REGIONAL SPENT FUEL STORAGE FACILITY (RSFSF)

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Abstract

The paper gives an overview of the meetings held on the technology and safety aspects of regional spent fuel storage facilities. The questions of technique, economy and key public and political issues will be covered as well as the aspects to be considered for implementation of a regional facility.

1. INTRODUCTION

Spent fuel storage is a common problem in all countries with nuclear reactors. Whatever strategy is selected for the back-end of the nuclear fuel cycle, the storage and transport of spent fuel will be important services. As of today about 130,000 tHM of the 200,000 tHM spent fuel arisings from power reactors are stored world-wide. About 70,000 tHM were reprocessed so far. From research reactors more than 62,000 fuel assemblies are stored world-wide .Final disposal facilities for spent fuel and high level waste are not available and are not expected to be implemented in the near future.

Safe management of spent fuel from power and research reactors involves the technology, resources and licensing procedures, so that the exposure to ionizing radiation of the operational personnel and the general public is controlled, and the environment is protected in accordance with national regulations and international consensus.

Most countries with power reactors are developing their own national strategy for spent fuel management, including interim storage. However, several countries with a small nuclear power programme or only research reactors, face the serious problem of extended interim storage and disposal of their spent nuclear fuel. The high specific costs for the construction of away-from-reactor extended interim storage facilities and/or geological repositories for the relatively small amounts of spent fuel accumulated in such countries, is obviously not reasonable and, therefore, from an economical point of view, access to a regional interim storage facility and/or repository for their fuel would be an ideal solution.

It is interesting to note that *de facto* Regional Spent Fuel Storage Facilities (RSFSFs) exist in several countries. The word "regional" is used in the broad sense of the word that is understood as a multinational Spent Fuel Storage Facility (SFSF) covering more than one country. However, there are certain advantages associated with the co-operation among different countries in the same geographical region.

In Western Europe, commercial considerations provided the incentive for the development of spent power reactor fuel management systems. Eurochemic was one of the most significant early projects for a multinational arrangement. COGEMA and UKAEA-BNFL are effective involved in interim storage of spent power reactor fuel from a number of countries, while awaiting reprocessing. In the former USSR, arrangements seem to have been largely politically motivated. The service offered by the USSR was mainly centred around their own national interest, such as the fuel leasing arrangements concluded with the former East Block countries. The arrangements continued until 1990 and were de facto suspended by legislation. Meanwhile, new arrangements are under investigation.

Research reactor fuel from all over the world is at present stored in wet interim storage pools at the Receiving Basin for Off-Site Fuels (RBOF) facility at DOE's Savannah River Site. Proliferation

concerns weighed heavily in this case. Some research reactor fuel is stored at Dounray, Scotland, waiting for its reprocessing.

The safety and economic benefits from the implementation of regional spent fuel storage facilities are very attractive in terms of reduction of the number of spent fuel storage facilities world-wide, enhanced economy due to the scale of storage construction, and easier safeguarding to ensure non-proliferation. However, there are still various problems to solve as to find operators of such facilities with governmental support and to convince countries of proliferation concern to participate. The time is ripe for serious discussion of such regional facilities and to begin planning for the day when neither take-back programmes nor the reprocessing option might be available.

The IAEA has made a start by convening two meetings of experts to collect and evaluate information on a regional spent fuel storage facility. The first one was held in December 1997, the second one from 28 September to 1 October 1998.

The main objective of the meetings was to discuss the different technologies and safety aspects of regional spent fuel storage facilities for power and research reactor fuel, requirements regarding logistics, geology and climate, the question of the final destination of the spent fuel, the linkage of regional storage to regional disposal, economic and legal questions of regional storage (profit center or cost sharing), and public and political issues that would influence the location and acceptance of a regional spent fuel storage facility.

It is recommended that the following specific regional issues be considered, i.e. the lack of research reactor fuel take back arrangements of Russian origin fuel and the lack of spent fuel storage facilities required for research reactor decommissioning.

2. THE REGIONAL SPENT FUEL STORAGE CONCEPT

In order to make regional storage attractive to prospective customers, the hosting country may also offer other services in additional to storage, as shown in Figure 1. The spent fuel management options catered for in this regional spent fuel management system are as follows (Fig. 1):

In the case where material is returned to the customer (**Option 1**):

- Spent fuel;
- High level waste (HLW) after reprocessing.

In the case where material is not returned to the customer:

- Ongoing storage of spent fuel and/or HLW (**Option 2**);
- Disposal of spent fuel and/or HLW **(Option 3)**.

Option 1

A hosting country that wishes to embark on a regional storage project should decide in advance what the final destination of the spent fuel would be. That is, whether the spent fuel is to be returned to the country of origin at the end of the storage period, or whether the material is to be disposed of in the hosting country.

Option 2

Another approach is to store the spent fuel on an ongoing basis without making provision for final disposal. The ongoing storage option may require repackaging of the stored materials during the long-term storage period envisaged.

Option 3

At the end of the interim storage period the spent fuel can be disposed of in a *final* disposal facility.

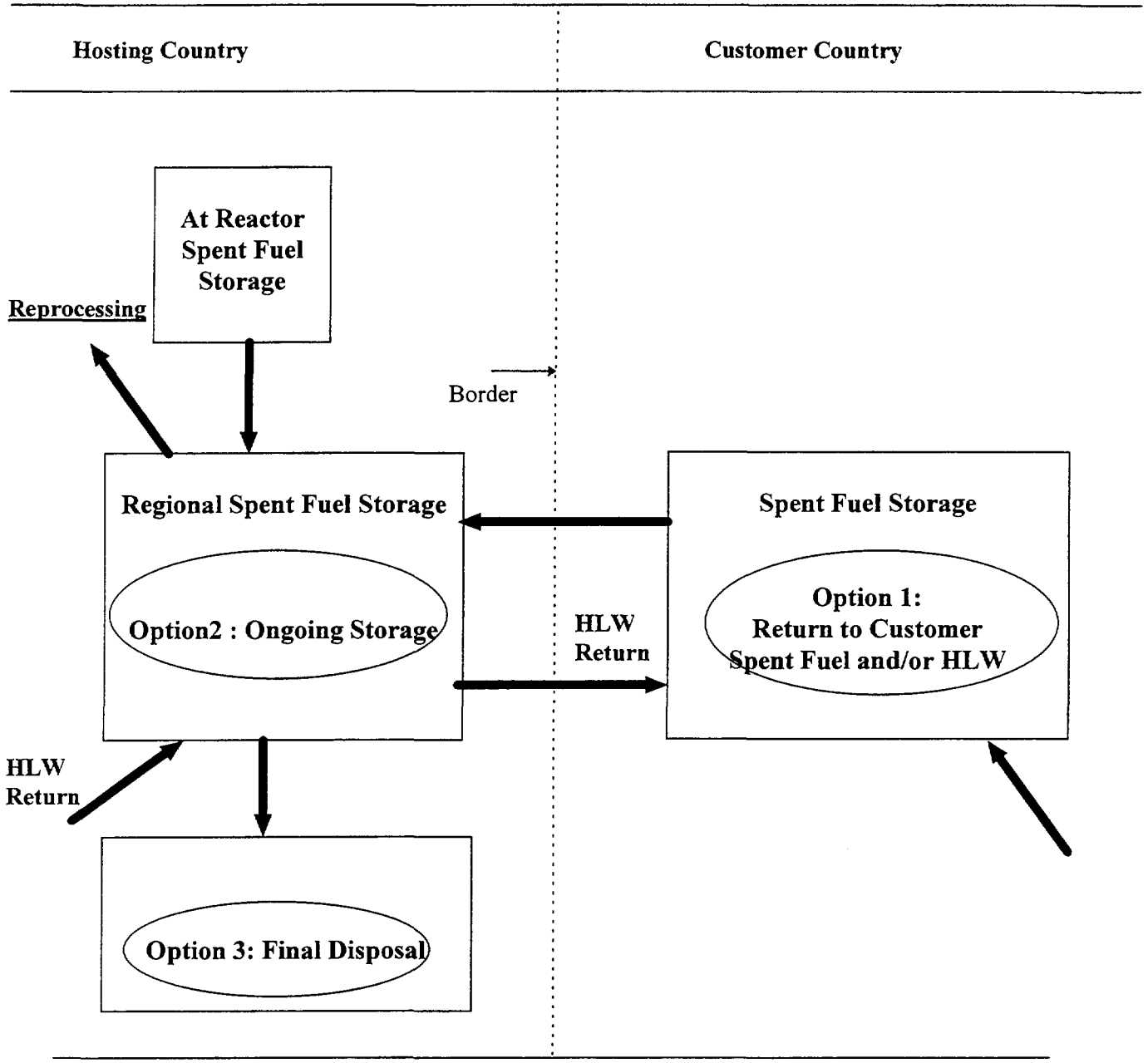

FIG. 1. Example of a typical regional spent fuel management

3. FEASIBILITY OF RSFSF

3.1. Technical feasibility

3.1.1. Spent fuel inventory

Spent fuel is located in all countries with nuclear power plants (NPPs). As of today 130,000 tHM of the 200,000 tHM spent fuel arisings from power reactors and more than 62,000 fuel assemblies from research reactors are stored world-wide. Up to 2010, the amount of stored spent fuel will raise to 225,000 tHM. The situation and its development can be seen in Fig. 2.

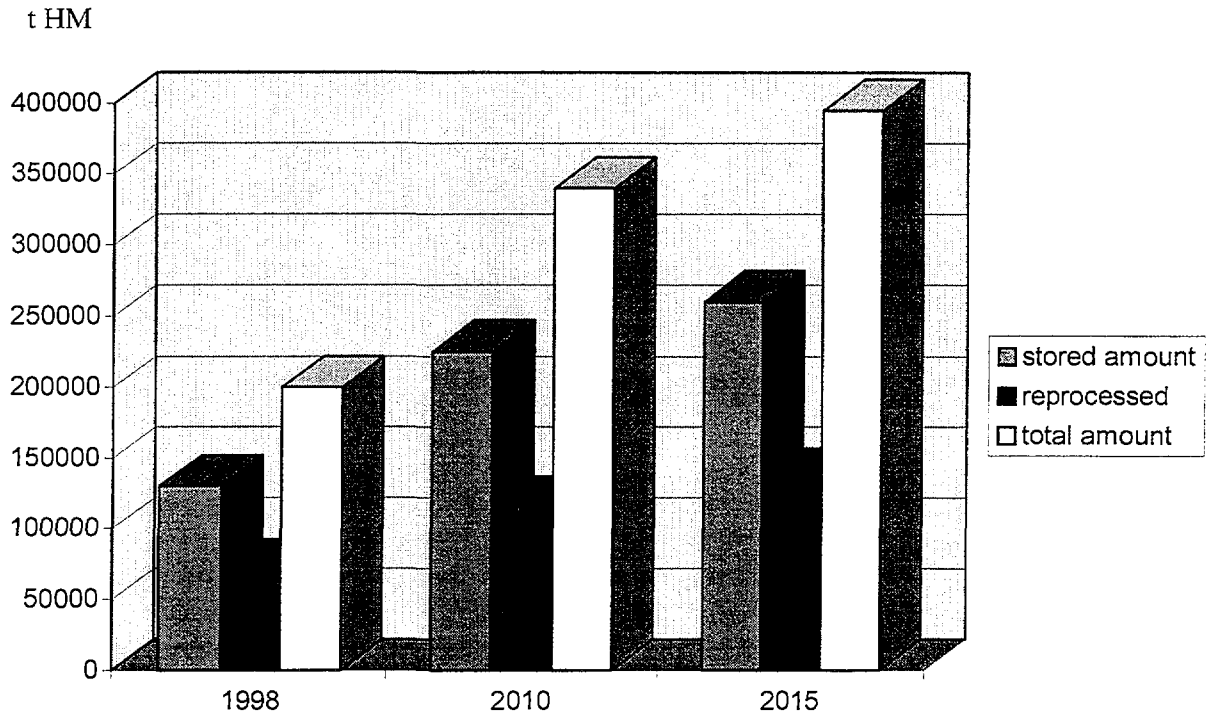

FIG. 2. Stored, reprocessed and total spent fuel arisings

3.1.2. Storage technology

In principle two different technologies can be considered: wet or dry storage facilities. Both technologies are proven.

Wet storage

Wet storage pools are common at a NPPs and at reprocessing plants, but exist also as stand alone facility. A general advantage of wet storage systems is the fact that stored fuel can be easily retrieved, controlled and checked. In the storage pools, a relatively large quantity of spent fuel can be stored at the same time. A general disadvantage of a wet storage system, is the need for active systems for cooling and cleaning the water, as well as for operator supervision and support systems. Cooling may only be disrupted for a short time span of several days. From cleaning the pool, secondary waste will be produced constantly.

Dry storage

Dry storage is used successfully in several countries for centralised intermediate storage, especially using metal casks and concrete silos. A general advantage of dry storage is the ease of implementation in the case where casks are used. Dry storage is easy to operate, as little or no active systems are needed. Dry storage can accommodate spent fuel as well as vitrified waste. The capacity can be easily adapted to the needs. Dry storage facilities usually have a high degree of safety, even against rare events such as an air crash.

Additional technical aspects

For handling of fuel to conditioning, repackaging, sealing and any treatment in connection with incidents and accidents, it is advisable to have a service unit (hot cell etc.) within the storage facility.

Recommendation for a regional storage technology

Dry storage systems are preferred for a regional solution for the following main reasons:

- no active systems;
- low maintenance;
- easy to operate and to adapt to the needs.

- open for all kind of fuel
- less secondary waste
- simplicity of accident prevention.

Further studies are required, however, concerning the economy of the chosen technology, taking into account the same level of safety and radiation protection.

3.1.3. Fuel acceptance criteria

All types of fuel should be accepted in the RSFSF, i.e. spent fuel from power reactors, research rectors and residues from reprocessing as e.g. vitrified high level waste. All types of power reactors should be addressed such as PWR, BWR, RBMK, WWER, HTGR, CANDU. Fuel from research reactors are more divers and care must be taken esp. to fuel leakage due to corrosion. Generally, there should be an acceptance also for leaky fuel elements. The acceptance criteria should be easy to fulfil by a potential customer as the attractiveness must be high.

3.1.4. Long-term stability of systems and stored fuel

The exact duration of the intermediate storage is not fixed yet as this will be done in the licensing process and in the commercial arrangements between service provider and customer. It can be imagined, that besides a straight forward storage of less than 50 years (e.g. several European storage facilities are licensed for 40 a), there might be the need for ongoing storage over an even longer period. Due care should be given to the long term stability of all its components and especially those components which are safety related including the fuel itself. The fuel can develop cracks, due to high burn up brittle fraction could occur. Especially research reactor elements can have corrosion pits from their pool storage period. The possible effects should be foreseen in the safety concept of the whole facility and addressed.

3.1.5. Conditioning of stored fuel

Preparation before storage

The preconditions for the fuel to be accepted by the RSFSF should be minimal. The way of fuel pre-preparation may be subject of special arrangement between customer and storage facility. The drying and He-filling of storage casks are such measures, which are useful to avoid corrosion.

Repackaging, consolidation and retrievability

It is very useful if not necessary to have facilities on the RSFSF site, which enable a repackaging of fuel or at least of storage units. This will give flexibility in handling incidents or accidents under due radiation protection. A special kind of repackaging is consolidation. This will save space for storage and thus be cost-saving. Intermediate storage means per se also having the possibility to retrieve the stored fuel at a certain time, e.g. to reprocess it. The retrievability is given normally with both systems, wet and dry.

3.1.6. Siting

General remarks

All site-related factors likely to affect the safety of the facility have to be evaluated. On the other hand, all impacts of the facility to members of the public and the environment also have to be addressed. Finding a suitable place for a RSFS is not very problematic from technical point of view.

Geology and climate

The geologic and climatic conditions in the host country will be very specific, so no general recommendations can be made. However, if possible, the most favourable site with the lowest geological and climatic influence should be chosen.

3.1.7. Safety

Safety criteria and standards

The RSFS shall have an internationally accepted safety standard. For that reason it shall be in accordance at least with the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management and the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. There are basically four safety objectives to achieve at any time during the whole storage period:

- safe enclosure of radioactive material;
- shielding;
- under-criticality;
- safe removal of residual heat.

The technology and the design should be aimed at optimising the radiological impact according to the ALARA principle.

Safety assessment

Before construction of the RSFS a systematic safety assessment should be carried out. It has to cover the whole lifetime of the facility with due care for the safe enclosure of the fuel over that time.

Accident and incident analysis

A very important part of the safety analysis is the accident and incident analysis. The safety objective is, that even in case of accidents or incidents there is no inadequate situation for people and environment.

3.1.8. Licensing

The RSFS has to be licensed according to national regulation of the host country. To make sure, that this licensing procedure leads to a high safety standard of the RSFSF, the host country should have experience in that field or, if not, co-operate with a customer country for that reason.

3.1.9. Infrastructure aspects

Transport

Transportation is the major logistic item for a storage facility. It can be assumed, that all transport goes on according to the IAEA Regulations for the Safe Transport of Radioactive Material. Transport is generally safe and reliable. No major transport accident was observed with spent fuel in the past. For convenience of handling it is strongly recommended, that the RSFS can be arrived by rail. Normally transport casks are heavy (about 80 - 120 tons), and this poses no problem for transport by rail.

Linkage to final disposal

The intermediate storage is connected with the question of what happens to the fuel after it. One of the possible options is final disposal. The basic element of linkage to a final repository will be the possibility of conditioning the fuel, whether on the spot of the RSFSF or elsewhere.

3.1.10. Safeguards and physical protection

The advantage of a few regional facility in comparison to many facilities in different countries is obvious: the safeguards control would be easier. There is no doubt that from a technical point of view appropriate measures can be taken at any potential site for a RSFS. The only (legal) precondition is, that the host country has signed the Convention on Physical Protection and the Treaty on Non-proliferation. This is preferable for customer countries too.

3.1.11. Research & Development

The storage periods envisaged by the RSFSF concept are in the order of magnitude 50 - 100 a or even longer. It is very important to evaluate the behaviour not only of spent fuel but also of components essential for safety of the facility for such long periods. There is proven evidence that storage over approximately 50 years can safely be done and several national licences have been granted for that period. Considerable information has been collected on fuel behaviour esp. during wet storage and to a smaller extent for dry storage too in the IAEA BEFAST-programme, which started in 1981 and was finished in 1996 (see TECDOC-944). There are still ongoing IAEA activities within the SPAR programme (Spent Fuel Performance Assessment and Research). However, it seems to be still a need for information especially on long term effects with high burn-up (60 - 75 GW·d/tHM) and also for new cladding material specially designed for high burn-up.

3.2. Economic feasibility

3.2.1. General remarks

There generally exists a need to reduce the cost of nuclear power generation. This objective can be achieved in a big part of utilities or countries, by closing the back end of nuclear fuel cycle in a cost effective manner. Basically exist three options of nuclear fuel cycle:

- direct disposal {once through};
- reprocessing {closed cycle};
- deferral of the decision.

In any case, spent fuel has to be temporarily stored for a limited period, depended on the chosen option. In determining whether to establish a regional SFSF, the cost and liabilities to all affected partners must be weighted against the benefits. The economic considerations would normally be the driving force for a regional solution.

3.2.2. Scope of service

The scope of service offered by the provider to the potential customer is interim storage, on the terms agreed between the customer and the service provider. In addition to the interim storage service offered, the service provider can offer other services, i.e.:

- repacking and consolidation;
- reprocessing ,
- final disposal.

3.2.3. Storage system, location vs. cost of service

The cost of interim storage services will depend on the cost of systems used for interim storage facility. Cost of the facility is deeply depending on the technical solution, and licensing procedure of the facility, however safety standards must never be compromised. In any case, storage system including storage location must go through optimisation based on the cost benefit analysis.

3.2.4. Liabilities, transfer of the title, financing sources and conditions.

Transfer of the title of spent fuel could take place:

- when the fuel is physically transferred, in which case the service provider accept full responsibility;
- at some future date, depending on the contractual arrangements.

Financial provisions for future liabilities of the host country have to be seriously considered in the process of establishing a regional storage facility. A very useful way is collecting financial sources through a fund, specially created and offered to the spent fuel storage and associated purposes.

3.3. Institutional feasibility

3.3.1. Organisations

Regional approach to the storage of spent fuel would require the involvement of relevant institutions. On a national level governmental and regulatory bodies as well as spent fuel producers and operators will take part in a process. On an international level institutions like IAEA, OECD/NEA, EURATOM, etc. may be involved.

3.3.2. Legal aspect

Safety, safeguard and licensing

For a regional spent fuel storage primarily, the laws and regulations of a host country will apply. Therefore, it is important that the hosting country has well established national legal framework and mature regulatory system. Internationally recognised safety principles, standards and practices should be applied. Regulations of host and customers countries should conform to relevant international conventions and treaties.Spent fuel and high level waste stored in a regional spent fuel storage is subject to international safeguards regulations. For safeguard control and inspections the relevant international organisations like IAEA or EURATOM are applied. For licensing, the laws and regulations of the hosting country will apply. It is advisable that the licensing system is well defined and transparent.

Ownership of spent fuel

There are three options regarding the ownership of spent fuel stored in such a facility:

- the ownership of fuel remains with the customer; after the storage period expires the fuel is returned to the owner;
- transfer of ownership to the host country is delayed and can take place at some later time, depending on contractual arrangements;
- ownership of fuel is immediately transferred to the host country; no return of fuel is foreseen.

If the take back of fuel is agreed among the parties the contract between the host and the customer country requires strong commitments on both sides. In such a case an international assurance that the agreements will be respected may be required.

Liability

Closely related to the ownership of spent fuel are future liabilities of the host and customers' countries. In case the ownership of spent fuel stays with the customer's country the liabilities of the host country can be covered by adequate financial provisions and agreements among partners. Storage fees should cover all expenses for storing, for unforeseen future events (i.e. future repackaging) and damages. When the transfer of ownership to the host country is included in the arrangement the service provider takes the full responsibility for the fuel. The liabilities of the host country include also future disposal of spent fuel. Such long-term responsibilities would definitely include the state of the hosting country regardless if the regional storage operator is private enterprise.

3.4. Ethical feasibility

The ethics of regional spent fuel storage depends to a large extent on the conditions under which the *storage burden* is shifted from individual customer countries to a single hosting country. These conditions determine whether or not the regional solution would be ethically justified. In order to treat the ethical issues systematically, two different approaches are used. The first approach is to consider the present generation's *obligations* both to itself and to future generations. The second approach is to weigh up the *consequences* of this generation's actions both with regard to itself and to future generations.

The IAEA Safety Fundamentals (Reference) incorporate, to a large extent, the obligations that apply to spent fuel management in general:

- *Human health* and the *environment* must be protected.;
- *Future generations* must not be unduly burdened as a result of the establishment of a regional spent fuel storage system in any particular country;
- *Third party* countries, which do not directly participate in the regional spent fuel storage arrangement, but which form part of the same region, must not be unduly burdened by this project;
- *Equity or balance* must apply among the participating countries.

3.5. Political feasibility

The political issue is clearly of considerable importance in the regional spent fuel storage concept. The state in the hosting country needs to put its blessing on the entire enterprise before it could be implemented. In the first place, when addressing the issues, it is important to keep in mind the *typical* perceptions of nuclear power that exist on the part of the public at large and politicians in particular. The spent fuel issue cannot be divorced from the nuclear issue. In some cases opposition to nuclear power is reflected in those areas where the industry is *perceived* to be most vulnerable, such as in the case of nuclear waste management.

What is usually uppermost in the mind of the public and therefore also of politicians in general is the *safety* of nuclear facilities. When dealing with the safety issue, it should be remembered that the public does not always appreciate the difference between the different types of nuclear installations.

Of great importance in promoting the regional concept at the political level, is to stress the *advantages* of the concept. It is uncertain which benefits would weigh most heavily with politicians: that is, enhanced safety, non-proliferation or commercial considerations. The weight of the benefit would clearly depend on the policies of individual countries.

The chances of successful implementation of the concept would be greatly enhanced in the case where there already exists a strong *bond* between the prospective participants to the regional project. Such a bond could for instance be a strong economic tie between countries falling in the same geographical area. The European Union is a good example of such a bond.

It is of course likely that the strongest opposition would emerge from within the political circles of the hosting country. Of considerable interest is where the initiative for the whole enterprise comes from. Namely, whether it comes from a private entrepreneur or from the institutional side within the hosting country.

4. BENEFITS AND RISKS

The benefits related to RSFSF cover almost all the aspects of the projects. Nonetheless there are some challenges and implications that must be faced in developing the project. These challenges should be known from the beginning or at least predictable.

4.1. Benefits

The techniques to implement a SFSF can be considered proven technologies. However, as the conceptual design of the systems used differs one from the others, some advantages can come from sharing the experiences done so far by means of pool of experts. Furthermore it is reasonably accepted that the limitation of storage sites lowers radiological risks associated with nuclear waste as well as environmental impacts.

The economic benefits are foreseen for hosting country as well as for the customer countries, because of the economy of scale. The host country, is expected to have economic advantages, in terms of funds from customer countries and/or profit on the operation of the facility. Important economic benefits to the local community of host country are expected too (employment, local infrastructure, economic incentives). The customer countries can have advantages in terms of unit cost of spent fuel stored.

The development of an international framework for the implementation of a regional spent fuel storage may have an important reflection for future regional disposal initiative (testing of international treaties feasibility, development of international framework for future co-operation, etc.). The existence of an international framework and treaties signed by the countries joining RSFS assures the transparency of back-end fuel cycle and limits therefore the possibility for nuclear proliferation.

4.2. Risks

The economic risks for hosting and customer countries could be:

- hosting country may fail in recovering its investment if customers leave the group in the development phase of the project or they don't provide the flux of spent fuels foreseen, making the unit cost of storage rises;
- customer countries may lose their investment if the host country fails in gaining the licence for constructing and operating the facility.

The stability of institutions and legal framework, could not be maintained in a long-term period, being the life period of SFSF much longer than life that many institutions, especially at international level, have been experienced so far. Public acceptance is crucially important and it could be the weak point in the process of project development. Furthermore the effectiveness of international treaties could be compromised by modifications in political relations among partners (host, customers and third parties) as well as changes in national borders.

5. IMPLEMENTATION

There are basically two ways in which a regional spent fuel storage service can be initiated. In the first place it can be initiated as an entirely private enterprise. In the second place it can be launched on the basis of a public or government undertaking with or without private participation.

5.1. Free enterprise approach

In the case of a free enterprise approach, it is assumed that a private spent fuel storage *service provider* in the hosting country decides for purely commercial reasons to provide a regional storage service to interested customers. That is, the service provider should stipulate whether or nor he is prepared to accept *ownership* of the spent fuel delivered to the regional storage facility. As a private company, the service provider cannot be expected to ensure long-term repository or even ongoing storage control. Therefore, in the final instance it is unavoidable for the state in the hosting country to assume such a long-term responsibility.

5.2. Institutional approach

On the basis of the above-mentioned difficulties associated with the long-term storage or final disposal of spent fuel, it is most likely for the state of the hosting country to initiate the regional storage project. The incentive for such a hosting country could be commercial, but would rather tend to be based on non-proliferation and safety considerations. In this case, the state of the hosting country may appoint a private operator to take charge of the storage operation, whilst the state assumes liability for all transactions concluded with prospective customers. Where the hosting country takes institutional responsibility as mentioned above, the hosting state would automatically assume the long-term obligations that a purely private service provider would not be able to

undertake. That is, the state would accept title of the spent fuel with a view to ongoing storage or final disposal in the hosting country.

6. RECOMMENDATIONS

The experts recognised the large benefits of regional spent fuel storage analysed in terms of the technical, economical, institutional and ethical/socio-political aspects involved and recommended to stimulate the debate on regional spent fuel storage and other steps in the spent fuel management process. IAEA should invite Member States to investigate the possibility of regional solutions to spent fuel problems within the global context.

Spent fuel storage as such is a well established and proven technology. Concluded that there are potentially a number of countries that could fulfil the site criteria for hosting a regional spent fuel storage facility, the discussion among Member States with regard to the implementation of such a regional solution should be encouraged.

The experts recognised that the political and public relations issues involved in regional spent fuel storage might present difficulties. There are still several issues that need to be discussed further, notably the institutional and socio-political questions. Any solution set up to expedite a regional storage project should facilitate transparency and the Agency should stress the benefits of safeguards application and the pursuance of non-proliferation objectives within a regional context. IAEA should undertake an analysis of the global spent fuel situation in order to assist with the identification of potential regional focal points. The institutional responsibilities for regional storage over extended periods need to be analysed by both the hosting and the customer countries.

7. CONCLUSIONS

It appeared from the preceding discussions that the regional spent fuel storage concept is entirely feasible, in principle. However, one should be aware of the many political and public acceptance issues that may arise in opposition to a regional concept. Never the less, there are many benefits in a regional solution like the obvious economies of scale achievable with regional spent fuel storage facilities. It is also clear that storing spent fuel in a few safe, reliable and secure facilities will facilitate safeguards and physical security and reduce the risk of proliferation, especially for highly enriched uranium fuel from research and test reactors.

ACKNOWLEDGEMENT

The IAEA wishes to thank the participants of the consultancy on regional spent fuel storage, Messrs. P. Bredell, South Africa, L. D'Andrea, Italy, B. Lorenz, Germany, Y. Kmosena, Slovakia, and Ms. I. Mele, Slovenia, for their fruitful contributions to this paper.

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