear energy in our modern societies.
The Nuclear Energy Agency has just completed a new study aimed at analysing the range of broad economic costs and benefits that may be incurred by - or derived from - a decision to use nuclear energy to generate electricity. This work was carried out by an NEA international group of experts, under the chairmanship of Professor P.M.S. Jones, Chief Economist of the United Kingdom Atomic Energy Authority (UKAEA) and Chairman of the NEA Nuclear Development Committee. This article outlines the main findings of the study.

Utility decisions regarding which technological option to select when creating additional electricity-generating capacity are chiefly based on an evaluation of the comparative costs of the options available. However, most of the time, these costs do not fully reflect the broader impacts of this energy choice on the economy and society at large. To formulate their future energy and resource development policies, governments therefore have to take into account a range of “externalities” which may support or discourage the adoption of a particular technology. However, the weight given to each of them, whether of an economic, environmental, health, or social nature, is often based on subjective judgement, as no generally accepted techniques exist to formalize the process.

To give a clearer picture of the range of factors involved, it is helpful at this stage to introduce a simple uncritical listing (Table 1) of the wider impacts attributed to nuclear power deployment, generally either to support or to discourage its adoption. The listed impacts can be split into three broad categories: economic, environmental and health, and social.

**TABLE 1. POSTULATED BROAD IMPACTS OF NUCLEAR POWER**

<table>
<thead>
<tr>
<th>Primary Impacts</th>
<th>Economic Consequences</th>
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<tbody>
<tr>
<td></td>
<td>Enhanced productivity</td>
</tr>
<tr>
<td>(a) Economic</td>
<td>Improved competitiveness</td>
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<tr>
<td>Direct cost savings</td>
<td>Improved terms of trade</td>
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<tr>
<td>Fossil-fuel price capping</td>
<td>Currency appreciation and enhanced economic growth</td>
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<td>Energy supply security</td>
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<tr>
<td>(avoided lost output)</td>
<td></td>
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<td>Avoided net fuel imports</td>
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<tr>
<td>Enhanced technology exports</td>
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<td>Electricity price stability</td>
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<tr>
<td>Intellectual capital gains</td>
<td></td>
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<tr>
<td>(b) Environmental/Health</td>
<td></td>
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<tr>
<td>Increased radiation levels</td>
<td>Changed levels of morbidity and mortality, therefore economic output</td>
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<tr>
<td>Nuclear accident consequences</td>
<td>Changed physical damage and environmental losses affecting resource utilisation</td>
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<tr>
<td>Avoided greenhouse gas emissions</td>
<td></td>
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<td>Avoided acid gas emissions</td>
<td></td>
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<tr>
<td>Avoided carcinogen emissions</td>
<td></td>
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<tr>
<td>Avoided fuel extraction and transport accidents</td>
<td></td>
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<tr>
<td>(c) Social</td>
<td></td>
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<tr>
<td>Changed employment levels</td>
<td>Some direct effects on resources</td>
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<tr>
<td>Changed risk perceptions</td>
<td>Changed institutional costs</td>
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<tr>
<td>(weapons, accidents, health, gene pool)</td>
<td>Changed economic efficiency</td>
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<td>Changed social consensus</td>
<td></td>
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<tr>
<td>Changed cultural impacts</td>
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<td>Changed ecological impacts</td>
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DECISION FRAMEWORK

The framework within which energy decisions are made is illustrated in Figure 1, which attempts to indicate the factors of influence and the complexity of their interactions. Future energy supply choices are influenced by the demand (Box F), the supply costs (Box G) and the existing policy framework (Box A). The current position (Box A) is continually influenced by changing decisions, whether legal, political, or economic, and the new standards (Box E) that are developed. The decision framework, to some extent, internalises any perceived external costs and effects within the decision-making process (Box E). New knowledge about the technologies concerned (Box B) and their effects on the public, the environment and the overall national economy (Boxes C and D) influence the governments, institutions and the public (Box H), which in turn generates new decisions. The process is dynamic but uncertain and protracted. It is subject to changes of fashion as well as changes in basic knowledge and understanding.

FIGURE 1. DECISION FRAMEWORK FOR ELECTRICITY

THE USE OF QUANTITATIVE MODELS

All countries and utilities employ quantitative models of one sort or another to help in energy planning and policy evaluation. These models differ considerably in their scope, size and complexity, depending on the needs of those developing and using them.
At the micro-level, electrical utilities will do their own demand projections, based on their evaluations of future developments in the economy and the relationship of these to electricity consumption in the markets served. They have their own electricity network optimisation models and their own microeconomic models enabling them to analyse the financial implications of alternative investment strategies. They take into account their expectations concerning the behaviour of other energy subsectors and the possible consequences of government fiscal and regulatory policies.

Investment in a nuclear plant will stimulate economic activity beyond what is reflected in the conventional resource cost analysis.

Those governments not wholly and exclusively committed to reliance on market forces to resolve priorities and determine investment choices and timing, will employ macroeconomic models. These link energy use to other sectors of the economy, and can be used to analyse the implications of different energy investment strategies, different fiscal policies, etc. on energy demand and the fuel mix. They also can be used to examine the future growth of energy demand given different assumptions about general economic growth. The implications of different energy strategies on the wider economy in terms of employment, balance of payments, and general economic stimulus can be explored.

At the global level, international agencies in particular may examine the global implications of population and economic growth for future energy demand, to establish the adequacy of resources, possible constraints on future world development and means of alleviating or overcoming such constraints.

The four principal types of quantitative models that have been applied to the analysis of the consequences of the development and utilisation of nuclear energy are illustrated in Figure 2. They range from microeconomic investment appraisal to macroeconomic impact analysis using conventional macroeconomic models or input-output analysis. Environmental (or other) impact analysis can also be conducted at the micro-level or macro-level employing similar techniques to those for economic analysis.
THE BROADER IMPACTS AND THEIR SIGNIFICANCE

Most of the individual impacts are examined from the perspective of their general implications for a national economy. The arguments put forward are not qualitatively affected by the question of whether a single plant or a programme of nuclear plants is considered, although quantitatively there will be differences. In extremis, some constraints that do not apply for individual plants could come into play with large construction programmes. The impacts are examined in two separate groups. The first group are those that are normally linked through macroeconomic models. The second group are those that may have impacts on the wider economy, but which are usually regarded as exogenous and sometimes unquantified factors (i.e., factors with values set independent of the remainder of the economy by outside forces). Environmental and health effects, a subset of the second group, are treated separately.
"QUANTIFIED EFFECTS"

Secondary investment effects

The act of investing in a new nuclear plant (or any other project) will stimulate economic activity beyond what is reflected in the conventional resource cost analysis. Those employed in the manufacture of parts, production of fuel, construction and operation of plants, etc. will in turn use their income to pay for goods and services, housing, etc. This will result in total increases in the regional or national income that can exceed the direct investment costs by a significant margin. This is the multiplier effect captured by input-output analysis or similar studies. Its magnitude is dependent on the nature of the technology involved and the extent of its reliance on domestic or imported goods. Japanese input-output studies have indicated that in their case the multiplier could be as high as a factor of two for nuclear investment.

Employment

The nuclear industry is a significant though not a major employer in OECD countries. In line with its contribution to Gross Domestic Product (GDP), it employs a few per cent of the workers of the industrial sector (4% in France). One characteristic of the industry is its relatively high proportion of skilled and graduate staff relative to most other major energy and manufacturing industries.

However, the direct employment (in global terms) provided by the industry in construction, operations and fuel services is lower than that involved in equivalent electricity supply industries using coal and possibly renewable sources. This argument has been used to pursue energy options other than nuclear power in countries with indigenous coal supplies, but it ignores the effects that changes in GDP have on employment.

In many countries where phase-out of nuclear power has been considered, studies indicate large economic consequences, of the order of a one per cent drop in GDP with an accompanying drop in employment. A rise in the electricity price also results in losses of jobs for several tens of thousands of persons. The fact of having a lower electricity price increases competitiveness and stimulates growth, increasing the GDP, which more than compensates for any other employment effects.

Balance of payments

The effect of policy choices on balance of payments is frequently used as an argument to favour one option over another on the basis that anything that reduces imports or increases exports is beneficial to the economy.

The nuclear industry can affect trade balances through the import or export of technology and fuels. Its potential for technology export has been advanced as an argument in many countries in support of its development, while its ability to substitute low-cost uranium imports for high-cost oil, coal or gas has also been argued in favour of its adoption.

Price stability

The introduction of an additional large-scale energy source, like nuclear power, into the world's energy supply mix helps to provide price stability. For example, the availability and use of the additional source reduces demand pressures on the fuels it displaces, and leads to their future prices being lower than they would otherwise have been. This benefits all fuel users, even though they themselves may not have adopted the new energy source. Thus the industrial countries' adoption of nuclear power will have helped to restrain the world market price of oil and coal to the benefit of the developing countries amongst others.
One study has endeavoured to quantify the effect on fossil-fuel prices of nuclear power's contribution to world energy supplies. The analysis has examined the cost implications of suspending nuclear power production globally, immediately or over a 10-year period. In both cases oil and coal prices are projected to rise to nearly double their 1990 levels by 2005, resulting in a real decline, in the case of Japan, of GDP by 1% in real terms by 2005. The effect of similar fuel price changes on other countries' economies would differ depending on their dependence on imported fuels.

Regional impacts

The regional impacts of investment in new generation capacity are similar to those discussed for national economies in the preceding sections. The local impacts are larger in relative terms on employment, environmental and infrastructural effects, and secondary for production. However, the benefits (though not the detriments) are likely to draw in labour and products from outside the region so that the local gains may be diluted.

OTHER IMPACTS WITH ECONOMIC CONSEQUENCES

Security of energy supply

One advantage sometimes claimed for indigenous fuels, for fuel-free energy systems or for technologies requiring low volumes of fuel (like nuclear power), is that they enhance the security of energy supplies. They can do this mainly by reducing dependence on external fuel sources; the supply of these fuel sources could be disrupted through political or other actions. Nuclear fuel itself is unlikely to be a source of supply security problems, since reactors are normally refuelled only once a year and fuel stockpiles are easy to establish and maintain.

Resource depletion

For both coal and uranium, the world resource base is so large compared with rates of consumption that this is not an important factor. Known uranium resources alone could provide all the world's energy requirements for centuries if fuel breeding is used.

Spin-off

All advanced technologies call for new materials, techniques and skills that can find application in other sectors of the economy with consequent economic benefit. Nuclear power has been no exception, and it has contributed to substantial technical progress in many fields. This use of products or skills developed as part of one technical programme in other spheres of economic activity is commonly called spin-off.

Socio-cultural effects

Nuclear power has provided a focus for opposition to advanced technology, to centralisation of decision-making and to other features of modern industrial society. As such it has contributed to a significant loss of social consensus and a degree of social conflict in many OECD countries, and this has imposed extra costs on society as a whole; though without nuclear power, another focus for this opposition would probably have been found.
ENVIRONMENT AND HEALTH

The environmental and health implications of electricity generation and use have become a major focus of attention. They were the theme of a Senior Expert Symposium in Helsinki in May 1991 and are under continuing detailed study in programmes co-ordinated by the OECD Environment Directorate and the International Atomic Energy Agency.

Three important points can be made at the outset. First, the impacts associated with electricity sources are not confined to the generation stage, but extend backward into fuel extraction and processing and into the construction stages of the plant itself, and forward toward reprocessing and final disposal of wastes. Second, the benefits and costs associated with individual options have to be measured against those of the alternative options. Third, these alternative options may include non-electricity options such as conservation strategies or direct fuel combustion that have their own environmental and health impacts.

The magnitude of the multiplier effect of the direct investment costs is dependent on the nature of the technology involved.
Nuclear power

In general, the radiological impacts on the public associated with nuclear power are comparable to or lower than those associated with other forms of power generation and equivalent energy conservation measures requiring the use of materials to achieve their effect (e.g. loft insulation, cavity wall insulation).

All authoritative studies concur that the calculated incidence of premature deaths arising from routine nuclear power generation (the numbers from radiation effects are too low to be detectable against the background of the effects of natural radiation and other hazards) is smaller than that from coal and oil production and use, both in absolute terms and expressed per unit of electricity produced.

Concern about nuclear power among the public focuses on a perceived risk of a major accident resulting in the release of a significant fraction of the fission products into the environment, and with consequent loss of life and ecological and economic damage.

Statistically, the financial risk associated with low-probability accidents is below 1% and probably below 0.1% of the generation cost. In practice, governments have been prepared to give international guarantees concerning compensation for major incidents, although the reactor owners must procure private insurance to cover a substantial portion of the risk. It is worth noting that equivalent assessment and guarantees are not normally provided for other types of power plants or indeed for other industrial sectors.

Fossil-fuelled generation

A brief reference must also be made to some social costs associated with fossil-fuel combustion that are avoided if these fuels are replaced by nuclear power (or other non-fossil-fuelled options). In general, using modern technology, these costs should be small for the latest power generation plants, with the possible exception of the effects of greenhouse gas emissions. This assumes that flue-gas desulphurisation and de-NOX technologies are incorporated into the plant design, that regulations and standards adequate for public protection are in place, and that the cost of these measures are taken into consideration. It will also be noted that “appropriate” standards for pollution emissions differ more for fossil-fuel emissions than for nuclear power plants. It is well-known that acid gas emission standards vary among countries, and that not all have as high a standard as would be desired by their downwind neighbours.

It is not widely appreciated that the combustion of coal in power stations releases quantities of radiation to the environment that are (in terms of potential biological consequences) similar in magnitude to the routine releases from the nuclear industry for comparable electrical output. Both are negligibly small relative to natural background radiation. Natural gas production and use also release radioactive radon to the atmosphere, and its unvented use for domestic cooking adds to the radiation doses in domestic properties. The additions, while small compared to natural background radiation, are comparable to those arising from the civil nuclear power industry. As is true of nuclear power, the costs attached to these effects are negligibly small.

Trace quantities of polycyclic aromatic organic compounds like α-benzpyrene are released from coal-fired plants. These are known carcinogens and could in theory lead to a small number of delayed premature deaths amongst the general population in much the same way as radiation releases. There is almost no scientific information on this risk in relation to power plants, although one estimate has suggested that it could be similar in magnitude to the effects of radiation releases from coal or nuclear plants (including the nuclear fuel cycle).

Acid gases are most significant from coal, oil and emulsion fuels. Natural gas does not contribute other than through small emissions of nitrogen oxides. Most fossil-fuelled plants now being constructed in OECD countries would be designed to reduce the emissions of sulphur dioxide and nitrogen oxides to “tolerable” levels. As is true of nuclear plants, the costs of the controls required to meet emission regulations would be incorporated into the investment cost analysis. In cases where the cost of the impact of the emissions is still considered as an “externality” by utilities, they would have to be considered by the appropriate governmental authorities.

Fossil-fuel combustion leads to the release of carbon dioxide and nitrous oxides, both of which add to the heat-trapping capabilities of the atmosphere. The principal greenhouse gas (apart from water vapour) is carbon dioxide, which currently accounts for some 50% of the global warming effect of the atmosphere. It is not the most effective gas: chlorofluorocarbons (CFCs) and methane have bigger effects per molecule, but both are present in much lower concentrations. Time is a factor in the effects of greenhouse gases since some, like carbon dioxide, have a much longer residence time in the atmosphere than others, like methane.

CONCLUSION

The standard microeconomic levelised cost analyses of nuclear and fossil-fuelled electricity generation, and the related analysis of the overall costs of operating a power network, are commonly regarded as providing sound economic guidance on power station choice. However, the analyses are usually conducted from the perspective of the electricity utility and tend to ignore the broader impacts that either benefit or impose costs on other sectors of the economy. Some of these occur within the boundaries of the country making the investment, some fall outside these boundaries.

There are, however, further effects arising from the choice of generation technology for investment that are not captured in the conventional analysis. Some are gains, some are costs and some are avoided costs associated with the use of other energy options. Most of these impacts have been cited in arguments for or against investment in nuclear plants at some time or other, and many have been advanced as arguments favouring the specific energy investment policies adopted by governments. Individually the arguments often sound plausible and convincing because they relate to specific public or policy concerns of the day. Security of supply, employment, balance of trade, and environment are examples.

With regard to the broader impacts not normally encompassed by investment appraisals, the NEA has concluded that there is no reason to suppose that any of them, with one notable exception, would yield significant costs or benefits to future nuclear investment, over and above those reflected in the resource cost analysis. “Significant” here is taken to be one or two per cent of the resource cost, which is well within the likely uncertainty surrounding the projected costs of generation.

The exception is the potential avoided cost of the incremental consequences of the greenhouse effect arising from fossil-fuelled plants (presuming that other emissions are reduced to appropriate levels). These effects are themselves highly uncertain, but could in extremis be roughly equal to the costs of coal-fired generation, or more likely to some 5% to 50% of this cost, depending on the course pursued by governments and the way future detriments are evaluated. Based on some current suggestions, these costs may be converted into market-price effects by means of carbon taxes based on technical goals and scientific judgement.

In these circumstances, it seems likely that the minimisation of total resource costs of electricity generation, taking account of projected real movements of costs over the life of the plants, will remain the most economically beneficial strategy for the long term.
Since the appearance in 1981 of the first issue of the OECD report on the safety of the nuclear fuel cycle, the fuel cycle industry has expanded considerably, with some sectors enjoying a five-fold growth in activities.

At present, the growth rate in OECD countries seems to have stabilized, and future trends will depend to a great extent on the general evolution of nuclear power capacity throughout the world. The fuel cycle facilities in operation or under construction have an extensive and well-documented safety record accumulated over the past 30 years by technical experts from facility operators and safety authorities.

At the front end of the fuel cycle (i.e. from mining to reactor fuel loading), no important changes have occurred in the overall pathways leading from uranium ore extraction to the production of fuel elements. However due to various considerations such as political decisions and economic competitiveness, more emphasis is being placed on the production of fuel for light-water reactors (LWRs) as opposed to gas-cooled reactors (GCRs) and fast breeder reactors (FBRs). The safety preoccupation has shifted from the “in-process” problems and worker dose concerns to the external impact of the facilities on the environment.

At the back end of the fuel cycle (i.e. from fuel unloading to disposal and recycling), a significant evolution has been observed over the past ten years. Reprocessing of fuel discharged from LWRs has become a key activity of the fuel cycle. The biggest changes in this area have occurred as a result of industrial experience in the French reprocessing plant at La Hague, the Tokai-Mura plant in Japan and the Sellafield plant in the United Kingdom. From the safety point of view, reprocessing is the most complex part of the fuel cycle, due to the fact that all nuclear materials are in easily dispersible forms and that large quantities of flammable solvents are used.

The safety issues associated with the decommissioning of nuclear fuel cycle facilities will require much attention to limit both the overall radiation exposure to the workforce and the dispersion of contaminated materials.  

THE COMPONENTS OF THE NUCLEAR FUEL CYCLE

The nuclear fuel cycle encompasses the procurement and preparation of fuels for use in nuclear power reactors, their recovery and recycling after irradiation, and the safe disposal of all wastes generated through these operations.

Those broad steps comprise a number of inter-related activities, the combinations of which provide the various fuel cycle options. The unit operations in the fuel cycle are:

- Uranium mining and milling
- Uranium refining and conversion to uranium hexafluoride
- Uranium enrichment
- Fuel fabrication
- Reactor operations
- Spent fuel storage
- Spent fuel reprocessing
- Transportation of nuclear materials
- Radioactive waste management and disposal options
- Decommissioning.

Not included in this discussion is the stage of fuel irradiation in nuclear power plants, which corresponds in the above list to the reactor operations.
Three main types of fuel cycle are commonly identified, depending on whether or not the spent fuel is reprocessed. The figure below shows a diagrammatic representation of the three main fuel cycle options:

- In the once-through fuel cycle, the spent fuel is considered as a waste material and is kept in storage until it is sent for disposal in a geological repository. This option is currently advocated by Canada, Sweden, Spain and the United States. Some other countries are developing it as an alternative.

- In the other typical reactor cycle, the spent fuel is reprocessed. The remaining uranium and generated plutonium in the fuel are separated from the fission products and are recycled as refabricated mixed-oxide (MOX) fuel for light-water reactors. The fission products are stored in liquid form for a number of years and eventually vitrified and stored for several decades in engineered facilities. This option is followed by Belgium, France, Germany, Japan and Switzerland.

- In the fast breeder reactor cycle, spent fuel is reprocessed and the resulting uranium and plutonium product can be recycled for use in a fast breeder reactor. This option has been developed in France, Japan and the United Kingdom.

The choice of a specific fuel cycle depends on a variety of different and sometimes conflicting factors. The economics of nuclear electricity production, the availability of uranium on the world market, the availability of other energy resources, environmental considerations, political motives and safety factors all play a determinant role in the final choice.

Until 2005, uranium requirements, spent fuel production, reprocessing capacity, enrichment capacity and fuel fabrication capacity are known on the basis of operating and scheduled nuclear power capacity. Beyond that year, it becomes difficult to forecast with any precision the future significance of, for example, the fast breeder option and other nuclear power options. Even the projected rate of growth of the more common reactor types in that period is uncertain.

Uranium mining and milling

Uranium is widely distributed in nature and is found in concentrations that make it economically feasible to mine. The recovery of uranium from ore with a concentration as low as 0.1% uranium is viable. The typical process for the extraction of uranium consists of crushing and grinding of the ore followed by chemical leaching by sulphuric acid or an alkali-carbonate solution.

The mining and milling of uranium are not activities that would give rise to accidents with serious radiological consequences for the public or the environment. These facilities are viewed as conventional mining activities and are carried out in accordance with their specific regulations. However, the most serious problems associated with uranium mining in underground mines are those pertaining to the workers' health. The combined effects of inhaled radon daughters and radioactive dust, as well as external gamma radiation are the main concern; for this reason special attention is paid to radiation protection practices. The recently discovered high-grade ore bodies with uranium concentrations of up to 15% (as in Canada) require that remote mining methods be developed and that much more stringent radiation protection procedures be implemented.
URANIUM REFINING AND CONVERSION TO URANIUM HEXAFLUORIDE

The end product from the first stage of the fuel cycle is called "yellow-cake", which consists of an impure uranium oxide compound (U₃O₈). Refining or purification processes are required to bring the uranium oxide compound to the desired purity before it is converted through a sequence of chemical forms to uranium hexafluoride (UF₆) or uranium metal. The uranium refining and conversion capacity in OECD countries is located primarily in Canada, France, the United Kingdom and the United States.

The use of flammable reagents in industrial quantities is controlled to minimise the risk of fires and explosions that might cause uncontrolled release of relatively large quantities of uranium. Special care is taken to avoid leaks during these conversion reactions and to avoid releases within the facility and to the environment. In many cases, the toxicity of the conventional chemicals that are used is more a concern than the radiological aspects of processing uranium.

URANIUM ENRICHMENT

Light-water reactors, which represent about 90% of nuclear power reactors in operation, use enriched uranium as fuel, i.e. uranium in which the percentage of the fissile uranium isotope (U-235) has been increased from 0.7% (the natural concentration) to about 3.5%. Enrichment is based on a physical process by which lighter isotopes are separated from heavier ones (i.e. U-235 from U-238). The two common processes involve gaseous diffusion through membranes or centrifugal acceleration in high-speed centrifuges.

UF₆ gas passes through cascades of steps in the enrichment unit to reach the designed degree of enrichment in the U-235 component. Large enrichment plants based on the gaseous diffusion process are located in France and in the United States. Centrifuge enrichment plants are found in Germany, Netherlands, Japan and the United Kingdom.

Enrichment by diffusion or centrifugal techniques has been demonstrated to be a safe and a reliable process, and no major radiological incidents have been reported.

The EURODIF installation and the adjoining nuclear power stations at TRICASTIN, France.
SAFETY OF THE NUCLEAR FUEL CYCLE

New enrichment processes, such as the laser enrichment process and the chemical process, are at the pilot or demonstration stage.

FUEL FABRICATION

Nuclear power reactor fuel can be in the form of uranium metal, uranium oxide or a uranium-plutonium oxide called mixed oxide (MOX).

With the closing down of old reactors, the production of uranium metal for gas-cooled and MAGNOX reactors is being phased out. Uranium oxide is used in the main thermal reactor programmes, and its production has reached industrial capacities of 8,800 tonnes heavy metal (THM) per year in OECD countries.

A great deal of experience has been gained with the conversion process for the fabrication of uranium oxide fuel, especially in France, Germany, Japan, the United Kingdom and the United States. The main hazard is associated with the use of corrosive, explosive and toxic chemicals that also become contaminated with enriched uranium. Some incidents have occurred, mainly involving the transfer of UF₆ to the plant, but no major accidents with radiological consequences have been reported.

In uranium oxide fuel fabrication plants, protection from releases of radioactive compounds is assured by dynamic barriers such as ventilation hoods and engineered safety systems.

Historically, the major development of MOX fuel came from the breeder reactor technology. Since that technology has not expanded at the expected rate, mainly for economical reasons, MOX fuel fabrication has been redirected from fast breeder reactors to light-water reactors. The safety measures to decrease the hazards associated with handling plutonium are very important in the process. The presence of plutonium constitutes the main radiological hazard related to MOX fuel fabrication.

The facilities have at least two physical barriers separating the plutonium from the ambient environment: the first one being the glove boxes, the second one the containment building. In addition, workers are protected by a dynamic barrier consisting of ventilation systems with very high-efficiency particulate filters that confine potential releases within the facilities.

SPENT FUEL STORAGE

After the fuel has been irradiated in reactors, it is stored for one to three years in pools at the reactor site. The fuel is then transported to a reprocessing plant equipped with large storage ponds, such as La Hague (France) and Sellafield (United Kingdom), or to another facility to await further processing or disposal.

The storage of spent fuel requires various protective measures, including shielding to handle the fuel, cooling to maintain the fuel at a given temperature, criticality control measures, and facilities for the control of water chemistry, decontamination and cleaning. From the safety point of view, dry storage has the advantage that a loss-of-cooling accident is impossible given adequate design and operation.

SPENT FUEL REPROCESSING

Currently existing or planned reprocessing plants use or envisage using a solvent-extraction process in which the mechanically sheared fuel is dissolved in nitric acid. Industrial experience with fuel reprocessing has been gained in the last 30 years in Belgium, France, Germany, Japan and the United Kingdom.

From the safety point of view, the dissolution of sheared spent fuel is not a high-risk operation as long as sufficient care is taken to dissolve the sheared fuel at a slow pace. Criticality considerations play a major role in the design and the layout of equipment. With the use of higher enrichment fuels, coupled with increased burn-ups in the reactor, criticality becomes more important, and neutron absorbers are added to ensure safety in all circumstances. The insoluble residues are very finely divided particles, and their high thermal output requires special attention during clarification and storage of the collected residues.
The difference in plutonium content from 0.6% in LWR fuel to a nominal 4.5% in LWR MOX fuel and 15 to 18% in FBR MOX fuel is the most important factor when designing reprocessing equipment. The higher plutonium concentration in MOX fuel calls for facilities with upgraded criticality controls and additional process control equipment able to detect abnormal dissolutions in order to avoid unexpected oxide accumulations.

PLUTONIUM STORAGE

Plutonium can be stored for various periods of time at different stages of the fuel cycle before it is passed to the fuel fabrication plant for incorporation into fresh fuel elements. The stored plutonium can take several forms. The liquid form requires very special precautions, since it produces hydrogen which must continuously be removed by ventilation in order to avoid production of explosive mixtures. The storage of liquid plutonium in any one tank is intrinsically limited by tank volume for criticality reasons.

The high-level liquid wastes that are produced are normally concentrated by evaporation and stored for a number of years prior to vitrification. Radiolysis, sludge precipitation and heat dissipation are the most important phenomena occurring in the storage tanks. Forced ventilation, agitation or air sparging, multiple filtration systems, and redundant monitoring equipment for temperature, liquid level control and leak detection ensure long-term safety.

TRANSPORT OF RADIOACTIVE MATERIALS

The transportation of radioactive materials has become a major industrial activity which covers all the nuclear facilities from mining to final disposal.

Depending on the concentration and quantity of fissile materials and of radionuclides, the containers are mechanically more resistant and the regulatory precautions more stringent. For example, containers used to ship spent fuel or waste canisters have been designed to withstand a train crash. A demonstration test carried out in the United Kingdom has shown that this type of container is fully resistant to such crashes. Special safety and security precautions are taken when plutonium is transported either as plutonium oxide, mixed oxide or MOX fuel elements. These precautions are exceptional when plutonium is transported from one continent to another, e.g. from Japan to Europe.

In addition to national regulations, there are also regulations for the safe transport of radioactive materials defined by the International Atomic Energy Agency guidelines, which are applicable to all countries and have to be strictly observed.

DECOMMISSIONING

All industrial plants have a useful lifetime at the end of which they are decommissioned; this lifetime is determined by economic, technical and safety factors. In the case of nuclear fuel cycle plants, decommissioning is considered at the design stage, when provisions are made to facilitate both decontamination and dismantling.

CONCLUSION

As in other industrial areas, incidents and accidents have occurred in the nuclear fuel cycle despite all the technical and procedural precautions. Roughly, these incidents may be grouped into the following basic types: criticality incidents, releases of UF₆, fires and exothermic reactions, leakage of radioactive material, contamination and loss of power supply.

In OECD countries, these abnormal events are reported by the plant operator to the authorities. Great care is taken to collect this information for the purpose of improving safety in the facilities and for informing the public and scientific bodies. Since even minor events are reported and collected in most countries, the public sometimes gets the impression that the nuclear industry is plagued by large, never-ending series of troubles and incidents. Certainly, abnormal events have occurred and will also occur in the future, but, compared to other industrial
safety record of all stages of the commercial nuclear fuel cycle is impressively good.

As an example, since the inception of the nuclear industry in 1942, only eight criticality incidents (which led to two deaths, five severe radiation exposures and eleven significant radiation exposures) associated with fuel plants have been reported throughout the world. Such a small number demonstrates the extreme care taken in both the design and the detailed operational procedures of fuel facilities.

Technical safety assessments are concerned primarily with radiological safety. This includes the radioactive contamination risk to man and his environment, and the analysis of the measures for abnormal occurrences such as criticality accidents, explosions or plant faults. The man-machine interface is another important aspect of safety management which needs more attention.

Finally the assessment of accident consequences is also essential to any safety analysis, since this aspect is directly connected to the public’s perception of abnormal events. To allow better comparison of incidents and to improve the information of the public, severity scales have been established in some countries for the evaluation and reporting of incidents.

The Nuclear Energy Agency is currently implementing a system of notification and analysis of incidents which have occurred in nuclear fuel facilities. The main objective of this system is to collect and disseminate any relevant information concerning events of safety significance and to feed back the appropriate conclusions, with a view to sharing experience and enhancing the safety of nuclear fuel cycle facilities.

The very good safety record of the civilian nuclear fuel cycle facilities in OECD countries is proof of the adequacy of the current regulatory practices. The steady decrease in personnel irradiation doses and effluent discharges into the surface waters and the air is an illustration of the continued improvement in the operation of the facilities and of the reduction of the radiological impact of the nuclear fuel cycle on humans and the environment.
Emergency exercises provide an effective means to identify deficiencies in emergency plans and procedures. In an exercise, deficiencies stand out more clearly than in any critical review of emergency provisions. Moreover, exercises are important to test new equipment, methods and procedures, and to enhance interfaces in the emergency organisation. Finally, organisations that are not normally associated with each other in their day-to-day work can, in the context of such exercises, establish closer personal contacts, which in many instances can be of paramount importance for a successful emergency response. Periodic execution of exercises is therefore considered an integral part of the overall regulatory requirement for nuclear installations.

When the impact of a nuclear accident affects more than one country, particular problems in applying emergency response plans and procedures may be experienced, due to differences in the organisational set-up, intervention criteria, etc., as well as to different public information policies. This was certainly demonstrated in Europe during the response to the Chernobyl accident. Such experience shows that modern emergency management must not only address domestic problems but be flexible enough to address the entire spectrum of accidents that could have an impact beyond the facility or the country in question.

For the above reasons, the NEA Committee on Radiation Protection and Public Health took the initiative to promote international co-operation on off-site emergency exercises and established a programme of work intended to overcome some of the problems in this field. The committee thought that the first action was to encourage the exchange of information on practices and experience related to emergency exercises. The committee also agreed that an effort should be made to arrange international emergency exercises. The purpose of international exercises would be to improve the co-ordination of emergency response systems and to seek consensus on approaches to the management of nuclear emergencies at an international level. Sharing experience and co-ordinating arrangements in this field are not only desirable but are essential if emergency responses to large nuclear accidents causing transborder consequences are to be successful.

**ORGANISATION OF EMERGENCY EXERCISES**

As indicated above, emergency exercises form an integral part of the emergency arrangements in OECD countries. In the wake of the Chernobyl accident, most countries revised their emergency plans and procedures to take into account the experience gained and lessons learnt. Also, new international conventions and guidance in this area have been issued and have had an influence on these arrangements. Emergency exercises are key elements in testing the interplay between plans and procedures and in identifying deficiencies. Figure 1 illustrates this interplay.

Emergency exercises are carried out with various levels of participation, from utility exercises to test the operation of the on-site

**FIGURE 1. EXERCISES ARE KEY ELEMENTS OF EMERGENCY MANAGEMENT**
arrangements to large national exercises involving the entire chain of organisations with responsibilities in a nuclear emergency.

To test various aspects of emergency provisions, different types of exercises are used. Experience shows that policy aspects are favorably developed and tested in so-called tabletop exercises, operating procedures in command-post exercises, while actual operations need to be effectively tested in field exercises.

The resources and time devoted to the conduct of emergency exercise planning and scenario development will be, by far, the most useful effort prior to the exercise. Inadequate planning will lead to an unsatisfactory and unsuccessful exercise. Experience has also shown that the exercise objectives have to be clearly defined and realistic. The objectives provide both the basis for developing the scenario and a means for evaluating the response by the emergency organisation. The more specific the objectives are, the easier it will be to determine whether the objectives were met or not. The objectives must also be as realistic as possible to avoid the exercise being dismissed as a game.

Management support and attention to the planning of an exercise is perhaps the single most important aspect affecting its success. A significant error constantly repeated in exercises is the desire of managers to “micro-manage” rather than delegate tasks to their subordinate staff. This may lead to a lack of timely decision-making just at the point where it is most needed.

**COMMUNICATION AND PARTICIPATION ISSUES**

Communications are another key issue in emergency exercises. This includes technical problems related to the use of language and terminology, communication system malfunctions, including equipment incompatibilities, and communication problems due to lack of clarity concerning responsibilities within the emergency organisation. These types of problems appear in almost all exercises and will certainly constitute a key issue in a real emergency.

As some countries have not fully integrated the international system of units in their vocabulary, the units will almost certainly cause a problem in exercises, whether national or international. Drills should be used to test...
some of these aspects in advance. Also, for the sake of realism, the telecommunication systems used during the exercise should be the same as those to be used during a real emergency.

Certain exercise objectives, for example those relating to protective actions, can only be fully achieved with the participation of the public. Considering the potential problems of involving the real public in an exercise, very little experience exists. What is done in some countries is to use the participation of school children to represent the public in exercising evacuation procedures.

To compensate for the lack of public participation, it would be useful to study the wealth of experience related to real non-radiological emergencies. In the United States, for example, as many as 90 emergency evacuations are carried out annually.

The efficiency of the emergency information function largely determines the success of an emergency response. In addition to public information officers, the testing of this function would require the participation of the media. It seems to be the experience of many countries that it is difficult to interest the media to play a role in an exercise; if involved, they tend to treat the exercise itself as a news story, and there is a good chance that some of them will try to sensationalise certain aspects of the exercise. To meet the objectives, it seems preferable to use journalist students or media consultants to represent the media. The drawback is that these surrogate measures cannot provide the same intensity and pressure that would exist in a real emergency.

INTERNATIONAL EMERGENCY EXERCISES AND THE NEA'S PLANS

The Chernobyl accident, apart from being the largest nuclear accident experienced so far, focused attention on the fact that radioactive contamination may travel long distances, without respecting national borders. This emphasized the importance of international arrangements on information exchange and assistance, as well as co-ordination of emergency provisions in general within the international community.
The two main conventions in this area, established by the IAEA after the Chernobyl accident, are being tested as part of the exercise programme of the IAEA Emergency Response System. Tests are also carried out within the European Community Urgent Radiological Information Exchange System, ECURIE. These tests normally involve a number of countries on a voluntary basis. Emergency exercises of a broader scope are carried out on a bilateral basis between countries having a nuclear installation situated close to a common border. Examples of countries that have carried out bilateral exercises are Sweden-Denmark, Germany-Switzerland and United States-Canada.

The initiative by the NEA to arrange international exercises aims to contribute to improved coordination of emergency response systems on a regional scale, and to help in seeking consensus on approaches to the management of nuclear emergencies on an international level. A plan for the arrangement of such exercises is presently being discussed within the Committee on Radiation Protection and Public Health.

The objectives of the exercises would concentrate on aspects which would greatly benefit from international co-operation. Notification and communication of emergency information, intervention levels for protective actions, radiological aspects of international trade, and public information policies are examples of issues that are going to be dealt with in these exercises.

In the first planned exercise, NEA countries will be called on to respond to a particular scenario using their own emergency plans and procedures. After having developed their responses, which should be done at a small tabletop level without interaction with other countries, the participants would come together to an international meeting to discuss their respective proposed actions. The necessary interfaces between each country's emergency response plans and procedures will be identified and any inadequacies pointed out.

This first exercise, to be held in 1993, will concentrate on policy aspects. The operational aspects of nuclear emergency measures will be addressed in future exercises.

Environmental sampling constitutes an important component of field exercises
Although there are many uncertainties about the future, one fact is clear. World electrical energy use will continue to grow over the next several decades to meet the needs of a rising population and to sustain economic growth. Although presently controversial, nuclear power remains one of the most environmentally clean sources of electricity available. Accordingly, even though many “wait-and-see” moratoriums are currently in place, most nations nevertheless favor keeping the nuclear option open — and particularly, keeping open the option to operate existing plants until such a time as cleaner and safer sources of electricity generation are developed and put in place.

THE NEED FOR AN INTERNATIONAL FRAMEWORK

With 423 nuclear power plants already connected to the world’s power grids in 1991, the notion of “keeping the nuclear option open” implies another clear conclusion. Namely, from now and throughout the next couple of decades, far more decisions will be taken on whether or not to extend the life of a nuclear plant than decisions on high-level waste repositories or new plant orders. Clearly, nuclear plant ageing and life management issues are coming to the forefront.

Due to both the scale and complexity of the machine involved, the ageing of plant components, systems, and structures will present a unique challenge to the industry, regulatory authorities, and energy policy-makers. Therefore, efforts are under way in essentially every nuclear nation, by both government and industry, to identify ageing mechanisms and to evaluate the corresponding solutions. These programmes fall under a variety of headings such as Plant Life Extension (PLEX), Nuclear Plant Ageing Research (NPAR), and Plant Life Management (PLIM).

Experience with ageing and life management is also building internationally — but it is building at uneven rates. Certain nations with the least amount of experience will be facing plant life decisions in the same time frame as their most experienced neighbors, if not sooner. An efficient mechanism is clearly needed to facilitate the exchange of experience between the concerned organisations in the different countries. International conferences and symposia are one type of mechanism for technical exchange — but they have their limitations. By their very nature, conferences tend to focus on current issues. What is needed is an international mechanism for resolving PLEX and PLIM issues before they raise problems requiring urgent decision.

International organisations can also assist in technical exchanges between nations and concerned organisations by forming working groups of experts to address such issues before a serious problem develops.

In the end, we are forced to admit that in spite of 6000+ reactor-years of experience and countless technical exchanges, many national and international plant ageing and life management activities still remain piecemeal and largely independent of one another. Significant duplication of effort exists from country to country and there are a great many areas where increased collaboration and exchange of experience would be beneficial.

SAFETY AND ECONOMICS — THE RESPECTIVE ROLES OF THE IAEA AND NEA

Both the OECD Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA) have worked for some time on questions relating to plant life and component ageing. Given the many aspects to be addressed, a division of responsibilities had to be established at an early stage between the two agencies so as to facilitate collaboration and avoid duplication. With its basis in the Organisation for Economic Co-operation and Development, it was natural for the NEA to be assigned the lead in the economic aspects of plant life management. The IAEA in turn, began several studies relating to the safety aspects of plant ageing.

Clearly, safety must be the primary concern for a regulatory authority involved in plant ageing.
THE MANAGEMENT OF NUCLEAR PLANT LIFE

issues. On the other hand, the decision on whether or not to extend the life of a nuclear power plant rests with the owner, not the regulator — and that decision depends on economics. Of course, the owner must meet certain safety criteria to operate the plant, but the bottom line on whether or not to attempt to meet those safety criteria is an economic one.

From a political perspective, the division of responsibilities was also justified. There are many conferences, technical exchanges, and independent national programmes already under way. What is needed is a way to more systematically pull it all together and to identify possible joint projects and areas for collaboration.

Because the industrialised countries which make up the OECD are closely linked by their similar economic and other interests, they often prefer to reach international consensus first within the NEA before addressing the issues on a wider but less homogeneous world scale. The commonality of OECD interests and working methods therefore led to the setting-up in 1990, within the NEA, of an international expert group on plant life management for the purpose of achieving a more systematic and higher level of collaboration on these issues. The Group brings together approximately 30 industrial, governmental, and international organisations from 15 countries.

THE NEA EXPERT GROUP ON PLANT LIFE MANAGEMENT

Plant lifetimes on the order of 70 years are believed to be technically feasible and about a dozen plants already have operated for 30 years. Nevertheless, experience also indicates that 10% of the world’s reactors have been permanently retired with an average lifetime of just 14 years. This observation led to concerns that many owners might retire their plants prematurely, not because of technical constraints but because of uncertainties related to economics, changing safety requirements, and public acceptance. A first task of the NEA PLIM Group was therefore to assist the various national government and industry programmes in systematically reducing the uncertainties associated with long-term operation and life extension of nuclear power plants. Specifically, the objectives of the Expert Group would be to:

1) Jointly identify the important elements of the plant ageing, life extension, and life management decision-making processes (e.g. Figure 1);

2) Identify the nature of information (safety, technical, and economic) which will be needed to support these elements of the decision-making process and to reduce decision-making uncertainties to an acceptable level; and

**FIGURE 1. PLANT LIFE MANAGEMENT DECISION-MAKING PROCESS**
3) Identify existing or needed sources of information (national or international, governmental or industrial), as well as assess the feasibility of obtaining that information.

One of the expected results of the teamwork within the expert group is the development of an international framework to help co-ordinate the various national programmes on plant ageing and life management.

CURRENT STATUS

The NEA Expert Group on Plant Life Management has received considerable interest and support since its inception. Two phases of work are currently envisioned. In the first phase, the existing PLEX, Life Assurance, and Life Management programmes in the participating nations will be identified, and a “state-of-the-art” report on plant life management programmes will be prepared.

This report, which will be established by systematically gathering information on national programmes, will lay out the results of an international survey and identify the important elements of the decision-making process, information requirements, and organisations developing that information on a country-by-country basis. The following topics will be addressed: qualified equipment and spare parts; regulatory processes (safety and economic); qualified manpower; cost/benefit analysis methodologies; critical components, systems, and structures; ageing management programmes (identification of ageing mechanisms, lifetime prediction, monitoring of ageing [inspections, testing, analysis] and monitoring of lifetimes [usage factors, acceptance criteria, etc.]); emerging issues and concerns; and public acceptance issues.

In the second phase, the experts will analyse the programmes from a more global perspective, and identify links between programmes and gaps in knowledge. Phase II will aim at identifying an overall framework under which the relationship of the various national programmes can be seen. The group will then form conclusions and recommendations concerning information requirements, the need for increased collaboration, special assistance, joint projects, etc. It is intended that the ageing programmes, concerns, organisations, etc. would be updated on a periodic basis. The NEA PLIM programme will also take into account the ongoing NEA study on “Qualified Manpower” and the upcoming NEA seminar on qualified equipment and manpower, which is scheduled for December 2-4, 1992, in Paris.

THE NEED FOR INTERNATIONAL STANDARD AGEING TERMINOLOGY

One side issue that has arisen as a result of the first NEA PLIM meeting was the recognition of the need to reconcile the wide variance of terminology and definitions used to describe plant ageing and life management. Clearly, NPP owners, operators, and regulators should have a reasonably consistent understanding of “obsolescence” in order to be understood by the public. But even beyond this, a common standard terminology is important for effective co-ordination, collaboration, and the exchange of ageing experience.

The NEA is therefore in the process of establishing another small working group, in coordination with the Commission of European Communities (CEC) and the IAEA, to resolve this issue. As a starting point, the group would rely upon the work already done in this field by the Edison Power Research Institute (EPRI) in the USA, the World Energy Council (WEC), and others. In addition to a multilingual glossary of terms (English, French, Spanish, German, Russian, and Chinese), an explanation of the underlying concepts will also be developed.
What is to be done with radioactive waste is a subject of serious concern to the public and stimulates constant discussion in which emotional arguments clash with the scientific and technical claims of the experts. Naturally, ever-more explanations can be given about the waste itself, its source and toxicity, and the length of time over which some of the waste will constitute a hazard to man and the environment. It can also be explained that it is just and necessary to manage and dispose of the waste produced by society, whatever that society’s attitude towards the industrial activity which generated the waste in question. But at the end of the day, the problem remains one of confidence in the experts responsible for designing the methods and techniques needed to perform the task.

The Austrian painter Anton Lehmden, one of the masters of the Viennese school of fantastic realism, made an original contribution to solving this problem by suggesting that radioactive waste be integrated into the environment: waste would be stored in the heart of familiar man-made forms alongside which man could live daily without risk.

Lehmden therefore conceived of egg-shaped structures, with a two to three-metre thick shell in stainless steel and concrete, lined with lead, designed to store radioactive waste. These structures bear some resemblance to the far-off planets photographed by the first space probes launched by the United States. However, the painter found his source of inspiration not in space but rather in the massive blocks of granite released during the ice age, which can still be found today scattered throughout the thick forests of north-east Austria bordering on the Czechoslovak border.

Lehmden’s idea — which attracted the attention of the Austrian Seibersdorf Research Centre — is that these “eggs”, measuring between 13 and 17 metres high and 21 and 25 metres long, would rest on a thick layer of gravel and sand, thus protecting them from earthquakes. The “eggs”, which would blend in naturally with the landscape, would provide sizeable storage space for waste over fairly long periods, with access to the waste remaining possible at any time to verify its condition or to transfer it to a final repository.

Whatever fate the experts hold in store for this project, such an original attempt to reconcile the needs of an industrial society with protection of the environment, and this vision of the relationship between man and nature, must be welcomed.

1. See the cover page of this issue. The editorial staff would like to thank the magazine L’Autriche présente which is the source of this note, as well as Professor Lehmden and the Seibersdorf Research Centre.
2. This centre analyses radioactive waste samples from throughout the world on behalf of the International Atomic Energy Agency. It also serves as a temporary storage facility for Austria’s radioactive waste.

J. de la Ferté

Professor Lehmden, an Austrian artist, introduces his original concept of egg-shaped containers for the storage of radioactive waste.
ISOE — AN INTERNATIONAL INFORMATION SYSTEM ON OCCUPATIONAL EXPOSURE

The NEA launched in 1988 the idea of creating an international system for information exchange in the field of occupational radiation exposure. The system would make it possible to combine the experience gained in nuclear power plant operation in the various OECD countries in order to promote improvements in operational dose management and optimisation of radiation protection. This idea, which was approved by the NEA Committee on Radiation Protection and Public Health, led to the official launching of the ISOE system on the occasion of the first meeting of its Steering Group, on 18 November 1991 in Paris.

The primary objective of the ISOE is to make available to its participants a computerised tool to accelerate the dissemination of operational experience in radiation protection of workers, and to facilitate the exchange of information between utilities on specific dosimetric problems and new maintenance operations with which they are confronted.

All types of power reactors operating in OECD countries will be included in the ISOE (PWR, BWR, GCR and Candu). The information in the system will concern the following three databases, defined as NEA1, NEA2 and NEA3:

NEA 1: Various performance indicators of special interest to radiation protection, such as collective dose, individual dose distribution and job-related doses; this information will be updated annually.

NEA 2: Information about methods and techniques used for effective dose control, such as information about materials used in specific components, chemical specifications for process water, and procedures for training and work planning; this type of information, which varies little from one year to another, will be updated in case of changes.

NEA 3: Brief descriptions of specific operations and radiation protection problems; this database, which will also contain information about contact persons at the nuclear power plants, will be continuously updated and will represent one of the main interests of the system.

The technical operation of the ISOE will be carried out by three technical regional centres, one in North America, one in Europe and one in Japan.

The initial participants in the system include operators and regulatory authorities from Belgium, Canada, Finland, France, Germany, Japan, Italy, Spain, the United Kingdom, the Netherlands, and Sweden.

Many utilities and the regulatory authority of the United States have expressed interest in the project and are expected to join in the near future. The International Atomic Energy Agency (IAEA) and the Commission of the European Communities (CEC) are also participants. A special co-operation agreement has been prepared with the CEC, which already runs a system of data collection on job-related doses, allowing complete information exchange between the common parts of the two systems.
power plants. The Committee’s task force on human factors completed in 1991 a report entitled “International Practices for Analysing, Regulating and Improving Human Performance of Maintenance Activities at Nuclear Power Plants”. This report, which should serve as a reference document on the management of maintenance outages and on shutdown operations, identified several recurring themes among the participating countries, including:

- despite the existence of administrative methods for transmitting work orders, problems remain with the accuracy of verbal communications and consistency in completing the documentation after maintenance activities;
- high rates of incidents involving human factors are related to poorly prepared work activities;
- no immediate changes are foreseen in the practices of the responding countries with regard to human factors in maintenance activities or in the regulations governing them;
- few countries have regulations governing the selection and training of maintenance personnel;
- topics proposed for future work include the tendency of skilled maintenance personnel to rely more on experience than on procedures to perform their tasks, and the appropriate training of subcontractor personnel.

The task force is currently studying the subject of “Management of Maintenance Outages and Shutdowns”, which involves, inter alia, describing key issues and topics that relate to utility maintenance outages in each country, and analysing events that illustrate important improvement activities.

FIRST MEETING OF THE NUCLEAR SCIENCE COMMITTEE

The NEA Nuclear Science Committee (NSC), formally created in October 1991 to take over the responsibilities of the former Nuclear Data, Reactor Physics, and Data Bank Committees, held its inaugural meeting on December 18-19, 1991.

While the new committee will maintain continuity in the scientific services of the Data Bank, and in the tasks of the previous committees, the scope of its activities has been extended to cover other scientific questions related to nuclear technology.

The new committee will co-ordinate all NEA activities in the field of nuclear science and respond closely to the developing scientific requirements of the nuclear community. In line with this objective, one of the first tasks undertaken at the meeting was to draw up a medium-term programme of work, extending to 1995, which includes the study of physics aspects of the evolutionary development of present reactor types, studies for advanced reactor types expected in the next century, and horizontal issues related to environmental and other general energy considerations.
Following the election of the committee’s officers, four working parties were established to oversee the committee’s activities related to nuclear data requirements, international cooperation on data evaluations, advanced computing for nuclear applications, and review of on-line monitoring technology. The committee then endorsed a programme of specialist meetings and conferences for 1992-94.

The next meeting of the Nuclear Science Committee is scheduled for early June 1992.

**REVISION OF THE VIENNA CONVENTION**

The NEA Group of Governmental Experts on Third Party Liability in the Field of Nuclear Energy is participating actively in the revision of the 1963 Vienna Convention on Civil Liability for Nuclear Damage, currently being negotiated in an IAEA Standing Committee.

The Vienna Convention represents the adoption on a global level of principles already included in the Paris Convention on Third Party Liability in the Field of Nuclear Energy, which was concluded in 1960 under the auspices of the NEA (then the ENEA), and which has only European parties. While the Paris Convention was revised in 1964 and 1982, however, the present exercise is the first revision of the Vienna Convention undertaken since its conclusion.

In part, the active contribution of NEA countries is a consequence of their combined experience and expertise in the field. It is also made essential by the existence of the 1988 Joint Protocol which links the Paris and Vienna Conventions by extending the benefit of each Convention to the Parties to the other, thus requiring a considerable degree of harmonisation between their provisions.

A number of proposed amendments to the Vienna Convention have obtained general support. On others, however, delegations are still far from consensus. The most controversial include the proposed introduction of provisions making the State in which an installation is located liable for accidents as well as the operator of the installation, and the question whether compensation claims by victims of a nuclear accident should be judged by national courts or by an international commission. The IAEA Standing Committee is also attempting to draw up a scheme to provide supplementary funding for compensation claims, beyond that available under the Paris or Vienna Conventions, but there are still fundamental differences of opinion as to the form such a system should take.

**NEW GENERAL-INTEREST PUBLICATIONS**

As part of its efforts to make the results of its work more accessible to a non-specialist audience, the NEA has undertaken to produce a series of general-interest reports on specific aspects of nuclear energy. Following the publication of a first general review in 1989, entitled *Nuclear Energy in Perspective*, two other reports have been prepared and will be published in mid-1992.

The first publication will focus on the *Economic and Technical Aspects of Nuclear Energy*. It will present an overview of the current expert consensus on the status of nuclear power technology and its economic position. In addressing the question of what nuclear power can and may be expected to offer the world’s energy and environmental policy-makers during the next decade, the report will cover areas such as the potential demand for nuclear energy, its economic competitiveness, as well as the relevant aspects of reactor performance and future technological developments.

The second report, tentatively entitled *Achieving Nuclear Safety*, will review the significant efforts that have been made in recent years to enhance the safe design and operation of nuclear reactors in OECD countries. It will show how these efforts, which in large part have taken place within various programmes of international co-operation, have led to a more coherent and consistent approach to safety, which in turn has gone a long way to minimising the risk of major accidents with the operation of today’s reactors.

In publishing these two reports, the NEA hopes to provide a useful contribution to the ongoing scientific and political debate on how to meet the world’s growing demand for energy in order to achieve sustainable economic growth.
Licensing Systems and Inspection on Nuclear Installations

This revised and updated study provides a description of the nuclear licensing regulations and practices applied in OECD countries with specific provisions in that field. The national systems have been described according to a standard format to facilitate comparisons and research. In most cases, the descriptions are supplemented by flow charts illustrating the procedures and specifying the different authorities involved.

The study covers twenty OECD countries: Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States.

144 pages
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Safety Assessment of Radioactive Waste Repositories: Systematic Approaches to Scenario Development

The analysis of the long-term safety of radioactive waste disposal systems requires the use of mathematical models and scenarios that simulate repository behaviour in response to future events. This report describes the approaches that have been developed in order to systematically identify the events and processes likely to affect this behaviour, and to construct and select representative scenarios for consideration in long-term safety studies.

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Living Probabilistic Safety Assessment for Nuclear Power Plant Safety Management

Recent developments in Probabilistic Safety Assessment (PSA) techniques have demonstrated their importance both in verifying the level of safety in nuclear power plants and in identifying any potential weak points.

One PSA application, which consists of the evaluation of the relative effect of changes in the plant's reference safety measures, appears to yield the most promising results. However, it must be ensured that such changes are incorporated into the plant's reference model. A PSA thus produced, reflecting the current plant configuration, is referred to as a "living" PSA.

This report presents the characteristics, the current status and the elements of existing Living PSA programmes in OECD countries and focuses on the long-term role of utilities in maintaining the "living" nature of PSAs and in applying them.

81 pages
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