The Role of Spent Fuel Storage in Multinational Approaches to the Backend of the Fuel Cycle

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Abstract: Storage and disposal strategies are closely linked in all national nuclear programmes. In a multinational context the options available and their linkages are more diverse. This paper considers these issues in two contexts: a regional storage and disposal scheme, as illustrated by the European SAPIERR project work and; an international fuel cycle strategy, as illustrated by the recent GNEP and Russian storage and fuel-cycle proposals. Recent debate on both storage and disposal has increasingly emphasised security concerns, and these could lead to options other than those optimising economic aspects. Moreover, because there is now a rebirth of the SNF recycling concept, the perception of international storage needs may change. The discussion assesses what kinds of multinational storage facility make sense for these different scenarios.

1. Background

In many of the countries with nuclear power, storage of spent nuclear fuel (SNF) is not, or is no longer, a major problem. This positive situation often results, ironically, from the unsuccessful attempts of national waste management programmes to move ahead with disposal projects. Delays on the repository front have compelled some countries to increase their storage capacities, either by re-racking pools at reactors or by constructing new storage facilities (e.g. Germany, Switzerland, Hungary). In any case, many programmes have planned for long periods of interim storage to allow SNF to cool sufficiently before moving to geological disposal, or simply to postpone the expensive task of implementing disposal, and thus allow time for funds to accumulate. Examples of the former include Sweden, Finland, and Japan; the latter approach is illustrated by the Netherlands and Slovenia.

There are, however, some prominent exceptions; in those countries that urgently need expanded storage capacities the reasons are usually political or societal rather than technical. The USA has manoeuvred itself into a corner by trying to implement an aggressive disposal strategy at Yucca Mountain, while centralised storage schemes have been blocked by law (at Yucca Mountain) or by opponents (in Utah: the private spent fuel storage initiative [1]). In Japan, there have been problems in gaining public acceptance at potential centralised storage sites. This problem is even greater in Taiwan.

Accordingly, support for multinational storage concepts has come in the past mainly from these countries with such problems. There have been projects in the USA (e.g. from the Non Proliferation Trust) and Japanese proposals for international storage of spent fuel for decades in Russian facilities [2]. The Russian authorities have also supported plans to launch commercial interim storage schemes. In the Russian case, one of the major drawbacks of the proposal from the point of view of potential customers is that the final disposition of the spent fuel (or the high level wastes that could result from reprocessing this fuel) is not clearly defined. If the fuel or the residues are to be returned to the customer after some time, then there is a much reduced incentive to use such a service, since the need for expensive deep disposal is, at best, postponed. Nevertheless, the most recent presentations of the Russian concept are open towards the possibility of including a disposal option [3].

Because of the relatively comfortable situation with availability of national stores, multinational storage of spent fuel is not, in itself, a technical necessity. Multinational *disposal*, on the other hand, is a topic which has become increasingly prominent over the past several years [4] and is a development that may well be necessary, if all of the world's SNF or HLW is to be disposed of safely in geological repositories. Numerous countries with small nuclear programmes would welcome multinational disposal projects that allowed them to profit from the potentially large economies of scale in repository implementation. In a few countries, the possibility of hosting such a multinational repository has been discussed (most clearly in Russia but also in China, Australia and, recently, in the USA). In recent times, increased concern about international nuclear terrorism has led to greater readiness to consider such options. If, or when, multinational disposal becomes a practical option, then the optimisation of interim storage strategies for the fuel to be disposed of becomes an important task.

There are several feasible options for storing the SNF that would go to a multinational repository: at the power reactors, at centralised national or multinational stores, or at the site of final disposal. The choice is also dependent on factors such as the siting of fuel encapsulation facilities and the number, and geographical distribution, of available repositories. A study on optimisation would have to consider the entire spent fuel management system, from production, through storage and transport, to disposal. The system attributes to be considered are broad; they include nuclear and conventional safety, security aspects, economics and, of course, the crucial societal issues affecting all nuclear matters.

Of course, there may be no intention to dispose of SNF – which may instead be destined for recycling – but multinational facilities may still be needed in this case, for interim storage of HLW or SNF and for final disposal of the HLW and that part of the SNF that can no longer be recycled. These multinational storage or disposal facilities can be envisaged at either a regional or a truly international scale. The following sections look at the storage implications of two of the main multinational scenarios – 'regional' solutions aimed at disposal of SNF and 'international' solutions aimed at recycling SNF – and at some of the permutations that lie between.

2. Regional Scenario: The European SAPIERR Project

A start has been made to examining the issues of regional storage and disposal in Europe, in the first SAPIERR (Pilot Initiative for a European Regional Repository) project, supported by the European Commission FP6 research programme. Organisations from 14 European countries[1] with interest in the concept of shared waste management facilities collaborated to define a possible HLW-SNF-ILW inventory for one or more regional geological repositories, together with the associated pre-disposal transport and storage implications. A range of options for implementation (not yet including identification of potential sites) was examined. The project reported at the end of 2005 [5, 6].

Making simple packaging assumptions, Figure 1 shows the number of containers of SNF arising in the 14 countries participating in the study, assuming for simplicity that there is no

[1] Austria, Belgium, Bulgaria, Croatia, Czech Republic, Hungary, Italy, Latvia, Lithuania, Netherlands, Romania, Slovakia, Slovenia, Switzerland.

new-build, that existing reactors run to the end of their planned life and that all SNF is encapsulated for disposal after 50 years cooling.

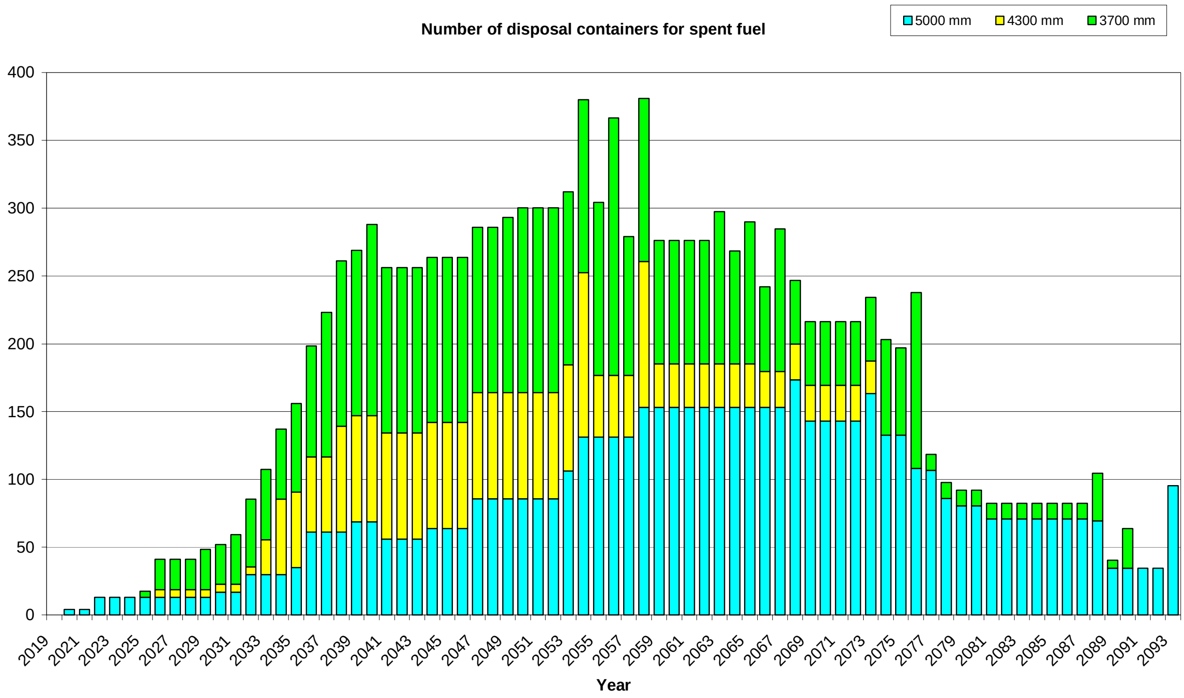

Figure 1: Throughput (number of containers, in three size groups) of an encapsulation plant (or plants) for all SAPIERR participant countries if fuel is packaged for disposal after 50 years cooling: see text for details [5].

Figure 1 shows that, by the middle years of this century, SNF packages could be being produced at the rate of 250–350 per year. This led the project to suggest a reference repository operational date at a time when there is a rapid increase in waste package production (assuming that an encapsulation facility is on stream): between 2031 and 2038. The HLW inventory considered in the project does not influence the operational date, owing to the small number of packages, compared to SNF.

This timescale was proposed in order to avoid the need for a large buffer storage facility for spent fuel. By 2035, about 850 SNF packages could be ready for disposal, if encapsulation was already available. The project thus suggested a commissioning date of 2030 for an encapsulation facility since a sequential encapsulation-disposal operation could then avoid the build up of large SNF storage requirements. However, it was noted that there are already more than 1100 containers of HLW requiring storage until 2053 and a further ~1000 will be produced over the next 20 years. SAPIERR thus considered that there is potential for considering a centralised storage facility for HLW that could also accommodate the small backlog of spent fuel packages that would accumulate until the encapsulation plant operates.

Interestingly, the proposed 2035 reference repository operational date suggested to the SAPIERR group that the siting programme should be underway by 2010–2015, requiring planning to commence soon if this regional approach is to be implemented efficiently.

A key consideration in SAPIERR was the location of encapsulation facilities for a regional repository. If this is at the repository site, disposal packages can be stored in an adjacent buffer store and transferred directly to the repository at the appropriate time, with no off-site movement of waste packages required and SNF/HLW being transported only once, from reactor/store to encapsulation plant. Uncoupling the encapsulation programme from the normally difficult process of repository siting is a clear advantage. The encapsulation system would need to make SNF disposal packages suitable for any of the potential repository siting environments being considered. The start time and rate of encapsulation could then be matched practically and economically to waste arising rates and storage needs. Multiple encapsulation plants could make different types of disposal package to match regional requirements, but HLW/SNF would then have to be transported twice.

SAPIERR considered a repository design option in which SNF/HLW are disposed of in multi-purpose containers (MPC). For example, the 'CARE' concept being evaluated in Japan [7] provides for long-term (hundreds of years) storage in shielded casks in open caverns which are subsequently backfilled and converted to a final disposal repository. If this repository and SNF management model were adopted, then 'encapsulation' in MPCs could be done at each reactor site or waste store. Disposable MPCs (that could be used for storage, transport and disposal) would need to be developed. Again, SNF/HLW need only be transported once.

This disposal concept, with a protracted period of easy retrievability, has other implications for international SNF storage and the potential for later re-use, which we discuss further in Section 4.

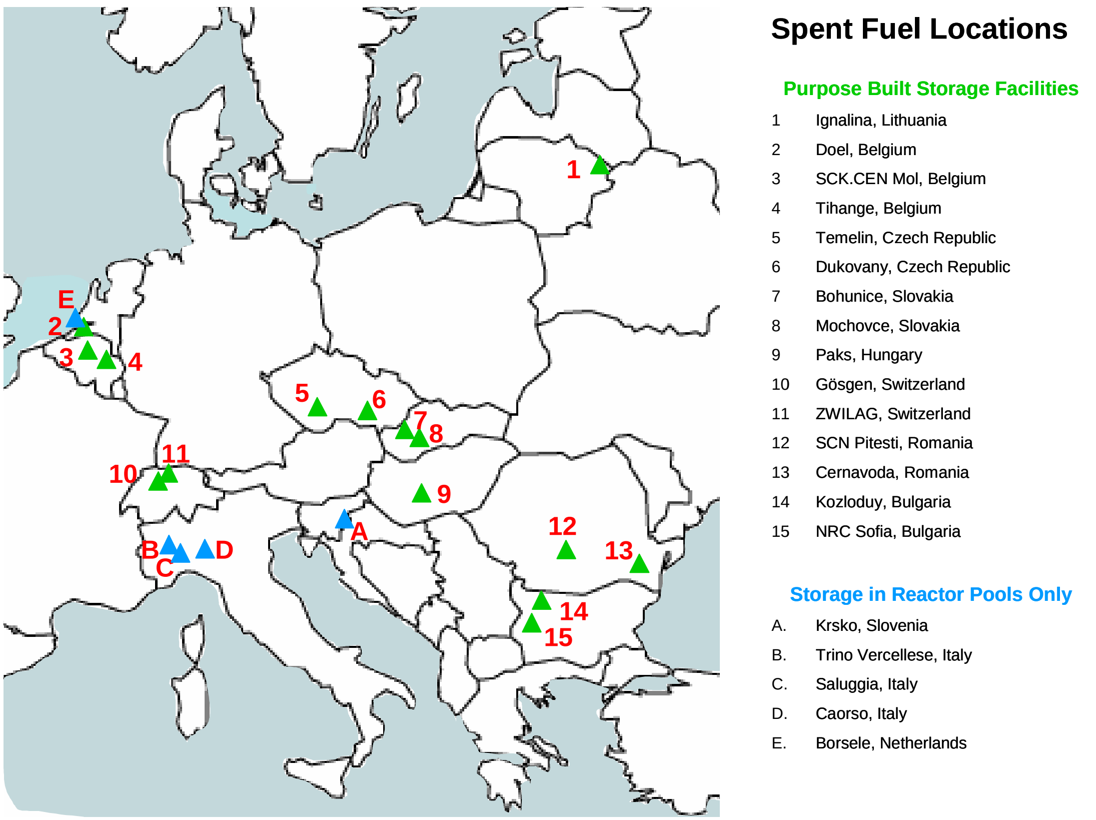

Figure 2: *Location of SNF stores in the SAPIERR countries. Only sites where extended storage is foreseen are shown. NPPs with fuel cooling in ponds and research reactors where fuel is moved off-site are not shown [6].*

At present SNF stores are scattered widely across the 14 SAPIERR participant countries, as can be seen in Figure 2. The rate of waste arising discussed above indicates that SNF transports into either centralised stores or encapsulation facilities would be almost a daily occurrence for several decades. SAPIERR concluded that rail, sea or river transport would be preferable to road transport in terms of environmental impact and social acceptability, with implications for siting centralised storage, disposal and encapsulation facilities to take advantage of harbours and the European rail network.

A different picture was considered likely to emerge if the encapsulation plant were to be remote from the repository or if there were to be multiple encapsulation facilities, but, in any scenario, substantial trans-boundary movements would be required.

The above summary of some of the first stage SAPIERR findings indicates that, if a regional disposal solution were to be pursued by agreement among all or any of the project participant countries, then there is no obvious requirement for dedicated regional storage facilities for SNF. If there is a decision to go for 'early' encapsulation (i.e. as soon as waste is 50 years ex-reactor), then the current and projected on-site storage facilities at the scattered locations in Figure 2 provide an adequate buffer to supply encapsulation facilities with SNF at a manageable rate – provided that a repository becomes available on a timescale of about 30 years.

If encapsulation begins later, then on-site storage for unpackaged SNF will need to be increased at some NPPs and stores. If a repository is late in entering operation, then a central buffer store for encapsulated waste will be required at the encapsulation plant(s). However, since any encapsulation facility will need some kind of buffer store (e.g. for HLW, as discussed above), the practical and economic implications are likely to be limited – but will rapidly become substantial if there are more than a few years delay in the capability to dispose (with an increment of 250-300 containers per year needing storage). As might be expected, a regional disposal solution simply scales-up (but focuses and concentrates) the storage planning problems faced by any national programme.

A two-year follow up project, SAPIERR-2, will begin toward the end of 2006 to look in more detail, among other things, at the influence of European storage strategies on disposal (and vice-versa) and at the issues of liabilities for the owners of regional stores or repositories. By 2008, the project will have suggested possible organisational structures for implementing shared regional facilities, at which point individual EU countries can decide if, how and when they should proceed into a definitive planning programme.

3. International Scenario: The Impact of GNEP and SNF Storage in Russia

GNEP (the security-inspired, US proposal for a Global Nuclear Energy Partnership) and the Russian proposals for accepting SNF from other countries are reported in detail elsewhere in this volume and are not described in detail here. The Russian proposals are explicitly for the back-end, i.e. they involve acceptance of foreign spent fuel for storage, reprocessing and possibly disposal. The chief focus of GNEP is on reducing the scope for "latent" proliferation by restricting the spread of enrichment and reprocessing technologies. But this implies that countries that do not have access to these must be supplied with reactor fuel – and, if the spent fuel is not to pose a later security risk, it must be taken back by the supplier (leasing) or be accepted by a third party for reprocessing or disposal. Each of these options/variants has implications for storage. Here, we look at the broader international impacts of these potential projects.

Both projects, if they are able to resolve the matter of the ultimate fate of SNF (or its waste by-products) accepted from other countries, *could* offer an attractive international service, as well as addressing global security concerns. A total back-end service might be offered to a country, either alone or to complement front-end services. Russia or the USA would take away that country's existing SNF backlog, take ownership, making a charge for the service, place the material in a centralised (effectively, multinational) store and would then be free to recycle as and when they consider convenient. New fuel, produced either through the conventional reprocessing route or using advanced proliferation-resistant technologies, would be used to supply both their own national reactor programmes and also those of a pool of international users.

At the moment, of course, none of the elements of such a back-end system can truly be considered to exist, let alone to be openly, commercially available for SNF from any NPP. In particular, the over-optimism amongst the US supporters of GNEP concerning the ease with which one can implement a commercially viable US reprocessing and fast reactor programme may have a high potential to impede practical progress towards enhancing global security. The really urgent tasks are collecting SNF and other sensitive materials for secure international storage – a fact also recognised by observers in the USA [8]. In practice, the most immediate hurdle is likely to be finding a location where imported SNF could be stored in the USA. Neither the Department of Energy nor the power utilities has yet been able to develop storage facilities, even for US fuel, and the issue of cross-country SNF transport to any such facility presents the biggest current legal challenge. There is a long, long way to go to turn GNEP from a high-minded concept into any kind of reality.

The Russian proposals seem more likely to offer short-term realisation. Russia already takes back NPP fuel but this is currently legally possible only for storage or for reprocessing with return of HLW. Efforts are underway at Government level to change this situation since it is recognised that the offer to accept SNF is unlikely to be universally attractive until a total solution is available. Accordingly, current suggestions for an "International Centre for SNF management and RW Disposal" at Krasnoyarsk [3] include a 40-50 year buffer store for both recyclable and non-recyclable SNF, and a geological repository.

4. Discussion

There are both practical and strategic aspects to developing international storage facilities for SNF. Many of these were explored in depth in a recent IAEA study [9], which also identified technical, legal and societal requirements for a regional SNF store. In the following discussion, we build on this baseline in the light of more recent developments, looking at the issues raised specifically by the scenarios presented in Sections 2 and 3.

First, there is the overarching question, as demonstrated in the initial work of the SAPIERR project, of whether international storage facilities (as opposed to disposal) are actually needed at all, if they are intended only to serve regional needs. For unpackaged SNF, a shared regional store seems to make little practical sense, especially as it would probably have to be designed to accommodate a significant range of fuel assembly sizes. In addition, the SNF might need to be transported twice – to the central store and then to either an encapsulation plant or a repository. However, as with a geological repository, there are clear economies of scale in developing a regional SNF store for encapsulated waste in standardised packages, as a buffer between encapsulation and disposal facilities – but only if disposal has to be delayed or otherwise uncoupled from encapsulation.

Even if there may be little economic advantage in a regional store, many observers point to the security advantages in early encapsulation and location at a central store. SNF is more secure in disposal overpacks at one site than unpackaged and scattered in many reactor storage ponds (especially in less secure parts of the world). Such security advantages would also accrue to a centralised store for unpackaged SNF if it were robustly contained in casks, especially if these were stored underground. However, in the European context discussed in Section 2, the practical and economic arguments in favour of regional stores are unlikely to dominate the political and public hurdles.

This picture changes if we consider current possibilities for large-scale international storage, rather than regional storage. A major store, in what are currently regarded as reasonably secure countries such as the USA or Russia, would likely be designed to contain only unpackaged fuel (or fuel only in simple “clean” containers) – because both countries propose to recycle rather than dispose. Of course, it is also possible that a similarly secure country (e.g. see the reinvigorated debate in Australia) might offer large-scale international disposal facilities to all comers, taking in unpackaged SNF, encapsulating it and disposing it directly – without any need for an associated long-term storage facility (unless political considerations mean that the offer provided is only an interim storage service).

In fact, there are several interesting strategic issues for countries that either choose, or are forced (by programme delays), to move to longer-term, pre-disposal storage of SNF. The renewed realisation of the potential advantages of recycling SNF suggests that its protracted storage over coming decades may be a positive strategy, even for countries currently with a national SNF disposal policy. By retaining the flexibility to retrieve SNF from either a store or a repository that effectively functions as a long-term store over it early decades, countries can keep open the option to re-use a valuable resource. If this shift to reprocessing gathers momentum over the next 10-20 years, it is interesting to speculate whether the most advanced SNF disposal programmes (in Scandinavia and the USA) will actually be fully implemented, or whether they will be converted or adapted to underground storage, and whether the possible provision of storage services by a ‘third party’ country such as Australia, not engaged in fuel manufacture or recycling, could become commercially and politically interesting.

Security considerations in any of these scenarios point towards any long-term centralised storage being in either highly resistant storage overpacks/casks for un-encapsulated SNF storage on the surface (in buildings or on pads), or in underground stores. As discussed above, a CARE-type concept combines all options: secure cask storage, underground, readily retrievable, with the possibility eventually to be converted into a repository. If implemented at a few tens of metres below the surface, instead of at typical disposal depths, it would be less expensive and, if the site is at the outset selected to allow access to a deep geological formation suitable for a repository, the facility could be converted later to disposal if the SNF is not to be recycled.

This type of facility holds many attractions if the global fuel-cycle envisaged in GNEP actually becomes reality. To ensure diversity of supply and commercial competition, several countries could be involved in providing fuel-cycle services internationally, so the concept of centralising SNF storage in only two countries (USA and Russia) seems unnecessarily restrictive. A globalised international fuel cycle might see a network of several, regional ‘GNEP Stores’ (e.g. North America, Russia, Europe, South America, Asia-Pacific) and, if located in secure underground facilities, they could offer all the safety and security advantages currently being sought by the IAEA, as well as making some economic sense to both users and providers.

5. Conclusions

Even in a national waste management strategy, storage and disposal requirements are intimately linked and intelligent system planning can ease technical and societal problems. In a multinational context, the pallet of options is much wider, but the challenges – especially in the political and societal areas – are much greater.

In both national and multinational waste management programmes aimed at geological disposal of SNF the importance of storage increases with increasing uncertainty about the availability of a repository. The initial SAPIERR work indicates that there is no pressing need to consider new storage facilities, provided there is a disposal facility on the horizon. However, if there is not a clear timetable for getting SNF encapsulated and underground, then the requirements on storage space increase. In particular, for a regional or international repository, the feasibility of keeping all the SNF at source prior to collection for disposal diminishes, owing to the spread in capacities and expected operational lives of NPP on-site stores. If storage has to last more than a few decades, the economic optimisation of usage of all the stores that would be available to a large national programme or a regional/multinational programme will be complex.

Where SNF disposal is not the aim, or where there is uncertainty over whether it will eventually be the chosen strategy, then it is necessary to plan for larger storage facilities, with long design lives – again, there is no qualitative difference between a large national programme or a multinational project. For the regional/multinational projects with no immediate SNF disposal objective that may arise in the next few years, it seems likely that wholly new storage facilities might need to be developed. Here, the obvious preference might be for secure, underground, dry storage facilities.

If GNEP is to take substance as a general global scheme (and here we would label the Russian proposals as one element of such a generic concept) then there is a case to be made for long-term, centralised stores covering the main regions of the world where there are users of nuclear power. Hopefully, any such scheme (involving fuel manufacture, storage and deep disposal facilities) would be brokered by the IAEA.

There is considerable ambition in GNEP – but also risks. It is crucial to ensure that GNEP, by linking the relatively simple concept of international fuel cycle services (as promoted by the IAEA) to the development of new fuel cycle technologies (which will take decades to bring to widespread commercial implementation), does not detract from the good intentions or capability of the former to deliver secure solutions on a relatively short timescale.

In all these scenarios, systematic studies are crucial. SAPIERR 2 will look at this in a European context, but the time has come for the IAEA to take a really practical role in helping to putting flesh onto the bare bones of GNEP and in assisting the development of the Russian proposals. We can continue just to talk, or we can begin to assemble the necessary pieces.

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