COMPAS: A European Project on the "Comparison of Alternative Waste Management Strategies for Long-Lived Radioactive Wastes". Scope, working methods and conclusions.

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Abstract:
The paper presents the content and major findings of a project on the "Comparison of Alternative Waste Management Strategies for Long-Lived Radioactive Wastes" (COMPAS) carried out within the 5th framework programme of the European Commission. Under the leadership of NNC (UK), the project was carried out by individuals representing waste management organisations from 15 European countries. After having compiled information on the nature and amount of long-lived radioactive waste to be managed, issues influencing the selection of waste management strategies and options, presently adopted national strategies as well as options for the future were addressed. Conclusions concerning key issues for the success or otherwise of strategies and management solutions were drawn.

1 SCOPE AND OBJECTIVE

Within the EU and the Applicant Countries there are currently several strategies for the long-term management of long-lived radioactive waste. There are several reasons for the diverse strategies in the member states such as differences in: the history of the nuclear power programme; reactor type; attitudes to reprocessing versus not reprocessing; the nature and quantities of wastes; geology; public attitudes etc. As the national needs and conditions tend to be unique there is no 'universal best approach'.

In order to review, at an international level, the various strategies that currently exist, to evaluate the advantages and disadvantages of the various strategies and their alternatives in the light of available technologies and national differences, and to identify the rationale for regional differences in current strategies, the European Commission awarded a project on the "Comparison of Alternative Waste Management Strategies for Long-Lived Radioactive Wastes" (COMPAS) to a consortium co-ordinated by National Nuclear Corporation Ltd (NNC, UK).

The COMPAS project established a thematic network within the 5th framework programme of the European Commission for the evaluation and comparison of the alternative long-term strategies for the management of long-lived radioactive waste that have been considered in the EU member states and Applicant Countries. National differences influencing strategy selection and the key drivers in the formulation of national policies were reviewed with the aim of reaching a common understanding of the differences in current strategies.

The overall aims of the project were as follows:

- To provide information on the major issues associated with a number of alternative waste management strategies for long-lived radioactive wastes, so that the key issues in a range of countries can be readily assimilated by policy-makers, those that implement policy, and members of the public.

- To evaluate and compare alternative strategies for the management of long-lived radioactive wastes, taking into account regional differences.

- To provide a forum for discussion and the transfer of information, enabling the participants from a cross-section of European countries, including Applicant Countries, to reach a common understanding of the rationale for existing and proposed waste management strategies.

Within these aims, the thematic network had the following objectives:

- To review the national inventories of long-lived radioactive wastes. The current or potential future roles of reprocessing and partitioning and transmutation techniques were considered, along with the impacts of these techniques on waste inventories.

- To identify the long-term waste management strategies for long-lived radioactive wastes that have been considered in the EU member states and Applicant Countries, and the issues influencing strategy selection.

- To carry out an evaluation and comparison of a number of alternative waste management strategies, representative of the range of strategies that have been considered in the EU member states and Applicant Countries.

- To provide a forum for the review of strategies that are currently adopted or proposed in the EU member states and Applicant Countries, and the processes by which they will be developed. National differences influencing waste management policy were identified and discussed in order to achieve a common understanding of the rationale for the regional differences in strategies.

- To present the current and proposed national practices and strategies on the management of long-lived wastes, along with their rationale, in a structured format that allows the essential information to be readily understood and assessed.

2 WORKING METHODS

2.1 Participants

The two-year project (2001-2003) was carried out by the following organisations:

- Commissariat à l'Énergie Atomique (CEA, France)

- Empresa Nacional de Residuos Radiactivos, S.A. (ENRESA, Spain)

- Gesellschaft für Anlagen- und Reaktorsicherheit mbH (GRS, Germany)

- Nationale Genossenschaft für die Lagerung radioaktiver Abfälle (NAGRA, Switzerland)
- National Nuclear Corporation Ltd (NNC, UK – co-ordinator)
- Nuclear Research & Consultancy Group (NRG, The Netherlands)
- Posiva Oy (Finland)
- Svensk Kärnbränslehantering AB (SKB, Sweden)
- United Kingdom Nirex Ltd
- Vyskumny ustav jadrovych elektrarni (VUJE, Slovakia)

Information on national data, practices, approaches and experiences was also provided by invited experts coming from these organisations as well

- Agencija za radioaktivne odpadke (ARAO) / Agency for Radwaste Management (Slovenia)
- Атомната централа Козлодуй / Kozloduy Nuclear Power Plant (Bulgaria)
- Comisia Nationala pentru Controlul Activitatii Nucleare (CNCAN, Romania)
- Ente per le Nuove tecnologie, l'Energia e l'Ambiente (ENEA, Italy)
- Hungarian Academy of Science
- Radioaktív Hulladékokat Kezelő Közhasznú Társaság (RHK KHT) / Public Agency for Radioactive Waste Management (PURAM, Hungary)
- Správa úložišť radioaktivních odpadů (SÚRAO) / Radioactive Waste Repository Authority (RAWRA, Czech Republic)
- TS Enercon Kft (Hungary)

The participation by waste management organisations of 15 countries ensured that most of the countries in both western and central Europe where there are, or have been, operating nuclear power plants were represented.

2.2 Methodology

The project was organised around a series of four workshops, each addressing one of the tasks and work packages of the project:

- The historical basis of the existing waste, its categorisation and the amount of spent nuclear fuel and waste that will have to be managed as a result of the existing nuclear power programmes and the other sources of radioactive waste. The roles of reprocessing and partitioning and transformation in affecting the waste to be managed were also addressed.
- Issues that determine the strategies adopted or considered by each country. These included international treaties, European directives, technical and financial issues as well ethical issues.

- Generic strategies that are being implemented or being considered and the reasons for choosing them. Issues affecting key decision points in the management of the fuel and materials in both the short and long term were identified.

- Key issues that affect the success or otherwise of implementing a long-term management solution, such as a repository and key aspects of the process leading up to a successful selection of a site.

In advance of each workshop, the participating organisations provided national information with regard to the issues at stake. The information was elicited by means of templates prepared in advance by NNC and discussed with the participants in an iterative process. The information was presented at the workshops and compiled by the project co-ordinator. This national information forms part II of the final project report [1] which reflects the status of the national strategies on 1st September, 2003.

At the workshops, comparisons were made and conclusions were drawn concerning commonalities and differences and their major causes. The major findings of the workshops were, after confirmation by project participants, compiled in interim reports and, after a revision in light of the lessons learnt during the whole project, they form part I of the final project report [1]. A summary report addressing the most important information collated and the major conclusions drawn, of about 40 pages, is also available.

3 RESULTS AND CONCLUSIONS

3.1 The waste to be managed

The project addressed the policies and strategies for the management of spent nuclear fuel (SNF) and long-lived radioactive wastes, namely high level waste from reprocessing (HLW) and long-lived low and intermediate level waste (LL-LILW), that have been developed in many of the EU Member States, Switzerland, and many of the Applicant Countries. A variety of classification schemes are in use for reporting waste quantities at international levels, national levels, and for internal use within the nuclear industry. Within the COMPAS project, the national waste categories were classified into the following categories

- spent nuclear fuel (SNF),

- high-level waste from reprocessing (HLW), and

- long-lived low and intermediate level waste (LL-LILW) that exceeds the alpha limitation for short-lived waste but where heat generation is low enough for the waste not to require cooling.

The main sources of spent nuclear fuel and long-lived waste are the civil nuclear power, research and defence programmes. Of these, the nuclear power plants are the major source, either directly as a result of their operation and decommissioning or as a result of reprocessing the Spent Nuclear Fuel (SNF). The reference scenario of the project for the quantity of radioactive waste to be managed was based on the reactors in existence as of January 2002 in the participating countries. The operating reactors number 164 and those that have been shutdown number 50.

Radioactive waste is also produced by industrial, research and medical activities, but the majority of the radioactivity from these sources is short-lived, that is, it has a half-life of around thirty years or less.

Of the material that originates in nuclear power plants, the majority of the radioactivity is associated with the SNF, which may be stored or disposed of directly or can be reprocessed to recover the remaining plutonium and uranium. In either case, the heat generated by the radioactivity of the SNF or the high-level waste generated by reprocessing will initially result in a requirement for cooling for several dozen years before it can be placed in a long-term management facility such as a repository.

The total amount of SNF in the countries participating in the project that will have been discharged from the power plants when they have all come to the end of their operating lives is estimated to be a total of 170 000 tonnes of heavy metal. Whether this material is managed in the form of fuel elements or not depends on whether it is reprocessed. Some spent fuel from many of the participating countries has been reprocessed in the past but, currently, there are no reprocessing contracts in seven of the countries, Germany has announced a date for the end of reprocessing and in five other countries reprocessing is the subject of a government review. The quantity of SNF that is currently planned to be reprocessed is estimated to be 124 000 tonnes of heavy metal, leaving 47 000 tonnes to be managed in the form of complete fuel assemblies. The resulting total volume of conditioned vitrified high-level waste from reprocessing the SNF is about 8 000 m^3.

In most countries, the plutonium and uranium recovered by reprocessing is regarded as a resource. The recovery of both metals has been greater than the demand for their use and there are over 140 tonnes of plutonium in stock, mainly in France and the UK. Thus, a significant proportion of the plutonium and uranium that is currently in stock may have to be managed as waste in the future. In addition to reprocessing, depleted uranium is produced when enriched uranium fuel is manufactured. There are currently over 220 000 tonnes of depleted uranium in stock and this amount is expected to increase as a result of future fuel manufacturing.

The waste whose radioactivity is too low to require cooling consists of a mixture of long- and short-lived radionuclides. In some countries, long- and short-lived wastes are separated and are managed differently. For example, approximately 99% of the non-heat-generating waste that will be generated in France from decommissioning nuclear power plants will be short-lived and is expected to be placed in surface repositories, while the policy in Germany is deep geological disposal for all waste. In total, it is estimated that over one million cubic metres of waste generated in the participating countries will be treated as long-lived waste.

Partitioning and Transmutation (P&T) is a suggested option for reducing the long-lived radiotoxicity of wastes and although there has been considerable progress in its development over the past ten years, P&T remains a long-term venture. The introduction of P&T would require long lead times and large investments in dedicated fast neutron devices, the extension of reprocessing facilities, and facilities for fuel and target fabrication. P&T is therefore regarded as a technique that could be incorporated as a planned component of waste management in new nuclear fuel cycles for future power reactors, rather than a technique which can be applied to historical wastes. P&T would not eliminate, in the long-term, the need for deep disposal or some other form of isolation from the biosphere, since not all long-lived radionuclides in the waste can be eliminated. The countries with the leading programmes include France, Japan and the USA who have long-term plans for further investment in nuclear power.

3.2 Issues for strategy selection

There is a wide range of requirements that must be met in developing a strategy for the long-term management of SNF and long-lived waste. These include international treaties and, for those countries that are, or who will shortly become, members of the European Union, there are relevant European Commission Directives. The most important international convention in the present context is the Joint Convention on the Safety of Spent Fuel Management and Radioactive Waste Management (June 2001) [2]. This and other important conventions and the relevant European regulations are implemented through their incorporation into national laws and regulatory requirements. Other agreements and directives cover important aspects such as:

- Export and import of radioactive waste,
- Disposal at sea and other options and
- Safeguards.

There are also the requirements to achieve a high level of safety, a low impact on the environment as well as the need to address technical, economical and ethical issues.

The fundamental safety principles in relation to the management of spent nuclear fuel and radioactive waste are stipulated in the Joint Convention on the Safety of Spent Fuel Management and Radioactive Waste Management. It came into force in June 2001 and all the countries represented in the COMPAS project have ratified, accepted or approved the Joint Convention.

The EC Directive 85/337/EEC on Environmental Impact Assessment (EIA), amended by the Directive 97/11/EC, sets out the minimum requirements on EIA that have to be implemented by each EU Member State. A new EC Directive on Strategic Environmental Assessment 2001/42/EC, the deadline for the transposition of which into national legislation is 2004, requires a systematic environmental assessment of 'plans and programmes' and is thus likely to be required at the stage before site-specific proposals are made.

The heat generated by SNF and HLW is an important technical issue that affects the timing of when these can be placed in a repository. The practice is to have a period of interim storage to allow the material to cool to facilitate its handling. Interim storage also has the added advantage of allowing short-lived radionuclides to decay before disposal.

Any chosen waste management strategy has to be economically viable, and achieving a cost-effective solution is an important aspect of managing national liabilities and resources, but it must not preclude achieving an acceptable level of safety and an acceptable approach to the ethical issues. It is generally accepted that there is no single morally correct way to allocate scarce resources or burdens. However, a range of issues associated with the long-term management of radioactive materials generate concern amongst stakeholders. These involve the following important principles:

- Intergenerational equity,
- intragenerational equity,
- sustainable development and
- the precautionary principle.

3.3 Derivation of generic strategies

3.3.1 Approach

The ways in which the issues identified previously have led to the national strategies that have been selected and are being considered were identified within the project in terms of three decision trees. The decision trees addressed the selection of strategies for the following:

- The management of SNF,
- the management of long-lived low and intermediate waste (LL-LILW) and
- geological disposal.

As a result of addressing the issues summarised in the previous section by means of these decision trees, a number of generic strategies have been derived.

3.3.2 Decision trees

The decision trees contain a number of decision nodes. In this paper, two nodes from the SNF strategy selection tree (Fig. 1) have been selected for discussion. The nodes are Node 1: Reprocessing and Node 9: Long-term management options. These nodes respectively represent the greatest divergence in the short-term management of SNF and the most important decision for the long-term management strategy. The options given under Node 9 are applicable to all long-lived materials; namely SNF, HLW and LL-LILW.

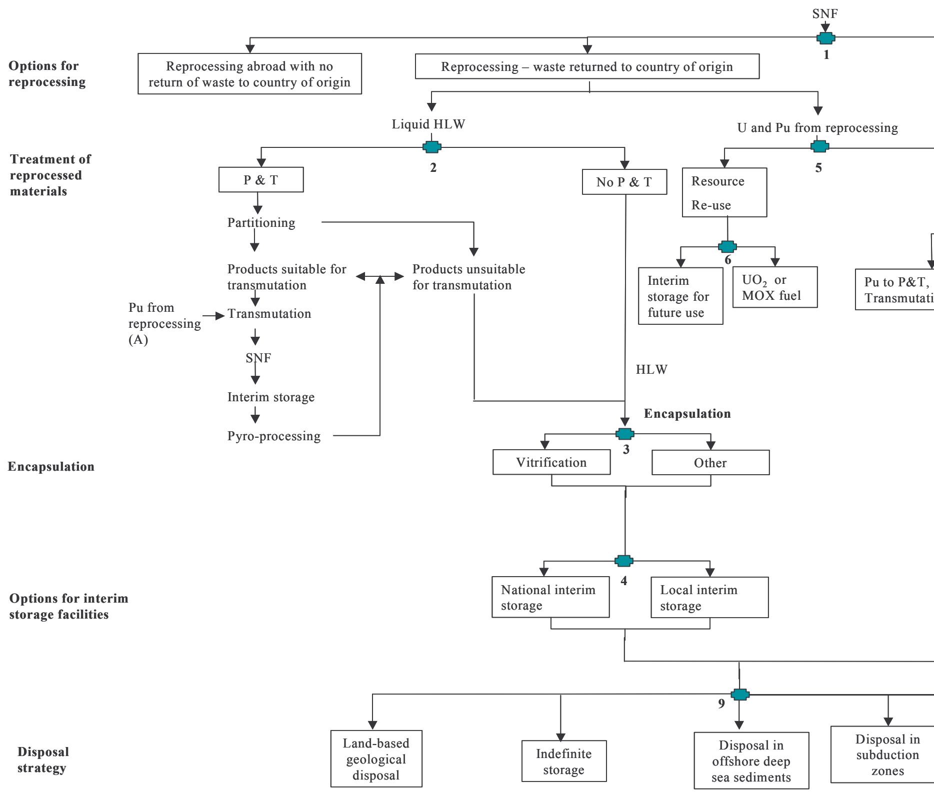

Figure 1 Decision tree for SNF strategy selection

3.3.2.1 The role of reprocessing (Figure 1, Node 1)

The main issues that affect the decision on whether or not to reprocess SNF are:

- maintaining a secure supply of nuclear fuel for energy production,
- safety and environmental considerations,
- the prospect of a future nuclear power programme that may include advanced nuclear fuel cycles,
- economics,
- safeguards,
- technical issues and
- military requirements.

After the end of the Second World War, most of the countries in Western Europe perceived the need to establish a secure supply of energy production and considered the closed nuclear fuel cycle as an essential element of this strategy. In addition, France, Germany and the UK saw additional security and economic advantages in a mixed programme of thermal and fast breeder reactors. Thus, Belgium, France, Germany, Italy, the Netherlands, Spain, Sweden and Switzerland established facilities or made arrangements for the spent nuclear fuel from their power reactors to be reprocessed. The Soviet Union also regarded the uranium and plutonium that would be recovered from SNF as a resource and, until the mid 1990s, the contracts that were signed with the utilities that operated VVER reactors in Bulgaria, Czechoslovakia, Finland, East Germany and Hungary required the fuel to be returned for reprocessing and for all the products of reprocessing to remain in the Soviet Union.

Now, however, the link between reprocessing and ensuring a secure supply of energy has largely disappeared. All the represented countries consider that they can currently obtain enough new uranium at reasonable prices to complete the present programme of commercial nuclear power stations. Germany and the UK are no longer proceeding with a programme of fast breeder reactors. Belgium, France, Germany, Sweden (a very small amount) and Switzerland are utilising MOX fuel in their commercial reactors but this is seen as an economically advantageous way of utilising the plutonium produced as a result of the existing reprocessing contracts rather than as a result of requiring the use of MOX to ensure a supply of fuel.

However, reprocessing would be a necessary component if new nuclear fuel cycles and P&T were adopted as components of a future nuclear programme.

In the early years of the civil nuclear power programmes in Western Europe, there was considerable uncertainty associated with the long-term safety of placing unprocessed SNF in a deep geological repository. Reprocessing, with the encapsulation of the HLW and the utilisation of the recovered plutonium and uranium was considered to produce a reduced waste volume with a reduced quantity of radiotoxic elements. Furthermore, the safe disposal of vitrified HLW was considered easier to achieve than the safe disposal of SNF. In the subsequent years, however, research into the direct disposal of SNF has considerably reduced the safety concerns and Finland and Sweden are well advanced in implementing the option of direct disposal.

Today, public opinion in some countries regards reprocessing as the less safe option because of concerns about the risks associated with transporting SNF and HLW. This is notably the case in Germany where concerns were also raised about safeguarding the produced plutonium. In addition, there is concern in Germany and Sweden about the radiological consequences of releasing radioactivity into the environment as a result of reprocessing. For similar reasons, the new Swiss Nuclear Energy Law imposes a 10-year moratorium on reprocessing of spent nuclear fuel, which will start in July 2006. Thus, in some countries, safety concerns are now seen as reasons for not reprocessing.

3.3.2.2 Long-term management options (Figure 1, Node 9)

The main issues that determine the long-term management option to be adopted are:

- safety of future generations,
- preservation of the environment,
- the precautionary principle,
- intergenerational equity and
- sustainability.

Economics has not influenced any country's overall strategy decision but instead influences decisions on timing, the number of facilities that should be constructed and design decisions.

The uncertainties or risks associated with some options, notably the disposal of SNF into outer space, disposal in ice sheets and disposal in subduction zones in ocean trenches are considered to be so great that all countries have discounted them. Although such options were previously discounted in the UK, a rigorous and public review, by the Government, of all options (except where they have been ruled out by international agreements), started in 2003.

The options of sea dumping and disposal in deep-sea sediments are politically and socially unacceptable in many countries and this has been reflected in international treaties such as the London Dumping and OSPAR conventions, so that the signatories are precluded from these options.

Thus, the long-term (i.e. greater than a few hundred years) options that are being considered are land-based geological disposal and indefinite storage and the option that is selected depends on the interpretation that is placed on the above principles and the evaluation of the safety associated with each option.

In Finland and Sweden, it has been concluded that the indefinite storage of SNF is not sustainable and therefore is not in accordance with the Joint Convention on the Safety of Spent Fuel Management. In order to fulfil safety requirements it relies on the continued action by future generations and therefore puts an undue burden on them. It has also being argued that safety and security in the case of indefinite storage is highly dependent on societal stability, which cannot be guaranteed. It also contravenes the principle of intergenerational equity because the generation that received the benefit from the fuel is not implementing a sustainable solution to its disposal. They are therefore implementing a strategy of selecting a site and constructing a land based facility for SNF disposal. The same general view is shared by Germany and Switzerland, and for the Netherlands, Spain and all the Applicant Countries, geological disposal is the preferred option although, in some of these countries, the option of prolonged storage for a few hundred years remains open. The Netherlands has decided to implement a strategy of prolonged storage for at least 100 years.

However, before a strategy of geological disposal can be pursued there must be an acceptance that the general strategy is adequately safe. Such acceptance has not yet been achieved for example in France. Similarly in the UK, the scientific justification and public acceptability of the disposal of radioactive wastes has been questioned. In these cases, further consultation is underway and a government decision should be made in 2006. A similar situation applies to Italy.

3.3.3 Generic strategies

The project identified a number of generic strategies for the management of SNF, vitrified HLW from reprocessing, other long-lived waste (LL-LILW) and for uranium tailings. In this paper, only SNF is addressed.

There are six possible generic strategies for the management of spent nuclear fuel that are being implemented or considered:

- No reprocessing of SNF
    - direct disposal of the spent fuel elements in a deep geological repository or,
    - indefinite storage of the SNF;
- Reprocessing of SNF
    - with deep geological disposal of the vitrified HLW or,
    - with the indefinite storage of the vitrified HLW;
- Partitioning and Transmutation
    - with deep geological disposal of the remaining waste or,
    - with the indefinite storage of the remaining waste.

The strategy of **direct disposal of SNF** in a deep geological repository is adopted in the Czech Republic, Finland, Germany (the only strategy for SNF arising after July 1, 2005), Romania, and Sweden. In Slovenia, deep geological disposal of SNF is the preferred strategy but no final decision has been made. In the UK, direct disposal in a deep geological repository is an option being considered for spent AGR and PWR fuel and also for research and prototype fuel. In Italy, direct disposal in a deep geological repository is an option for some spent PWR and BWR fuel. The strategy is also an option in France, Hungary, the Netherlands, Slovakia, Spain, and Switzerland for all types of SNF including that from research reactors.
In the Czech Republic, Hungary, Italy, Romania, Slovenia and Switzerland, the disposal of spent nuclear fuel in a national repository or in a multinational repository abroad are both future options. In the Netherlands the possibility of a regional repository is not excluded. In Slovakia, the disposal of spent nuclear fuel in a national repository or shipment of the spent fuel to Russia are both options. In Romania and Slovenia, shipment of spent fuel from research reactors back to the country of origin (USA) for disposal there has been carried out and is an option for existing fuel.

In Finland and the Netherlands retrievability is a precondition of the disposal concept. In Switzerland, retrievability is required for the observational phase of the repository. Similarly in Romania, a pre-closure period of approximately 100 years, during which time waste can be retrieved, is proposed and will be addressed in future regulations. In Sweden, a preliminary operation stage when about 10% of the spent fuel is deposited is planned; this stage will be followed by a thorough evaluation and the canisters shall be retrievable if for some reason direct disposal or the method of geological disposal is abandoned. In Italy, requirements on reversibility will be specified in a Technical Guide to be issued by the regulator shortly.

The **indefinite storage of SNF**, both from nuclear power plants and research reactors, is currently being considered as a possible option in the UK.

There are facilities for **SNF reprocessing** at La Hague in France, Sellafield in the UK and Mayak in Russia. In France, reprocessing of SNF is the current strategy and a future option. In the UK, currently SNF from the Magnox and AGR stations is reprocessed at Sellafield. In the case of Magnox fuel, reprocessing is seen as a necessary waste management strategy for dealing with otherwise unstable fuel or fuel assemblies, therefore direct disposal and long-term storage of unprocessed Magnox spent fuel are seen as not technically available. For spent AGR and PWR fuel, reprocessing is a future option.
The shipment of spent nuclear fuel for reprocessing abroad, at either Sellafield or La Hague, is a current strategy in Germany, the Netherlands, and Switzerland. In Germany this practice will be discontinued from 1st July 2005. Future reprocessing is an option in the Netherlands and the subject of current discussion in Switzerland. In Italy, currently all of the Magnox fuel and some of the PWR and BWR fuel has been sent to the UK for reprocessing; future reprocessing is an option for the remaining PWR and BWR fuel. In the Czech Republic, the option of reprocessing SNF abroad has not been excluded, but it is not economic at present.
The shipment of SNF to Russia for reprocessing used to be the practice in Bulgaria, Hungary, Slovakia and for the Loviisa plant in Finland. This practice ceased in the 1980s and 1990s. The shipment of SNF for reprocessing abroad is no longer an option in Finland. In Bulgaria, Hungary and Slovakia, the reprocessing of spent nuclear fuel in Russia, with or without waste return, is a future option and the subject of current debate.

Reprocessing with deep geological disposal of vitrified HLW is an option in the following countries: Bulgaria, France (reprocessing is the current strategy; a variation is to have 100 to 300 yr storage for HLW), Germany (reprocessing is one of the current strategies, but it is to stop by 1st July 2005), Hungary (reprocessing is an option with or without waste return), Slovakia (reprocessing is an option with or without waste return), Italy (reprocessing is the current strategy for Magnox fuel and is an option for PWR and BWR fuel), Netherlands (reprocessing is the current strategy with prolonged storage for at least 100 yrs), Switzerland (reprocessing is the current strategy, however, the new Nuclear Energy Law enforces a 10-year moratorium on reprocessing - starting July 2006), UK (reprocessing is the current strategy for Magnox fuel and some AGR fuel and a future option for PWR fuel and remaining AGR fuel).

Reprocessing and indefinite storage of HLW is an option for the UK.

Partitioning and transmutation (P&T) as a strategy for minor actinides and fission products is currently not available. It is actively researched in France, Italy, the Netherlands and Spain. In Bulgaria, the Czech Republic, Hungary, Sweden and the UK, research into P&T is being monitored and if proven technologies emerge, this may be a future option.

3.4 Key issues for the acceptance and implementation of strategies

The construction of a facility for the long-term management of spent nuclear fuel and long-lived radioactive waste is one stage of a multi-step process.

The process starts with the decision on the use of nuclear energy and other related issues, such as the use of reprocessing, since this defines the reference scenario for the volume of spent nuclear fuel and radioactive waste that has to be placed in a facility. At the next steps a decision has to be made on whether or not to proceed and, if the decision is not to proceed, the process must return to the previous step. If the facility incorporates the concept of retrievability, the management of the spent fuel and the waste may not end with its emplacement since there is the option for its retrieval for further processing before it is re-disposed or another option is employed.

In order to identify the issues that are important in gaining acceptance for a long-term waste management project, it is important to identify the stakeholders and the main decision-makers. Not all stakeholders will be decision-makers and will therefore need to have the opportunity to communicate the issues that concern them to the decision-makers.

Past experience has shown that there are five levels of decision makers who determine whether or not a long-term management option will be implemented. These levels are the national government, the regional government, special courts, the local municipality and the public. The decision-making role of members of the public depends on national arrangements.

Important aspects in obtaining the acceptance of any long-term radioactive waste management facility have been found to include:

- acceptance of the overall strategy,
- an appreciation of the nature of the waste and the associated risks,
- a recognition of both the need for a solution and the principle that the generation that has benefited from the activities that have produced the waste has a responsibility to ensure it is managed safely in the long-term,
- the facility should result in a net benefit to the local community when its advantages are compared with potential detriments.
- the responsibilities of all the parties: the waste producers, the operator, the regulator(s) and the local, regional and national authorities must be clear, known and recognised.
- decision-makers must have confidence that the regulator and regulatory process will ensure that risks to the present and future generations is/will be acceptably low.
- independent expert advisory groups can make an important contribution,
- similarities in approach internationally,
- a stepwise approach to the design of facilities, research and development, siting and the acceptance of facilities,
- funding must be available,
- a restriction on the waste that will be managed by the facility e.g. to the waste from existing facilities, can be a factor.

In this paper, only some of these issues are addressed further:

An important element in obtaining acceptance for a long-term waste management facility is an **appreciation** of the nature of the waste, the risks associated with its long-term management and the development of ways in which these risks can be reduced to an acceptably low level by the design and the licensing process. Local consultation groups have been shown to be a very effective means of developing local participation and the appreciation of the issues.
Nuclear host communities, where the waste is already stored or where waste is being produced, tend to be the communities that are most interested in the implementation of a permanent, safe solution. They have also a level of familiarity with the nuclear industry, a knowledge of the risks from radioactivity and how these are controlled, as well as an interest in the continued partnership with industry and government with a view to long-term community development.
In recent years, the majority of the underground investigations for siting deep geological repositories that have been accepted by local municipalities are located near existing nuclear facilities, and the only existing facility for the prolonged storage (100 years or greater) of waste is also near a nuclear facility.
Recognition by local municipalities and the electorate near candidate sites that a permanent facility(ies) for housing the waste must be constructed and that the generation that has benefited from the activities that have produced the waste has a responsibility to ensure that it is managed safely in the long-term is also an important issue. This was one of the factors that led to the acceptance of a repository at Olkiluoto both by the Finnish government, the parliament and the municipality of Eurajoki.

Evidence from the recent successful applications suggests that, after safety, the most important issue for the local community is that the facility should result in a **net benefit** when its advantages are compared with potential detriments. Some of the benefits that have been relevant in recent applications are:

- Enhancement/maintenance of the local economy;
- Enhancement of the local infrastructure;
- Direct financial benefits.

Among the potential detriments are:

- Loss of reputation, including aspects such as reduced house prices and harm to the local tourist industry;
- Loss of revenue from consumables.

An important issue is the trust that the decision-makers have in the **regulatory process**, which will include ensuring that the risks to present and future generations is/will be acceptably low. The regulator may also have a role in the site selection process. In some cases, the creation of independent expert groups, who are then consulted on aspects of the design and siting process is considered to make an important contribution towards gaining acceptance. An example is the Expert Group on Disposal Concepts for Radioactive Waste, EKRA, in Switzerland, whose views are broadly accepted. In the siting proposals of AkEnd in Germany, it is proposed that the process is continuously monitored by a Control Committee while an appointed Decision Maker supervises the procedure and decides when the process can move to the next step. Advisory groups are also used in countries that are revising or selecting their strategy. The respective roles of the various actors, as well as their behaviour, are also important. The responsibilities of not only the waste producers, the operator and the regulator(s), but also those of the local, departmental and national authorities, must be clear, known and recognised.

In addition to recognising and addressing the issues that have been summarised previously, the successful implementation of a long-term waste management strategy requires an open, transparent and staged process. Some of the basic requirements for the implementation of a specific long-term waste management strategy include:

- the existence of a legal framework,
- identifying the stakeholders that shall take part in the process and
- the definition of the stakeholders' role in the implementation process.

One of the important aspects of the implementation is that it must include a clear, phased decision-making process that:

- has been developed in consultation with all stakeholders;
- has clear decision points;
- explains how decisions will be taken and
- provides opportunities for the stakeholders to contribute meaningfully to the process.

A stepwise approach to developing and implementing waste management strategies is emerging, both in terms of selecting the waste management options and the siting process. The stepwise approach to implementation has been defined as a process that involves discrete and easily monitored steps, facilitates the traceability of decisions, allows feedback from the public and/or its representatives, and promotes the strengthening of public and political confidence in the safety of a facility, together with trust in the competence of the regulators and implementers of waste management projects. This approach ensures flexibility and the ability to reverse decisions that are subsequently considered to be unacceptable.

4 SUMMARY

There are many industrial, medical, research and military sources of radioactive waste but the main source of spent nuclear fuel and radioactive waste in the fifteen countries that participated in the COMPAS project are the civil nuclear power plants. Radioactive wastes are either produced directly as a result of operating and decommissioning the plants or as a result of reprocessing the spent nuclear fuel.

Some spent nuclear fuel from many of the participating countries has been reprocessed in the past but, currently, there are no reprocessing contracts in seven of the countries, Germany has announced a date for the end of reprocessing and, in four countries, it is the subject of a government review. There is an assumed date for the end of reprocessing at facilities in the UK.

In any scheme for the management of spent nuclear fuel and the high-level waste from reprocessing, a period of storage is required. Initially, a period of up to fifty years is necessary to allow cooling before it can be placed in a repository but, for economic, technical and social reasons, longer periods of storage for both heat generating and other long-lived wastes may be required before disposal is implemented. The policy in the Netherlands is to store radioactive waste for at least 100 years, and prolonged storage is being considered as an option in some other countries.

Partitioning and transmutation is currently not seen as a practical option for the management of the wastes that will arise from the fuel cycles of the existing operating reactors and those that have been shutdown for decommissioning. Its potential for future fuel cycles was not addressed.

The long-term management of spent fuel and long-lived radioactive waste requires addressing both scientific and social issues and research on both aspects is continuing in all of the participating countries.

Nearly all the countries that have participated in the project are pursuing land-based deep geological disposal as the preferred long-term management option for spent nuclear fuel (that is not consigned for reprocessing), high-level vitrified waste and long-lived radioactive waste. A range of positions are taken in these countries as to the probable timing of implementing a final disposal facility. The main basis for a strategy of land-based deep geological disposal is that the safety of a store for an indefinite period cannot be established and all the options that involve placing the waste away from landmasses are either prohibited by international conventions or the risks or uncertainties are considered to be too great. Only the UK is considering indefinite storage as part of a review of all long-term management options.

However, whereas the technical and scientific knowledge to support deep geological disposal is available in some countries and is being developed in others, the implementation of deep geological disposal has been opposed in many countries and there are different perceptions of the urgency for its implementation that depend on national policies and social, logistical and economic issues. The incorporation of the requirement for disposal in national legislation has been an important factor in the programme for implementation in those countries where it has proceeded. Implementation as soon as practicable is based on the principle that the generation that has benefited from the activities that produced the waste should fulfil its responsibilities for its management (intergenerational equity). However, in three of the participating countries, retrievability from deep geological repositories is a legal requirement. In a further seven of the countries, the option of retrievability is being considered and in some of these countries retrievability has already been incorporated into their disposal concept.

For economic and practical reasons, the possibility of utilising a multinational repository is being considered by some of the participating countries that have relatively small amounts of radioactive waste.

In recent years, the majority of the underground investigations for siting deep geological repositories that have been accepted by local municipalities are located near existing nuclear facilities, and the only facility for the prolonged storage (100 years or greater) of waste is also near a nuclear facility.

Experience has shown that four of the important aspects of gaining acceptance for a disposal facility are:
a) an open, inclusive and transparent process (including dialogue between the scientific community, politicians and members of the public),
b) a stepwise process where each stage is assessed and agreed before the next is started,
c) well-defined roles for all the participants in the process and
d) ensuring that the host community has distinct benefits from hosting the disposal facility, which outweigh any potential adverse economic and environmental effects on the area in which the facility is situated.

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