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Technical, economic and institutional aspects of regional spent fuel storage facilities

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FOREWORD

Spent fuel from nuclear power reactors requires safe, secure, environmentally sound and efficient management. It is a certainty that with the number of power plants planned to be used, spent fuel will continue to accrue. Appropriate management of increasing spent fuel arisings is thus a key issue for the steady and sustainable growth of nuclear energy. More than four hundred nuclear power reactors are in operation today and have already accumulated a large amount of spent fuel stored either at or away from the reactor sites.

With the lack of operational spent fuel and high level waste repositories, and a majority of Member States still to decide about the ultimate destination for spent fuel arisings, "long term storage is becoming a progressive reality" as was concluded at a recent IAEA Conference on Storage of Spent Fuel from Power Reactors. Consequently, in many countries with nuclear power plants, the major current issue in the area of spent fuel management is the need to expand existing capacities at reactor sites or to provide additional storage space to accommodate upcoming spent fuel arisings. Member States have referred to storage periods of 100 years and even beyond, and as storage periods extend, new challenges arise in the institutional as well as technical area. From the institutional point of view, there are challenges in the management of liabilities and knowledge, experience and information over longer time spans and several generations. Technical challenges include the longevity of spent fuel packages and behaviour of structural materials of storage facilities. Conversely, several Member States are considering taking nuclear power plants out of service in the very near future. Consequently, spent fuel storage facilities on reactor sites would need to be decommissioned in several of these cases.

Considering the limited capacity of at-reactor (AR) storage, various technologies are being developed for increasing storage capacities. At present, many countries are operating away-from-reactor (AFR) storage, in the form of pool storage or as dry storage, and additional storage capacity is under construction, mainly of the dry type. The dry storage technologies being developed are varied and include vaults, horizontal concrete modules, concrete casks, concrete silos and metal casks.

A particular challenge faces several countries with a small nuclear power programme or only research reactors in their efforts to arrange for extended interim storage and then disposal of their spent nuclear fuel. The costs and complications of providing for away-from-reactor storage facilities and/or geological repositories for the relatively small amounts of spent fuel may be prohibitively high, motivating interest in regional solutions. Regional cooperation and approaches are seen to provide attractive and challenging prospects for Member States, for instance from the economic, safety, environmental and security points of view. The preparation of this document was recommended by the members of the IAEA's former Regular Advisory Group on Spent Fuel Management. As a consequence, a series of Technical Committee Meetings was organized by P. Dyck of the Division of Nuclear Fuel Cycle and Waste Technology. The objective of the meetings was to review and discuss the different technologies and safety aspects of regional spent fuel storage facilities for research and power reactor fuel, the preparation of fuel for transport and storage, the acceptance criteria for the reception of the fuel assemblies and the expected storage time. In addition, participants discussed environmental, institutional, and ethical issues as well as the political feasibility and the overall benefits and risks of implementing a regional facility. In parallel to the study of regional storage concepts, the IAEA also organized a study on multinational repositories and the results of this study were published in late 2004.

The IAEA officer responsible for this publication was W. Danker of the Division of Nuclear Fuel Cycle and Waste Technology.

EDITORIAL NOTE

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1. INTRODUCTION

Spent fuel storage is a common issue in all countries with nuclear reactors. Whatever strategy is selected for the back-end of the nuclear fuel cycle, the storage of spent fuel will be an imminent and vital component. Worldwide, the spent fuel generation rate, now at about 10 500 t HM/year, is expected to increase to about 11 500 t HM/year by 2010. Since less than one third of the fuel inventory is being reprocessed, about 8000 t HM/year on average will need to be placed into interim storage facilities. At the beginning of 2003, about 171 000 t HM of spent fuel were stored in storage facilities of various types. The total amount of spent fuel cumulatively generated worldwide by the beginning of 2003 was close to 255 000 t HM. Projections indicate that the cumulative amount generated by the year 2010 may be close to 340 000 t HM. By the year 2020, the time when most of the presently operated nuclear power reactors will be close to the end of their initially licensed operational life time, the total quantity of spent fuel generated will be approximately 445 000 t HM [1]. Storage of spent fuel will cover longer periods of time than originally expected. The usual design life of such facilities is in the range of 40 years, but storage up to 100 years and even beyond is now under discussion [1, 2].

The IAEA has addressed the issue of safe spent fuel management specifically by means of the Joint Convention on Spent Fuel and Radioactive Waste Management [3]. The main objectives of this Convention are to achieve and maintain a high level of safety worldwide, to ensure that there are effective defences against potential hazards, to prevent accidents with radiological consequences, and to mitigate those consequences if they should occur during any stage of spent fuel management. Whereas transport is not the specific objective of the Joint Convention "transboundary movements" are addressed with respect to States of origin of the material, State of destination and transit States. The safe international movement of nuclear material and the rights of third States, not necessarily transit States, are of particular concern to IAEA Member States and accordingly have been addressed in General Conference Resolutions.

After the terrorist attacks of 11 September 2001, it was recognized that the terrorist threat has to be further investigated with respect to international transport of radioactive material and to the security of fuel cycle facilities, including spent fuel storage facilities. These heightened security concerns were pointed out on several occasions by the Director General of the IAEA [4] who established an international Expert Group to report on multinational approaches (MNA) that might be used to reduce the threat. This MNA Group reported its findings in early 2005 [5]. Most countries with power reactors are developing their own national strategy for spent fuel management, including interim storage. However, several countries that have small nuclear power programmes or only research reactors, and hence no possibility for early disposal, face the challenge of arranging extended interim storage of their spent nuclear fuel. The high cost for interim storage facilities for small amounts of spent fuel accumulated in such countries implies that, from an economical point of view, access to a interim storage facility provided by a third country for their fuel would be a desirable solution. Such a facility is defined in this report as a regional spent fuel storage facility (RSFSF).

In Western Europe, commercial considerations have already provided an incentive for regional services being provided for fuel supply and for reprocessing. Recently there has been increased interest in the concept of regional disposal facilities, as witnessed by the activities of international bodies [6]. Completely new proposals for RSFSFs have also emerged and are being internationally discussed. The proposals range in scope up to 20 000 t HM of spent fuel, 20 billion US$ and storage periods up to 80 years [7].

For the purpose of the present publication, research reactor spent fuel was not considered in detail because of the special nature of the material and the implication thereof on the RSFSF concept. The need for collecting widely distributed research reactor fuel into RSFSFs certainly exists. To some extent, however, the problem is being eased through agreements of the USA and Russia to repatriate research reactor fuels from countries to which they have supplied such material.

The safety and economic benefits from the implementation of RSFSFs could be attractive because reducing the number of spent fuel storage facilities worldwide results in economies of scale for storage and in easier implementation of security and safeguards measures.

2. REGIONAL SPENT FUEL STORAGE CONCEPT

The regional spent fuel storage concept forms part of the overall nuclear fuel cycle and therefore should not be seen in isolation, as shown in Figure 1.

There are three categories of stakeholders involved in a regional spent fuel storage system — the hosting country offering a regional spent fuel storage service, the customer countries sending their spent fuel to the hosting country for storage, and third party countries having an interest in the storage system. The incentives on the part of the hosting and customer countries to enter into a regional spent fuel storage arrangement would clearly depend on the specific circumstances existing in those countries. These incentives could be of a technical, economic, financial, political or institutional nature. Third party countries would typically be countries that have a regional interest in the storage system, for example because they share common borders with hosting and customer countries or may have to allow spent fuel transportation across their territories. Third party countries may also have specific interests with regard to the future use of the spent fuel intended for regional storage, in particular related to existing consent rights and to non-proliferation concerns.

Basically, three options are available by which the hosting country can specify the storage service offered to its customers:

Option 1: The spent fuel is stored in the regional storage facility for a specified period determined at the beginning of the storage agreement. Since storage is the only service offered, the customer country agrees to take back the spent fuel at the end of this period, although there may be an acknowledged possibility of the spent fuel remaining in the regional storage facility beyond the termination date, if agreed by both the parties There is, of course, also the possibility that the storage period could be left open-ended altogether.

Option 2: The spent fuel is stored in the regional facility for a specified (or unspecified) period, after which it will be sent for reprocessing. It is possible that the storage period could be extended as agreed among the parties. Reprocessing services can be available in the hosting country or be obtained from another country. The reprocessor is assumed in this report to provide a service based on the undertaking that the high level waste will be returned either to the customer country directly, or to the regional storage facility or to a disposal facility if the latter is available within the hosting country or in a multinational repository in a third country should this have been developed under one of the scenarios sketched in reference [6]. The disposal possibility for the HLW is not considered to form a direct link to the regional storage system as such and is included only for completeness sake. The other materials resulting from reprocessing do not form part of this management system and are therefore not further discussed.

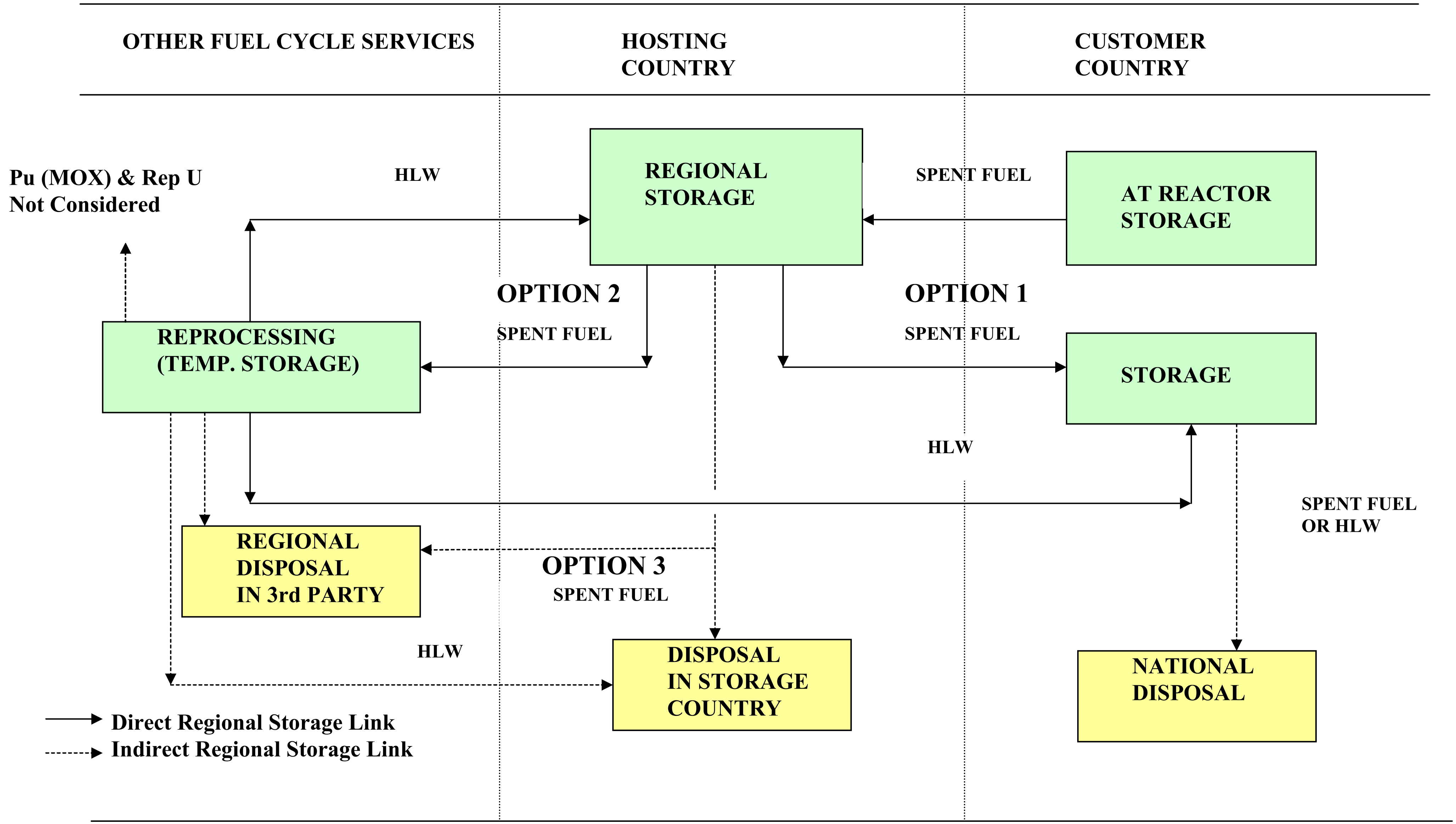

FIG.1. A regional spent fuel storage system in the context of the nuclear fuel cycle.

Option 3: The spent fuel is stored for a specified (or unspecified) period in the regional storage facility, after which it will be transferred to a regional disposal facility in the hosting country or in a multinational repository as mentioned in option 2. Although this is certainly a possibility, direct disposal for spent fuel is also not considered to form a direct link to the regional storage facility.

The overall system depicted in Figure 1 therefore makes provision for only three possible exit points, namely the return of the spent fuel to the customer country at the end of the regional storage period (Option 1), reprocessing and the return of the high level waste for disposal in the storage host country or storage in the customer country (Option 2) and the direct disposal of the spent fuel in a repository in the hosting country or a multinational facility (Option 3).

3. FRAMEWORK FOR IMPLEMENTATION

3.1. Technical requirements

3.1.1. Safety criteria and standards

The RSFSF must, at a minimum, comply with the national regulations of the host country and with internationally accepted other requirements. For that reason it shall be in accordance at least with:

- Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management. [3]

- International Basic Safety Standards for Protection against Ionising Radiation and for the Safety of Radiation Sources. [8]

- State of art technology shall be used to adhere to the ALARA principle and in order to enhance public acceptance. It is recommended that equipment should be available for repackaging defective fuel at the storage facility in order to keep radioactive effluents in the host country reasonably low.

3.1.2. Safeguards and physical protection

As long as there are the relevant conventions and treaties on safeguards and physical protection the RSFSF has to fulfill all demands that these reports prescribe. It can be expected that this will be the case over the entire lifetime of the RSFSF. The advantage of a few regional facilities in comparison to many facilities in different countries is obvious: the control would be easier.

It is recommended that the measures taken for safeguards and physical protection shall be based on experience and sound knowledge of the latest developments worldwide in these areas. Design and operations of a storage facility should take into account the optimization of safeguards and security concerns, including international terrorist activities and actions of sabotage. The technology chosen for storage (wet or dry) can influence these issues, as is clear from recent debates on the relative advantages of each [9–11]. In addition, the respective consequences resulting from future changes in properties of the spent fuel should be considered.

3.1.3. Fuel acceptance criteria

All types of spent fuel related items could be accommodated by a properly designed RSFSF, i.e. spent fuel from various types of power reactors, spent fuel from research reactors and residues from reprocessing, e.g. vitrified high-level waste. Criteria for acceptance will be developed depending upon the expected types of spent fuel or other materials to be stored. Defective fuel may also be accommodated at the storage facility, provided technology is available dealing with such defects. The acceptance criteria should therefore be based on the following:

- design and characteristics of the fuel assemblies and other materials to be stored,
- radioactive inventory based on burnup calculations using an accepted computer code,
- surface dose rates and contamination levels,
- other data, as needed.

3.1.4. Long term stability of systems and stored fuel

The exact duration of intermediate storage is subject to commercial arrangements between service provider and customer and will be laid down in the licensing process. It can be reasonably assumed that in addition to a straightforward storage period of less than 50 years (e.g. several European storage facilities are licensed for 40 years) the need could persist for ongoing storage over an even longer period. As the facility thus may be in operation for a period of 50–100 years or even longer, due care should be given to the long term stability of all its components and especially those which are safety related. If it is not possible to guarantee long term stability of all the storage system components for the planned storage operation period, there has to be an adequate maintenance and repair concept incorporated into the facility design, especially with respect to radiation protection.

Fuel behaviour is another source of technical long term changes, i.e. the fuel can develop cracks and brittle fracture could occur, in particular with high burnup fuels [11]. Research reactor fuel elements are especially vulnerable to corrosion pits from their pool storage period. Such effects should be foreseen and addressed in the safety concept of the whole facility.

Technical provisions should be available for the handling of defective fuel. These would include, among others, encapsulation, consolidation, etc. It is considered necessary to have the capabilities for cask maintenance. This would provide flexibility for the handling of incidents or accidents in accordance with the ALARA principle. It might also be a necessity for continued storage over a prolonged period to care for irradiation and other effects on material integrity.

3.1.5. Selection of site

All site-related factors likely to affect the safety of the facility have to be evaluated. In most or all potential host countries, it will have to be demonstrated by means of an Environmental Impact Assessment (EIA) that the members of the public and the environment will not be adversely affected. Guidance can be found for that process in the existing IAEA recommendations for nuclear power plants (e.g. Reference [12]).

Finding a suitable site for any storage facility, including a RSFSF, is not considered to be very problematic from a technical point of view. The problematic issues are connected with political questions and these are addressed in the forthcoming chapters. If the facility is intended to be an additional facility on an already existing site, then some of the necessary site data will be available from the site investigation already done for the existing facilities.

The geologic and climatic conditions will be very specific to the host country, so that no general recommendations can be made. However, the facility design and materials should be appropriate for the geologic and climatic conditions at the site.

When selecting a site, the question of what happens to the fuel after intermediate storage ends is important. If the ultimate objective is final disposal with potential retrievability, the fuel could in principle be conditioned into a form acceptable to final disposal site. As there is no final disposal facility for spent fuel in current operation, it is not possible at present to define final disposal acceptance criteria in detail. However, there are several investigations and studies about possible final disposal arrangements in progress, from which general acceptance criteria can be derived. Guidance for the subject is given by References [13, 6] and the literature quoted in those documents. The most important technical question concerning linkage to a final repository will be related to the possibility of conditioning the fuel, whether at the RSFSF or elsewhere. If conditioning for disposal is to be done elsewhere, appropriate measure will have to be taken to ensure safe re-transfer of the spent fuel.

3.1.6. Infrastructure aspects

During the successive phases of construction, operation and decommissioning of the RSFSF, a different set of industrial services is needed. These could include production of heavy mechanical equipment, maintenance workshops for equipment, etc. Easy access to such services could be an advantage, especially if the RSFSF offers additional services such as re-packaging, consolidation, etc.

Human resources of different levels of qualification are needed for operation, maintenance and security. The infrastructure needed to provide acceptable living conditions for these employees and their families must either exist or need to be established within acceptable distances from the RSFSF.

3.1.7. Storage technology

Proven storage technology complying with the technical requirements mentioned above as well as those given in a series of relevant IAEA publications [14–16] is available. Decisions on deploying wet and/or dry storage will depend on various considerations such as existing facilities, costs, and safety aspects among others [1,17, 18].

Standardisation is considered to be beneficial to both the RSFSF and for the customers. The number of different types of transport casks for spent fuel is large and a reduction to a few standardised containers would improve the efficiency of operations at the RSFSF. On the other hand, it also may be attractive for the RSFSF to accept different types of transport casks, as this will allow customers to use any number of existing casks. The efforts required for the RSFSF to cope with all kinds of casks might easily be compensated for by the potential for attracting a larger number of customers. Decisions regarding standardisation should be based upon systems optimisation considerations.

With regard to long term behavior of fuel and material components in wet and dry storage, the IAEA has organized coordinated research projects to document the results of related research. These research projects began with the BEFAST series that operated from 1981 until 1996

[19–21] and then continued with the SPAR series that began in 1997 [22]. These efforts continue under the SPAR-II coordinated research project, approved in 2004 for completion in 2008.

3.1.8. Licensing

3.1.8.1. General licensing considerations

The RSFSF must, at a minimum, be licensed according to the national regulations of the host country and according to other internationally accepted requirements. To assure compliance with reference [23], the host country should have licensing experience available or co-operate with an experienced customer country. Guidance can be obtained by adopting relevant recommendations for licensing existing storage facilities or for nuclear power plants with due regard for the differences in technology and safety issues for a storage facility [14].

Normally the licensing procedure for a RSFSF will begin when the organization that plans to run the RSFSF applies for the license and submits the relevant documents to the host country regulatory authority.

3.1.8.2. Safety assessment

As part of the licensing procedure, a systematic safety assessment will be carried out. Such a safety assessment should cover the entire lifetime of the facility, demonstrating that the safety measures to manage the fuel will ensure compliance with the design values for:

- radiation exposure to personnel,
- radiation exposure to the public,
- radioactive discharges.

With this safety assessment, the overall feasibility of all handling, transport and other procedures affecting radiation protection and safety must also be demonstrated. Further guidance is given by Reference [16].

3.1.8.3. Accident and incident analysis

A very important part of the safety analysis to be submitted with the license application is the accident and incident analysis. The safety objective is that, even in case of accidents or incidents, exposure to the public remains within regulatory limits. It is useful firstly to analyse all internal impacts, i.e. impacts from the facility itself and the different procedures that will take place inside the facility (handling, transport, storage, repackaging). Secondly, all impacts coming from outside are then analyzed, including both natural impacts (climate, natural phenomena, etc.) and man-made impacts, either incidental or accidental (such as air crash, etc.), or resulting from acts of sabotage or terrorism, respectively.

The aim is to foresee any possible event and to define countermeasures. Safety analyses for existing facilities show that, even after events that have an extremely low probability of occurrence but would imply severe consequences, the required level of safety can be demonstrated.

3.1.9. Operations

The basic requirements for operation are provided in Reference [15]. Operations include conducting the following activities:

- receiving, handling and storage of spent fuel
- maintenance of functionality
- safeguards and physical protection
- monitoring and environmental protection
- quality assurance
- information and data management
- training
- management and administration

Due to the extended storage periods envisaged (up to 100 years) and considering the rapid changes of information technology, the transfer of data in a usable form to future generations could become difficult. Special attention must be paid to the standardisation of data formats, content of the information, and data management. The facilities should implement and maintain a data processing and preservation system that would accept the data from the customers and create and keep the history data records.

3.1.10. Transport

Transportation is a major logistics challenge for a regional storage facility, both on-site and off-site. On-site transportation will be covered by the RSFSF licensing process. Thus it is not considered further in the context of this evaluation.

Transport casks for spent fuel represent a well-proven technology. This applies also to dual-purpose casks which are additionally suitable for storage of the spent fuel.

Surface transportation of spent fuel to remote locations by truck, train and ship/barge is also well proven technology. Transportation of spent power reactor fuel casks usually does not take place by air due to the heavy weight of the casks and for other safety reasons. Depending upon the eventual overall scale of a RSFSF and on the siting options, there will possibly arise considerations which are not covered by the IAEA Regulations, such as whether to transport spent fuel through high mountain areas or when temperatures below minus 40 degrees centigrade prevail.

Transportation of spent fuel to a remote RSFSF does not present in principle a new technological challenge. However, new technical, logistical, organisational and economic solutions might be developed, depending on the overall proposal for such an undertaking.

In 1961, the UN entrusted the IAEA with setting up recommendations for the safe transport of radioactive material. The IAEA Regulations for the Safe Transport of Radioactive Material [24] are recommendations that serve as the basis for international and national transport regulations. These apply to all modes of transport by land, water and air. Most Member States have adopted the IAEA Transport Regulations. So far the safety record is excellent. There is no case known in which radiation induced injury to members of the public resulted from transportation of spent fuel.

Emergency response during transport accidents is addressed by the IAEA through its safety guide on planning and preparation for emergency response to transport accidents [25].

Physical protection of radioactive material is covered by the Convention of on the Physical Protection of Nuclear Material [26]. For transport on international routes like waterways, sea and air the sending and receiving countries have to agree on security measures. Countries through which the spent fuel must transit will impose their own measures. The terrorist attacks of 11 September 2001 will also have a substantial impact on the scenarios to be considered for international spent fuel transportation.

Despite many measures to control and minimise risks, in recent years the transport of radioactive material has become a matter of particular interest to Member States. In some parts of the world, substantial concern about the safety and security of transport has arisen among members of the public – and this has been frequently expressed at the political level.

Those concerns have been addressed during IAEA General Conferences, for example by means of a Resolution on "Measures to strengthen international co-operation in nuclear, radiation, transport and waste safety" [27]. Specifically, international maritime spent fuel transportation is addressed and the rights of small developing island nations and other coastal states are considered. Member States that have not adopted the IAEA Transport Regulations are encouraged to do so.

"Transboundary movement" is addressed in the Joint Convention on the Safety of Spent Fuel Management INFCIRC 546 [3] with respect to responsibilities of the States of origin of the material (sender) and the States of destination (receiving). The rights of transit states are stressed. Transporting spent fuel in international waters does not relieve any responsible party with regard to third party States that might not even be transit countries. The logistics related to the transport of spent fuel casks is a complex task. The transit countries may have different interests and obtaining licenses for transportation could be difficult. All aspects of the transportation, including political, economical and financial interests of the transit countries and their regulations will have to be taken into account before the implementation phase of a RSFSF project.

3.1.11. Decommissioning

As noted by Safety Series No.116 *'Design of Spent Fuel Storage Facilities'* [14] and No.117 *'Operation of Spent Fuel Storage Facilities"* [15], decommissioning of the RSFSF should be considered in advance. A decommissioning plan should be prepared prior to construction of the storage facility, subject to regular updating throughout the operational period. The respective parties should agree upon responsibilities and funding for decommissioning in advance.

3.1.12. Research & development

Proven technology is available to be applied for a RSFSF. Hence, no additional R&D work is required to implement such facilities. For storage periods of 50 to 100 years or more, there are several aspects of RSFSF operations requiring continuing R&D; the most important open questions concern the behaviour not only of the spent fuel but also of all other components essential for safety of the facility. It is reasonably assumed that storage over approximately 50 years can be done safely and several national licenses have been granted for periods approximately that long.

Considerable information has been collected on fuel behaviour, especially during wet storage and to a lesser extent for dry storage, in the IAEA BEFAST coordinated research programme [19–21] cited in Section 3.1.7 above. As noted, the sequel IAEA Spent Fuel Performance

Assessment and Research coordinated research programme continues this important work [22]. Although there is already much information on fuel behaviour, there is still a need for information especially on long term effects with high burnup (60–75 GW·d tHM) and also for new cladding material specially designed for high burnup.

In addition, information is needed on facility component materials behaviour during long term storage. Besides radiation damage effects, such topics as corrosion, mechanical strength and long term stability of seals have to be addressed by further R&D programmes worldwide. All relevant information should be collected and be available to any authority involved in licensing a RSFSF, as well as to the designers of the storage facility.

Specifically in connection with licensing, R&D work would also be useful for further development of formalized approaches for evaluation and assessment of concepts. Whereas collecting relevant information on the conditions and requirements for safe storage is one important aspect, the evaluation of this information and finally deciding whether it justifies granting a license are other important aspects. If these evaluation criteria could be harmonized internationally, it could significantly help the acceptance of the licensing process and thus enhance the confidence in the safety of the RSFSF in the host country as well as in customer countries and third parties.

3.2. Economic and financial considerations

3.2.1. General considerations

In a competitive electricity market, it is important to explore approaches to reducing the cost of nuclear power generation, without compromising on safety. This objective can be achieved for many utilities or countries in one way by addressing their responsibilities for the back end of the nuclear fuel cycle in a cost effective manner.

In order to be attractive to both hosts and customers, a regional storage facility should be economically sustainable and also advantageous for economical reasons. Ideally it could be located at a potentially suitable site for further spent fuel management activities, but in any case, decisions on any regional storage system, including its location, should be based on an optimization process including a cost-benefit analysis.

In determining whether to establish a RSFSF, the costs and liabilities to all affected partners must be weighed against the benefits. Costs will be incurred for all activities over many years from site selection for a new facility (including phased development or capacity extension of an existing facility) through construction, licensing procedure, start-up, operation, transport, maintenance, and decommissioning of the facility. Thus, economic considerations would normally be an important (but not the only) driving force for a regional solution.

3.2.2. Financial sources and conditions

Financing a regional storage facility can be accomplished in several ways. For example, customer countries may jointly establish a special fund to be used for this purpose. Alternatively, the host country may take a fully commercial enterprise approach. This latter approach involves collection of fees that will cover all costs plus profit.

A realistic approach and solution will depend also on other issues, and these should be clearly defined in real contractual conditions. The long term consequences of the agreements should be covered and expressed in an extremely precise contract between the host and the customers.

Financial provisions for future liabilities of the host country have to be seriously considered in the process of establishing a regional storage facility. The final destination of the spent fuel should be determined and associated costs for activities after storage should be met.

3.2.3. Economic evaluation

The economic evaluation of any regional storage facility requires at least the following:

- cost of implementation - e.g. siting, safety and security analysis, licensing fees, public acceptance, design, research and development, construction, etc. A significant portion of the development cost may be for the service facilities needed interface for fuel reception, handling, treatment, potential repackaging, consolidation, etc.
- operational costs - operations, taxes, ongoing licensing fees, maintenance expenses, insurance against liabilities, etc.
- decommissioning costs.

Economic evaluation of existing storage facilities shows that many aspects of storage costs will decrease as a consequence of carefully conforming the facility design to accommodate features and requirements applicable specific to the application under consideration. Transport cost and transit fees from potential customers to the facility are important issues in assessing the overall costs and feasibility of the storage facility system.

3.2.4. Potential host countries and customers

Potential countries that could choose to provider a storage service include:

- Countries wishing to take advantage of a business opportunity.
- Countries willing to improve global nuclear prospects, e.g. by strengthening non-proliferation efforts or enhancing safety and security.
- Countries with advanced nuclear waste management programmes that are willing to accept additional spent fuel for storage.
- Countries which have existing reprocessing facilities with a realistic reserve storage facility.
- Countries with small or extensive nuclear programmes that have favourable sites that could be developed for using jointly with other countries.

Potential customers include:

- Countries with small nuclear programmes that cannot realistically develop economic, safe and secure back-end facilities.
- Countries with large or small nuclear programmes that may see an attractive economic or political advantage in using a regional solution.

3.3. Institutional considerations

3.3.1. Organizations

A regional approach to the storage of spent fuel would require the involvement of a variety of relevant institutions, including national, multilateral, supranational (e.g. European Union) and international entities. On an international level, institutions like the IAEA, OECD/NEA, EURATOM, etc. may be involved. On a national level, governmental and regulatory bodies, local authorities, and oversight bodies, as well as spent fuel producers and facility operators, will take part in a process. Non-governmental organizations and appropriate independent oversight bodies also may play a role in the public acceptance process. As the regulatory control will be the responsibility mainly of the host country, the role of its regulatory body will be very important. The regulatory body must meet the requirements of [3], concerning adequate authority, competence and financial and human resources to fulfil its responsibilities.

All organizations participating in the process must be sufficiently permanent to perform their roles throughout the duration of the RSFSF project.

3.3.2. Legal aspects

3.3.2.1. Legal and regulatory framework

"The ultimate responsibility for insuring the safety of spent fuel…management rests with the State" [3]. All countries with nuclear programs should already have developed adequate legal instruments to regulate nuclear activities. Generally, these legal arrangements are based on internationally recognised guidelines and recommendations.

For a RSFSF, the laws and regulations of a host country will apply primarily. However, laws and regulations of the customer country also will have to be taken into consideration, and in some cases conflicts must be resolved. Therefore, in accordance with the provisions of the Joint Convention, it is important that the hosting country has a well-established national legal framework and a mature regulatory system. The national legislative and regulatory framework would provide [3]:

- the establishment of applicable national safety requirements and regulations for radiation safety,
- a system for licensing of spent fuel and radioactive waste management activities,
- a system of prohibition of the operation of a spent fuel or radioactive waste management facility without a licence,
- a system of appropriate institutional control, regulatory inspection and documentation and reporting,
- the enforcement of applicable regulations and of the terms of the licences,
- a clear allocation of responsibilities of the bodies involved in the different steps of spent fuel and of radioactive waste management.

As the host country's licensing system will be applied, it is very important that this system is well defined and transparent. All licensing procedures and regulatory requirements should be publicly available, clearly defined, understandable and translated into the languages commonly used by international community. The same transparency requirements could be applicable also to the host country's finance, corporate, labour and liability laws, especially if the private (commercial) enterprise approach is applied. For a RSFSF, a set of international guidelines for licensing purposes would also be useful.

Regulations of host and customer countries should conform to relevant international conventions and treaties and be satisfactory to both. Due to the very long term nature of the RSFSF project, special regulations and standards may need to be developed in the field of long term data management, in order to ensure the transfer of the important data to future generations.

3.3.2.2. Safeguards and physical protection

Spent fuel stored in a RSFSF in any non-nuclear weapons state party to the NPT [28] is required to be subject to IAEA safeguards. The customer state also may require safeguards to be applied in a RSFSF located in a Nuclear Weapon State Party to the NPT. The IAEA applies international safeguards control and inspection. Additionally, EURATOM safeguards would also apply in the case of a RSFSF located in the European Union.

The Convention on the Physical Protection of Nuclear Material [26] specifies levels of physical protection for nuclear materials in international transport. Consideration currently is being given to extending the scope of this convention to domestic peaceful nuclear activities. The Nuclear Suppliers Guidelines also specify levels of physical protection that should be applied in a state importing nuclear material [29]. The IAEA also has produced guidelines for the physical protection of nuclear materials and facilities [30]. Protection against sabotage and/or terrorism may also be a significant issue in the future developments of national and international legislation.

3.3.2.3. Ownership of spent fuel

Another challenging issue for a RSFSF is connected to the ownership of spent fuel and transfer of title. Because RSFSF operation is a long term project and the final destination of spent fuel may not be known, 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 (or reprocessing products if appropriate) 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 (or reprocessing products if appropriate) is foreseen.

The agreement to take back the spent fuel in the distant future may be a risk for both sides. On the customer's side, possible institutional uncertainty may result in not providing conditions for fuel take back, while on the host's side the delay in taking back fuel may cause negative public reactions and jeopardize the whole project. Because of the need for agreement to take back spent fuel, the contract between the host and the customer countries requires strong commitments on both sides. An international assurance that the agreements will be respected may be required.

The second option includes the possibility of transfer of title at some future time, depending on possibilities in both the host and the customer countries. The risks associated with this option are similar as for the first one and some international assurance may also be required.

In the third option, the problems of taking back fuel are avoided. This option may be the most attractive to the customers' countries. The host country takes the responsibility for storage and for the final disposition of the spent fuel. However, difficulties may arise because no disposal route is yet available or because spent fuel can be treated also as a potential resource. These issues should be negotiated very carefully between the parties.

3.3.2.4. Liabilities

Liabilities attach to the obligation of the spent fuel owner to ensure that the spent fuel is properly managed and finally disposed of in a safe and secure manner. These liabilities are a cost in managing normal operations of a RSFSF. In addition, abnormal operations must be addressed through contracts in the context of national laws and applicable international treaties.

Future liabilities of the host country of the regional spent fuel storage facility are strongly related to the issue of spent fuel ownership. Where the ownership stays with the customer country and the obligation of a customer country is to take back fuel after the expiration of the storage period, adequate financial provisions and agreements among partners can cover the liabilities of the host country associated with the spent fuel. Storage fees should cover all expenses for storing, for unforeseen future events (i.e. future repackaging) and potential damages. A special fund should be created to cover future liabilities. For very long storage periods, the simpler option may be transfer of title by mutual consent of the parties.

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 then include also future disposal of spent fuel. Accepting such long term responsibilities would definitely involve the government of the hosting country, regardless of whether the regional storage operator is a private enterprise. The liabilities of the customer's country are limited to financial obligations as agreed in the contract. Obviously, these obligations should include the expenses for storage and for disposition of the spent fuel.

Appropriate arrangements, possibly including a special fund, should be established to satisfy liabilities for spent fuel management created by ownership in the host and/or customer country due to the very long term nature of storage facility operations.

The liability for the nuclear damage shall be managed in the context of the Vienna Convention on Civil Liability for Nuclear Damage [31]. This liability is strongly related both to the spent fuel ownership and to the RSFSF ownership. Determination of this liability could be a very complex task, so that further investigation of this issue is strongly recommended before establishing a RSFSF. The contracting parties must pay special attention to this issue when preparing contracts.

3.3.2.5. Third Party rights and concerns

The international supply of nuclear material frequently takes place under arrangements that confer certain rights to the supplying country and obligations on the receiving country. The most relevant right for the purpose of considering RSFSF proposals is the right of the supplier to give or withhold its consent to the re-transfer of the supplied nuclear material beyond the borders of the receiving country, which would here be the customer for a RSFSF. Consequently, the supplying country may wish to satisfy itself that the technical, legal, financial, safety and other aspects of a proposed RSFSF satisfy its own concerns, as well as the concerns of the host and customer countries. In some cases multiple suppliers with separate rights may be involved. The consent rights of the country supplying the nuclear fuel would also affect the ability of the RSFSF host country to make final disposition of the spent fuel.

Sometimes a Third Party country, without having consent rights, may have concerns about the transfer and/or storage of nuclear material. Typically such concerns could be non-proliferation, transport or safety related. The international non-proliferation, transport or nuclear safety regulations would inform this circumstance.

3.3.2.6. Time considerations

The long time scale over which a RSFSF project would be conducted raises issues of its own. Firstly, it requires the establishment/maintenance of institutions for the regulation of a RSFSF (including accounting for the fissile material), both national and international, whose existence could be considered long by current standards. Fortunately, institutions like the IAEA already have other obligations with similarly long (or longer) lifetime requirements, such as the maintenance of a system of international safeguards. Secondly, the long time scale requires a stability of national situations that has proven, in some cases, difficult to obtain. It will be critical, for example, for the relationship among the States involved in a RSFSF to remain consistent, so that the customer state will not later regret its transfer or the host state be unable to execute the agreed conditions of disposition. Changing non-proliferation credentials and nuclear fuel cycle policies provide examples where the stability of the relationship between countries involved in nuclear transactions has produced friction. Thirdly, the long time scale requires stability in the legal and regulatory structure of the host state to ensure that the economic and safety assumptions under which the RSFSF was established are maintained. Finally, financial stability of the managing organization in the host state is required, in order to assure the customer of continued proper management of its fuel.

3.4. Political and public acceptance considerations

Political considerations are clearly of great importance in the implementation of a RSFSF system. In most countries, the political process requires a measure of transparency in providing information to the public with regard to the nuclear industry. The need for transparency imposes a continuing responsibility on the nuclear industry when putting its case to the public in general and to the politicians in particular.

Therefore it will be necessary for the hosting country as well as the customer countries involved in a RSFSF to ensure sufficiently broad political acceptance of the storage concept within their respective countries before the concept can be implemented. For this reason, it is desirable in analysis of the RSFSF concept to define the public communication dimensions of the problem in general terms. However, it is recognized that such an approach can have only limited value, as the political situation varies not only from one country to another, but also from region to region within the same country. Despite these differences, it may be helpful to provide a broad outline of a generic approach to the problem.

An example of a generic model for public transparency is the RISCOM model [32, 33] that is currently being used in the EU for evaluating the public acceptance situation in various European countries. According to the RISCOM approach, there are basically three models for achieving transparency in public communication: the ‘technocratic approach’ with the implementer taking the initiative, the ‘decisionistic approach’ where the decision-makers (politicians) take the lead, and the 'pragmatistic approach' based on consensus seeking among the various stakeholders. Each approach has its strong and weak points. The choice of approach will largely depend on the political system in a specific country. The technocratic model is the one that may be used in countries where the implementer (the body seeking approval for its storage plans) has the necessary autonomy in approaching the public directly in regard to the storage project. The decisionistic model may be used in countries where decisions of this nature are typically made by the government and/or the legislature with the implementer only providing the necessary technical information. The pragmatistic model may be applied in countries that tend to rely on compromise and consensus-seeking devices involving the implementer, the decision-makers and the stakeholders.

Public communication in many countries is prescribed by way of legislation, government policies and regulatory action. This may take the form of public information dissemination, public consultation, public hearings, etc. and these processes are typically prescribed in environmental and nuclear regulatory legislation. Generally speaking, the technocratic approach has fallen out of favour as it often resulted in a "decide, announce and defend" position. This approach normally led to a polarized situation and produced negative results in obtaining public support for nuclear industry initiatives. The decisionistic approach implies that the decision-makers need to create procedural mechanisms to enable the implementer to put its case to the public. This may be done at various stages of the public communication process. The decision-makers will finally decide whether or not a project would go ahead. The success of this approach would largely depend on the efficiency of the decision-makers (politicians) in moving the entire decision-making process forward. The pragmatistic model is based on voluntary consultation and consensus seeking and appears to be the most successful process, provided it is appropriate to the situation in the country where it is applied.

Against the background of the different approaches to achieving transparency, public perceptions of the nuclear industry need to be taken into account. As spent fuel management is an integral part of the nuclear industry, any public opposition to nuclear power would tend to spill over into the spent fuel management domain. In some cases, in fact, opponents of nuclear power have focussed on those areas such as nuclear waste management where the industry is perceived to be most vulnerable,. Opposition groups (local and international) would therefore tend to concentrate their efforts in such areas.

The all-embracing concern on the part of the public is clearly the safety of nuclear installations, now and in the future - the long term effects of ionising radiation on human health appear to weigh especially heavily in the public mind. Another aspect of safety, in a general sense, that recently emerged as a concern is the danger of physical damage to nuclear installations caused by sabotage and terrorist attacks. When dealing with the safety issue, the differences between the different types of nuclear installations and the relative safety risks need to be clearly pointed out in any discussion at the political level. It is important for the public to understand what a spent fuel store is and what the risks are, before the concept of regional spent fuel storage can be appropriately evaluated in a public forum. The real challenge in public communications is to create the necessary conditions under which an effective public dialogue can take place among the various stakeholders. Only then would it be possible to make the necessary technical distinction between different types of facilities and their impact on public safety.

Of great importance in promoting the regional concept at the political level is the need to stress the benefits of the concept. Different benefits, e.g. enhanced safety, non-proliferation or commercial advantages, may have different weights in any given political situation. The weight of the benefit would clearly depend on the preferences or policies of individual countries. At the same time, it also would be necessary for the initiator of the concept to explain the long term risks and obligations, especially safety and financial, that would typically flow from such an undertaking.

The chances of successfully implementing the concept would be greatly enhanced in the case where there already exists a strong relationship among the prospective participants to the regional project. Such a relationship may, for instance, involve strong economic and political ties among countries falling in the same geographical area. On the other hand, where similar ties do not exist between regional countries, the regional concept would clearly be more difficult to implement and could be expected to encounter stronger opposition, especially within the hosting country.

It is of course very likely that strong opposition would emerge from within the political circles of the hosting country. Of considerable interest is whether the motivation for the whole enterprise is proposed for purely economic reasons or whether there are broader political goals. In the case where the project is undertaken for non-proliferation, security or other overarching policy reasons, there might be more public acceptance than if the project is undertaken purely for financial reasons.

As nuclear issues have been internationalised to a great extent during the past few decades, non-governmental organizations operating on a global scale may focus attention on the regional spent fuel storage concept. For this reason it is important for the stakeholders in the RSFSF enterprise to communicate effectively with the all parties concerned, in order to ensure broad agreement on the purpose of the entire project.

4. ETHICAL CONSIDERATIONS

Spent fuel storage needs to be carried out under specific conditions in order to be ethically justified. This assumption applies whether storage is carried out as a national or an international project. These conditions typically relate to the safety principles for regional storage discussed in the following paragraphs. The point is that regional storage would tend to impose higher ethical requirements on the storage operation than would be the case for national storage. Because more than one country is involved in the regional operation, unethical behaviour of one of the group would also tend to affect the others. For example, unethical behaviour by the hosting country in compromising safety principles would seriously implicate the customer countries.

The ethics of regional spent fuel storage depend to a large extent on the conditions under which the storage **burden and benefits** are 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 could be 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 on itself and on future generations. From the following discussion, it appears that these two approaches are complementary, in the sense that an obligation to do or not to do something is created specifically in order to avoid an undesirable logical consequence or result or to ensure a desirable consequence at a later stage. By taking into consideration both approaches, a clearer idea can be obtained about the ethical implications of regional spent fuel storage.

Obligations

The IAEA Safety Fundamentals [34] incorporate, to a large extent, the obligations that apply to spent fuel management in general. Of particular importance are the obligations with regard to the protection of human health and the environment, the protection of future generations, the protection of third party countries across national borders, and the avoidance of undue burdens on future generations. From these general principles some specific obligations can be derived for regional spent fuel management:

- *Human health* and the *environment* must be protected. This obligation implies that internationally accepted s*afety standards* must be applied and that due care needs to be taken to protect the environment in the case of a regional storage facility, including its decommissioning.
- *Future generations* must not be unduly burdened as a result of the establishment of a regional spent fuel storage system in any particular country. The hosting country responsible for storing spent fuel from other countries will have to accept obligations, including decommissioning of the facilities, that extend over long periods of time. Therefore, if future generations in the hosting county are not to be unduly burdened, customer countries must honour their contractual obligations.
- *States* in the region that do not directly participate in the RSFSF arrangement shall not be unduly burdened by the RSFSF. Transit through such States shall be subject to those international obligations that are relevant to the particular modes of transport selected. However, exercise by ships of maritime, river, and navigation rights and freedoms as provided for in international law shall not be prejudiced or affected.
- *Equity or balance* must apply among the participating countries. According to the obligation that exists with regard to equity, there must be a fair balance between the spent fuel storage burden transferred to the hosting country and the compensation received by the hosting country. This obligation is especially important where hosting countries are less affluent than customer countries.
- The arrangement between the participating countries must be comprehensive, clear, distinct, and open to all parties within the region. The agreements entered into between the hosting country and its customers with regard to the *final destination* of the spent fuel are of particular importance to the hosting country.

Consequences

The above ethical obligations apply to the participants involved in a regional storage arrangement and they are largely based on the *potential adverse consequences* that could result if these obligations are not fulfilled. For a RSFSF, a causal relationship exists between the obligation to do or refrain from doing something ***and*** the adverse consequences that could occur as a result. Such voluntary restraint by the participants in a RSFSF forms the basis for them to assume these ethical obligations and to assess the consequences of their decisions.

There are two types of consequences of interest when participants consider specific RSFSF decisions:

(1) **Intra-generational consequences**: These are the consequences of this generation's actions with regard to itself. Therefore this generation should exercise the necessary care to protect itself against certain undesirable consequences.

(2) **Inter-generational consequences**: These are the consequences of this generation's actions for future generations. Therefore, this generation should protect future generations from adverse consequences that could flow from actions carried out today.

Decisions by this generation about an RSFSF concept for managing spent fuel cannot be separated from ethical considerations that will have consequences for future generations.

5. IMPLEMENTATION

The following sections discuss the possible approaches and processes to implement a RSFSF. The table (presented in the Appendix) identifies various aspects of implementation and describes many of the technical, economic, institutional, and ethical and socio-political aspects that should be considered when evaluating such a facility.

5.1. Approaches to implementation

The various aspects of a RSFSF are discussed in some detail in the preceding sections. In order to gain an overall impression of the processes involved in establishing such a system, a simplified diagram (Figure 2) is presented for illustration. The diagram attempts to define, in broad outline, the major components of the RSFSF and focuses mainly on the interactive processes involved.

It is important to note the complexity of the interactions between the hosting country, its customer countries, and involved third parties. These interactions need to be formalized at the various levels of decision-making between those countries participating in the development of a RSFSF. The national institutional processes that would play a role in the establishment of a RSFSF are greatly simplified for the purposes of this analysis and are expressed as the legislative (lawmaking) process, the executive (government administration) process, the regulatory (authorizations) process and the operational (spent fuel management) process. An important process not illustrated is that of decommissioning. These processes would typically operate in a top-down fashion within the national context, depending on the national constitutional system. Figure 2 is not specific about the structure of the different processes, as they are typical and generic of the functioning of all modern states. Furthermore, the scheme does not attempt to be exhaustive; on the contrary, it merely describes the basic building blocks necessary for establishing the infrastructure of a RSFSF.

In Figure 2, the hosting (or receiving) country is depicted adjacent to one of its customers (sending country or country of origin). In order to successfully create a regional storage system it would be necessary to put in place certain mechanisms between the host and customer countries. The sequence in which these mechanisms need to evolve is not important at this stage. The relevant mechanisms to be established between the respective governments (regardless of sequence) are as follows: first, development of a clear understanding of the concept at the international level (this may involve the IAEA); second, adoption of international instruments regulating relations between countries (conventions, treaties, etc.); third, adherence to regional institutional requirements where these exist (e.g. the European Union); and fourth, establishment of the bilateral agreements governing the regional arrangement, including agreements that either country may have with a third party. Depending on the constitutional requirements of the participating countries it also might be necessary to enact new legislation enabling the regional project to proceed. These interactions are not shown in the accompanying figure.

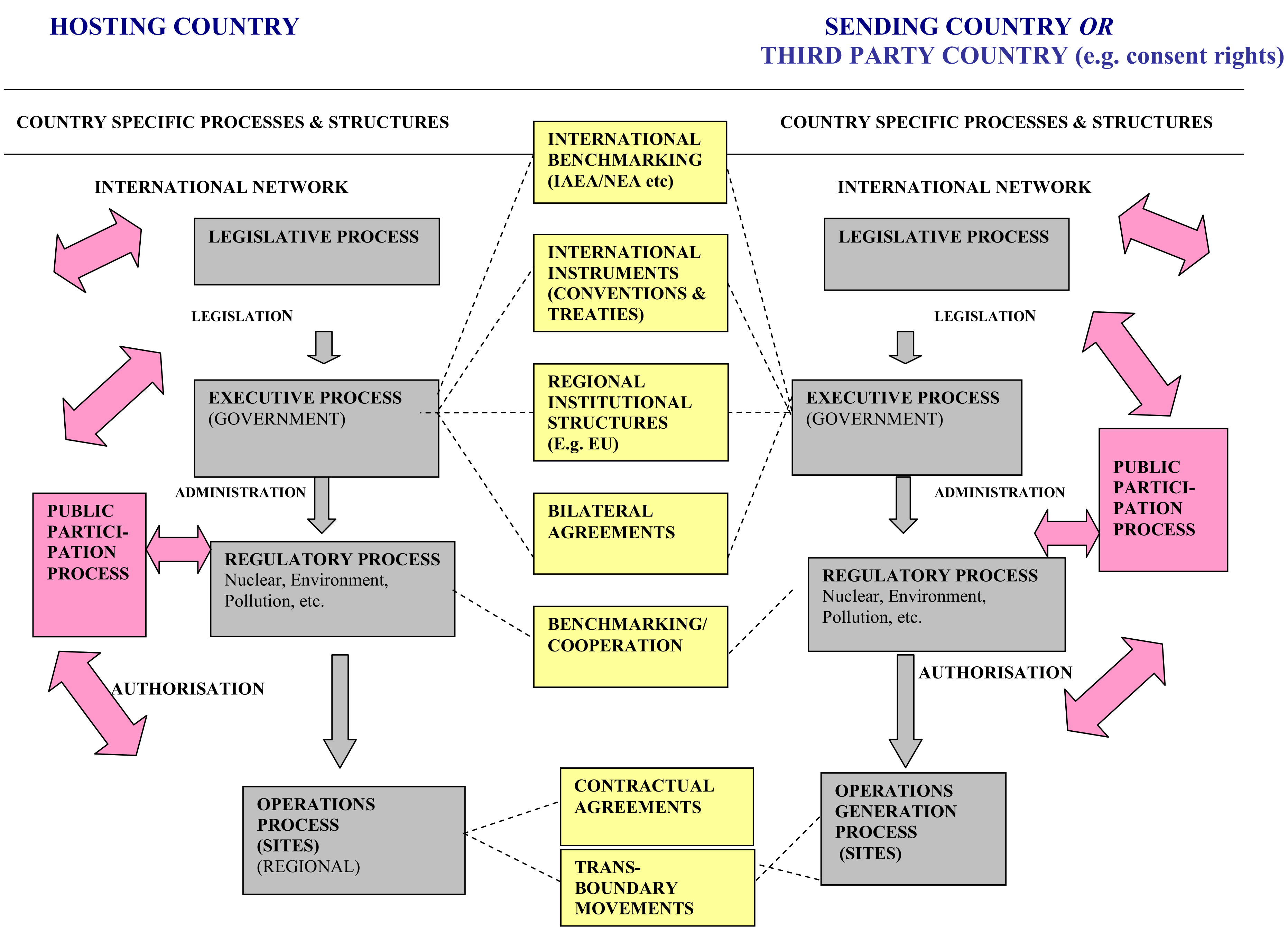

FIG. 2. Regional spent fuel storage model.

At the regulatory level, there is a clear demarcation between the hosting and customer countries in terms of territorial jurisdiction, as each country is responsible for its own regulatory standards. Despite this independence, there is a need for benchmarking the respective regulatory standards against international norms, such as those recommended by the IAEA, OECD/NEA, ICRP, etc. The host and customer country regulators may need to establish a co-operative agreement for resolving potential regulatory conflicts, including those raised by involved third parties.

At the operational level, the organizations (either government or private) responsible for the day-to-day management of the spent fuel would have to comply with the institutional superstructure put in place between the governments of the participating countries. They would typically be national generators (utilities) and/or spent fuel/radwaste operators and could also be international waste management agencies. It is important to note that these spent fuel management operators, whatever their affiliations, would require licenses from the relevant regulatory authorities in the host and customer countries, as well as any transit countries. Where a site for regional spent fuel storage does not exist yet, such organizations may have an active role in the site selection process. Based on the institutional infrastructure established at government level, the responsible operators would enter into contractual arrangements for transferring the spent fuel from the customer to the hosting country. The responsible regulators would establish rules applying to the physical transfer of the spent fuel.

The involvement of the public in the entire process is important to the success of the regional storage project. Public involvement can take place at various levels within the country hierarchy, as is shown in Figure 2. This involvement could range from the legislative level, through the governmental level and right down to the operator level. The processes involved are clearly country specific. There is legislation in many countries today that requires public participation including public hearings, etc., especially in the environmental impact assessment process. It should be noted also that in democratic countries the members of the legislative body are officials who have been elected by the public to represent the public's interests. The non-government organizations involved in the nuclear debate also have a global information network that could be expected to respond to any initiative to establish a regional storage system.

The processes discussed so far were confined to that of a single host country in relation to one of its customer countries. But clearly there may be several such customer countries participating in similar processes in the RSFSF.

Apart from the customer countries, there are also third party countries that might have an interest in the storage project. Third party countries could be neighboring countries, transit countries or countries having consent rights to the spent fuel to be transferred. Therefore, the hosting country would also have to put in place the required institutional mechanisms with regard to such third party countries. These institutional mechanisms most likely will be similar to those established between the host and customer countries. Therefore, Figure 2 illustrates that the interaction between the hosting and customer country could also be read as the interaction between the hosting and a third party country.

A summary of the most important parameters involved in establishing a regional system is provided in Table 1. The infrastructural requirements of the system are grouped into five categories: technical; economic/financial; institutional; socio-political; and ethical aspects. Table 1 provides pointers to specific topics to be addressed for each of the five categories. Although these issues are not discussed in detail in this present report, they complement the implementation model depicted in Figure 2, in particular by indicating the complexity that lies behind the simplified representation.

Figure 2 may be useful also in demonstrating the manner in which the entire storage project could be launched. There are principally two ways in which a regional spent fuel storage system can be initiated. The project could be initiated as an entirely private enterprise or it could be launched on the basis of a public or government undertaking with or without private participation.

Whether the initiative for a RSFSF comes from private enterprise or from government, the approach is feasible only with the direct involvement of the executive level in the hosting country. From this level the various processes could be initiated, depending on the constitutional set-up in the hosting country.

5.2. Processes for implementation

The management of an international spent fuel storage facility is a long term activity that requires direct involvement of the government of the host country. The government can choose how to delegate its responsibility and control the development and operation of the RSFSF.

5.2.1 Private enterprise initiative

In the case of a private enterprise approach, it is assumed that a private spent fuel storage *service provider* in the hosting country decides for various reasons (commercial, non-proliferation, environmental, etc.) to provide a regional storage service to interested customers. The service provider would have to define very clearly the scope of its service offered to the customers. The service provider will be required to stipulate whether or not it is prepared to accept *ownership* of the spent fuel delivered to the regional storage facility. Ownership of fuel will be extremely important in developing the licensing approach.

If the service provider decides to accept ownership, it also would have to accept full liability for all future costs involved in the management of the spent fuel, including that of final disposition. On the other hand, if the service provider decides not to accept ownership, it would merely be liable for the storage of the spent fuel until disposition. In this case the service provider's liability will be limited to the storage operation only.

If the service provider does indeed decide to take over title to the spent fuel, it would have to be involved in the solution to final disposition. If the host country allows the service provider to take title to the spent fuel, the responsibility of solving the final disposition of spent fuel would become the responsibility of that country. But even if the storage provider decides to avoid final disposition by opting for ongoing storage, it would still have to ensure the long term control of the storage facility, which would include decommissioning of the facility. Because of inherent uncertainties in the long term viability of a private enterprise, the hosting country government must be prepared at some future time to assume long term responsibility for the spent fuel.

5.2.2. Institutional initiative

The incentive for a country to host a RSFSF could not only be commercial but also be based on non-proliferation and safety considerations. The host country may appoint a private operator to take charge of the storage operation, while the state assumes liability for all transactions concluded with prospective customers. Third party countries may be supportive of the concept for non-proliferation and safety considerations, including enhanced protection from sabotage and terrorism. If the host state takes title to the spent fuel it assumes responsibility for ongoing storage or final disposition in the hosting country or elsewhere.

6. BENEFITS AND RISKS

The potential benefits and risks related to a RSFSF cover almost all the aspects of the project: technical, economic, institutional and socio-political. Accordingly, there are some challenges and implications that must be addressed in analysing the development of the project, in order to evaluate properly the risks and benefits.

6.1. Benefits

6.1.1. Technical benefits

The techniques implemented to design, construct, operate and decommission a spent fuel storage facility are developed and tested worldwide, and they can be considered proven technologies. However, sharing of existing experience between the host and customer countries through the transfer of technology may optimize the design of the facility as well as enhance its quality and safety aspects. This transfer of technology may also be beneficial to other nuclear facilities in the host country.

Furthermore it is reasonably accepted that the limitation of the number of storage sites can lower global radiological risks as well as environmental impacts associated with storage of spent fuel, since there would be fewer possibilities that some countries, with less capability, would develop their own facilities. Storage at a RSFSF can enhance security against sabotage and terrorism by allowing more robust security measures at a central location when compared to several widely dispersed facilities.

In the event that certain countries encounter difficulties in deploying storage capacity needed to avoid premature plant shutdown, development of a RSFSF could allow continued power plant operations, resulting in many benefits to society. These include technical as well as other benefits (e.g. economic, environmental, socio-economic, etc.) that will be discussed below.

6.1.2. Economic benefits

An RSFSF is expected to bring economic benefits to the hosting country as well as for the customer countries. However, a full understanding of economic situation and a reliable estimate of benefits of regional storage cannot be obtained by either the host or customer without also considering the costs associated with a final disposition solution.

The host country, that will bear the burden of storing the spent fuel, is expected to receive economic benefits in terms of receipt of funds from customer countries and/or profit on the operation of the facility. In the case where the facility is developed and operated by private companies, the State can generate income by taxes or royalties on spent fuel storage operations. Important economic benefits to the local community that hosts the facility will be obtained from local taxes, employment opportunities, development of local infrastructure, and any direct economic incentives that are provided.

The customer countries will not have the burden of development, construction and operation of a national facility. The balance of two options (regional and national SFSF) could be favourable for the customer countries in terms of unit cost of spent fuel stored. However, it is possible that the driver for the customer country to send spent fuel or high-level waste to a RSFSF may not be lower costs.

The economic advantages for both hosting and customer countries can be enhanced by economies of scale, potentially achievable in all the phases of the project, from siting through to decommissioning of the plant.

If the RSFSF allows nuclear power plants to continue operation when otherwise they would be forced to shut down, the economic benefits are obvious. The nuclear power plant will remain a source of revenue for the owner and there will not be the need to spend valuable resources to develop replacement power, thus allowing those resources to be used for other societal needs.

6.1.3. Institutional benefits

The development of an international framework for the implementation of a RSFSF may have an important impact upon future regional disposal initiatives. The implications of developing a multinational geologic nuclear waste repository are considered to be more difficult to face than developing regional storage facilities because of the permanence of the disposal system.

The regional spent fuel storage facility could provide an opportunity to:

- demonstrate the feasibility of international treaties and conventions involving the transfer of spent nuclear fuel
- create an international framework for future co-operation for multinational repositories
- strengthen the will of the public and politicians to solve global challenges of great relevance in an international context
- eliminate the need to develop, manage, regulate, and decommission storage facilities in customer countries seeking an international solution

6.1.4. Socio-political benefits

The existence of an international framework and treaties signed by the countries cooperating in a regional solution for the storage of spent fuel increases transparency of the back end of the fuel cycle and limits therefore the possibility for nuclear proliferation. It also may lead to increased safety and protection from sabotage and terrorism by virtue of international interest in the facility.

Relevant social benefits are foreseeable for countries and/or specific regions inside countries, in terms of infrastructure and economic incentives, where the facility is located. It is possible that specific agreements could be established through negotiations among all parties involved to provide benefits to the host country or communities in the host country that are unrelated to direct development of the facility. These could include environmental or social programs.

6.2. Risks

6.2.1. Technical risks

Technical risks are similar to those of national storage programs. The development of a RSFSF does not present any unique technical risk. It should be noted, however, that the implementation of a RSFSF is likely to result in increased transportation that will take place over longer distances and through or near countries that may not otherwise be impacted.

There have been some suggestions that a RSFSF may involve a longer operational period than storage at or near a nuclear power plant. Depending upon the type of storage facility constructed and the length of time that the spent fuel is in storage, there may be a need to repackage the spent fuel during storage or before it is moved. However, this would be true of any storage facility if the storage period were extended.

6.2.2. Economic risks

Economic risks are borne by both the host and the customer countries. For the host country, the risk is that, if customers do not send spent fuel to the RSFSF as planned, the operation of the facility will lose profitability and public support. For the customer country, the risk is that advance payments will not result in an operational RSFSF, thereby increasing the unit cost of further spent fuel handling. There is an additional risk associated with the withdrawal or bankruptcy of the operating organisation subsequent to the start of operation (i.e. after the storage facility has been established and spent fuel is located in the host country). It is also conceivable that costs could change after the operation is underway, such that the project no longer remains economically viable. This could occur for variety of reasons such as: increased transportation fees from transit countries, increased operation costs at the facility, increased costs to purchase storage containers, licensing fee increase, etc. These risks must be addressed in carefully negotiated binding agreements.

Any devaluation of properties in a hosting community can be compensated by economic incentives.

6.2.3. Institutional risks

The life period of a RSFSF could be much longer than the life that many institutions have experienced so far. Certainly, the time period for which the public must be protected from ionising radiation associated with spent nuclear fuel is longer than the existence of any government or institution. However, the progress made in recent decades in the direction of stable international treaties is encouraging and this progress can be considered as a reliable base on which future agreements can be built. As an encouraging precedent, new institutions to oversee nuclear operations have been created when, for example, the former Soviet Union dissolved.

Another area that needs to be carefully considered is data management. It may be a challenge to maintain the required knowledge of spent fuel characteristics and burnup history that will be important to any future spent fuel handling or repackaging.

6.2.4. Social and political risks

Public acceptance is crucially important and could be the weak point in the process of RSFSF development. Sufficiently broad acceptance is a necessary condition to the success of the project, although it may not be sufficient. The consideration of public opinion, by means of political organizations, media and public debates, has to be maintained throughout all the phases of the facility life, with the goal of assuring people that the facility can be operated safely.

There could be a possibility after operations have begun that public support is lost as a result of an accident, whether directly associated with the project or not. In this case, it may be necessary for the host and customer countries to negotiate an equitable agreement regarding future operations.

Political continuity is an issue that has to be considered in developing a RSFSF. The effectiveness of international treaties and conventions could be compromised by modifications in political relations among partners (host, customers and third parties) as well as changes in national borders.

7. CONCLUSIONS AND RECOMMENDATIONS

The discussion above has illustrated that implementing a RSFSF facility would involve simultaneously addressing a wide range of diverse challenges. The appendix to this report tabulates the numerous issues that have been touched upon in the study. It appears, however, from the discussions that the challenges can in principle be met; the RSFSF concept is technically feasible and potentially economically viable. The technical committees producing this report did not identify any obvious institutional deficiencies that would prevent completion of such a project. Storing spent fuel in a few safe, reliable, secure facilities could enhance safeguards, physical protection and non-proliferation benefits. The committee also recognized, however, that the political, social, and public acceptance issues are real and difficult to address. The added difficulty due to the regional nature of the facility could well be balanced by the benefits. However, the State considering hosting such a site and the States considering being customers for such a site will need to make their own decisions on the relative weights to place on these risks and benefits and the final decision on the establishment of a RSFSF. The debate on regional spent fuel storage concepts should be stimulated and initiatives to further explore and/or implement regional spent fuel storage concepts supported.

APPENDIX: ANALYSIS OF THE SALIENT ASPECTS OF A RSFSF SYSTEM

Aspects	Technical	Economic	Institutional	Ethical & Socio-Political
Need	• Additional storage capacity • Alternative locations for storage	• Affordable, viable and competitive storage service option • Economic considerations typically the driving force for a regional solution	• Non-proliferation concerns • Safety concerns • Security concerns	National differences in public attitudes **Ethics:** • obligations to future generations • consequences for future generations **Politics:** • Interest in regional solutions; balance of driving and restraining forces in regional approaches
Benefits	• Transfer of technology • Enhanced safety standards • Enhanced quality of facilities • Reducing the number of storage sites worldwide • Simplifying safeguards control of storage sites worldwide	**Hosting country:** Benefits to industry • lower unit cost of storage • attractive return on investment • potential utilisation of fissionable material Benefits to affected communities: • technology transfer • socio-economic aspects • tax • infrastructure **Customers Benefit:** additional storage option	**Hosting and Customer country** • Easier safeguards control • Common safety standards • Improved national legal framework • Creating an institutional framework for future regional disposal initiatives	• Socio-economic benefits: jobs, infrastructure, taxes • More choices for suitable locations • Reduced environmental impacts • Increased transparency

Aspects	Technical	Economic	Institutional	Ethical & Socio-political
Risks	• Similar to national stores • Increased transportation	**Hosting country:** • Insufficient fuel transferred • Devaluation of properties **Customer country** • Service doesn't materialise or is withdrawn • Commercial failure of storage organisation	• Possibility of institutional control being neglected in customer countries due to hosting country assuming full responsibility for storage • Potential institutional instability	• Affected communities possibly becoming dependent on socio-economic support • Increased challenge for local public acceptance
Participants	**Hosting country:** • Basic nuclear expertise • Developed legal and regulatory framework • Proven spent fuel management capability • Optimised technical systems **Customers:** • limited nuclear infrastructure	**Hosting country:** • Countries with small nuclear programmes • cCountries with large nuclear programmes • Countries involved in the nuclear industry without NPPs **Customers:** • Countries with small nuclear programmes	**National level:** • Governmental bodies • Regulatory bodies • Operators and generators • Others **International level:** • institutions (IAEA, EURATOM, etc.)	**Role players:** • Operators and generators • Regulators • Politicians • Institutions (e.g. IAEA) • Industry • Interest groups • Media • Public

Aspects	Technical	Economic	Institutional	Ethical & Socio-political
Storage System	• Well established spent fuel storage technology • Safe and secure storage systems with minimal environmental impact • Flexible acceptance criteria • Limited standardisation • Repackaging capability for extended storage or further transportation	• System optimisation based on cost benefit analysis	• Host country responsible for own safeguards and regulatory systems (confined to national borders) • Customer countries responsible for safeguards and regulatory systems (confined to national borders) • Compatibility between institutional systems of host and customer countries • Regulations of host and customer countries to conform to international conventions and recommendations	The following aspects need to be balanced in defining the storage system**:** • Open and transparent process • Technology • Options for future utilisation • Safety and protection of environment • Assurance against proliferation
Storage Location	• Overall site suitability • Good infrastructure	• Storage facility preferably located at a potentially suitable site for further spent fuel management • Storage facility economically sustainable	**Host country:** • Stable national legal framework • Maturity of regulatory system • Economic stability • Social stability	• Host country politically stable • Host and customer countries with good NPT commitments • Host country with proven ability in managing nuclear facilities • Host and customer countries deriving more advantages than disadvantages • Third party country interests to be respected

Aspects	Technical	Economic	Institutional	Ethical & Socio-political
Storage Time	**Customer needs** • Flexibility • Durability **Ensure** • Monitoring • Retrievability • Containment integrity • Physical security **Period up to 100 years:** • Storage technology available • Additional monitoring requirements likely as durations extend **Period 100 to 300 years** • Special maintenance programme Possible repackaging	**Beginning:** • Economic incentive • Storage capacity limitations • NPP decommissioning **End:** • Repository available • Reprocessing desired • Take back • Political decision	• Maintaining institutional stability • Maintain regulatory and safeguards control • Implementation difficulties foreseen in the long run	• Definition of storage period required at the beginning • Adherence to agreed storage period • Demonstration of compliance to contractual responsibility for regional storage will be carried out • Transparency regarding the commitments for termination; take back, final disposal or reprocessing arrangements
Final Destination	Ensure safe condition of material for further management	Economic effect of extended storage difficult to predict	• Host- and customer compliance with contractual commitments • International assurance that agreements will be respected **Storage options:** • Return of fuel to owners; ownership remains with customer • Extended storage; delayed transfer of ownership • No return of fuel; ownership transferred to host country	Open debate on facility time frame and destination of material

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ACRONYMS

AFR	away from reactor (spent fuel storage)
ALARA	as low as reasonably achievable
AR	at reactor (spent fuel storage)
BEFAST	behavior of spent fuel assemblies during extended storage
EIA	environmental impact analysis
EURATOM	European Atomic Energy Community
Gwd	gigawatt-days
HLW	high level waste
ICRP	International Commission on Radiological Protection
MNA	multi-national approaches
MOX	mixed oxide
NPP	nuclear power plant
NPT	Non-proliferation Treaty
Pu	plutonium
R&D	research and development
RSFSF	regional spent fuel storage facility
SPAR	spent fuel performance assessment and research
tHM	metric ton heavy metal

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