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Viability of Sharing Facilities for the Disposal of Spent Fuel and Nuclear Waste

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VIABILITY OF SHARING FACILITIES FOR THE DISPOSITION OF SPENT FUEL AND NUCLEAR WASTE

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AN ASSESSMENT OF RECENT PROPOSALS

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FOREWORD

For a long time, ideas have been put forward and initiatives launched regarding cooperation in the nuclear fuel cycle, including both regional and multilateral approaches, to dealing with reprocessing, storage of spent fuel or, more recently, disposal of radioactive waste. The rationale behind the multinational disposal concepts ranges from concerns about the capability of some countries to implement safe national nuclear waste management programmes in a timely fashion, to questions about the availability of suitable geological formations; and, of course, the economies of scale in repository implementation are a major driver.

In addition to these issues of cost, environmental and safety considerations, other benefits of such approaches for storage and underground disposal are security and non-proliferation advantages, which have become increasingly important after recent terrorist events worldwide. The IAEA has supported, since the 1970s, multilateral initiatives that seek to reduce access to weapons usable nuclear material technologies.

Among different cooperation concepts, the sharing of facilities for dealing with radioactive waste management was proposed and developed through conferences and expert group meetings, as well as technical publications. The experience gained in other international frameworks, such as groupings in the European Union, was also reviewed. It was concluded that the scenarios and approaches proposed in earlier IAEA publications require further consideration regarding the conditions for their implementation, their viability, and the benefits and challenges inherent in the alternatives proposed.

It is useful to consider the wider issue of spent fuel disposition (reprocessing/encapsulation, storage and disposal) when discussing the option of shared repositories for the disposal of spent fuel and high level waste from reprocessing. This proper account to be taken of new initiatives and technologies in predisposal activities and their impact on the viability of developing shared disposal facilities. To encourage discussion on this topic, relevant information has been updated and is presented in this report.

The IAEA would like to express its thanks to all participants involved in the drafting of this report. Special thanks are due to C. McCombie (Switzerland) for his leading role in discussions during the consultants and technical meetings, and for his contribution in drafting and finalizing this report.

The IAEA officers responsible for this report were B. Neerdael and S. Hossain of the Division of Nuclear Fuel Cycle and Waste Technology.

EDITORIAL NOTE

CONTENTS

SUMMARY

The long-term management of waste at the back-end of the nuclear fuel cycle remains one of the most critical issues affecting the acceptance of nuclear power and consequently the challenges associated with the global expansion of nuclear power. A full solution to the responsible long term management of the waste implies a credible disposition strategy, an institutional framework to allow its implementation and the scientific, technical and industrial capabilities to carry out the necessary activities. Safe and secure repositories are needed not only for countries with nuclear power programmes but also from the many additional countries that produce long-lived wastes from other nuclear applications in research, medicine and industry. Those countries may encounter some difficulties to develop or to implement a national strategy. One approach to avoid this situation would be the implementation of multinational or regional facilities. These have been recognized to have potential advantages in the areas of safety, nuclear security, non-proliferation, environmental impact and economics.

The main objective of this document is to give an updated overview of changing global attitudes towards nuclear power and of potential developments in the nuclear fuel cycle, with a view to assessing how these changes may influence the viability of establishing multinational disposition approaches for spent fuel. In this report the earlier work done on multinational initiatives for storage and disposal is referred to but it is not repeated in the detail. Instead, recent initiatives are described and their impacts on the viability of implementing multinational disposal facilities in the future are assessed.

Following the introductory Chapter, relevant aspects of the nuclear fuel cycle and some of the recently proposed developments that affect spent fuel disposition are described in Chapter 2. Technological alternatives for spent fuel disposition have been spelled out, all of which lead to a need for geological disposal that will require safety demonstration. The developments in reactor and fuel cycle technologies will have direct impacts on disposal, in both a technical and a strategic manner. At a technical level, the advanced approaches will change the nature and the volumes of long-lived radioactive wastes. Positive aspects are that smaller or fewer geological repositories may be needed. However, the new waste forms need to be properly characterized, in particular with respect to their long term behaviour. The advanced technologies and complex infrastructures needed for preparing new fuels and for advanced processing of spent fuel imply that multinational approaches will almost certainly be necessary in these areas since the capabilities will not be established in all countries.

Specific initiatives that have been proposed in recent years in order to make the fuel cycle more international are discussed in Chapter 3. Most of these multinational approaches have been focused on controlling the front end of the fuel cycle (enrichment) and on reprocessing, since these are the most sensitive technologies that would clearly be best restricted to a limited number of locations. The focus of the present report, however, is on the specific impacts of the proposed approaches on spent fuel disposition, and especially on the feasibility of multinational geological repositories.

All of the various initiatives described in Chapter 3 are currently theoretical concepts or at most study projects related to the possibilities for multinational cooperation. In Chapter 4, they are assessed with respect to their potential impact on the viability of multinational spent fuel disposal facilities. For each, an overview is produced of their strengths and weaknesses.

Selected critical issues to be faced in implementing multinational repositories are addressed in Chapter 5. Specific key issues have been identified as being sensitive or challenging by nature, not in a technological sense, but from a sociological perspective. All these issues are discussed in depth, along with drivers and frames that affect the disposal of spent nuclear fuel and long-lived and high-level waste.

Finally in Chapter 6 conclusions are formulated and suggestions are made for the future. The report concludes that multinational shared disposition facilities are a viable approach to enhancing the economics, safety, security and non-proliferation aspects for nuclear power globally. Legacy and other wastes have to be safely disposed of and small and new nuclear Member States are looking at partnering. Nuclear security concerns have led to new proposals and initiatives that further expressed the need for global cooperation to make safe disposal available in due time to all Member States.

All States should recognize that secure spent fuel disposition is an essential element of all nuclear power programmes, that the problem is global in nature but also that a solution is mandatory. International cooperation should be strengthened in order to achieve this global solution and the involvement of international organizations further stimulated. International cooperation should, however, never be used as an argument to postpone a decision or to establish a wait-and-see approach.

1. INTRODUCTION

1.1. Background

Responsible use of nuclear power requires that – in addition to all of the safety, security and environmental protection measures associated with power plant operation – credible solutions are developed for dealing with the wastes produced. These wastes include spent fuel (SF), if it is regarded as waste, high level waste (HLW), if reprocessing is carried out, and all other radioactive wastes produced as a result of nuclear power production. A full solution to the responsible long term management of the wastes implies a credible spent fuel disposition[1] strategy, an institutional framework to allow its implementation and the scientific, technical and industrial capabilities to carry out the necessary activities.

There are no operating geological repositories for final disposal of spent fuel or of HLW resulting from reprocessing spent fuel. The fundamental feasibility of implementing safe repositories is questioned by a significant fraction of the population in most countries. Accordingly, spent fuel disposition remains perhaps the most critical unresolved issue affecting the acceptance of nuclear power and consequently the challenges associated with the global expansion of nuclear power.

> *"Spent fuel disposition" is understood in this report to encompass all activities following the discharge of the spent fuel from a reactor core, including any storage at the reactor site or away from the reactor, transportation, any reprocessing and subsequent recycle activities, the conditioning of spent fuel or any remaining waste materials, the interim storage of the conditioned wastes or spent fuel and the final disposal.*

There is a technical consensus that the end point for spent fuel disposition must include geological disposal, either of the spent nuclear fuel itself or of long lived waste products produced by reprocessing the fuel. This is the only approach judged feasible for providing the necessary long term passive protection of humans and the environment.

The geological repository is likely, in turn, a sensitive aspect in spent fuel disposition. In some advanced countries, great progress has been made towards implementation of geological repositories for SF/HLW disposal. For example in Finland, Sweden, and France the most challenging step – identifying a final repository site – is at or near completion. Although some countries have been able to make progress towards a national spent fuel disposition system, many have scarcely begun and several national programmes are blocked for political, technical or economic reasons, with no clear path forward. In all cases, the implementation process is long and complex and the costs that will be involved in construction and operation of the facilities are high.

For some national nuclear programmes – in particular small or new nuclear programmes – repository implementation can be especially difficult. Furthermore, the inventories of HLW or

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[1] It should be noted that this is a wider definition than is used in many other reports (see the box above)

SF in such countries grow slowly, so that it can be many decades before enough waste is accumulated to justify beginning with disposal. To bridge this gap, dry or wet storage capabilities for spent fuel can be constructed centrally or at reactor sites and these allow time for the necessary difficult decisions to be prepared and acted on. During this time, however, spent fuel will be stored at the surface in many diverse locations around the world. Although, with the investment of sufficient resources, the individual facilities can be constructed and operated in a safe and secure manner, their large number may pose an unnecessary potential global safety and security threat. One approach to avoid this situation would be the implementation of multinational facilities. These have been recognized to have potential advantages in the areas of safety, security, environmental impact and economics [1-4].

Already in the 1970s, the IAEA supported multinational initiatives for these reasons. When the concept became again topical at the beginning of this decade, IAEA support continued. A key technical document, *“Developing multinational Radioactive Waste repositories: Infrastructural framework and scenarios of cooperation”* [5] was published in 2004 and summarized the status at that time.

In the intervening years, several developments have altered the global nuclear framework in a way that increases interest in nuclear power, in geological disposal and in multinational approaches to achieving this.

Firstly, there has been a marked increase in the nuclear power ambitions of existing nuclear energy nations and of new countries considering introducing nuclear power. This reflects:

- surging demands for energy in general, and especially for electricity, resulting from economic development and population growth;
- the improved technical efficiency and economic viability of electricity from existing plants around the world;
- energy security concerns as global demand increases for petroleum and natural gas; and
- increased awareness of the impact of carbon dioxide emissions on the global climate and weather.

Spreading nuclear power to numerous nations will require a global framework and extensive multinational cooperation if safety standards are to be maintained from power plant operation through to final disposition. For all countries using nuclear power, safety is a global issue since history has illustrated dramatically how nuclear accidents in any country can severely impact acceptance in all others.

Secondly, there has also been a continuing debate about nuclear proliferation and security risks. This debate has been fuelled by concerns about the spread of nuclear technology making it easier for States to break or withdraw from the Non-Proliferation Treaty (NPT) and to initiate nuclear weapons programmes and by the growth in international terrorism. The most immediate concerns are related to enrichment and to reprocessing technologies that could extract plutonium from spent nuclear fuel. Concentrating SF/HLW at fewer, well secured locations rather than having it widely distributed lowers the risks of its misuse by terrorists.

The third and newest point is that interest has grown in advanced reactor types and advanced fuel cycles. This arises for a number of reasons:

- If nuclear power plants are to spread throughout the world, then more efficient fuel use, improved passive safety systems and proliferation-resistant reprocessing routes are key goals.
- In the beginning of the 2000s, the U.S. retreated from the strongly anti-reprocessing stance that it took for some decades and is now considering closed fuel cycles in its national strategy. Since the USA also controls the actions taken by foreign users of US fuel technology, any developments will also influence the availability of the reprocessing option available in other countries.
- New back-end processing may result in waste streams that reduce the real or perceived burden of demonstrating the safety of geological repositories over long times. It may also ultimately result in waste streams that offer more flexibility in developing concepts for national or multinational repositories.

Ensuring that the benefits of nuclear power can be offered around the world on a much larger scale than at present requires that the complete nuclear fuel cycle, including the final disposal step, must be based to a far greater extent than hitherto on multinational cooperation.

This has led to a number of new initiatives and projects which are described in the present report. The objective is then to assess their specific impacts on the viability of multinational facilities for disposal of spent fuel or of the waste products resulting from its processing.

1.2.Early studies on multinational approaches

1.2.1. Disposal Studies

The IAEA-TECDOC-1413 [5] was published with the aim of providing a reference document for Member States potentially interested in multinational repository concepts as hosting, partner or third party countries. The main objectives of the document were to develop potential scenarios of cooperation that might be applied for the implementation of multinational repositories and to define the requirements that should be followed by Member States interested in pursuing such a cooperative effort. Three main scenarios were identified as potentially feasible and were described in the document.

The first is the *cooperation scenario* in which a shared repository is developed by a group of partner countries. Two or more countries join in a mutual agreement on building a repository in one or more of the participating countries, rather than having a national facility in each and every country. If a group of countries belong to the same geographical region, a repository can be called a regional repository; otherwise, it is called multinational repository.

The next option is an *add-on scenario* which assumes that a host country that has already implemented a national repository at some later stage offers to complement its national inventory of wastes for disposal by wastes imported from other countries. Motives for such a decision could be of an economic nature — share or decrease disposal costs — or related to safety and security. In practice, in the add-on scenario, the repository remains effectively a national repository, but with a part of the nuclear waste inventory arising from another country.

In the third option, the *international or supranational scenario,* a higher level of control and supervision is implemented. The operation of such a repository (or network of repositories) would be fully in the hands of an international body perhaps with the governing body employing a competent industrial consortium to actually construct and operate the repository.

Each host country would, in this scenario, cede control of the necessary site to the specified international body. The additional complications of creating an extraterritorial framework and of developing a financial model that is appealing to the host country and solving the myriad technical problems associated with opening a geological repository were regarded in Ref. [5] as making this scenario unlikely in the near-term future. However, increasing global concerns over proliferation and nuclear security today may make countries more willing to cooperate in this area and thus make the *international or supranational* approach more credible.

An additional concept — relatively new at the time that document under Ref. [5] was being produced in 2004 — was also mentioned, namely fuel leasing. This concept assumes that the uranium producer or fuel fabricant does not transfer title of the fuel when it is delivered to the user. Instead the fuel is leased for use in the reactor and returned to the supplier when unloaded from the reactor. Such a concept would allow all countries, even those with small nuclear programmes, to benefit from nuclear power without being faced with the challenge of managing the spent fuel and providing all necessary infrastructure by itself. However, it was recognized that for providing leasing services, the fuel supplier must be in a country that will accept the return of spent fuel from other countries, i.e. in an international repository host country, or else the fuel supplier must have access to a multinational repository in a third country.

In the report, the benefits and challenges of a multinational approach, both for the host and for the partner countries, were addressed. Important benefits and challenges were recognized in the areas of security, environmental safety, non-proliferation, economics, institutional requirements, and public acceptance and support. The principal conclusions drawn were:

(1) Multinational repositories can enhance global safety and security by making timely disposal options available to a wider range of countries. For some Member States, multinational repositories are a necessity, if safe and secure final disposal of long-lived radioactive waste is to replace indefinite storage in surface facilities.
(2) The global advantages of multinational repositories are clear and the benefits can be significant for all parties, if they are equitably shared. For individual countries, the balance of benefits and drawbacks resulting from participation as a host or as a partner must be weighed by the appropriate national decision making bodies.
(3) Implementation of multinational repositories will be a challenging task. However, there are a number of conceivable scenarios under which their development might take place.

This report endorsed the conclusions of an earlier IAEA Report [1] on this topic:

(1) The multinational repository concept does not contradict ethical considerations.
(2) The high ratio of fixed to variable costs for a repository ensures that considerable economies of scale will apply.
(3) Transport of nuclear material is so safe that the distances resulting from a multinational repository will not have a significant impact on public health.

This led to the following key recommendations:

(1) The concept of multinational repositories should continue to receive support from all countries that have an interest in a shared disposal solution.
(2) Discussion on the advantages, drawbacks and boundary conditions for multinational concepts can be initiated by interested countries without prior definition of potential host countries.

(3) Proponents of national and multi-national repository concepts should acknowledge that both types will be implemented and should try to ensure that activities undertaken in either case do not negatively impact the other.
(4) The potential interactions between recent proposals for nuclear fuel cycle centres and for multinational repositories should be studied in more depth, in particular in connection with security and safeguards issues.

Also described was a list of areas in which further work could be usefully done to advance multinational concepts. These areas included: safety and security, liabilities, legal and regulatory, economics, inventories and social sciences. The present report documents advances made in some of these areas.

1.2.2. Multinational storage options

Soon after the publication of the repository study [5], the IAEA also produced a report on multinational storage developments [6]. The following storage scenarios were looked at:

- Spent fuel is stored in a regional facility and returned at a specified time to the originating country
- Spent fuel is stored in a regional facility prior to reprocessing; HLW is returned to the originator or to a regional storage or disposal facility
- Spent fuel is stored in a regional facility and transferred directly to a regional disposal facility (in the same or another country)

The report discussed infrastructural issues of relevance, in the categories technical, economic/financial, institutional, socio-political, and ethical. In its conclusions, it was recognized that the regional spent fuel storage concept is technically feasible and potentially viable and that storing spent fuel in a few safe, reliable, secure facilities could have safeguards, and security benefits. There have been suggestions that multinational storage schemes might be more easily implemented than final disposal projects with their indefinite timescales. However, public and political opposition to accepting foreign fuel for storage has also been strong, unless definite agreements for sending the material back to the owner are in place. Moreover, modular storage systems can be implemented in any country and with dry storage technologies there are little benefits from economies of scale. Accordingly, the potential benefits of regional cooperation are judged to be greater for disposal than for pure storage facilities.

1.3. Recent developments in multinational approaches

Since the publication of the above-mentioned reports, there have been a number of important developments influencing the viability of multinational facilities for disposition of spent fuel. The drivers for these initiatives are mixed and inter-connected. They include:

- Growing concerns that the global expansion of nuclear power could lead to spreading sensitive technologies like enrichment and reprocessing and also spreading spent fuel (with its remaining fissile material content) at numerous national locations around the world.
- The continuing difficulties of national programmes (with some limited exceptions) in identifying technically and socially acceptable sites for geological repositories, and the realization that the very long times required to bring a repository into operation exposes it to political changes before completion.

- The awareness that new or small nuclear programmes may not be able to afford to handle their spent fuel in a safe and secure manner, and that a reliable solution to spent fuel disposition is an essential part of responsible nuclear power and hence critical for the global expansion of nuclear power.
- The fact that dry storage technology for spent fuel is available everywhere at reasonable costs, meaning that spent fuel processing and repository emplacement of nuclear waste can be deferred until optimal technologies are developed and deployed.

The most relevant studies and initiatives that have been undertaken are described in Chapter 3 of this report and their impacts on the viability of multinational disposition strategies are discussed in Chapter 4. The initiatives are of greatly differing scope and depth, so that they can not be categorized in any unique way. Some are specific projects that could lead to development of shared facilities in the relatively near future. Some are merely theoretical concepts at present. Some are truly global, others restricted to specific regions of the world. Finally some fit to the add-on scenario described in [5], whereas others are based on the cooperation scenario. The currently most concrete initiatives are as follows:

- The *Multilateral Approaches (MNA) Study* of an IAEA Expert Group [7]: this is an overarching strategic study looking at how multilateral approaches throughout the nuclear fuel cycle can enhance global safety and security.
- Russian initiatives such as the *Global Nuclear Power Infrastructure (GNPI)* initiative [8]: this is centred on proposals to establish multinational facilities providing shared ownership for enrichment, reprocessing and eventually disposal.
- The *Global Nuclear Energy Partnership (GNEP)* originally proposed by the USA [9]: this is a far-reaching effort aimed at promoting the global expansion of nuclear power while minimising security risks by encouraging States to rely on assured fuel services rather than acquiring indigenous enrichment and reprocessing capabilities. Success in GNEP would result in a small number of suppliers that provide assured supplies of fresh fuel and spent fuel disposition services for the rest of the world.
- The *SAPIERR projects* [10, 11] established under the auspices of the European Commission: this is a project devoted to pilot studies on the feasibility of shared regional storage facilities and geological repositories, for use by European countries.

These major initiatives are described in Chapter 3, together with accounts of other recent discussions and proposals related to the topic of multinational spent fuel disposition.

1.4. Objectives of the report

The objectives of the report are:

- To give an updated overview of changing global attitudes towards nuclear power and of potential developments in the nuclear fuel cycle, with a view to assessing how these changes may influence the viability of establishing multinational disposition approaches for spent fuel
- To summarise recent international developments specifically aimed at enhancing multinational cooperation in the nuclear fuel cycle in general, and particularly in concepts related to final disposition of spent nuclear fuel
- To comment on how and when such developments might influence the viability of multinational approaches

- To address in more detail some of the key open technical and strategic issues that were identified already in earlier IAEA work and that strongly affect the probability of success of multinational approaches
- To identify areas in which further work could be done to advance the progress of multinational approaches towards the final disposition of spent nuclear fuel.

1.5. Scope of the report

In this report the earlier work done on multinational initiatives for storage and disposal is referred to but it is not repeated in the detail included in the corresponding TECDOCs 1021, 1413 and 1482 [1, 5, 6]. Instead, recent initiatives are described and their impacts on the viability of implementing multinational disposal facilities in the future are assessed. This assessment is based on examination of the strengths of the proposals and the opportunities they provide for advancing multinational initiatives. However, it considers also their weaknesses and the threats that they might pose for national disposition programmes or for multinational cooperation prospects.

In principle, the disposition of spent fuel can involve various types of nuclear facilities, including reprocessing plants, storage facilities, encapsulation plants and repositories – all of which can be national or multinational. The focus of this report, however, as of its predecessor reports in 2004 and 1998, is on disposal facilities. The reason for this is that this final step in disposition has proven to be the most challenging of all – not in a technological sense, but in a sociological context. Lack of public confidence in safe disposal and the absence of any geological repositories for SNF/HLW are the two factors most often cited today as arguments against nuclear power. Furthermore, safe and secure repositories are needed not only for countries with nuclear power programmes but also from the many additional countries that produce long-lived wastes from other nuclear applications in research, medicine and industry. Several of the specific key issues on multinational repositories that have been identified in work to date to be of an especially sensitive or challenging nature are discussed in more depth in this report. Finally, conclusions based on the analyses are presented and suggestions are made for further work that could advance the progress of multinational cooperation in spent fuel and radioactive waste disposition.

1.6. Structure

Following this introductory Chapter, relevant aspects of the nuclear fuel cycle and some of the recent proposed developments that affect spent fuel disposition are described in Chapter 2. Specific initiatives that have been proposed in recent years since the publication of the document under [5] in order to make the fuel cycle more international are discussed in Chapter 3. Most of these multinational approaches have been focused on controlling the front end of the fuel cycle (enrichment) and on reprocessing, since these are the most sensitive technologies that would clearly be best restricted to a limited number of locations. The focus of the present report, however, is on the specific impacts of the proposed approaches on spent fuel disposition, and especially on the feasibility of multinational geological repositories. Chapter 4 discusses the disposition-specific aspects of the recent multinational initiatives. Selected critical issues to be faced in implementing multinational repositories are addressed in Chapter 5. Finally in Chapter 6 conclusions are formulated and suggestions are made for the future.

2. NUCLEAR POWER AND NUCLEAR FUEL CYCLE DEVELOPMENTS AS DRIVERS FOR MULTINATIONAL INITIATIVES

2.1. Introduction

In choosing their policies for the peaceful use of nuclear energy, states make decisions exercising their sovereign rights, taking into account also their international treaty commitments under, for example the NPT. They may, in principle, choose to pursue purely national nuclear programmes under their exclusive control to meet their nuclear energy generation requirements. Proposals have however been made to restrict the further spread of sensitive technologies that could give a capability for weapons production to additional countries. Measures that can be taken to ensure that restrictions do not affect security of fuel supply include supplementing the commercial market with assurance of supply mechanisms, such as backup guarantees by governments and reserves of nuclear material under IAEA auspices [12]. The IAEA refers to “sensitive technological areas” relevant to the application of safeguards as being: (a) uranium enrichment; (b) reprocessing of spent fuel; (c) production of heavy water; and (d) handling of plutonium, including manufacture of plutonium and mixed uranium/plutonium fuel. [13]

However, spent fuel itself also contains fissile Pu and U, as well as extremely hazardous radioactive wastes. It can therefore present a security risk, in that — if not properly managed — it could make nuclear proliferation by States or malevolent acts by terrorist groups more feasible. Moreover, the potential availability of spent fuel services to countries may assist in the decision for a country to introduce nuclear power. The chosen disposition route for spent fuel — what wastes will be disposed of and where — is therefore a crucial issue affecting the global development of nuclear power.

For some States, in particular for those not contemplating reprocessing, either because their inventories are too small or because continued use of nuclear power is not assured, direct disposal of spent nuclear fuel in a geological repository is an appropriate strategy. In fact, the most advanced programmes in Finland and Sweden are proceeding down this route. However, nuclear power concepts now under development are aimed at closed fuel cycles requiring spent fuel processing and follow-on use of recovered nuclear materials in complementary nuclear reactors. As indicated above, for safety, security, non-proliferation and economic reasons, it might be best to limit the number of facilities for such advanced treatments.

For the same reasons, multinational disposal arrangements for spent fuel or waste products produced in its processing will also be increasingly necessary as nuclear power expands and as the new fuel cycle concepts are implemented. The clear increase in interest in using nuclear power and the goal of managing the expansion in ways that reduce risks of proliferation and terrorism are strong drivers for implementation of shared spent fuel disposition facilities; spent fuel disposition services that include disposal will be part of the new nuclear power deployment paradigm.

Ultimately, a credible waste solution must include three elements:

- a technological and safety approach that will assure the public health and welfare and protect the environment;

- an institutional framework that will secure the benefits of the waste solution chosen, with clearly defined rights and responsibilities that are acknowledged and accepted by all parties, providing reliable disposition at affordable costs and providing sustainable performance throughout all phases of operation; and
- the scientific and technical capabilities and industrial facilities needed to implement the strategy, including a geological repository for long-lived nuclear waste.

2.2. Technological spent fuel disposition options

As shown in Table 1, today there are two currently implemented technological spent fuel disposition alternatives and a third is under development.

TABLE 1. TECHNOLOGICAL ALTERNATIVES FOR SPENT FUEL DISPOSITION

Spent fuel disposition strategy	Comments
(1) Direct disposal of spent fuel assemblies in a geological repository	Technically relatively straightforward to implement; requires long interim storage or else poses demanding heat load on geological repository; makes least use of potential energy of nuclear fuel; establishes “plutonium mine” in long term. Major societal challenges in siting.
(2) Reprocess using Purex process and recycle Pu and/or reprocessed uranium; vitrified waste to be disposed of in a geological repository	Reduces volume of high level waste; reduces radiotoxicity of repository inventory and needs less time to reach toxicity comparable to natural uranium; reduces heat burden; increases energy utilization; raises proliferation threat through use of sensitive technology; raises threat of nuclear terrorism. Major societal challenges in siting.
(3) Reprocess to partition uranium and all transuranics; recycle uranium, consume transuranics in fast spectrum reactor; vitrified waste to be disposed of in a geological repository	R&D and commercial investment is necessary to establish industrial viability; advanced fuel cycles potentially offer possibilities for various strategic choices regarding uranium resources and for optimization of waste repository sites and capacities, while keeping almost constant both the radiological impact of the repositories and the financial impact of the complete fuel cycle

All three technological alternatives for spent fuel and radioactive waste disposition lead to a need for geological disposal that will require safety demonstration. However, the radiotoxicity of wastes resulting from each technology will affect the repository designs differently.

Figure 1 shows how the residual radiotoxicity associated with the repository inventories for different disposition options will vary with time. From this observation one can conclude that option 3 offers potential advantages for the future, particularly in relation to the global expansion of nuclear power — but it can be implemented in full only some decades from now. Option 1 remains the baseline and the closest to implementation. Regardless of progress in Option 3, Option 1 will likely remain the preferred choice of some States. Option 2 is a transitional technology and, assuming that Option 3 is eventually shown to be technologically superior, and that the overall costs of nuclear power deployment under an arrangement designed around Option 3 are competitive with other arrangements, existing Option 2 facilities will likely be replaced by Option 3 technology as the Option 2 facilities retire from service.

It should however be noted that the radio-elements providing the highest radiotoxicity seldom turn out as the dominating elements in the long term safety assessment of disposal facilities. The highest doses come from mobile fission and activation products.

2.3. Reactor technology considerations

At the end of 2008, there were 439 nuclear power reactors in operation around the world, 34 more under construction and nearly 250 more in various stages of planning. As nuclear power increases, the need to have responsible spent fuel disposition arrangements in effect will become more urgent – as long as suitable arrangements are not in place, some members of the public and political leaders will remain openly sceptical and opposed to further reliance on nuclear power. Delaying the implementation of responsible spent fuel disposition arrangements may therefore limit the contribution of nuclear power to global energy supplies. The nuclear contribution to reducing greenhouses gases will not of its own, prevent global warming, but it is increasingly recognized as being a necessary part of the solution.

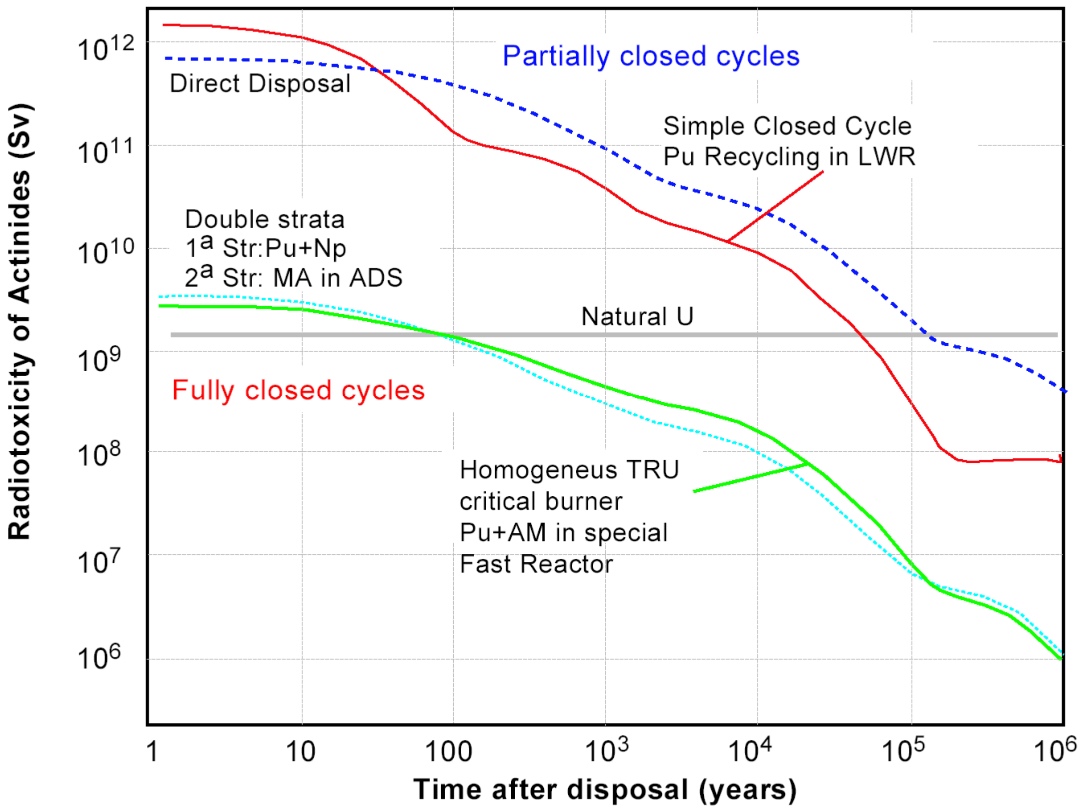

FIG. 1. Decrease with time of radiotoxicity associated with the repository inventories for different disposition options.

Most existing and almost all new reactors are water cooled reactors fuelled with natural or low enriched uranium fuel of UO_2 oxide pellets clad in zirconium alloy. Originally reprocessing spent fuel from such reactors was intended to produce plutonium that could be deployed as fuel in a future generation of fast reactors. Low uranium prices and unexpectedly slow growth in nuclear energy led to the introduction of fast reactors being delayed and, as a consequence, an alternative route for using the plutonium was developed. This involves the use of mixed plutonium-uranium oxide (MOX) fuel in the current and near future generations of reactors. Pressurized light water reactors (PWRs) can run with a part, or perhaps all, of their cores fuelled with MOX. Boiling light water reactors (BWRs) are also capable of using MOX fuel, but because more extensive control modifications are needed, are less suitable for this purpose. Next come Russian VVER reactors and pressurized heavy water reactors which could use MOX, but do not at present do so. Important in the present context is the impact of MOX usage on spent fuel disposition. Direct disposal of spent MOX is feasible, although the higher heat loads and longer lived toxicity have implications on the design and operation of repositories. Current reprocessing facilities are capable of accepting MOX; hence there is also an alternative path forward for the current generation of nuclear plants. Future recycling capability to extract all transuranics will concentrate first on the current reactors.

Spent MOX fuel does pose additional reprocessing complications and, as of today, burning MOX repeatedly brings reduced reactivity and increased radiological burdens. The ^{239}Pu content is reduced to 60% or less, and the percentage of the even isotopes, 238, 240 and 242, increases, adding neutron dose to workers. Until partitioning and transmutation is available, multiple MOX recycle will likely not be practical.

The long working life of current reactors and especially their lifetime extensions to 60 years (with additional extensions under consideration) implies that they will be the workhorses for the future of nuclear power over the next decades. New reactors may use different fuel forms for which there is currently no option other than direct disposal of spent fuel. The new reactors will included gas-cooled pebble bed reactors under development in China and South Africa with UO_2 fuels clad in pyrolytic carbon and silicon carbide; barge-mounted reactors with plate-type fuel; liquid metal or gas cooled fast reactors, and reactor concepts like the Atoms for Peace reactor, using zirconium cermet fuel with UO_2 kernels. The volumes of spent fuel arising from these reactors, especially those designed for long core life, will be far less than for the workhorse LWRs and HWRs. The spent fuel from the new reactors can be stored until recycling technology is developed, or disposed of in a geological repository under disposition option 1.

The next (fourth) generation (Gen IV) of nuclear power reactors is aimed at greater safety margins, higher thermal efficiency and eventually breeding to prolong nuclear power beyond the era when uranium is relatively abundant and inexpensive. They will be used to consume the growing inventories of separated plutonium and some will feature closed fuel cycles including transmutation of transuranics. They may continue to use oxide fuels, or carbides, nitrides, metals or cermets, which will likely be processed using modified or different (e.g., pyroprocessing) recycle technologies. The programmes developing the new power reactors normally incorporate spent fuel disposition arrangements integrated with the reactor development activities. Spent fuel disposition is included in the Gen IV programme to assure that all issues affecting successful deployment are resolved early on. At present, none of these reactors, except the oxide fuelled variants, have a known spent fuel disposition technology on the planning horizon.

Significant efforts to develop advanced fuel cycles are also being made within the IAEA project, INPRO (International Project on Innovative Nuclear Reactors and Fuel Cycles) [14], established in 2001. The objective is to bring together technology holders and users so that they can consider jointly the international and national actions required for achieving desired innovations in nuclear reactors and fuel cycles. As well as facilitating coordination and cooperation among the advanced nuclear nations, INPRO aims to address the specific needs of developing countries that are interested in innovative nuclear systems. Both Gen IV and INPRO have been recognized at the highest levels as being important for the continuing development of safe, innovative advanced nuclear power systems.

2.4. Impacts of new reactors and fuel cycles on geological disposal

The developments in reactor and fuel cycle technologies will have direct impacts on disposal, in both a technical and a strategic manner. At a technical level, the advanced approaches will change the nature and the volumes of long-lived radioactive wastes. Positive aspects are that smaller or fewer geological repositories may be needed. However, the new waste forms need to be properly characterized, in particular with respect to their long term behaviour. As illustrated in Figure 1, shorter toxic lifetimes can result and this may ease the problems of finding suitable repository sites and of developing expensive, long-lived engineered barriers. The expanding variety of fuel and waste types implies that handling and disposal facilities must be polyvalent. The technical advantages that advanced reprocessing methods and transmutation can bring in waste disposal may not be available for all types of advanced fuels. In any case, the scientific and engineering facilities needed to cope with diverse future fuel and waste streams will place new demands on the technical capabilities of the organizations treating the wastes and ultimately carrying out disposal. As discussed below, most of these technological developments increase the arguments in favour of shared repositories that avoid the necessity for all nuclear power programmes, however small, to develop all of the required technologies.

The new possibilities opened by reactor and fuel cycle developments influence strategic as well as technical thinking on disposition options. In particular, disposal strategies may change; spent fuel may become less of a liability and more of an asset, so that direct disposal will become less attractive. A key point, however, is that they do not eliminate the need for geological disposal. There are extensive inventories of existing spent fuel or wastes where new technologies can not be retroactively applied. Furthermore, none of the advanced treatments will eliminate all long lived wastes resulting from nuclear power generation. Lastly, other nuclear technologies also produce long-lived wastes that must be emplaced in geological repositories.

Recently, two studies were carried out to examine the impacts of advanced fuel cycles on radioactive waste policies and in particular on the disposal.

The first study, performed by a group of experts under the umbrella of the NEA Nuclear Development Committee, was published by the OECD mid-2006 [15]. Altogether 13 advanced fuel cycles within three families to illustrate differences between various technologies and levels of recycling capability were investigated and analyzed to assess their qualitative and quantitative impacts on the performance of different repository concepts. The fuel cycle schemes considered include options already at the industrial and commercial development stage, as well as very innovative variants which have not yet been fully demonstrated. Four schemes were chosen for comparison using selected 11 comparative assessment indicators:

- 1a (“once-through” PWR reactor, reference)
- 1b (Pu recycled once in the MOX for PWR)

- 2a (multi-recycling of Pu in the MOX for PWR)
- 3cV1 (all actinides recycling into carbide fuel for gas-cooled fast reactor)

The HLW repositories assessed in the study cover various deep geological formations that are considered adequate for long-term isolation of radioactive waste from the biosphere. The assessment was carried out for hypothetical, conceptual repositories in granite, salt, clay and tuff formations.

Although the emphasis within the study was on HLW, the impacts of advanced fuel cycle schemes on LILW generation, management and disposal were also briefly addressed. Results indicated that issues raised by secondary waste should not be neglected, in particular for innovative schemes leading to the generation of new types of waste with new chemical and isotopic compositions.

The main objective of the second study – Impact of Partitioning, Transmutation and Waste Reduction Technologies on the Final Nuclear Waste Disposal (RED-IMPACT) – was to investigate the impact of nuclear fuel cycles including partitioning and transmutation on the subsequent management of the radioactive waste. The synthesis report was published at the end of 2008 [16]. The basic approach was to compare issues related to radioactive waste management in a "once-through" fuel cycle with those for advanced nuclear fuel cycles. In the terminology of the RED-IMPACT project, the reference "once-through" fuel cycle was called scenario A1. Similarly to the NEA study, RED-IMPACT divided the fuel cycle schemes (called “scenarios” here) into two basic groups “industrial” and “more innovative”. Consequently, the impacts of five scenarios were analyzed:

- A1 – direct disposal of spent fuel with no reprocessing
- A2 – all spent PWR fuel is recycled once and the MOX spent fuel is disposed of directly after its reuse in PWR; the inventory for disposal includes spent MOX fuel, vitrified waste from reprocessing and LILW arising from reprocessing
- A3 –Pu and U are recycled in a fast reactor; disposal is only for HLW (containing all the minor actinides) and LILW
- B1 – similar to A3 but the minor actinides are also recovered by reprocessing and recycled in the fast reactor
- B2 – involves a combination of LWRs, reprocessing, and an Accelerator Driven System (ADS); disposal of HLW from reprocessing of UO2, MOX and ADS fuel elements, plus LILW

The project led to complex assessment of the impact on waste management prior disposal, repository design, long term safety and management of LILW, taking into account three alternative environments for geological disposal: clay, granite and salt [17].

The repository design considerations focused on the thermal impact of the new waste forms on the dimensions of the repository. The main results are summarized in Table 2.

For disposal in granite and clay, the radiological consequences of the disposal of HLW and spent fuel were analyzed for the case of the normal evolution scenario; for disposal in salt a brine intrusion scenario was analyzed, because no release of radionuclides from the salt dome is expected as long as the salt dome remains intact. The main conclusion that can be drawn from the dose calculations performed for disposal in granite, clay and salt is that the introduction of advanced fuel cycles has only a limited impact on the doses resulting from the geological disposal of the corresponding high-level waste or spent fuel. This is because the doses are essentially due to mobile fission and activation products. The amount of these products generated is not significantly influenced by the introduction of advanced fuel cycle scenarios.

TABLE 2. MAIN RESULTS OBTAINED WITHIN THE STUDY (ALL INDICATORS ARE GIVEN AS VALUES RELATIVE TO THE REFERENCE "ONCE THROUGH" FUEL CYCLE A1)

	Gallery length (clay, salt)	Maximum dose (granite)	Maximum dose (clay)	Cumulative released radiotoxicity (1 Ma, clay)	Radiotoxicity after 500 a	Human intrusion dose (500 a)
A1 (PWR)	1.00	1.000	1.000	1.0000	1.0000	1.0000
A2 (PWR, 1x recycle. Pu)	0.97	0.316	0.316	0.164	0.803	2.72
A3 (FR, multi-recycle. Pu)	0.59	0.231	0.160	0.0044	0.499	1.36
B1 (FR, multi-recycle. Actinides	0.32	0.218	0.151	0.041	0.0042	0.0155
B2 (PWR + ADS)	0.49	0.11	0.130	0.040	0.0053	0.0818

The cumulative radiotoxicity released into the biosphere, integrated up to 1 million years, was calculated only for disposal in clay. It also strongly depends on the amount of ^{129}I present in the disposed waste and consequently of the amount of spent fuel that is reprocessed. When looking at the results of the cumulative radiotoxicity released into the biosphere, one should note that during reprocessing a large fraction of the ^{129}I is separated from the high-level radioactive waste and is either directly discharged or conditioned in a matrix that will also have to be disposed of somewhere. The radiotoxicity in the high level waste or spent fuel at 500 years is drastically reduced by including an ADS or fast reactors in the fuel cycle. This is true also for the doses calculated for human intrusion.

A key general point emerging from both studies is that none of the advanced fuel cycle technologies eliminates the need for geological disposal. None of the advanced treatments eliminates all long lived wastes resulting from nuclear power generation. Moreover, there are extensive inventories of existing spent fuel or wastes where new technologies can not be retroactively applied. Lastly, other nuclear technologies also produce long-lived wastes that must be emplaced in geological repositories.

2.5. Influence of new fuel cycles on multinational approaches

The advanced technologies and complex infrastructures needed for preparing new fuels and for advanced processing of spent fuel imply that multinational approaches will almost certainly be necessary in these areas since the capabilities will not be established in all countries. Although States may, in theory, still today decide to implement their own reprocessing plants, indigenous fuel cycle arrangements in all countries are unlikely in a scenario with greatly increased nuclear power and new processing technologies. For disposal, the situation may be different. At one extreme, new developments of the type discussed could, in principle, have impacts on national disposal planning – but little or no impact on multinational approaches. States may still opt to dispose of their own spent fuel or may agree to accept returned wastes from reprocessing and dispose of these in a national repository. In practice, however, multinational approaches are likely to be increasingly attractive throughout the whole backend, including disposal. Nuclear fuel suppliers may become more willing to accept returned spent fuel if advanced processing can extract more valuable recyclable materials and also result in less toxic, shorter lived waste streams. If disposal is primarily foreseen for non-fissile, relatively short-lived wastes, the range of potential host countries becomes wider. Flexible integrated schemes with different repository types being allocated to different host countries may become more feasible.

Mechanisms may be identified in which one or more States agree to share certain aspects of a spent fuel disposition arrangement that will be carried out in specified locations. Depending on the timing, economics and reliability of this combined system, States that agree to be only users of nuclear power may decide to require advantageous spent fuel disposition arrangements. The key requirements may be assurances of fresh fuel supply and of a disposition route for the radioactive wastes. The driving factors in such decisions include the following:

(a) Until States having nuclear power define their strategies and engage in programmes that will provide a safe disposition solution, “the spent fuel problem” will continue to be considered, to be unsolved. This will undermine public acceptance and thereby impede the acceptance of nuclear power. Introduction of new nuclear capacity will be more acceptable with a credible multinational disposition strategy than with no strategy or a national strategy that is clearly realisable only at very long times and very high costs.

(b) The wish to recover from its spent fuel materials (Pu and U) that can be re-used in energy production may lead a State to reprocess its inventory. However, reprocessing can also be pursued to provide weapon materials. Spreading reprocessing technology may raise risks of proliferation, and reprocessing plants, separated plutonium and hazardous radioactive materials, may be targets for terrorists.

(c) Spent fuel and HLW inventories themselves represent a potential terrorist target for sabotage, through the intentional dispersal of hazardous radioactive material. Maintaining adequate physical protection at an operating reactor is necessary in any case to protect the reactor, its core inventory of nuclear material and any fresh fuel stored at the nuclear power plant, especially fresh MOX fuel. If the spent fuel remains at the nuclear power plant after the reactors are shut down and decommissioned, the likelihood of adequate protection may decrease over time.

(d) Dry or wet spent fuel storage technologies provide practical means to construct increased storage capacity that is affordable and within the technological means of most States. Using additional wet or dry spent fuel storage could allow a State to postpone repository decisions. Prolonged postponements may be attractive in the short term but may raise or exacerbate the security concerns noted above.

Any of the disposition paths mentioned in this Chapter may be taken by individual States to meet their national requirements in any of the ways described in the IAEA studies on multinational storage or disposal [5, 7]. Any individual State, could, if it so desired, provide services to other States. A group of States could cooperate in creating arrangements to meet the needs of the participating States, sharing the costs and responsibilities, and the group of States could decide to offer spent fuel disposition services to other States. A global solution to solving the spent fuel disposition problem could consist of a mixture of these approaches offering assurance to all participants.

However, siting a repository is politically contentious under the best of circumstances and engaging additional States in a multinational process that attempts to fix the conditions of service over the time scales involved may be much more complicated, depending on how the terms are fixed initially and the changes that occur over time. Nevertheless, sharing facilities brings obvious economic, technological, security and environmental benefits if a reliable scheme can be instituted that will weather changes in need, competition, economic well-being, environmental concerns and public/political acceptance. Any sharing arrangement will be enhanced by anticipating the conditions likely to arise and by agreeing at the outset on the basic abiding principles under which issues will be addressed and resolved. Fixing the conditions in legally binding instruments backed by the governments of the States participating will be more likely to weather complications than less formal arrangements.

A sharing arrangement could be created under a convention that would allow States to offer or subscribe to spent fuel disposition services under binding arrangements. If such an arrangement involved the IAEA in a central role, the arrangement could provide a platform under which all participants' needs are addressed in a competent and fair manner.

Many of the questions that must be answered before realisation of such schemes have been addressed — not for the first time — in multinational initiatives proposed over the past few years. Chapter 3 describes these recent developments.

3. RECENT DEVELOPMENTS IN MULTINATIONAL INITIATIVES

Since the publication in 2004 of a previous TECDOC [5], there have been several significant developments related to the question of multinational disposal facilities. It should be noted that some of the proposals listed below consider wider aspects of the fuel cycle than disposal; in fact, most place emphasis on enrichment and reprocessing. However, this report analyzes the proposals from the perspective of final disposition, even though this may not be the primary focus of the proposal. Some new impulses have been at the overarching conceptual level but others directly affect the add-on scenarios, the cooperation scenarios and also the leasing option that was mentioned in the TECDOC. The following developments are briefly described in this chapter

International strategic studies and statements:

- the proposals of the MNA Expert Group established by the IAEA
- the World Nuclear Association report on security of supply
- proposals put at the special event at the 2006 General Conference of the IAEA
- studies of the National Academies of USA and Russia

Initiatives based on possible add-on and leasing scenarios:

- the US GNEP proposal
- the Russian GNPI proposals
- other repository sharing or fuel leasing proposals

Initiatives based on cooperation scenarios:

- the SAPIERR Project
- the Arius Association

3.1. International strategic studies and reports

3.1.1. MNA Expert Group

The Multinational Nuclear Approaches Expert Group (MNA) was set up by Director General ElBaradei of the IAEA in 2004 to explore options and develop proposals for improved controls, including possible multilateral oversight arrangements of the nuclear fuel cycle [7]. The Group comprized individuals with practical experience in the nuclear field drawn from 26 countries, and participating as independent experts. The topics covered by the Group included all aspects of the nuclear fuel cycle, with most emphasis on the especially sensitive technologies such as uranium enrichment and fuel reprocessing. The topics of greatest relevance in the context of the present report - storage and disposal of sent fuel and radioactive wastes - were also prominent, however.

In the following text, those passages that are of most direct relevance to the work on disposition are cited directly. These sections are directly related to earlier statements from the Director General in which he has emphasized the need to consider the merits of multinational approaches to the management and disposal of spent nuclear fuel and radioactive waste. He has pointed out that not all countries have the appropriate conditions for geologic disposal – and that, for many countries with small nuclear programmes for electricity generation or for research, the financial and human resource investments required for research, construction and operation of a geologic disposal facility are not available. Accordingly, the DG had already concluded that considerable economic, safety, security and non-proliferation advantages may therefore accrue from international cooperation on the construction and operation of international nuclear spent fuel and waste repositories.

The Expert Group had three objectives:

- *"To identify and provide an analysis of issues and options relevant to multilateral approaches to the front and back ends of the nuclear fuel cycle;*
- *To provide an overview of the policy, legal, security, economic, institutional and technological incentives and disincentives for cooperation in multilateral arrangements for the front and back ends of the nuclear fuel cycle; and*
- *To provide a brief review of the historical and current experiences and analyses relating to multilateral fuel cycle arrangements relevant to the work of the expert group."*

The principal characteristics used to assess multilateral nuclear approaches, were "assurance of non-proliferation" and "assurance of supply and services". For the latter, a system for supplying material or services would have to include back-up sources of supply in the event that an MNA supplier is unable or unwilling to provide the required material or services.

For uranium enrichment, spent fuel reprocessing, or spent fuel disposal and storage, the following multilateral options were regarded as feasible:

Type I: Assurances of services not involving ownership of facilities.

Type II: Conversion of existing national facilities to multinational facilities.

Type III: Construction of new joint facilities.

For each, advantages and drawbacks were defined relative to a system including only national facilities under current safeguards.

Of most relevance here are the conclusions that the Expert Group drew concerning spent fuel disposal.

> *"At present there is no international market for spent fuel disposal services, as all undertakings are strictly national. The final disposal of spent fuel is thus a candidate for multilateral approaches. It offers major economic benefits and substantial non-proliferation benefits, although it presents legal, political and public acceptance challenges in many countries. The Agency should continue its efforts in that direction by working on all the underlying factors, and by assuming political leadership to encourage such undertakings.*
>
> *The final disposal of spent fuel (and radioactive waste as well) in shared repositories must be looked at as only one element of a broader strategy of parallel options. National solutions will remain a first priority in many countries. This is the only approach for States with many nuclear power plants in operation or in past operation. For others with smaller civilian nuclear programmes, a dual-track approach is needed in which both national and international solutions are pursued. Small countries should keep options open (national, regional or international), be it only to maintain a minimum national technical competence necessary to act in an international context.*

The MNA Group also considered the leasing option, while recognizing that it could be politically difficult for any State to accept spent fuel not coming from its own reactors. It was pointed out that a fuel leaser does not necessarily have to itself dispose of the returned spent fuel. It could also be sent, through an IAEA-brokered deal, to a third party State or to a multinational or a regional fuel cycle centre located elsewhere. The most direct IAEA involvement could result in the IAEA becoming an active participant in spent fuel disposal schemes, thereby making leasing with take-back of fuel a more credible proposition.

The Group perceived both symbolic and practical advantages with MNAs. They can serve to build public and political confidence, result in a greater degree of scrutiny from peer review and reduce the number of sites where sensitive facilities are operated, thereby reducing proliferation and terrorist risks. In addition, they can improve the prospects for universal safe, secure and environmentally sound storage and disposal of spent nuclear fuel and radioactive waste, while providing benefits of cost-effectiveness and economies of scale. The difficulties with multilateral approaches were also recognized. These include the loss of State sovereignty and restriction of commercial freedom that can be perceived by smaller countries.

The Expert group suggested five specific approaches to multilateral nuclear approaches in general. The application of these to spent fuel disposal is discussed in Chapter 4.1.

3.1.2. WNA views on security of supply at the back end of the fuel cycle

In May 2006, the World Nuclear Association also published its views on security of supply in the international fuel cycle [18]. Again, most emphasis was on provision of enrichment and reprocessing services. However, the disposal issue was also addressed and the following conclusions reached.

> *"If, for a given State, spent fuel is considered as an ultimate waste form to be disposed of, then the existence of regional or international repositories must be favoured from a global non-proliferation viewpoint in order to limit in the long-term the dissemination of "plutonium mines", and to reduce and optimize international safeguards resources. …. The development of international waste repositories not requiring safeguards (i.e. specifically for vitrified HLW) could be an incentive for certain countries to choose reprocessing if associated services for waste disposal were offered. … A leasing/take-back approach should also be envisaged for any country that uses or wishes to use nuclear power, but may not be in a position to implement safe and secure disposal."*

The WNA distinguishes between spent fuel repositories where safeguards is an issue and vitrified HLW repositories where this is not the case. This argument is used to justify a decision by the reprocessing country that HLW can be sent back to the user country. This is an important point for countries like France which wish to provide reprocessing services globally but have laws requiring the return of resulting HLW. The drawbacks from the user country point of view are obviously that security problems may still result from the extremely hazardous HLW and that expensive geological disposal facilities are still required. The concerns and objectives of the nuclear industry were that nuclear power should be utilized and expanded in a way that minimises safety and security risks. To achieve this, the WNA encouraged States with already developed back-end facilities servicing foreign regional customers to avoid the spread of sensitive nuclear technologies worldwide by the establishment of multi-lateral nuclear fuel cycle centres operating under full IAEA safeguards.

3.1.3. Proposals at the 2006 IAEA General Conference

At the 50th IAEA General Conference a Special event took place, the subject being a *New Framework for the Utilization of Nuclear Energy in the 21st Century: Assurance of Supply and Non-Proliferation*. There was broad participation from governments, regulators and industry. Discussions mainly covered assurance of fuel supply, but assurance of back-end services was also raised. Several proposals were made for assurance of fuel supply. All proposals dealt with assurances in case of a political disruption not connected to non-proliferation. The assumption was that other disruptions should be managed by the market.

Opening the meeting, IAEA Director General ElBaradei posed a number of points for consideration, including questions on issues of financing, liabilities and the role of the IAEA. Although the discussion focussed heavily on the front end, similar questions could be posed about storage and disposal facilities for spent fuel returned to a leaser, and it is important for security reasons to ensure that these topics are not wholly lost in the current urgent demands to sort out the front end. Coinciding with the opening of the meeting, the Nuclear Threat Initiative (NTI: a US-based charitable body) announced that it would contribute $50 million (donated by the investor Warren Buffet) to the IAEA to help create a low-enriched uranium stockpile to support nations that make the sovereign choice not to build indigenous nuclear fuel cycle capabilities, contingent on two conditions: that the IAEA takes the necessary actions to approve establishment of this reserve; and that one or more Member States contribute an additional $100 million in funding or an equivalent value of low enriched uranium to jump-start the reserve.

Other proposals were made by Russia, Germany, UK and Japan. This is a positive development. However, given the reality of the current international security situation, attention is being focussed on front end issues as a first step to establish multilateral nuclear approaches, with the back-end issues to be progressed at a later stage. Nevertheless, attention must be paid to the fact that disposition solutions for spent fuel must also be progressed.

3.1.4. US National Academies and Russian Academy of Sciences initiatives

In 2006, a project with the title "Internationalization of the Civilian Nuclear Fuel Cycle" was initiated under the joint leadership of the Committee on International Security and Arms Control and the Nuclear and Radiation Studies Board of the US National Academies [19]. This is a joint study by the U.S. National Academies and the Russian Academy of Sciences (NAS and RAS) aimed at providing an assessment of the technical, economic, legal/regulatory, and non-proliferation criteria necessary for the implementation of an international civilian nuclear fuel cycle. The NAS-RAS joint study is addressing a number of primary issues and questions. The most relevant part of the Academies' study in the present context concerns providing fuel services to countries that already have Light Water Reactors or would be interested in constructing Light Water Reactors if they did not have to develop the entire fuel cycle. The ultimate objective of the committees is to carry out an analysis of the criteria necessary to achieve an international fuel cycle beneficial for suppliers and consumers alike and supportive of international non-proliferation efforts.

Another related NAS-RAS initiative led to joint US-Russian National Academies Workshops on *Setting the Stage for International Spent Nuclear Fuel Storage Facilities* [20, 21]. The first workshop was held in Moscow in 2003; the second in Vienna in 2005. Attached to the first event was a study visit to the Eastern Siberian town of Krasnokamensk, where local politicians were offering to initiate an international repository project. The discussions in the later meeting focussed on packaging and shipping of spent fuel, liability and insurance during shipping and receiving at a repository, the adequacy of national legislation and country perspectives on the Russian proposals for international spent fuel storage. The meeting illustrated the interest within Russia and the USA, at scientific and technical levels, to develop a Russian project. A third joint workshop of the US National Academies and the Russian Academy of Sciences was held in April 2007 in Vienna to discuss ideas and impediments in further internationalizing the fuel cycle. RAS and NAS members noted that a spent fuel/waste take-back offer would present to an incipient NPP country the single-most significant incentive that could be offered by the major nuclear power nations. The need to avoid splits between the have/have-not with respect to country's nuclear fuel cycle standing was recognized as vitally important. Also reconfirmed was the resistance to proposals that IAEA Member States give up their 'rights' to using nuclear technologies. In the published report on the 2007 Workshop [21], the important finding and conclusion in the context of the present report also has implications for the Russian and US initiatives described in section 3.2 below. The following text is extracted from the report:

> *"Arrangements that would provide assured return of spent nuclear fuel could provide a much more powerful incentive for countries to rely on international nuclear fuel supply than would assured supply of fresh fuel, because assured take-back could mean that countries would not need to incur the cost and uncertainty of trying to establish their own repositories for spent nuclear fuel or nuclear waste. …..The United States, Russia, and other suppliers should increase their emphasis on establishing mechanisms for assured fuel-leasing or reactor-leasing services, including take-back of all irradiated fuel. …….. The United States and Russia should work together on cooperative approaches that would make it possible to enter into fuel-leasing arrangements in which they would guarantee to*

> *supply, and to take back, fuel for the lifetime of reactors built in "newcomer" states, with the fuel taken back to Russia for now, or to the United States as well if circumstances someday make that possible."*

Yet another Russian initiative led to a major conference in Moscow in 2005, organized by Rosatom with the support of the International Atomic Energy Agency (IAEA), entitled *Multilateral Technical and Organizational Approaches to the Nuclear Fuel Cycle Aimed at Strengthening the Non-Proliferation Regime.* In keeping with the conference title, the dominant theme was nuclear security and the role that multinational initiatives can take in achieving this. The meeting was opened by the Russian minister, who described a possible international network of nuclear fuel cycle centres acting as service providers. In the context of the present report, the interesting question is whether such centres could provide a disposal service. In practice, Russia does not regard spent fuel as a waste, but as a resource that can be processed to recycle valuable fissile material. Russia is able legally to import spent fuel for storage and reprocessing, but retains the right to return HLW.

Rosatom also promoted the concept of an international spent fuel management centre in Russia. Estimates were provided of the resources that would be needed to establish an international regional centre in Russia for storage, reprocessing and disposal of HLW. There is already Russian, Bulgarian and Ukrainian spent fuel in storage at the Krasnoyarsk site. Potential disposal sites have been identified at two locations, 4 and 30 km from the store. Current drilling exploration underlines the Russian intent to build a deep repository in the future.

3.2. Current specific add-on and leasing initiatives

In addition to the rather general discussions that have taken place at meetings such as those described in the previous section, there have been some more specific and more committing proposals tabled by the USA and Russia. Both proposals are by major nuclear powers that are eventually going to have large national repositories; both involve acceptance of spent fuel from foreign countries; hence both reflect the principles of the add-on scenario developed in [5].

3.2.1. US GNEP proposal

The Global Nuclear Energy Partnership (GNEP) [9] presents a nuclear paradigm, which, when fully deployed, would provide assured spent fuel disposition services for all participants. In this case, the framework will include suppliers and recipients in a common scheme, with the roles of each depending upon their abilities and willingness. The overall arrangements will have to be compelling if they are to limit the spread of reprocessing technology and even more compelling if they are to encourage a limited number of States to host spent fuel disposition facilities and ultimately geological repositories.

GNEP, started as a US initiative in February 2006. In January 2007, the USDOE published its "Global Nuclear Energy Partnership Strategic Plan GNEP-167312, Rev 0" [9]. This brief document provides a useful overview of the GNEP vision and of how DOE intends to implement this. The following three goals of GNEP are all of great importance for global environmental, safety and security reasons:

- Wider-scale use of nuclear energy
- Decreasing risks of proliferation and nuclear terrorism
- Addressing the challenges of disposal

In May 2007, the United States hosted the first Ministerial level meeting and welcomed China, France, Japan and Russia as Partners. Under GNEP, the Partners seek to promote the global expansion of nuclear power under a set of agreed “Principles” (see text box below) that are intended to inhibit the spread of nuclear weapons by limiting the spread of sensitive nuclear technologies (uranium enrichment and plutonium separation) that are used in peaceful nuclear applications and also for the manufacture of nuclear weapons or other nuclear explosives. States participating in GNEP will seek to shape the provisions for infrastructure development, for reliable fuel services (fresh fuel and spent fuel disposition), and programmes for the development and deployment of proliferation-resistant “grid-appropriate” reactors that will be significantly easier for States to implement than for today’s commercial-scale reactors.

In its early public statements, the US government recognized the fact that GNEP could be seen as discriminatory by small user States and acknowledged that more must be done to include these States in the Partnership. During 2007, the membership of GNEP did increase and, in particular, included countries that – unlike the initial grouping – are not weapons states or potential major suppliers of fuel cycle services. At the end of 2009, 25 countries[2] had signed up to GNEP and a larger number participated as observers [22]. Some of the new countries do not yet have nuclear power but wish to develop it. It was stressed that GNEP is not directed against any state developing nuclear technology for peaceful purposes. Also, it would not require developing states to renounce fuel production on their own soil, since one principle is that *“States participating in this cooperation would not give up any rights”*.

GNEP PRINCIPLES

1. Expand nuclear power to help meet growing energy demand in a sustainable manner and in a way that provides for safe operation of nuclear power plants and management of wastes.
2. In cooperation with the IAEA, continue to develop enhanced nuclear safeguards to effectively and efficiently monitor nuclear materials and facilities, to ensure nuclear energy systems are used only for peaceful purposes.
3. Establish international supply framework to enhance reliable, cost-effective fuel services and supplies to the world market, providing options for generating nuclear energy and fostering development while reducing the risk of nuclear proliferation by creating a viable alternative to acquisition of sensitive fuel cycle technologies.
4. Develop, demonstrate, and in due course deploy advanced fast reactors that consume transuranic elements from recycled spent fuel.
5. Promote the development of advanced, more proliferation resistant nuclear power reactors appropriate for the power grids of developing countries and regions.
6. Develop and demonstrate, inter alia, advanced technologies for recycling spent nuclear fuel for deployment in facilities that do not separate pure plutonium and eventually eliminating stocks of civilian plutonium. Such advanced fuel cycle technologies, when available, would help substantially reduce nuclear waste, simplify its disposition and draw down inventories of civilian spent fuel in safe, secure, and proliferation-resistant manner.
7. Take advantage of the best available fuel cycle approaches for the efficient and responsible use of energy and natural resources.

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[2] Armenia, Australia, Bulgaria, Canada, China, Estonia, France, Ghana, Hungary, Italy, Japan, Jordan, Kazakhstan, Republic of Korea, Lithuania, Morocco, Oman, Poland, Romania, the Russian Federation, Senegal, Slovenia, Ukraine, United Kingdom and the United States.

Of special interest are the discussion that took place before joining GNEP in Australia and Canada, which together produce more than 60% of the world's uranium. The Australian Government made it clear when it signed up to GNEP that it did so only on the basis that Australia can not be compelled to import nuclear waste and that it reserves its right to enrich uranium. The former issue, repatriation of foreign spent fuel, has also led to debate in Canada. Advocates of hosting international disposal facilities can be found in both countries, but the governments are aware of the significant public opposition that would arise to such a proposal at present. Canada and Australia have also suggested that they might also enrich uranium. Further countries interested in keeping this option open are South Africa and Argentina and these have restricted their involvement to observer roles.

Participation in GNEP is open to any State that is willing to accept the GNEP Principles. Developmental activities are overseen by the GNEP Steering Group, which supervises activities carried out by working groups. Two working groups are currently in place: Working Group 1 on Infrastructure Development and Working Group 2 on Reliable Fuel Services.

GNEP anticipates a fuel cycle arrangement under which assistance and assurances of supply of fresh fuel would encourage States to build and operate nuclear power reactors and return their spent fuel to GNEP recycling centres, where the spent fuel would be processed and separated into constituent streams. The scheme is illustrated in Figure 2.

A State may in the future elect to lease its fuel from a supplier. Fuel leasing is under investigation within GNEP, for example, and while GNEP arrangements are not fixed at this point, under a leasing arrangement the reactor operator would presumably use the fuel to produce power and when the fuel is spent, the owner would take it back, not necessarily take it back to the State where it was produced, but the fuel owner — i.e., the leaser — would be responsible to remove it from the reactor and take responsibility for its disposition. The economic model for leasing is not yet established and many fundamental questions remain: how much would the lessee be required to pay and when? Who would bear the costs arising from fuel failures?

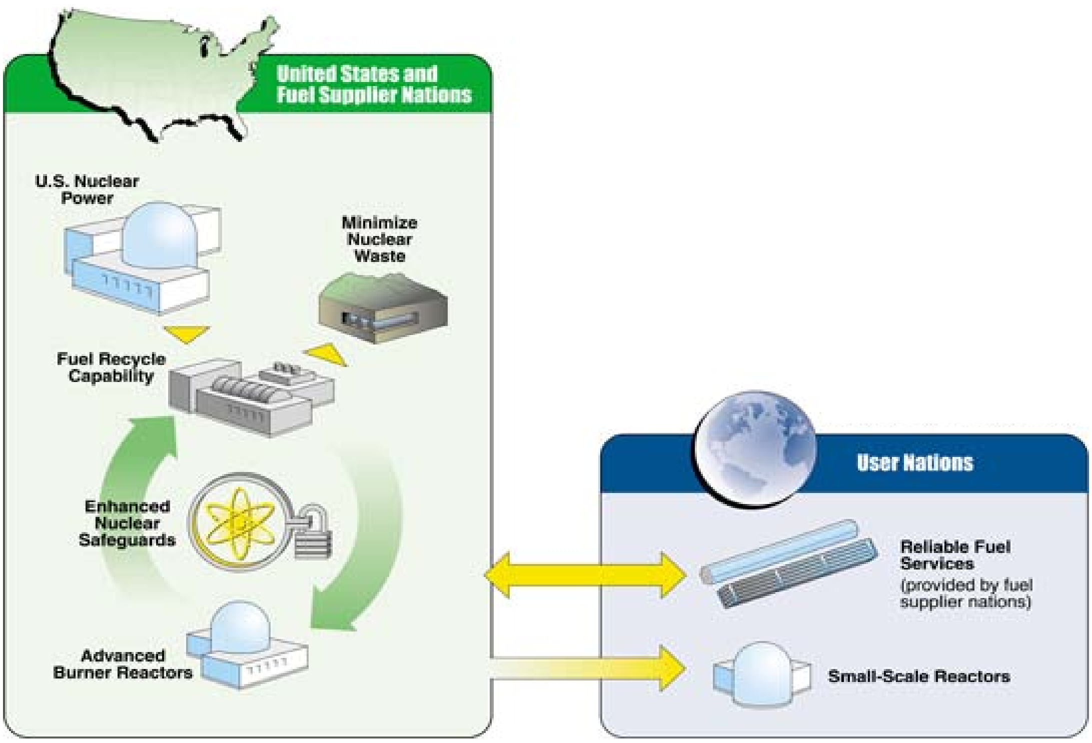

FIG. 2. Key Elements of GNEP.

From the point of view of the present report, a key feature of GNEP is that it also contains a coordinated research and development programme to develop the enabling transuranic partitioning and transmutation technologies required to fulfil the global GNEP spent fuel disposition commitments. GNEP has yet to consider whether all wastes would be stored in GNEP repositories what would clearly make nuclear power more acceptable to a greater number of potential States.

Examining the long-term dimensions of GNEP, ultimately there would be an agreed scheme under which the majority of States operating power reactors will agree that their spent fuel would be taken back to the producer, or else moved for disposal to a third party host country that is also a GNEP member.

The expansion of GNEP to many countries beyond the original group that would like to supply fuel cycles services is a positive development, but at the time of writing much remains for it to be successful[3]. While progress in attracting additional States is significant, progress in securing funding to finance the development and demonstration of the enabling transuranic partitioning and transmutation technologies within the United States is problematic.

3.2.2. Russian GNPI proposal

Even before the GNEP initiative was announced, the Russian Federation had made proposals on the same lines [8]. Although there are similarities between the proposals, there are also conflicts, as has been pointed out by Rychin [23]. Russia is aggressively expanding its domestic nuclear programme — and also consolidating plans to expand the nuclear services provided across the globe. Russia plans to supply nuclear power plants, enrichment services, and reactor fuels. A key question that is open is to what extend the services will spread to reprocessing and also disposal of HLW from reprocessing.

To improve the international framework, the Russian global initiatives are being progressed. In January 2006, Russian President Vladimir Putin announced an initiative to develop a Global Nuclear Power Infrastructure (GNPI) capable of providing access to the benefits of nuclear energy to all interested countries in strict compliance with non-proliferation requirements. Establishment of a network of international nuclear fuel cycle centres (INFCC), including enrichment services, under IAEA safeguards, is a key element of such an infrastructure. Specific proposals for action have already been put forward. In 2006, Sergey Kirienko, head of then Russian Federal Agency for Atomic Energy, announced a first step towards development of the GNPI — the establishment on the site of Angarsk Electrolytic Chemical Combine of a so-called International Uranium Enrichment Centre (IUEC), which is considered as a pilot INFCC.

In August 2007, pursuant to the inter-governmental agreement between the Russian Federation and Republic of Kazakhstan the IUEC was established as a joint stock company between two major nuclear fuel cycle service providers, Russia's TENEX and Kazakhstan's NAC Kazatomprom [24, 25]. By the start of 2009, the centre was working on its first contract. Russia plans to retain 51 percent of IUEC stock, leaving 49 percent for foreign buy-in. Kazakhstan already owns 10 percent of these 49 percent. Two additional members, Armenia

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[3] Subsequent to the preparation of this report, the USA in 2009 undertook a policy review of GNEP, which led to a slowing down of US domestic research on reprocessing technology. As of October 2009, the US proposed changes to GNEP to broaden its participation and change the name. Implications of the changes for disposition are unclear.

and Ukraine, are in the process of joining the IUEC — each country is expected to hold 10 percent, leaving 19 percent of IUEC available as of November 2008.

The Centre is oriented chiefly to States not developing uranium enrichment capabilities on their territories. In so doing, the Russian side will not transfer to IUEC participants the uranium enrichment technology or information that constitutes a State secret. The IUEC is set up as an open joint stock company and is governed by a management board consisting of IUEC shareholder States, with the IAEA as an observer. . The main function of the IUEC is to provide IUEC participating organizations with guaranteed access to uranium enrichment capacities. [25] The major economic incentive for IUEC participation is that its shareholders receive dividends from enrichment operations.

Russia also elaborated on another element related to the GNPI, by announcing further that it would establish an assured supply mechanism for LEU at the IUEC. This would be an LEU reserve that would be made available to the IAEA for supply of LEU to its Member States. The reserve would consist of 120 metric tonnes of LEU, sufficient for two full cores for a 1,000 megawatt-reactor. The purpose of the reserve would be to provide the IAEA with means to assure supply to recipient states in case of a political decision by suppliers to deny nuclear fuel [12, 26]. In March 2010, IAEA Director General Yukiya Amano and the Director General of the Russian Federation´s State Atomic Energy Corporation (ROSATOM), Sergey Kirienko, signed an agreement to establish a reserve of low enriched uranium (LEU) for supply to the IAEA for its Member States [26].

To provide an improved framework for its activities, Russia has established the State Atomic Energy Corporation, Rosatom, which runs all nuclear assets of the Russian Federation, in both the civil and the weapons areas. It was established on 18 December 2007, following the adoption of the Federal Law on the State Atomic Energy Corporation, which took effect from 5 December 2007. The changes are part of Russia’s strategy to reorganize the country's nuclear industry in order to boost nuclear energy production and strengthen Russia's presence in the global nuclear market.

In the context of the present report, it is interesting to note the potential follow-up stages of GNPI-INFCC implementation that are mentioned by Russia. These include organizing a *“timely solution of SNF management issues by reprocessing and the disposal of residual waste within the framework of international NFC centres with the use of modern fast reactor and spent fuel management technologies”*.

The Russian initiative builds upon G8 policies on curbing the spread of sensitive nuclear technologies and is a practical input into the implementation of the G8 accords reflected in the Declarations on Non-Proliferation at the summits in 2005 and 2006.

3.3. Current specific partnering initiatives

In addition to the above developments that could eventually lead to multinational repositories under an add-on type scenario, there has been progress on the complementary approach of partnering. This is described in the following sections.

3.3.1. SAPIERR Project

In the period 2003 to 2005, the EC funded project, SAPIERR-1 (Support Action on a Pilot Initiative for European Regional Repositories), was devoted to pilot studies on the feasibility of shared regional storage facilities and geological repositories, for use by European countries. SAPIERR-1 was designed to help the European Commission clarify basic questions affecting the issue and to identify new research and technical developments that may be needed to implement regional solutions to European radioactive waste disposal [10]. Twenty-one organizations from fourteen countries took part in the SAPIERR-1 project, which addressed legal aspects, inventory questions and possible options and scenarios for regional disposal. The main activities within the project were:

(1) reviewing the international and national legal or regulatory issues that would affect implementation of regional storage facilities or repositories
(2) constructing a reference inventory of the radioactive wastes arising in all of the 14 countries from which organizations joined the SAPIERR working group
(3) evaluating potential designs, implementation timescales and likely costs for shared regional repositories, based on existing documented data on European national programmes
(4) looking at potential scenarios for organizing the implementation of European regional repositories
(5) identifying those aspects that require further study or research before proceeding further.

The legal studies made clear that the implementation of a regional repository would almost certainly necessitate changes in a number of national legal systems [27]. The various national attitudes towards shared disposal concepts are often reflected in the policies and in the legal / regulatory framework of the countries. Many countries currently ban import of wastes for disposal (e.g. Austria, Croatia, Czech Republic, Finland, France, Hungary, Latvia, Lithuania). Very few legally ban export; Finland and France are exceptions. A few explicitly acknowledge the possibility of import or export and some have no formal position. A few countries (e.g. Switzerland) have already formulated rather detailed conditions under which import or export of wastes might be permissible.

In the review of economical issues, the SAPIERR I project compared diverse international cost estimates that have been published for spent fuel disposal [28]. The costs of geological disposal are high (80,000 to 1,200,000 €/ton of spent fuel) and only partially dependent on the amount of waste disposed of. Because of this, geological disposal is disproportionately expensive, sometimes even impossible, for countries with small nuclear power programmes or with only nuclear activities other than power production. In those countries the volume of waste is too small to justify or finance a national repository. Long-term storage to accumulate enough waste and financial resources or sharing repositories with other countries are the only alternatives.

Even for countries with larger nuclear programmes, cooperation and sharing could be attractive. A shared repository not only pools technical and financial resources, but also provides a wider choice of suitable geological formations and guarantees international supervision.

The SAPIERR I study on options and scenarios was complemented by identification of requirements on trans-national research and development to be carried out in future; such an output is a requirement of the Support Action instrument. Requirements were defined in the areas of technology and engineering, geological and environmental investigations, socio-political studies and establishment of institutional frameworks. The top priority items are related to the institutional framework to be established since increased activities could then be set into an overall systematic approach. This would entail proposals to coordinate national plans of countries interested in regional solutions and to establish efficient, transparent structures for guiding and executing future projects.

The top level conclusions drawn from the SAPIERR I project were [10]:

- The potential benefits of multinational, regional repositories are recognized widely throughout the EU.
- The most obvious benefits are in the economic area, where shared repositories would lead to substantial reductions in expenditure throughout the Community.
- Many or most of the problems faced by regional repository initiatives are common to those being tackled by national disposal programmes, in particular concerning the task of siting the facility.
- If shared regional repositories are to be implemented, even some decades ahead, efforts must already be increased now.
- Before greatly enlarging the scale of the work on regional repositories, a structured framework should be established.

A further project, SAPIERR II (Strategic Action Plan for Implementation of European Regional Repositories), built on the pilot studies of SAPIERR I to develop options for organizational frameworks and project plans that could lead to the establishment of a European Repository Development Organization (ERDO) for European regional repositories [11]. To clarify issues related to the structure and future programme of the potential ERDO, a series of specific studies were carried out on organizational structures, legal liabilities, economics, safety and security and public and political acceptability. The options distilled from these studies will be presented to interested countries and organizations, in order to identify potential end-users and to achieve consensus on a preferred way forward: the first steps of implementation or a further programme of preparatory work.

The tasks addressed in the sub-projects. Their principal conclusions were as follows:

(1) Preparation of a management study on the **legal and business options** for establishing a European Repository Development Organization (ERDO) leading to one or more proposed frameworks (options) for such an organization. The conclusion was that various options are feasible ranging from an Intergovernmental Organization to a commercial company [29].

(2) A study on the **legal liability issues** of international waste transfer within Europe. Even in national disposal programmes, the issues associated with long-term transfer of liabilities are complex. For a regional repository, the challenges are still greater and will require for their solution intensive interactions between the partners in any shared repository initiative [30].

(3) A study of the potential **economic implications** of European regional storage facilities and repositories. The study analyzed the economic implications for potential users of such facilities and also for host countries. Total disposal costs for a repository for a large SAPIERR inventory were estimated (based on comparisons with national projects) to be around EUR 10 billion. The overall impact of opting for a shared rather than numerous solo solutions in the nations amounts to a saving to the EU of at least EUR 15 billion. The potential advantages of hosting a shared facility were considered in detail [31].

(4) Outline examination of the **safety and security impacts** of implementing one or two regional stores or repositories relative to a large number of national facilities. The major security advantage may be through making secure disposal facilities available to small

countries at an earlier time than the far future dates when they might implement national facilities [32].

(5) A review of **public and political attitudes** in Europe towards the concept of shared regional repositories. The work is linked to Task 3 since public attitudes can be strongly affected by local and national benefits. This is obviously the biggest of all challenges and requires much work [33].

(6) Development of a **Strategy and a Project Plan** for the work of the ERDO. The first tasks of an ERDO would be agreeing a progressive, slow, staged strategy that would lead to the definition of potential host countries and eventually, to potential repository sites and definition of a parallel science and technology programme that could be addressed by the ERDO after its initiation.

At the end of the project in January 2009, the SAPIERR shared storage and disposal concept had been developed to a level where political level buy-in was necessary for further progress. Accordingly, small European countries were invited through their Energy or Environmental Ministries to send representatives to Working Group that would through 2009 prepare specific proposals for establishment of a European Repository Development Organization (ERDO). The conclusion of the Working Groups deliberations may be either:

- future work could be handed over to the suggested new multinational ERDO, thus establishing a firm basis for progress, or
- content and timing are defined for further actions required before an ERDO can be established or
- the participants conclude that further efforts are not productive in this area at this time.

Any of these three potential outcomes would have a large impact on subsequent European work on disposal and hence on public attitudes to nuclear power. If an ERDO were to be established soon, then intensive cooperation leading to significant cost reductions could result. If further study is needed this will also be done through cooperation between countries. If it is decided that regional repositories are not realistic, pressure will increase on various small EU countries to initiate or build up national disposal programmes.

If the ERDO initiative is successful, it may also act as a role model for regional groupings in other parts of the world, such the Arab States, Asia, Central- and South America or Africa.

3.3.2. Arius Association

All nuclear power programmes, large and small, and all countries possessing long-lived wastes from research or isotope production reactors should be able to indicate a way towards a permanent solution of their waste problem. Exploring possibilities for regional cooperation — together with the buildup of national expertise in waste management — is an appropriate approach. For this reason, the Arius association [34] was formed in 2002 to promote regional and international solutions worldwide.

Arius is non-commercial and aims to attract members and interest from around the world; currently, however, it currently has a strong European focus. Arius has both organizational and individual members. The support of international bodies and of national programmes is also needed to ensure progress. Accordingly, continued interactions with other international bodies such as the IAEA, the European Commission, the WNA and the NEA are maintained by Arius. Maintaining contact with those countries that have decided on purely national solutions is also important. It is the sovereign right of any country to make such a decision and it is important both for these countries and for Arius members to make clear that there is no conflict arising here: national and multinational repositories must both be implemented.

The initial goals of Arius are to organize studies of the technical, legal, political and societal issues associated with multinational storage and disposal options, and to ensure that these options remain a topic for discussions on the world stage and are recognized as a feasible future choice for countries that opt for this strategy. Arius undertakes a number of studies aimed at answering some of the principal questions surrounding international solutions.

Arius is also a key driving organization behind the SAPIERR project described in the previous section

3.4. Other proposals

The major initiatives described above are being undertaken by governments. In addition to these, there are a number of further concepts in circulation that might also be found applicable for multinational cooperation. The listing below is not intended to be complete, but illustrates the range of ideas in play.

At the Carnegie International Non-Proliferation Conference in Washington in November 2006, Dr. Pierre Goldschmidt, a former Head of the IAEA Department of Safeguards, explained how he believed nations could be provided with guarantees of fuel supply within an international scheme [35]. A Supplier State and a Recipient State could negotiate bilateral terms for a fuel supply contract. Fresh fuel would be leased to a nuclear power plant in the Recipient State, with the supplier in the Supplier State remaining the owner of both the fresh and spent fuel at any point in time. The spent fuel would have to be returned to the Supplier State after a minimum cooling time and, if not, the delivery of any further fresh fuel would be suspended. The power plant would pay a specified monthly amount into a dedicated account to cover transportation costs of the spent fuel to the Supplier State and all management, storage, conditioning and final disposal costs after its return. The account would be managed by an international organization such as the EBRD, the IMF or possibly the IAEA. The supplier might include provisions whereby the Recipient State would have to take back HLW but the contract would be most attractive to the Recipient State if it resolved completely its spent fuel and HLW management problems.

A further innovative nuclear fuel leasing arrangement, the TRUST (Terms for Reliable Uranium Service Transactions), was proposed at a 2007 PNNL Workshop on Cradle to Grave Nuclear Fuel Supply Assurances [36]. The proposal was based on the assumption of the existence of spent fuel disposition services.

At a more general level, discussions of multinational disposal concepts and of fuel leasing or take-back have also taken place in the various studies that have been launched on the wider topic of global nuclear expansion. In one of the early such studies published by MIT in 2003 [37], the proposal was made that "fuel cycle states" could provide services to " privileged" states that would withdraw from nuclear activities other than reactor operation and would receive benefits including in particular elimination of spent fuel/waste management challenges. The American Academy of Arts and Science (AAAS) in 2008 established the Global Nuclear Future Initiative [38] with the objective of helping to ensure that the expansion of nuclear power does not result in a corresponding increase in nuclear proliferation or nuclear terrorism. One element included in the study is the need to establish international regimes to manage the fuel cycle. At a technical meeting organized by the

Landau Network–Centro Volta in Como, Italy in 2008, exchanges on the issue of Expanding Nuclear Power to New States led to a final document [39] including the following text: *"Geological repositories are essential and a global network of international repositories would assure that all countries would cope with their waste in a responsible manner".* The authors of the final report also noted that some of the participants expressed a willingness to consider hosting geological repositories.

4. IMPACTS OF NEW MULTINATIONAL INITIATIVES ON VIABILITY OF SHARED FACILITIES FOR THE DISPOSITION OF SPENT FUEL AND NUCLEAR WASTES

All of the various initiatives described in Chapter 3 are currently theoretical concepts or at most study projects related to the possibilities for multinational cooperation. In this Chapter, they are assessed with respect to their potential impact on the viability of multinational spent fuel disposal facilities. For each, an overview is produced of their strengths and weaknesses.

4.1. Impact of MNA recommendations

As was recorded in Chapter 3, five approaches were presented by the MNA group:

(1) *Reinforcing* ***existing commercial market mechanisms*** *on a case-by-case basis through long-term contracts and transparent suppliers' arrangements with government backing. Examples would be: fuel leasing and fuel take-back offers, commercial offers to store and dispose of spent fuel, as well as commercial fuel banks.*

(2) *Developing and implementing* ***international supply guarantees*** *with IAEA participation. Different models should be investigated, notably with the* ***IAEA as guarantor*** *of service supplies, e.g. as administrator of a fuel bank.*

(3) *Promoting voluntary conversion of* ***existing facilities to MNAs****, and pursuing them as* ***confidence-building measures****, with the participation of NPT non-nuclear-weapon States and nuclear-weapon States, and non-NPT States.*

(4) *Creating, through voluntary agreements and contracts,* ***multinational, and in particular regional, MNAs for new facilities*** *based on joint ownership, drawing rights or co-management for front-end and back-end nuclear facilities, such as uranium enrichment; fuel reprocessing; disposal and storage of spent fuel (and combinations thereof). Integrated nuclear power parks would also serve this objective.*

(5) *The scenario of a further expansion of nuclear energy around the world might call for the development of a* ***nuclear fuel cycle with stronger multilateral arrangements*** *— by region or by continent —* ***and for broader cooperation****, involving the IAEA and the international community.*

The Expert Group focussed primarily on the most sensitive technologies, namely enrichment and reprocessing. Can the options listed be applied also to disposal facilities?

Option 1 cannot at present be applied to waste repositories since there are no existing commercial market mechanisms. If there could be implemented the straight commercial service that would be provided is directly related to the add-on scenario proposed in [5]. This would be an ideal solution from many points of view. The allocation of responsibilities, including for regulatory aspects, remains clear and is already carefully described in existing IAEA documentation. The user countries have no further responsibilities once they have paid for the spent fuel to be removed. Potential problems arise with security of supply, however.

Unless there are a number of host countries offering this service, the user countries are faced with the possibility of the withdrawal of services at some future time, thereby necessitating an expensive national repository after funding has been used for the export option. A perhaps more serious drawback from the user country viewpoint results if the disposal service is restricted only to spent fuel and does not include other wastes that must be allocated to a geological repository. In this case, there may be little interest from the user country in sending spent fuel. A potential problem from the add-on host country view may be that the spent fuel delivered does not satisfy some set of acceptance criteria and therefore leads to increased costs or even to safety problems with the facility. Such points need to be regulated in bilateral or multilateral contracts before fuel transfers begin.

Option 2 regarding supply guarantees was designed mostly to deal with possible disruptions in the fuel supply market. Presumably, the guarantee offered by the IAEA would depend on obtaining prior agreements by fuel suppliers to maintain the supply of fuel to any country if its standard supplier withdrew the service for non-justifiable reasons. The same concept could be applied to a disposal service — but only if multiple suppliers were operating. This reinforces again the point that there should not be only one single multinational repository in operation at any given time.

Option 3, converting national to multinational facilities is clearly ruled out for the leading repository programmes in Finland, Sweden and France because there are strict policies or laws against this in each of those countries. Whether this approach will become possible under GNEP, e.g. for Russian or US repositories remains unclear. If it did, this would again reduce to the add-on disposal scenario previously discussed.

Option 4 – voluntary agreements on multinational or regional facilities — when applied to repositories — corresponds to the partnering scenario of [5]. The current example of efforts being made to progress towards realisation of this scenario is the SAPIERR project described and discussed elsewhere.

Finally, Option 5 moves in the direction of the supranational approaches suggested in [5]. The credibility of such an approach may be higher when it is, as in the MNA proposals, concerned with all fuel cycle facilities and not just repositories. Willingness to cede land for a full fuel cycle nuclear park might be more easily found since this could bring more high-tech activities into a country than is the case for disposal alone.

MNA proposals: strengths and opportunities

A prime strength of the MNA study is that it represents the consensus of a wide range of senior officials from numerous countries, all of whom are convinced that global nuclear safety and security can be improved by multilateral cooperation. The experts took an integrated view of the whole fuel cycle and their considerations concerning the back end covered all of the cooperation options identified in earlier IAEA work. Add-on, partnering and supranational scenarios are all included. The MNA study also clearly recognized the problems associated with winning sufficient political and public support to allow a country to voluntarily host a multinational repository.

In principle, the publication of this high-level document, initiated by the IAEA and authored by such a broad and competent group should provide a sound basis for specific, more detailed work to implement some of its proposals. In particular, the 5th option presented illustrates a consensus that could give the IAEA an opportunity to take a more prominent leadership role in promoting supranational structures that could advance multinational initiatives.

MNA proposals: weaknesses and threats

The weakness of the MNA study is that it remains very conceptual or theoretical. There are no execution plans, no incentives, and no specific follow-up proposals. Some reluctance to move ahead may be due to the fact that some advanced disposal programmes still perceive multinational options as a threat to their national disposal projects. One concern is that host communities for national repositories may be apprehensive that foreign wastes will also be disposed of in the facility. Another assertion is that the prospect of multinational facilities becoming available, and thus the exports of wastes becoming a possibility, might lead to a reduction in the political and financial support for national repository programmes.

4.2. Impact of GNEP

The published GNEP plan comprises a domestic portion that concentrates strongly on technological issues associated with enhancing the US capabilities for undertaking key fuel cycle activities, and an international portion that is concentrated on building the Partnership. The domestic programme is important to the USA because of the national expertise that has been lost over the past decades due to the earlier political decision to pursue only the direct fuel cycle option and the later economic considerations which led to continuing with this approach. The incentives for again taking up the development of advanced fuel cycles are now multiple. Concerns about the security of the nuclear fuel cycle have grown, due to non-proliferation requirements and to the rise of terrorism in a scenario with world-wide growth of nuclear power. Thus there is interest in new fuel cycle technologies and in spent fuel management approaches that can address such concerns. In the USA, there is an additional benefit from re-introducing, through GNEP, fuel reprocessing technologies that can reduce the volumes of HLW to be disposed of. This might postpone for a long time the need for a second repository in the USA[4].

The key security aspects of GNEP, involving concentration of sensitive nuclear activities (especially enrichment) in a few countries that would then act as fuel suppliers to others, are however, global issues. For the proposed approaches to work, the world must be divided into suppliers of nuclear fuel services and countries that are only nuclear power users. The current strategy is, however, weak on one key point of great relevance to the present report – how to offer back-end services that will help to win the support of other nations and thus achieve the success in the area of enhancing global security.

GNEP: strengths and opportunities

GNEP has several potential strengths. Most apparent of these is that a large number of countries have decided to participate and that this participation covers all levels up to high political offices. If GNEP is successful, low CO_2 energy production can be made available to many States without a large increase in the risks of nuclear proliferation or terrorism. If the fuel "take-back" option functions, whether to the USA or to any other fuel leaser, then the "add-on" scenario of the IAEA will have been successfully implemented. Rather than

[4] In 2009, the US reconsidered proposals to move to early implementation of reprocessing facilities based on current technologies and decided to return to a more long-term research and development programme on advanced nuclear fuel cycles.

unwanted waste dumps, repositories may become just another type of service facility that enhances world security. This could encourage a third party country to host a repository and thus becomes part of the GNEP provider group rather than the user group.

Opportunities arise if spent fuel becomes a potential asset rather than a long-lived toxic waste material. New processing routes alter the waste streams and therefore introduce new flexible schemes for allocation to repositories. Waste stream become shorter lived and therefore repository requirements may become less stringent.

GNEP: weaknesses and threats

Small or new nuclear programmes have little trouble in obtaining fuel cycle services such as fuel supply and reprocessing; they have difficulty in implementing disposal strategies that are technically and economically credible. However, GNEP currently under-emphasises back-end issues and focuses very much on the front-end. More specifics are needed concerning the option of returning spent fuel for processing in plants in the supplier country. For the arrangement to be attractive to the user country, it must be able to send back spent fuel without having to accept HLW from the processing. However, some GNEP provider Partners (e.g. France) will certainly not retain HLW. Furthermore, GNEP take-back for newly supplied fuel will not suffice if the user countries already have an existing spent fuel inventory. If they are to avoid the need for an indigenous geological repository, then all their spent fuel must be exportable. Even then, other long-lived wastes will remain as problems (historical, operational NPP and non-NPP). GNEP, with its strong message that advanced reprocessing of spent fuel is the way ahead may be perceived as a threat that can undermine advanced national programmes based on direct disposal. This could have a wider effect since the most advanced disposal programmes (in Finland and Sweden) do in fact intend to emplace conditioned spent fuel into their repositories. Although increasing numbers of countries have signed up to GNEP, support in the USA itself is not universal. A collapse of GNEP, with its explicit acknowledgement of the potential benefits of spent fuel take-back could threaten the credibility of multinational nuclear initiatives in general.

4.3. Impact of Russian GNPI initiative

Should Russia consider to further develop its GNPI Initiative with regard to the back-end of the NFC it could propose establishment of another international centre for SNF management (either for storage or reprocessing with/without final disposal of the resulting HLW). Under existing national legislation, Russia can import spent fuel since this is not regarded as waste. Federal Law No 7(2002) «On Environmental Protection» prohibits import of radioactive waste to the territory of the Russian Federation and establishes conditions for import of SNF. Import to the Russian Federation of irradiated fuel assemblies from nuclear reactors in foreign states for temporary "technological storage" and/or reprocessing is permitted in cases where a positive review has been made of a "unified project" which shows that an overall reduction of the radiation exposure risk and an improvement of the ecological protection level will result. Before entering into an international contract on SNF service an intergovernmental agreement between the Governments of the Russian Federation and a customer country should be concluded which will specify conditions of SNF management including NW treatment. Subsequently, the international contract with the authorized Russian organization will contain obligations on SNF reprocessing after the expiration of technological storage time or its return to the originator. The import contract will also set out detailed conditions for the subsequent HLW remaining in the Russian Federation or its return. For example, SNF has been imported by Russia from Ukraine and Uzbekistan in each case with provision for the return to the customer country of the HLW. The other examples without returning of the HLW resulting from reprocessing of imported SNF are take-back of the research reactor SF from Latvia and Libya.

Fuel cycle services may be economically attractive for Russia since they provide either income or fuel for the future, or both. However, at present, the law does not allow import of SNF or wastes for direct disposal.

To be successful in this respect, Russia should consider to present a credible option for spent fuel treatment that would be attractive to potential users and which, at the same time, would satisfy international requirements for safety and security. For success it will require a range of important international stakeholders to be highly comfortable with what is offered and the conditions attached. There are complex political, societal and security issues at stake, as well as just the technical aspects of developing engineered facilities.

What, then, will be needed to make feasible in Russia a Spent Fuel management Centre? A detailed analysis of this issue was made in [40] and some of the conclusions among others were:

(1) **Overall acceptability of the scheme to the international community is important.** This applies in particular to the European Union and the United States – the former because disposal outside the EU is not a policy presently supported and the latter because of the issues with US-flagged materials. However, all nations and groups of nations that become involved will have to present the scheme's credentials to their own public and institutions with great commitment;
(2) **Clear economic advantages must result, both to the users and to Russia.** The scheme will obviously need to have benefits for both implementer and user;
(3) **International support and recognition is essential.** The major nuclear nations and international agencies and associations (IAEA, EC, OECD/NEA) should acknowledge that Russia wishes to provide a valuable international service that will enhance the global security and safety environment because all technical aspects of the project will be developed to the highest international standards;
(4) **Active involvement of the IAEA** in establishing the project (and, later, in an oversight monitoring role), thus underwriting its overall credibility.

Russian GNPI initiative: strengths and opportunities

A great strength of the Russian GNPI initiative is the support of the Russian government which has been prepared to engage in the political and public debate associated with a proposal to import spent fuel. This contrasts with the situation with GNEP in the USA, where the "take-back" option was presented in the initial international proposal but never seriously discussed in the USA. Thus, the Russian option is the most credible example of the add-on scenario developed by the IAEA. In fact, currently "take-back" of the spent fuel with no return of waste has already functioned for selected countries with Russian origin fuel (e.g. from Bulgaria) and is envisaged in the Agreement with Iran.

A multinational facility for processing could be implemented in Russia in the relatively near term and for enrichment this has already been done. These could help to "kick start" more the global option including disposal of HLW from reprocessing imported fuel. The discussions on Russian acceptance of foreign spent fuel that have taken place over the past years also initiated some considerations of the specific benefits that a host country could receive. In particular they have highlighted the fact that the revenues can be used for causes such as remediation of contaminated sites. This is a major positive point that could serve as an example to other potential host countries. It is important to spread the message that radioactive waste can be safely stored and disposed, coupled with the message that a state or a local community can derive positive socio-economic benefits from providing such services. Russia has taken a large step forward in that these issues are even incorporated in the current legal frameworks.

Russian GNPI initiative: weaknesses and threats

A weakness of the Russian proposals in the context of the present report is that Russia has currently no large-scale infrastructure for reprocessing and disposal of resulting HLW. Shipping of spent fuel to a country in which there are no appropriate management facilities could have negative public and political impacts. An obvious solution to this problem would be an internationally supported effort to assist Russia (and any other potential multinational repository host) in implementing a state-of-the-art facility.

The continued provision of services would depend on continued political and policy support in Russia. This is a potential weakness in any national agreement to import radioactive materials. In the past, commercial reprocessors in the UK, France and Russia have all reversed policies for retaining HLW and thereby caused small customer countries to have to initiate national disposal programmes. Thus security of supply of a disposal service could be problematic if there is only a single multinational option available. As in the GNEP case, a service that accepts only spent fuel and not other long-lived wastes will also have little attraction for user countries since it would not relieve them of the need for a national geological repository.

4.4. Impact of SAPIERR

There are several arguments favouring further progress towards regional repositories in Europe. The EC and the European Parliament strongly support smaller EU countries combining their efforts. There currently are small nuclear programmes with a demonstrated interest in regional solutions, as witnessed by their participation in Arius and/or SAPIERR. Furthermore some further expansion of the number of nuclear power countries in Europe is probable (e.g. Portugal, Poland and a restart in Italy). Lastly the opposition that was shown by some of the larger European programmes towards regional solutions has died down as these programmes have moved towards successful siting of their national repositories.

On the other hand, there are factors that reduce the near term interest in regional repositories. Some small programmes that were intending to shut down, e.g. in Slovenia are now considering extending reactor lifetimes and also building new plant. This fact together with the prospect of the closed fuel cycle growing in importance could lead to decisions to prolong surface storage rather than moving to direct disposal of spent fuel. Another blockage on the road to shared repositories in a partnering system could be that the add-on alternatives discussed above begin to look more probable. The key question concerning the partnering approach is obviously which partner will be the repository host. This siting question is discussed at more length in Chapter 5.1. Siting is most problematic for final repositories; multinational cooperation could also involve shared encapsulation plants or interim stores; it may be easier to find willing hosts for such facilities.

The proof of the credibility of regional solutions in Europe may come after completion of the ERDO Working Group described above. If sufficient numbers of European countries are not prepared to sign up to a European Repository Development Organization of the type proposed, then this could be a signal that the partnering approach should be dropped or at least postponed for some lengthy period of 10 years or more.

If the ERDO approach is successful in promoting cooperation in Europe, then it may also be applicable elsewhere in the world. The most promising application may be with groups of countries that are all starting out on a nuclear programme, rather than with countries at different levels of maturity. If so, then the Arab States may be candidate since various countries in that region have expressed interest in introducing nuclear reactors. Other groupings that have been suggested are in South East Asia or in Central and South America.

SAPIERR: strengths and opportunities

A major strength of the SAPIERR projects is that they demonstrate, by the support given by the EC and by the wide range of participating organizations in the associated working groups, that there is great interest in the concept of shared repositories. The project has addressed many of the key issues raised in [5], e.g. economic advantages of multinational repositories, liabilities, safety and security, inventories, legal and regulatory questions. Most importantly the final results of SAPIERR-II provide concrete proposals on how a formal multinational repository organization could be established in Europe. This provides a real opportunity for progress in Europe and for providing a practical example to countries in other regions of the world. The agreement at political level by a number of European nations with small or no nuclear power programmes to participate in a Working Group developing plans for a formal European Repository Development Organization is also an obvious strength.

SAPIERR: weaknesses and threats

Weaknesses in the scope of the SAPIERR work are that it focuses on repositories (and stores) but neglects other fuel cycle facilities (encapsulation, reprocessing etc.) and that it does not directly address the sensitive issue of siting strategy. As for other high profile initiatives, a threat to the credibility of the multinational concept in general could result from failure of the initiative. In the SAPIERR case, the ultimate goal is to establish a follow-on grouping of countries that are prepared to establish a multinational disposal entity. If this is not achieved, and if no follow on initiative is established, then the concept might be dropped or postponed for some long time. Initially SAPIERR was perceived as a potential threat by some national European programmes that supported instead technology transfer to allow all European countries to have national facilities. Recent discussions, however, have led to a consensus that European cooperation in this field includes a continuous spectrum of possibilities from technology transfer to shared facilities.

4.5. An example of multinational agreement

In [5], extensive lists were given of past examples of bilateral or multilateral agreements that have led to radioactive wastes being transferred for disposal from one country to another. In this section, we look in some detail at further cases where such transfers are being implemented or considered. The extended description of the Slovenian-Croatian situation is of topical interest because other European countries (e.g. the Baltic countries) are considering joint investment in a new nuclear plant and because increasingly national electrical utilities are becoming part owners of power plants in other countries.

The multinational disposal concept is an option of topical interest for Slovenia and Croatia [41, 42]. The interest is not determined only by the expected economic advantage of a regional or multinational repository. In the Slovenian-Croatian case the multinational concept is important because of another aspect – i.e. the shared responsibility of both countries for the waste management from a single jointly owned NPP.

The construction of the Nuclear Power Plant Krško in Slovenia near the Slovenian-Croatian border was a joint investment by Slovenia and Croatia, two republics of the former Yugoslavia. The plant was completed in 1981 and commercial operation started early in 1983. The obligations and rights of both investors during the construction and operation were specified in two bilateral contracts signed in 1974 and 1982. These contracts were fairly detailed on construction, operation and exploitation of the nuclear power plant, but they said very little about future nuclear liabilities. The electricity production was equally shared between the two countries and both parties participated in management of the NPP.

In 1991, after Slovenia and Croatia became two independent countries, the agreement on the ownership and exploitation of the NPP Krško was re-negotiated and a new contract signed in 2003. According to the new contract, decommissioning and disposal of spent nuclear fuel (SNF) as well as low and intermediate level waste (LILW) are the responsibility of both parties, and the financial resources for covering these liabilities should be equally provided. Regardless of shared ownership of waste, the agreement opts for a single disposal solution for LILW as well as for SNF, but the details are left open.

More clear elaboration of these responsibilities is given in the programme of the decommissioning and disposal of radioactive waste from the NPP which was jointly prepared by the Slovenian and Croatian waste management organizations in 2004. In the Joint Decommissioning and Waste Disposal Programme for NPP Krško, the preferred solution for the waste is one repository for LILW from both countries and one geological repository for the entire spent fuel inventory. According to the IAEA terminology, these two repositories may also be regarded as multinational repositories, or more precisely, as regional repositories. Furthermore, if the proposed joint disposal solution is compared to the scenarios for multinational repositories, parallels can easily be drawn with the “cooperation scenario”, in which Slovenia and Croatia agreed to jointly develop and implement the disposal solution in one of the two countries.

However, the hosting country for the repository remains as yet undefined. In the existing version of the Joint Programme, the repository concepts for LILW and for SNF are developed for generic sites. A decision on the hosting country is left to future discussions and negotiations between the two parties. According to the Joint Programme, the LILW repository should be in operation by 2018 and the geological repository for SF and high level waste by 2065.

In spite of these agreed intentions for shared disposal facilities, the siting and construction of the LILW repository in Slovenia is not being conducted as a joint project. Slovenia, following the requirements of the 2002 Nuclear Act, needs to provide the repository operation by 2013 and is at present making great efforts to successfully conclude the siting of a repository. The project is conducted as a national project. Croatia is not taking part in this project and the question of whether it will participate in the construction of the LILW repository in Slovenia remains open. So far no explicit initiative to clarify this issue has been given from any site. If in the future the cooperation of the two countries on this project is readdressed, there are, in principle, two possibilities for jointly continuing the project:

- If Slovenia is agreed as a hosting country for the LILW repository, the joint disposal programme may be amended to include the time schedules and other plans of the Slovenian national LILW disposal. Further development of a regional repository may follow the "cooperation scenario", if financial arrangements for implementation include also the previous Slovenian investments into the development and siting of a national repository.
- If Slovenia is not agreed as the host country, or if the agreement is not achieved in time, Slovenia would implement a national repository; however, the option of an "add-on scenario" for development of a regional repository may also be considered. The Slovenian national repository may be upgraded into a regional repository at some later stage, if this can be successfully negotiated between the two countries. The agreement should include a decision on future long-term liabilities as well as adequate consideration of the fact that this option does not lead towards the real "regional" repository, but instead the repository remains a national facility with waste inventory from both countries.

Both options have many variations which depend on adjustments and fine tuning during the negotiations between the partners. However, if none of these joint options have been accepted by the end of the NPP operational period, each party is liable to take one half of LILW and one half of SNF and provide its own disposal solution. But it is important to note that possibilities for shared Slovenian-Croatian disposal facilities exist and that studies being done on multinational scenarios may be helpful in further addressing a joint solution.

Important aspects and conditions identified in [5] on regional/multinational concepts, and through the SAPIERR project, as essential for implementation of a regional repository may have an impact on Slovenian-Croatian disposal projects and therefore need to be carefully examined. Financial arrangements, legal and institutional requirements and socio-political aspects are very likely to play decisive roles in implementing a joint disposal solution, and will certainly require thorough consideration in the future.

Financial arrangements have partly been addressed in the contract on shared ownership of the nuclear power plant, but at a very general level. In case of a joint disposal solution, both parties are liable to cover the cost of its implementation. The two Funds should equally finance all activities related to the disposal of LILW and SNF, as previously approved by the Inter-governmental commission. These financial arrangements may be sufficient for the initial stage and preparatory phase, but at the latest when the hosting country becomes known they will certainly have to be upgraded and details specified, taking into account the asymmetric situation of the hosting and partner country. Decisions will have to be made on revenues allocation, on the involvement of private organizations in the development and construction of the repository and - most importantly - on the securing of financing. Careful consideration will also be needed for financial arrangements regarding the siting project for a repository and, in particular, public involvement in the siting process and incentives to local communities. Sharing of financial risks of increased costs, extra expenses due to delays in construction or obtaining licences, unexpected additional work etc. will also have to be clarified. No such mechanism has been included in the present contract on shared ownership of the NPP.

Regarding the legal aspect, an important question that will have to be addressed in the future is the ownership of waste and its transfer from partner country to the host country. This may prove to be complicated in the case of spent fuel. Although at present SNF is considered as waste in both countries this may change in the future, and SNF may be recognized as a resource. Clear agreement will be needed for liabilities extending far into the future and a decision will have to be taken on whether to share liabilities also in the future or to transfer them to the hosting country. In the case of a shared repository for spent fuel, an agreement on safeguard will also be needed. For any spent fuel of United States origin, clarification regarding the consent rights may also be required.

Transport and trans-boundary movement of waste and SF do not seem to be a problem. Export and import of waste are conditionally allowed in both countries and — as Slovenia and Croatia are two neighbouring countries — no third country will be involved in the trans-boundary movement.

There are also other issues important from the perspective of long-term waste management, which have so far been ignored by both partners. The question of possible NPP lifetime extension is more and more frequently discussed in both countries but its influence on the disposal plans has so far not been addressed. Another delicate issue is that of radioactive waste not originating from the nuclear power plant; both countries have such wastes, although in limited quantities. But the existing plans for a joint solution are developed exclusively for the NPP, and therefore are limited only to waste from the NPP. In case of a shared repository the disposal of non-nuclear-energy wastes remains open.

Above all, however, the implementation of a regional repository will require sufficient political and public support in both countries. In case of a complete failure of negotiations between the partners and no agreement being reached on a shared repository, the Slovenian LILW repository — if successfully constructed — will remain a national repository, intended for 50% of LILW inventory from NPP as well as for LILW from other nuclear applications. Croatia is liable for its own waste. According to the provisions of the contract on shared ownership of the NPP Krško, the Croatian part of the waste needs to be removed from the site and transferred to Croatia by 2025 at the latest.

5. SELECTED KEY ISSUES

5.1. Siting strategies

Initiatives aimed at developing regional, multinational facilities have been criticized as being not credible until such time as a country agrees to host such a facility. Are such initiatives really “castles in the air”, i.e. unrealistic fantasies with no identified location and hence with no hope of being implemented? The most obvious counter to such criticism is that, if a lack of an agreed site implies that a waste disposal programme has failed, then there are remarkably few successes in the national disposal programmes around the world today. Finland is the only country where a site for deep disposal of commercial spent nuclear fuel and/or HLW has been agreed to at all necessary regulatory and legal levels. A few other countries are quite close to this stage (e.g. Sweden USA and France), but they have not yet cleared the final hurdles. Furthermore, all these programmes, including the Finnish success, have spent decades in the siting process.

It therefore seems very premature to write off budding programmes for multinational repositories as unrealistic because they have not identified a host country in the first years. In practice, multinational strategies, like their national counterparts, may take many years for siting and, in fact, they can be modelled directly on successful national siting approaches.

These national approaches are summarized below before considering how they can be adapted and applied to the multinational case.

Successful national repository siting is dependent on achieving at the outset a sufficiently broad consensus amongst stakeholders on the following premises:

- A safe solution for the long-term management of SNF and HLW is required by all parties. The parties referred to in the national case are communities, regions, or political jurisdictions (e.g. States in the USA, Cantons in Switzerland, counties in Sweden, etc.)
- Geological disposal in a deep repository is the only available approach to day that can guarantee the required level of safety — if the repository is properly implemented at a well chosen site.
- Numerous, small repositories are for reasons of cost, safety and security clearly less effective than fewer or even a single shared facility.
- Hosting such a shared facility can result for the host party not only in real or perceived drawbacks but also in specific benefits, such as financial gains, broader economic developments or increased political leverage.
- If these benefits are judged to outweigh drawbacks, willing hosts will come forward. In any case, a repository will not be imposed on any party against its will.

Assuming that all of these premises are accepted by the involved parties, consensual siting begins to look feasible. However a transparent process leading to identification of technically or socially acceptable sites is still required. Much progress towards identifying a suitable process has been made by national waste management programmes in recent years. The characteristics of a suitable siting process are broadly agreed to be as follows:

- It is adaptively staged and acknowledged to be a multi-year process that will evolve as the implementers take on board feedback from all stakeholders.
- The siting process is based on objective, transparent, well-documented criteria, which, however, should not be overly prescriptive.
- The objective is to identify sites where demonstrably safe repositories can be implemented and the process is not based on claims that a "safest" site can be identified.
- The process includes true dialogue between all stakeholders, especially potential hosts, with the objective of ensuring that it is regarded as fair and equitable by all.
- The aim is to identify informed and willing repository hosts and to retain their support throughout the repository implementation process.

What are the differences between this idealized national repository siting process and a multinational process? Almost none is the answer.

When the interested parties are sovereign nations rather than sub-national entities, the hurdles to be surmounted are basically the same — although they are undoubtedly set higher. Furthermore, some siting options at the national level, such as imposing a facility on a community if no volunteers came forward, are not open in a multinational process. This "last resort" option has arguably played a role in some national repository programmes. The US Congress overrode the State of Nevada veto on the selection of Yucca Mountain. The Swiss government, after a Cantonal referendum led to the loss of a potential site at Wellenberg, changed the law so as to remove veto rights. In Germany, the AkEnd government advisory group was divided on whether a government ruling could unilaterally fix a site in the event that no willing communities came forward.

Increasingly, however, national programmes are accepting that host communities must be willing. Japan is looking for voluntary sites. The Swedish implementer, SKB has agreed to accept any local veto despite legislation that would allow the government to overrule this. Both the UK and Canada have recently chosen strategies based on consensual siting. In such an environment, willing national hosts in a multinational initiative do not appear to be out of the question. A further hopeful indication that optimisation of waste management can occur above the national level is given by current toxic waste disposal projects. In Europe, several nations export and import toxic wastes in order to make use of the best available facilities.

Where to first implement regional or multinational repositories? The most intensive work on this concept is being done within the SAPIERR project which was described above. The ultimate objective of SAPIERR-2 is to propose a practical implementation strategy and organizational structures that will enable a group of countries to work on shared EU radioactive waste storage and disposal activities. The concept is, however, also applicable in other regions of the world where small nuclear programmes exist or new nuclear programmes are being proposed. For example, further bodies could be established in the following global regions

- Asia: Taiwan and Korea have in the past had huge problems in siting national disposal facilities even for LLW, although recently the latter now has successfully attracted voluntary siting communities. Both have problematic geological environments and would be clear candidates for partnering, despite their substantial nuclear programmes. Other possible participants would be the countries in the region that have been reported to be now considering initiating nuclear programmes. These include Malaysia, Thailand, Vietnam, Australia and the Philippines.
- Arab States: The Gulf States have already established a cooperative effort to introduce nuclear power. Jordan has also expressed the wish to do so and has supported regional disposal concepts. Other Arab countries such as Algeria, Tunisia, Morocco, Yemen and Egypt are potential candidates.
- Central/ South America: Mexico needs a disposal solution as do Brazil, Argentina. Chile and Venezuela are also considering the nuclear option.
- Africa: South Africa has great nuclear ambitions. Other African countries, such as Ghana, Nigeria, and Namibia that are contemplating introducing nuclear power will also need access to a repository

A very important point to note is that not only those countries that have or will have nuclear power plants require access to a geological repository. Other nuclear technology applications also produce long-lived wastes that should be disposed of in this way. The quantities are modest, but the hazard potential is not. Regional repositories offering a safe disposal service would therefore contribute to environmental health and safety also in such non-nuclear power nations.

5.2. Regulatory and legal aspects

The feasibility of multinational repositories is directly affected by the legal and regulatory aspects in host and partner countries, as well as in third parties.

A state that seeks to accommodate a multinational repository within its territory will have to ensure that an appropriate legal framework is in place allowing the import of SNF and/or HLW and that its regulatory system satisfies the IAEA requirements laid out in IAEA publication, Safety Standards Series No GS-R-1 [43]. Similarly the national legislation of the partner country will have to allow export of waste. The current situation concerning export and import laws, regulations and national policies is summarized in [27]. Many countries forbid import of radioactive wastes, relatively few forbid export; several have specific requirements that must be satisfied before export or import.

Legal aspects related to third parties are mainly possible restrictions on future transfers of enriched material imposed by many countries supplying nuclear fuel and the need to obtain the consent of the supplier country before transferring SNF to a multinational repository and agreements for the spent fuel transit through third countries en route to multinational repositories.

5.3. Liabilities and long term rights

The responsibilities and liabilities related to long-term waste management have often raised special concerns in national disposal programmes, and the relevant issues are more complex in the multinational case. It is generally agreed that the responsibilities and liabilities must be identified, quantified where possible and managed by ensuring that an appropriate framework is established for management of waste. The provision of sufficient funds is linked, ultimately, to the safety of the public and therefore financial and non-financial liabilities are both involved. This link is recognized in the Joint Convention of the International Atomic Energy Agency of 5 September 1997 [44] concerning the safety of the management of irradiated nuclear fuel and radioactive waste, which states in article 22 that "*each Contracting Party shall take the appropriate steps to ensure that adequate financial resources are available to support the safety of facilities for spent fuel and radioactive waste management during their operating lifetime and for decommissioning.*" This link is also made by the European Commission, and it is at the basis of a recent proposed directive on establishing decommissioning funds.

In many nuclear countries the national frameworks have been established to assure that waste management funds are accumulated. However, another level of complexity is introduced when one considers liabilities and responsibilities associated with the operation, closure and long-term safety of a multinational repository that contains spent fuel and HLW from a number of participating countries. The questions raised are then, not only what financial liabilities arise and how much funding must be set aside, but also who bears the responsibilities for ensuring safety at all times and for providing sufficient funds for all eventualities both pre- and post-closure.

A more detailed study of legal liability issues in relation to multinational approach that looks principally at organizational responsibilities and financial liabilities has been performed within the SAPIERR II [11] project. The project provides a review of actions which may have to be taken during and after the operation of a multinational disposal facility, considers who shares responsibility for such actions and looks at how responsibilities can best be allocated to ensure that they will be fulfilled in a way which protects future generations from harm, be it physical or financial. Some of the issues involved concern legalistic points of title to wastes, contracts at different national and international levels etc.

The project concludes that the challenges faced to develop multinational/regional facilities are to a large extent common also to national repositories, going through the same series of phases during its long development history.

Throughout these phases, responsibilities for decisions and actions must be clearly allocated if conflicts are to be avoided. Issues like ownership of land for a repository, ownership of radioactive wastes from their time of production to their final disposal, responsibilities in relation to the transport of nuclear material to the repository, licensing, waste acceptability and operational safety during the implementation and repository operation and pre-closure inspection and post-closure monitoring must be properly addressed and agreed upon. In particular it is important that the financial liabilities are clearly allocated and funding arrangements agreed upon for the pre-construction and construction period, during the repository operation and for the post-closure period.

Ultimately, at some future time, all responsibility for buried wastes will revert to a national government, or to a supra-national organization.

One obvious complication results from potential disposal of wastes in a multinational repository. Does the ultimate responsibility which unavoidably falls on a national government then extend for the host government to all of the wastes which have been imported? Rather than accept such a situation, it is conceivable that the host government might insist on State Treaties which continue to share responsibilities for the unlikely event of retrieval out into the indefinite future. It is equally conceivable that the customer country governments would be prepared to accept this shared responsibility. Given that no responsible country would allow its wastes to be exported to location judged to be less safe than that of a national disposal project, shared responsibility for a common international facility may well be more attractive than full responsibility for a national repository. This sharing could be under bilateral or multilateral agreements, but the probability that supra-national organizations would be directly involved is high.

Responsibilities and liabilities related to the development and implementation of a multinational repository can be tackled in different ways. Two scenarios for allocation of responsibilities were developed in [31, 32]: a commercial and a non-profit organization. A third possibility is that the major nuclear States have such strong security concerns that they offer a "free" service to small or new nuclear power nations

In a general model for a commercial organization it is assumed that a designated repository company will build and operate a repository and users will pay for the disposal service provided, either as wastes are delivered or up-front by reserving space in the repository. The repository company will either terminate after closure or be absorbed by the national Government. A long-term monitoring regime will be established and covered by the fund for longer term needs. Variations to this model are possible depending on host and partner countries.

A scenario of non-profit organization assumes a joint venture between some countries that are sharing a disposal facility located in one of them. Sharing of responsibilities and liabilities in the operational phase could then be more likely. However, the issue of liabilities must be addressed carefully and timely addressed and resolved.

5.4. Fair funding mechanisms

Developing a multinational repository is a decades-long undertaking; therefore, for all involved countries there are lasting economic risks associated with the implementation of the project as well as with potential failure of the project or significant delays, including those that could result from changes in the political systems in the host or partner country. For successful implementation of such a joint undertaking it must be of special concern how to provide fair, timely, stable and sufficient financing throughout the whole duration of the project and how to address the financial risks after the repository closure.

In [5] the financial arrangements for multinational repositories were only briefly discussed. Bilateral agreements affecting simultaneously both host and partner are assumed either through a co-financing scheme for the entire project development or though issuance of bonds, to be repaid over a number of years out of operating revenues, or the issuance of stock. It is emphasized that, regardless of the financial arrangement, it is crucial that the financing is secured and that this involves sharing of all possible financial risks.

According to further elaboration of this issue in [31], sharing of costs and financial arrangements for covering the risks depend on the organizational structure chosen for implementing the project. If a non-profit organization is chosen and a cost based service is to be developed by a consortium of repository users, then equitable financial burdens should be placed on the partners. In a partnership type of organization, such as is often the case in national programmes, an important consideration is the "fair" distribution of costs amongst partners, given that these partners will deliver different volumes of different waste types on differing timescales.

The financial arrangements and the distribution of costs may vary from project phase to project phase. The costs through the preparatory stages may be distributed amongst participants in various ways, depending upon the organizational structures chosen for the implementation. If a cooperative or an association structure is chosen, this implies equal voting rights in the organization, but not necessarily equal funding levels. Principles (for example: waste volumes) must be set for funding and mechanisms foreseen for adjusting payments at the time of implementation to account for actual conditions.

Similar dependence between organizational structure and sharing of costs arises during operation of a multinational repository. In principle, the running costs of the repository and the accumulation of funds for closure and long term monitoring can be financed by income from users who pay a fee to dispose of their wastes. A problem can arise with this system — and also with any national repository catering for independent users — in that incentives may be needed to persuade the users to move their materials out of their interim stores and into the repository. This is because the continuing outlays for maintaining existing stores are less than the costs that arise for transport and for emplacement of the wastes in the repository. If there is no shortage of interim storage capacity, this situation can arise even if the users have already contributed to the capital costs of the repository. One mechanism that can avoid this problem is to have user countries reserve space in the shared repository and compel them to pay for this space, even if it is not being used. In any case, successful technical and commercial operation of a shared repository can only be achieved if users are constrained to define in advance their proposed shipments and to adhere to agreed schedules.

Post-closure funding arrangements for a regional or multinational facility must consider additional aspects beyond those for a purely national one. Relative to the substantial costs of any repository project, the funding needed on a continuing basis for monitoring activities is small. The implementer can be compelled to establish at closure a dedicated fund which is large enough to generate sufficient interest for an effectively indefinite monitoring programme. The governments of future generations can then at any time take a political decision to terminate the monitoring and use the funds for other purposes, if they so wish. Public acceptance at the outset of disposal operations, however, may well be enhanced if dedicated funds were protected by legislation from being diverted for some (long) specified time period.

Financing of retrieval, is perhaps more problematic. In principle, one could establish a dedicated fund also for retrieval but the retrieval costs can be high and setting aside much funding for potential retrievability may not be the best use of society's resources.

Various arrangements are conceivable for ensuring that funding is available for monitoring or inspection actions in the future.

- A post-completion activity fund is established as a special purpose trust fund, charged to secure the repository implementer's obligations, and administered by the implementer alone from inception.
- A post-closure activity fund is established as a special purpose trust fund, charged to secure the repository implementer's obligations, with administration of the fund passing from the repository implementer to the host country Government only on repository closure (perhaps including a first period of "confidence monitoring").
- A post-completion activity fund is established as a special purpose trust fund, charged to secure the repository implementer's obligations, and administered by the host Government from the beginning of repository operations.

In a multinational arrangement, the user nations, who will obviously also have to contribute to any fund that is set up, may expect to have oversight possibilities to ensure that accumulated funds are not misused.

5.5. Safety and security

The expected global security and safety benefits were recognized as major arguments for supporting the concept of multinational repositories and encouraging potential host countries to offer their cooperation to interested partner countries [45-48]. Providing a proper disposal facility accessible also to countries that may not be in a position to implement a state of the art national repository may contribute to safety and security on a global scale. It may also reduce proliferation concerns. Emplacing the SNF deep underground inside a facility that is highly monitored, with numerous engineered and administrative controls, can enhance both physical security and safeguards relative to most surface storage facilities. In addition the multinational repository approach could be useful in further reducing the environmental impacts for small countries with limited resources. With a multinational approach the environmental risks associated with under-funded or marginally-funded repositories that might result in some countries could be avoided. For the host country the implementation of a multinational repository could incur a negative incremental long term environmental impact because it will become the disposal site for radioactive material generated by partner countries. Such potentially greater environmental impacts require that the benefits of cooperation are equitably shared between host and partner, and fees paid to the host by partner country are to be assumed.

This SAPIERR-II report on safety and security [32] concludes that the required safety and security standards are achievable for multinational facilities and confirms that a shared project presents no technical issues that will not have to be overcome in national projects. International treaties and conventions, and the comprehensive system of international guidance, national regulations and control mechanisms, ensure that a shared regional repository and associated waste management system will be at least as safe and secure as any national repository and waste management system. Indeed, a shared waste management system and final repository offers a potential safety advantage over separate smaller national systems primarily as a result of the pooled financial and human resources that can be invested to ensure implementation to high technical standards. A shared final repository also offers a security advantage in the long-term against proliferation of nuclear materials, since the number of sites at which nuclear material is held is reduced. Furthermore, since the combined efforts of several countries may give better prospects for joint realisation of a project at an earlier time than if national projects proceed independently, this presents a small but tangible benefit due to a reduction in the average time that spent fuel is stored at national facilities.

The growing energy demand worldwide and the need for expansion of peaceful use of nuclear energy in existing and in new countries increased the non-proliferation, security and safety concerns. Initiatives like GNEP and GNPI have been proposed to alleviate these concerns. However, recognizing that enrichment and reprocessing are the most sensitive technologies, both initiatives concentrate strongly on these and consequently neglect the disposal problem. But spent nuclear fuel becomes more of a proliferation risk as it cools with time and SNF and HLW are both security concerns from the beginning. Accordingly, more attention should be devoted to arrangements that will remove such materials as early as possible from small user countries.

5.6. Timing of repository implementation

The disposal plans in many countries have been developed based on the assumption of no new nuclear build. The time for repository operation was determined according to the needs of already accumulated and future wastes from current operating nuclear power plants or facilities under decommissioning. At present many countries are reconsidering their energy policy and discussing options for increased use of nuclear energy.

Any decision for construction of new nuclear power plant(s) will also create a need to re-examine the disposal plans, not only from the perspective of re-adjustment of disposal capacity but also the timing for repository implementation may be re-considered. The impact may be stronger for small nuclear programmes. The adjustments may go in two directions:

- a country may decide to go for extended storage and therefore shift repository implementation further into the future, or
- a country may decide to extend the repository operation in order to accommodate the newly generated spent fuel or HLW (as will be the case in Finland).

Extension of repository operation may be quite costly decision. A cooperative approach to extended storage and to delayed disposal of waste may become attractive for countries facing such challenges. This tendency would negate the potential security and non-proliferation benefits of having waste emplaced underground. One option that multinational repositories could offer to address this problem is that, instead of extending the operation periods of national repositories, partner countries could harmonize their plans and to use one common repository at a time.

5.7. Public and Political Attitudes

Public opinion polling

A recent review of public and political attitudes to shared repositories was carried out as part of the SAPIERR-II project. In the relevant report [33], the analyses were done through (1) a literature review illustrating the main reasons why governments and citizens may be in favour or against a shared management of radioactive wastes; (2) the results of the Eurobarometer surveys, (3) the analysis of European Union Member States’ legislation and of the position of their national Agencies, (4) recording the views of international bodies about multinational repositories; and (5) analysis of a brief questionnaire handed out to local representatives of European municipalities hosting nuclear facilities.

Of greatest interest might be a comprehensive public polling of attitudes towards multinational cooperation in waste disposal. Unfortunately, the wide surveys done in the scope of the EU Barometer [49, 50] in 1998 and 2002 were not carried forward into more recent polls. A comparison of the two surveys mentioned revealed that the percentage of European citizens that believes that radioactive wastes should be disposed of within the national borders of the producing country decreased from 75% to 63% and the share of EU citizens in favour of regional repositories increased from 12% to 18%. The 1998 results showed that most of European population were against of their own country accepting foreign wastes (80%). This is hardly surprising perhaps, given the facts that the repositories were referred to in the questionnaire as "underground tips" and that three-quarters of Europeans polled believed that there was no safe way of getting rid of highly radioactive waste! In the 2002 survey the facilities were labelled as underground disposal facilities — and the percentage of the population believing that waste was not being disposed because there was no safe way was less than 50%. In the most recent 2008 survey, 41% of Europeans on average still totally agree that there is no safe way of getting rid of high level radioactive waste, while just under a third (31%) tend to agree. Clearly, much effort is needed to make any kind of HLW repository acceptable, whether national or regional.

Not all surveys have been so negative, In Germany, the Institute for Technology Assessment and Systems Analysis in Karlsruhe carried out in 2003 a survey on international disposal [51]. The results were quite different from the results of the Eurobarometer. 55.6% of the respondents preferred international solutions, whereas only 31.5% were in favour of a national solution. It is also interesting to note that 40% of the respondents accepted the idea of a multinational repository located in Germany, and 40% were against, whereas the rest were undecided. However, 80% declared themselves against the repository being sited in their own region of Germany (whether the facility be national or international).

Unfortunately, in the Eurobarometer surveys published in 2005 and 2008 no question on multinational repositories was included. Therefore, a chronological analysis of the evolution of EU citizens regarding the level of support to this initiative cannot be undertaken.

The authors of the above mentioned SAPIERR report themselves carried out a very restricted survey of local authority leaders from communities with nuclear facilities. It is clear that a survey of such a limited and selected group of individuals cannot be representative of public views. However, the study provided a valuable opportunity to explore reactions of relevant public officials to a set of questions that could usefully be put at a later stage to a wider spectrum of public representatives. 56% of the sample agreed with the possibility of collaborating among EU countries to develop shared repositories. 23% require further investigation and debate and 11% do not know or do not answer. According to most of the local representatives, the location of a shared repository should be chosen through a volunteering procedure.

Potential barriers to repository hosting

From a policy-maker point of view, multinational repositories may be seen as hurdles for national disposal programmes. First of all, multinational repositories could constitute a disincentive for the development of national repositories, by offering an alternative solution to the problem of the HLW and SF disposal, thereby reducing the priority and funding of national disposal programmes. This does not need to happen, as illustrated by the fact that some countries already follow a dual track strategy: preparing the necessary steps to establish national repositories, but also leaving the door open to the possibility of joining a multinational repository. Examples of countries with a dual track strategy include Belgium, Czech Republic, Hungary, Latvia, Lithuania, the Netherlands, Slovakia, Slovenia and Switzerland. Secondly, the fear that a national repository would accept HLW and SF from foreign countries could make national repositories less acceptable to local communities. This has been observed to be a controversial issue in some countries, despite firm assertions by institutions with high credibility, such as the EU, the IAEA and national governments, that no country will be forced to accept foreign HLW.

Opponents of shared repositories have put forward ethical arguments. For example, Marshall [52] and Murray [53] assert that it is unfair for a country to make itself responsible for wastes produced in other countries. This view has also been strongly opposed [54]. In particular, it is stressed that multinational repositories do not take advantage of lower environmental standard or financial difficulties of a developing or transition country. This ethical point is recognized clearly by those promoting multinational repository concepts. For example, EC Council Directive 2006/111/EURATOM on supervision and control of shipments of radioactive waste and spent fuel states that in case of shipment to countries not belonging to the EU, the authorities of the state of origin shall not authorise shipments to third countries that do not have the administrative and technical capacity and regulatory structure to manage the radioactive waste or spent fuel safely. Similarly, article 27 of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management states that trans-boundary movements are only allowed if the importing country has the administrative and technical capacity, as well as the regulatory structure, needed to safely manage the spent fuel or the radioactive waste. In addition, the Joint Convention prohibits the shipment of its spent fuel or radioactive waste to a destination south of latitude 60 degrees south for storage or disposal.

One key point that could influence public acceptability is the economic benefit for the hosting country. It can be argued that an approach based on community volunteering together with a fair compensation system could result in a fair sharing of the costs and benefits. The economic aspects report [31] from the SAPIERR II project details the numerous financial and other benefits that a host country and community might receive. In the most successful national geological disposal programmes, e.g. in Finland and Sweden, it has been shown that the net benefits of hosting a repository can be judged as so positive by local communities that competition for the facility can result. These cases may act as role models for inclusive, fair negotiations with potential host countries and communities for multinational facilities.

Some current national positions on multinational disposal

Country	Disposal Policy for HLW/SNF, Attitude towards international repository
Austria	Has an anti-nuclear policy and a preference for finding an external repository solution. There were early negotiations with intent to export Zwentendorf NPP fuel before the power plant was abandoned.
Belgium	Follows dual track approach – but with clear priority on a national solution based on its advanced national disposal programme.
Bulgaria	Earlier returned SNF to Russia and intends continuing to do so, if possible.
Croatia	Currently owns spent fuel from Krysko NPP in Slovenia, but bans any import of spent fuel and radioactive waste.

Country	Disposal Policy for HLW/SNF, Attitude towards international repository
Czech Republic	Follows an official dual track approach, with 1st priority national. Between 1995 and 1997 fourteen re-importation transports of fuel spent took place by rail from Slovakia to Czech Republic
Finland	Firm policy and Law - national only; advanced national disposal programme. Between 1981 and 1996, 330 tU of Finnish spent fuel was shipped to the USSR
France	Firm policy and Law - national only; advanced national disposal programme. Previously accepted SNF for reprocessing with no waste return. The current spent fuel reprocessing contracts have a clause stipulating return of the wastes to their country of origin
Germany	Policy is for national disposal only; previously exported SNF for reprocessing both with no waste return and with waste return..
Hungary	Follows dual track approach – but with clear priority on a national; solution based on its advanced national siting programme. Will consider international solution only after having elaborated and approved a national strategy for deep geological disposal. Formerly exported SNF to Russia
Italy	Long term storage; no national siting programme; export not excluded. Previously exported SNF for reprocessing both with no waste return and with waste return.
Lithuania	Follows an official dual track approach. Importing radioactive waste and spent nuclear fuels into Lithuania is not allowed.
Romania	Import of radioactive waste (including spent fuel) is not allowed
Russia	The Russian government has supported the idea of repatriating Russian spent fuel – and has proposed accepting foreign SNF for reprocessing, while retaining the option of returning the HLW to the country of origin.
Slovenia	Dual track; if national option, then after many decades. The programme establishes that national repositories should be considered only if multinational solutions will be unavailable.
Spain	The 6th General Plan on Radioactive Waste states that the option of multinational, international or regional repository should be considered, notwithstanding the problems of public acceptance that it may imply. Has exported long lived wastes to USA and France.
Sweden	Firm policy and Law - national only; advanced national disposal programme. Previously exported SNF for reprocessing with no waste return and also swapped SNF with Germany
Switzerland	Swiss national policy does not formally exclude multinational solutions but today is focussed entirely on implementation of national repositories. The Government recognizes that if an acceptable international option should arise later, the waste producers could choose to participate
United Kingdom	No official policy Previously accepted SNF for reprocessing with no waste return Operates substitution policy for reprocessing wastes
USA	The US government has also supported the idea of repatriating spent fuel. There are no laws against this, but strong opposition has been apparent even for the import of low-level wastes to existing repositories.
N.B. Many of the countries that have a policy that includes multinational repositories currently have legislation that forbids import of radioactive wastes.	

Position of international organizations

Multinational repositories are a common topic at the IAEA, reflecting direct interest of many Member States. The 2006 Summary Report of the Second Review Meeting of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (JC/RM.2/03/Rev.1) [55] noted that many contracting parties mentioned the concept of regional repositories. Director General Dr. Mohamed ElBaradei affirmed in his "Statement to the Forty-seventh Regular Session of the IAEA General Conference 2003:

> "*Our consideration should also include the merits of multinational approaches to the management and disposal of spent fuel and radioactive waste. Not all*

countries have the appropriate conditions for geologic disposal — and, for many countries with small nuclear programmes for electricity generation or for research, the financial and human resource investments required for research, construction and operation of a geologic disposal facility are daunting. Considerable economic, safety, security and non-proliferation advantages may therefore accrue from international co-operation on the construction and operation of international waste repositories. In my view, the merits and feasibility of these and other approaches to the design and management of the nuclear fuel cycle should be given in-depth consideration. The convening of an Agency group of experts could be a useful first step".

In its web page, the IAEA states:

"For many countries, the option of reprocessing the fuel abroad is unlikely to be affordable. Moreover, if the fuel is shipped abroad for reprocessing, the problem of the final disposal of any returned high level waste will have to be addressed anyway. Sooner or later, every country with at least one research reactor, which continues to operate beyond the termination of acceptance programmes of the countries of origin, will need a final solution for spent fuel and/or high level waste. Clearly, access to a multinational long-term interim storage facility and eventually a multinational repository is the optimal solution"

More recently in 2008, in a high level report to the DG by the Director General for the Commission of Eminent Persons (Feb 2008), it is confirmed that [56]

"For countries with limited waste or without access to geologically suitable disposal sites, multinational disposal at sites with good geology might be an option. Several studies have identified the potential benefits, in terms of possible economic, non- proliferation, safety and security advantages, of multinational disposal as well as the institutional and political issues standing in the way. The IAEA could help States arrive at a solution that fits their needs.

The EU is also favourable to trans-boundary waste transfers under certain conditions. The draft Proposal for a Council Directive (Euratom) on the management of spent nuclear fuel and radioactive waste included in the „Nuclear Package" allowed the possibility of shipments of nuclear waste from one Member State to another or to a third country, provided that they meet EU and international norms and standards. The original Explanatory Memorandum on the Directive contains the following relevant text [57]:

"Export of waste is also specifically mentioned in the Article. It is recognized that for certain Member States with very limited accumulations of waste, export to other countries probably represents the most viable option from the environmental, safety and economic points of views. However, these transfers can only be sanctioned providing the very strict conditions listed in the Article are respected. These conditions include the limitations and criteria concerning export of radioactive waste to third countries included in Euratom Directive 92/3. The proposal does not seek to limit a country's right to be self sufficient in all matters of management of its waste, but does seek to encourage the sharing of facilities and services wherever possible."

Finally, trans-boundary shipments are provided for in Article 27 of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, which was signed by 42 countries. The Joint Convention allows trans-boundary shipments, provided that they respect some safety requirements [44].

5.8. Potential impacts on national programmes

A sensitive issue over the past decade has been the potential or the perceived impact of multinational repository initiatives on disposal programmes that have chosen a purely national approach. It is a documented fact that nuclear opponents in some countries have used as an argument to provoke opposition the assertion that their national repository could be compelled to import foreign wastes. This tactic has been used even in Sweden, despite the fact that national legislation bans import, national policy is firmly opposed and EC assurances have been given that this will not happen. It is important for all countries that leading nations successfully move ahead to demonstrate that geological repositories can be safely built and operated. Accordingly, multinational initiatives should take care that they do not disrupt these successful programmes.

On the other hand, it is crucial for the development of nuclear power world wide that all nations adopting the technology can have access to safe and secure repositories. Since this means for some that multinational repositories will be necessary, the advanced nuclear programmes must also take care not to hinder credible cooperation initiatives of others.

A responsible approach for small countries is to adopt a dual track strategy in which both national and multinational options are kept open. This implies that national resources must be devoted to addressing the disposal issue rather than simply adopting a "wait and see" attitude. The resources needed will however be less than what a fully independent disposal programme would require since there can be a sharing of tasks and also a transfer of knowledge into small programmes from their partner organizations.

5.9. Role of IAEA and other international organizations

The IAEA currently plays an important role in assisting Member States in examining the issues surrounding shared facility arrangements for spent fuel disposition It will continue to remain proactive in seeking consensus and facilitating constructive steps, assisting Member States individually, should they seek national solutions to their needs, or assisting groups of Member States should they seek collective arrangements incorporating facility sharing.

As in nuclear safety and security, the IAEA can seek to increase its activities related to developing the best approaches to developing and implementing sound spent fuel disposition strategies, publishing guidelines and facilitating the promulgation of best practices.

Should Member States so decide, the IAEA could engage in the development of a legal instrument that could bring together Member States wishing to participate in the development and implementation of a spent fuel disposition service, and if so decided, to engage in extra-territorial agreements to host spent fuel disposition operations under IAEA auspices, securing competent industrial participation and Member State regulatory oversight.

Depending on whether such arrangements are based upon user fees (lump sum, pay-as-you-go, or payments over defined periods and specified conditions), or under a universal fee structure based upon a surcharge on nuclear electricity and other nuclear energy products, the IAEA may be called upon to collect and administer a superfund that would be established for such a purpose. Such a fund could be operated under a cooperative arrangement with the World Bank, for example, to ensure that it remains fiscally sound.

The European Commission can at a regional level perform tasks analogous to those that have been identified for the IAEA globally. In practice the EC has in fact been very supportive, including providing funding for the SAPIERR projects. This support was provided through the R&D Directorate; from the present point on, however, the more logical connection is to the Transport and Energy Directorate which handles policy issues of this type.

The OECD/NEA has been rather silent on the issue of multinational repositories, presumably because many of its key member countries are those with advanced disposal programmes and thus those that most fear negative impacts as discussed in section 5.8. As the advanced programmes become definitive, however, tensions ease and, ultimately, the relevant nations could become technology providers for the multinational repositories discussed in this report.

6. CONCLUSIONS AND FUTURE OUTLOOK

6.1. Conclusions

Safe and secure disposition is a necessity for the future of nuclear power

Firstly, some general conclusions can be drawn on the necessity for, and the approaches to, waste disposition in nuclear programmes, independently of whether the arrangement made are national or multinational:

- Safe, secure and affordable arrangements for the disposition of spent fuel are absolutely essential for nuclear power to be acceptable and nuclear power is recognized to be an unavoidable component of measures needed to meet growing energy demands, assure energy security and limit global CO_2 emissions.
- The arrangements must include a clear strategy, an institutional framework and scientific and industrial infrastructures – together with a sufficient level of support from scientists, politicians and the public. Public and political acceptance will be improved when complete systems are in place demonstrating in practical ways how the many challenges are to be met.
- There is no technical urgency for the implementation of final disposal facilities since dry or wet storage technologies for spent fuel provide a safe and economical means to manage spent fuel arising for many years into the future. However, public and political acceptance will be improved when complete systems are in place demonstrating in practical ways how the many challenges are to be met.
- Spent fuel may be disposed of directly, may be reprocessed to recover for re-use the residual uranium and the plutonium created, or, as the enabling technologies are proven, may be processed to recover these materials and to separate other long-lived isotopes for transmutation.
- Reprocessing involves technologies and separated nuclear materials that could further a State’s nuclear weapons ambitions, and could create attractive terrorist targets involving the theft of nuclear materials suitable for use in nuclear explosives or in radiological dispersal weapons. Hence, reprocessing should be carried out only under conditions that would not exacerbate proliferation or terrorism concerns.
- Whichever process is adopted, there will remain nuclear wastes that must be isolated from the human environment for extremely long periods of time. The scientific and technical consensus today is that this can be achieved only if these residual wastes are immobilized and emplaced in stable geological formations. All responsible States that

use nuclear power or any other nuclear technologies producing long-lived radioactive wastes must take measures to ensure that they have access to safe and secure geological repositories.

Global cooperation can make safe disposal available to all States

In the specific context of the present report on the viability of shared facilities for spent fuel disposition, the increasing interest in nuclear power expansion also has direct consequences:

- The international community has a common interest in assuring that all nuclear fuel cycle activities are carried out according to methods and criteria that assure public safety and security at all stages in the processes — no matter where these activities take place. Accidents, security risks and negative environmental impacts anywhere in the world will reduce public acceptance and affect adversely the future of nuclear power. International efforts are underway to ensure global safety and security in the front end of the fuel cycle, in nuclear power plant operation and in reprocessing. Attention must also be devoted to spent fuel disposition, especially since this presents unique technical and societal challenges.
- States may — in the exercise of their sovereign rights — choose spent fuel disposition arrangements that are wholly national in character. No State should be compelled to accept wastes from another country against the national will. However, some States may combine with like-minded partners to form regional centres, or they may commercial arrangements to export their spent fuel to a willing recipient country, or they may join in international compacts established for the purposes of providing assured spent fuel disposition services.
- For new nuclear programmes or for small programmes, the benefits of a multinational disposition option become more obvious. With only one or a few NPPs, the cost of a geological disposal facility (which is of the same order as the cost of an NPP) increases significantly the cost of electricity. Moreover, small countries may not have the technical resources that are need to establish the credible level of national disposal programme that is needed to make use of nuclear power justifiable.
- On the other hand, if small programmes nuclear programmes expand significantly, they may generate sufficient revenues to finance a national repository programme. The Finnish successful disposal programme originally funded by only 4 NPPs is a positive example.
- The widespread interest in expanding existing nuclear programmes, introducing new programmes and revising policies that until now aimed at phasing out nuclear power can all have important consequences on the optimal timescales on which repositories should be implemented. These may be much extended — and this can have direct implications on storage requirements. Nevertheless, an early practical demonstration of operating deep geological repository would enhance public confidence.

Nuclear security concerns have led to new proposals and initiatives

Over the past few years since the publication of the previous IAEA TECDOC [5] on multinational repositories, the increasing interest in nuclear power expansion, together with increased concerns about non-proliferation and nuclear security, has led to important new initiatives for spent fuel disposition:

- Recent proposals for multilateral approaches to the overall fuel cycle are focussed on limiting enrichment and reprocessing facilities, but they may be more acceptable to a wider range of nuclear power user nations if they include provisions for shared disposal facilities.

- An add-on scenario in Russia, which has been proposed by the Government, may become more realistic, at least for reactor fuels supplied by Russia. Reactor fuel will be supplied to Iran on this basis.
- An add-on scenario in the USA has become more credible with the GNEP proposals for take-back of spent fuel. The details of such an arrangement need to be further clarified.
- Other countries participating in GNEP may be more likely to agree to host a multinational disposal facility if this allows them to be part of the nations providing nuclear services.

Small and new nuclear states are looking at partnering

There have been advances in initiatives for partnering of small or new nuclear nations in spent fuel disposition:

- In Europe, the SAPIERR project aims at establishing an official multinational European Repository Development Organization (ERDO) that will move towards implementation of one or more regional repositories in Europe.
- Other parts of the world where nuclear power programmes are just being initiated (e.g. in the Arab States) may well consider such regional options.

Developments in nuclear technologies will have direct impacts on disposition strategies

Increased interest in new reactor types, new fuel cycles and new reprocessing technologies may have significant impacts on both national and multinational disposal concepts:

- Direct disposal of spent fuel may be regarded as less attractive when long term deployment of reactors, including plutonium fuelled fast reactors, is a probable scenario.
- The waste streams that emerges from advanced reprocessing approaches, particularly if combined with partitioning and transmutation facilities, may change repository inventories in ways that allow changed disposal methods. The volumes will be lower; some waste streams will be much less long-lived than those from today's Purex process.
- The future attractiveness of reprocessing will depend on the relative value of the energy content of the recovered fissile materials and the costs of the reprocessing and fuel re-fabrication steps. Both of these factors will change with time as uranium resources are used up and as advance reprocessing methods are developed.

Legacy and other wastes also have to be safely disposed of

Despite the potential advances in spent fuel disposition approaches, historical problems will still have to be dealt with:

- Not all of the spent fuel currently stored around the world will be treated by advanced technologies.
- In nuclear power countries there are long-lived wastes, other than spent fuel or HLW that also need to be disposed of in a geological repository (e.g. reactor core internals).
- In non-nuclear-power countries, there are also long-lived wastes that need to be disposed of in a geological repository (e.g. from medicine, industry and research).

Multinational shared disposition facilities are a viable approach to enhancing the economics, safety and security of nuclear power globally

The studies referred to in the present report indicate that concentrating disposition facilities into a few, well chosen locations can give an overall system that is more economic, safer and more secure than having spent fuel stored at the surface at many scattered national sites. The key question is whether the multinational approach needed to achieve this is viable, given the technical and societal challenges to be faced. Of course, absolute proof of viability will be obtained – as in national programmes – only when specific projects are developed and suitable sites have been identified and the necessary consents obtained. This is a process lasting years or decades.

The only practicable indication of viability in the interim period is that confidence in ultimate success is sufficient to justify proceeding further with the relevant project work. In the multinational case, specific shared repository projects have not yet been initiated. However, progress has been made towards the required degree of multinational cooperation. Research reactor fuel and spent sealed sources are routinely repatriated to their countries of origin. Some progress has been made towards schemes such as GNEP and GNPI in which fuel suppliers take back the spent fuel. Most concrete are the joint actions being taken in Europe towards shared disposal facilities for use by States with small nuclear programmes or radioactive waste inventories, e.g. in the SAPIERR project and its follow-on Working Group.

These developments give confidence to assert that multinational disposition facilities are a viable approach that will lead at an as yet undefined future time to the availability of appropriate repositories for all hazardous, long-lived radioactive wastes.

6.2. Future work

In this section, the key developments of the past years in the area of multinational repository developments, as described in previous chapters, are considered in turn. The objective in each case is to suggest associated actions that might help increase the feasibility of the approaches that have been proposed in the various studies. Following the specific suggestions related to the listed ongoing initiatives, an overarching set of proposals is presented for discussion.

6.2.1. Specific suggestions related to ongoing initiatives

Actions by international organizations

It could be beneficial if international organizations in their support for the spread of nuclear power continue to emphasize the necessity for including credible disposal strategies in the planning of States that introduce or expand their nuclear capacities. The resurgence of nuclear energy should not be open, as was the initial growth phase, to the accusation that the waste problem is unsolved. At the introduction of nuclear power, it was justifiable even from a purely technical angle to postpone for decades the implementation of geological repositories. Cooling times of 40-50 years were foreseen in almost all programmes. Today cooled spent fuel or HLW is available and it can be demonstrated that deep repositories can be safely implemented.

Both national repositories and possible multinational repositories should be internationally recognized as solutions. The IAEA was an early supporter of cooperation in fuel cycle facilities and over the past several years it has increased its efforts in his area. However, the various studies performed under IAEA auspices have not yet led to many specific actions. The important proposals of the MNA Group should be taken up and their practicability further explored. The important role of the IAEA in any type of multinational repository project is widely recognized; in a supranational scenario its role would be crucial.

The EC has also supported multinational or regional approaches over recent years, even to the extent of providing significant project funding. For any European solution, the role of the Commission is critical. One specific avenue that could help progress here would be for the EC to consider how the hosting of a multinational repository could be integrated into a regional development plan that brings benefits to the host country, region and community. A different issue for the EC concerns that acceptability of disposal routes outside the EU. Currently, EC policy is that Europe should be self-sufficient in its waste disposal strategies. This principle may not be necessary if GNEP and other add-on options should lead to state-of-the-art disposal facilities being offered elsewhere. This issue could become topical if negotiations between Russia and some Eastern European countries proceed.

The OECD/NEA has been mostly silent on the issue of multinational repositories or has put most emphasis on presenting the concerns of some of its advanced member countries that discussion of multinational options might harm national programmes. An alternative approach is possible. Countries with advanced national programmes might point to the existence of multinational grouping as evidence that they will not be compelled to import wastes from such groups. The advanced countries can also contribute directly to the success of multinational programmes by making their expertise and advice available, where necessary on a commercial basis.

GNEP

The most urgent requirement to be met by GNEP if it is to become a credible vehicle for helping new nuclear nations is to assure a broadly supported and adequately funded future. If this can be done, GNEP can continue to strengthen international technical cooperation in the fuel cycle by establishing and maintaining its organized working groups in the various relevant areas. In the context of the present report, however, the possibly contentious issue of spent fuel “take back” must also be addressed. If repatriating commercial spent fuel to the USA or to other GNEP fuel provider countries is a serious hurdle, then these countries can also support the efforts to establish multinational disposal facilities in third party countries. In any case, it would demonstrate more clearly the willingness of supplier countries to assist users if these suppliers did not have national legislation banning acceptance of foreign radioactive wastes. The supplier countries in GNEP should also recognize that the disposal problems of small user countries will not be solved by spent fuel leasing arrangements alone. Historic waste inventories and long-lived wastes from non-power applications must also be disposed of in geological repositories.

Continuing theoretical and practical research on advanced processing routes and, in particular, on their impact on waste disposal is necessary. It should, however, be acknowledged that existing technologies — including PUREX reprocessing and direct disposal of spent fuel will continue for many years. Given the conclusion drawn earlier on the important balance between reprocessing costs and the energy value of recovered fissile materials, a specific study on these points is recommended.

Russian options

Given the support it has at governmental level, the Russian possibility of implementing an add-on option for disposing of HLW from foreign SNF reprocessed in Russia may be the most realistic at present. However, for a feasible process to be established, Russia would have to relax its current position on the acceptance of spent nuclear fuel, with no return of wastes. Moreover, the lack of existing geological repositories in Russia or of active projects in the area renders the Russian option less credible. A major national programme to rectify this would be valuable. In practice, the international community could even support and help to shape and finance Russian option through a concerted multinational project aimed at implementing a Spent Fuel Management Centre.

SAPIERR

A clear indication of the feasibility of the regional European repository concept studied in SAPIERR will result from the follow-on efforts to found a dedicated European Repository Development Organization (ERDO). If these are successful, a stable platform will exist for further development. The probability of success will be enhanced if the active support of the EC is assured. The CATT project [58] encouraging cooperation between European States and the CARD project [59] aimed at assessing the feasibility of Technology Platform on Geological Disposal that emerged after CATT both indicate that the EC can create suitable mechanisms for promoting contacts between States, whether they have national or multinational repository objectives. But participation decisions in a formal ERDO will be taken by individual countries. Accordingly, extensive bilateral discussions involving national waste agencies and government officials will precede any formal decision on the ERDO formation. The ERDO Working Group that is meeting through 2009/10 provides a forum for such discussion .It is also important that those countries with purely national disposal programmes be kept fully informed so that they do not perceive any new developments as a threat.

In addition to moving the European cooperation ahead, the SAPIERR group could — most effectively in conjunction with the IAEA — make its relevant experience available to potential regional grouping of countries in other parts of the world. For such work, detailed studies on inventories, legal situations, public acceptance etc. will be necessary for the new groupings, just as they have been for SAPIERR.

In both cases, European and elsewhere, it is important to continue to recognize the fundamental principle that successful repository projects do not begin by prematurely deciding at the outset on the most suitable sites. Site selection for national repositories is a multiyear process; less can not be expected for multinational initiatives.

6.2.2. Overarching considerations

In addition to the specific points made above in connection with individual recent initiatives, it is possible to formulate some overarching suggestions that could be addressed by the international community and that could lead to specific guidance or requirements from international bodies like the IAEA and the EC:

- All States should recognize that secure spent fuel disposition is an essential element of all nuclear power programs, that the problem is global in nature and that a global solution is mandatory. International cooperation should be strengthened in order to achieve this global solution.
- All States should declare which options they are considering for spent fuel disposition, and which of these they are following up with specific development activities. All of the options discussed in this report (national, multinational, direct, reprocessing, etc.) are

acceptable. States may change their preferences at any time, for any combination of reasons. They may also deliberately keep alternative options open in a “dual track” strategy. As has been emphasized by the Risk Group of the European Nuclear Energy Forum, however, "the possibility of multinational solutions, in particular for minimizing waste management costs, should not be used as an argument to postpone a decision or to establish a wait-and-see approach" [60]. Each country should actively work towards a waste disposal solution.

- A global entity could be identified or created specifically to represent the common interests of the international community in assuring safe and secure spent fuel disposition and radioactive waste disposal. In cooperation with organizations like the IAEA, the EC, WENRA etc., it could engage in the following activities:
  - Development and promulgation of standards and criteria affecting all technical and policy aspects of spent fuel disposition
  - Enhancement of transparency and cross cooperation to benefit the spent fuel and radioactive waste disposition activities of all States
  - Establishment of a framework for the creation of a network of regional spent fuel disposition centres which provide assured access to other States and provide attractive arrangements to host States
  - Establishment of a network of international spent fuel reception centres for the purpose of maintaining secure storage of spent fuel from participating States pending the availability of multinational repositories and advanced processing capabilities
- While various frameworks may be envisioned to provide the stability required for final spent fuel disposition, a framework under extraterritorial arrangements concluded under the IAEA may offer arrangements most likely to support the development of multinational disposal facilities, and steps are recommended to create a legal and functional entity to permit this to proceed.

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