Nuclear Fuel Cycle Centres - an Old and New Idea

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Abstract

Nuclear technology originally developed in only a few countries – arising out of weapons programmes. In the early years, the concept of nuclear fuel cycle centres was topical. In the 1950s, the IAEA charter itself allowed centralized plutonium storage and management. Studies were performed (e.g. by INFCE) on regional nuclear fuel cycle centres and on international spent fuel management but did not come to fruition. Nevertheless, the fuel cycle was truly international during the 1960s and 70s, with services such as uranium production and enrichment, fuel fabrication, reprocessing and reactor supply being carried out in a limited number of countries and sold to others. Even the back-end of the cycle was to some extent internationalised, with the UK, France and Russia all retaining wastes produced by the reprocessing of foreign fuels.

However, with time, further national nuclear capabilities were developed by countries looking for increased independence from the big suppliers, seeking commercial opportunities or seeking an independent nuclear weapons capability. To restrict further weapons development, whilst allowing peaceful use of nuclear energy, the Non-Proliferation Treaty (NPT) was conceived, including inspection rights in non-weapons states. Three major problems with the current system have grown in importance in the intervening years:

- Some countries did not accept the restriction of nuclear weapons to a self-selected group of countries – especially as, for a long time, these countries showed little signs of implementing the agreed reductions in their nuclear arsenals.
- The growth of terrorism around the world has heightened the importance of nuclear security and the problems of protecting adequately and reliably against the threats when there are numerous fuel cycle facilities scattered across many countries.
- Use of nuclear power implies that safe disposal routes must be available for the wastes. This part of the fuel cycle has encountered major setbacks in every country and has not yet been internationalised.

The conclusion to be drawn is that, to address each of these problems in an integrated fashion, the time is ripe to reconsider the global benefits of nuclear fuel cycle centres for both front-end and back-end activities. Arguments focussing on the front end have been set out in a number of recent studies. There has also been increasing support for the concept of shared multinational repositories. These recent studies are described and the potential benefits of concentrating front-end and back-end fuel cycle activities into multinational fuel cycle centres are summarised. Specifically, we propose that the international community takes concrete steps to expedite any credible proposals for shared repositories. One option is to support, technically and financially, the initiatives of

smaller countries interested in implementing a common facility. The most immediate start, however, may be by improving existing Russian proposals. For example assistance with repository development could be provided and mechanisms could be developed to enhance transparency and thus international confidence in Russian projects.

Introduction

Nuclear technology originally developed in only a few countries – arising out of weapons programmes. The dilemma that was recognized early was how to prevent the spread of nuclear weapons capabilities but still allow the widespread peaceful uses of atomic energy. These twin goals led to the Atoms for Peace proposal of President Eisenhower in 1953 and then to the foundation of the IAEA.

In the early years, the concept of nuclear fuel cycle centres was topical. The IAEA charter itself allowed the Agency to be involved in centralized plutonium storage and management. Various studies were performed on regional nuclear fuel cycle centres and on international spent fuel management. These are documented in IAEA (2004)[1], from which part of the historical material in the sections below is extracted.

These ideas for complete nuclear fuel cycle centres did not come to fruition. However, in practice a few countries (including non-weapons states such as Germany and Sweden) did develop into international suppliers of nuclear technology. The fuel cycle was truly international in the 1960s and 70s, with services such as uranium production and enrichment, fuel fabrication, reprocessing and reactor supply being carried out in a limited number of countries and sold to others. Even the back-end of the cycle was to some extent internationalised with the UK, France and Russia all retaining wastes produced by reprocessing of foreign fuels. In some countries, the potential benefits of localising all fuel cycle activities in a single centre were recognized, e.g. a nuclear fuel cycle centre was proposed at Gorleben in Germany, including reprocessing, storage and disposal.

Nevertheless, expanded fuel cycle capabilities were developed by countries looking for increased independence from the big suppliers (e.g. reprocessing in Japan, Italy and Belgium), or seeking commercial opportunities (e.g. reactor construction in Japan and Korea). To prevent weapons development, whilst allowing other technologies, the NPT was conceived, including inspection rights in non-weapons states.

Three major problems with this system have grown in importance in the intervening years:

- Some countries did not accept the restriction of nuclear weapons to a self-selected group of weapon states – especially as, for a long time, these states showed little signs of implementing the agreed reductions in their nuclear arsenals
- The growth of terrorism around the world has heightened the importance of nuclear security, i.e. of closely controlling all hazardous nuclear materials, including enriched uranium, plutonium, spent sealed sources, spent fuel and highly active radioactive wastes.

- Use of nuclear power implies that safe disposal routes must be available for the wastes. This part of the fuel cycle has not been internationalised. In fact even at a national level it has encountered major problems. For small countries that have been supplied with nuclear power stations, the high costs of disposal make national projects difficult or unfeasible.

The conclusion to be drawn is that the time is ripe to consider again the global benefits of nuclear fuel cycle centres for both front-end and back-end activities. In the following text, we look firstly at the specific proposals and initiatives that have been launched over the years with the objective of promoting fuel cycle centres covering all sensitive technologies or, more restrictedly, covering the especially contentious area of final disposal in geological repositories

Early fuel cycle centre initiatives

Regional Nuclear Fuel Cycle Centres RFCC (1975-7)

In 1975 the IAEA launched a study project to examine the economic, safety, safeguards and security aspects of a multinational approach to nuclear fuel cycle facilities. For the purposes of the study, RFCCs were envisaged to include spent fuel storage, fuel reprocessing, plutonium fuel fabrication and waste disposal. The study group reported in 1977 (Meckoni et al 1977)[2] with very encouraging results, arguing that from many perspectives considerable advantages could be expected from the RFCC concept. Firstly, the intergovernmental agreements envisaged for RFCCs would bring non-proliferation advantages. These agreements would lead to enhanced safeguards and physical protection, and improved siting of facilities. Secondly, the study argued that economic and operational advantages in geological disposal could also be expected, although the report argued that repositories would probably not be co-located with reprocessing and fuel fabrication plants. Although the study was well received by many countries, no concrete steps were taken to develop the concept further.

International Spent Fuel Management Group (1982)

This grew out of International Fuel Cycle Evaluation (INFCE) study of the IAEA (INFCE 1980)[3]. The group was convened in 1979 and also reported in 1982 (IAEA 1980)[4]. Its brief was to investigate whether there were economic, logistical or strategic reasons for developing international arrangements for spent fuel storage, and how these arrangements might be set up. The report did not include much discussion about the disposal of fuel in the host country. Under the main scenarios studied, spent fuel would be returned to the customer country after a number of years, either in its original form or following some further conditioning. However, it was argued that international arrangements would be most attractive to customer countries in the future if they included *"...an overall solution to their need to close the back-end of the fuel cycle (including radioactive waste disposal)."* The report argued that countries most suitable as a host for an international spent fuel store would be those with a nuclear energy programme and with previous experience of handling spent fuel. International fuel stores were expected to deliver savings for those national programmes generating less than 5000

tonnes of fuel. The report also contained some discussion of the key elements of the international agreements which would need to be drawn up for an international spent fuel venture. It concluded that, in the short term, no demand for international arrangements existed.

International Plutonium Storage (IPS)

The expert group on IPS was set up to develop ideas for how the IAEA could act upon the rights provided for in article XII.A.5 of its 1957 statute, which allows for it to implement international storage facilities for excess plutonium. The group set out a number of concepts for an IPS. The study was based on the assumption that under an IPS agreement, all separated plutonium in excess of current requirements for safeguarded use in reactors, fuel production and research would be stored under international control (IAEA 1982)[5]. Problems were encountered in developing practicable approaches, however, and the idea was effectively dropped until around 1993 when further international controls on fissile materials were again discussed at the IAEA General Conference. Two new concerns had arisen in the intervening years. First, nuclear weapons disarmament meant that large stockpiles of special fissionable materials - plutonium and HEU - were expected to be recovered from dismantled weapons. Second, stocks of separated civil plutonium were seen to be growing and these also needed transparent safeguarding. These concerns were expanded upon by Stoll and McCombie (2001)[6] and the IAEA Director General (El Baradei, 2004)[7] recently noted that the manner in which to eliminate Plutonium stocks is a matter that should be resolved and acted upon with urgency.

Relevance of fuel cycle centres to future nuclear energy usage

Driven in part by the renewed interest in the future use of nuclear power, various recent US studies have considered the requirements that should be fulfilled to encourage such a development. Choi and Isaacs (2003)[8] propose a new nuclear regime with improvements in economy, safety, waste management and proliferation resistance. The system described includes plutonium burning, HEU down-blending, recycling, improved radionuclide separation, transmutation in reactors and geological disposal. The authors stress that an international framework is essential. Most of the fuel cycle facilities mentioned are currently in operation – with regional or international storage and disposal being a prominent exception.

As pointed out by Bunn (2003)[9] , the spread of nuclear power technology, even within the framework of the NPT, has one clear weakness in the non-proliferation context. Countries can develop effectively all of the technologies needed for weapons production without actually taking the last step. His proposed solution is not to try to amend the NPT to ban enrichment and reprocessing in non-weapons state, but rather to provide incentives for states voluntarily to forgo such activities. The solution put forward is an arrangement in which they are offered a complete life-time fuel service on condition that they do not reprocess or enrich. This service must include not only fuel supply, but also return of the spent fuel. Bunn suggests that a commercial consortium from Russia, Britain and France could provide such a service. As mentioned earlier in this paper, the issue of final

disposal is the key problem here. Recently, only Russia has demonstrated a readiness to contemplate this, following the cancellation of the disposal services originally offered by French and UK reprocessors.

A further US study on the Future of Nuclear Power (MIT, 2003)[10] also notes that there is considerable scope for international sharing of waste storage and disposal facilities. The authors recommended that a network of centralized facilities for storing spent nuclear fuel should be established in the USA and internationally.

An important point made by Isaacs (2004)[11] is that, if one is concerned about increased use of nuclear power leading to higher risks of proliferation, then one must think beyond the "enhanced proliferation-resistance" often aimed at for single facility types. While it is desirable to improve the proliferation-resistance of individual facilities, it is the integrated risk of facilities, materials, and know-how - including those that already exist - that must be assessed in coming to an understanding of the proliferation risk of a given 'nuclear future'.

Proposals for shared back-end facilities (repositories)

The concentration of only the back-end of the fuel cycle into a few countries might appear less problematic. The materials to be disposed of are less sensitive than separated fissile materials. Only spent fuel itself is sensitive in a non-proliferation sense, and the spent fuel has a large built-in protective characteristic because of its intense radiation. However, final disposal of radioactive waste is a very long-term technical and societal challenge that has taxed most waste management programmes – even those committed to purely national solutions. Although the potential advantages of shared repositories are apparent (McCombie 1999)[12], the concept of one country accepting wastes from another country for final disposal has been strongly criticised by some national waste management programmes, with claims being made that any such proposals might seriously hinder these national programmes. There has, nevertheless, been an interest in the multinational approach for a long time, and support is increasing rapidly. The most important initiatives in the area are summarised in the following sections.

OECD/NEA Study (1987)

The Radioactive Waste Management Committee (RWMC) of the Nuclear Energy Agency published a preliminary study on possible international approaches to radioactive waste disposal in 1987 (NEA 1987)[13]. The report was not widely publicised, and attracted little attention from national governments. The creation of an international repository through the commercial extension of national programmes was judged to be a more credible route than the formation of an international project. The study concluded that there were no apparently insurmountable safety, technical, economic or institutional obstacles to serious consideration of the concept. Nevertheless, because of slow progress in the development of national repositories, the committee did not believe that the time was right in 1987 to embark on a comprehensive generic study.

Chinese Initiatives (began early 80's)

In the 1980s, there were proposals for international disposal in the Chinese Gobi desert. Some of the discussions were initiated by Austrian utilities seeking a backend solution for spent fuel from the planned Zwentendorf reactor. The proposals were negatively received by politicians and the public in some countries, such as Switzerland, that were suggested as possible customers. Later, China again showed interest in waste import (e.g. a letter of intent with was signed with Taiwan in 2000) and is currently running a national programme that "*could be technically easily extended to include foreign wastes*" (Hibbs 2002)[14]

Synroc Study Group, Australia

In 1983, the Australian government commissioned a report from the Australian Science and Technology Council on Australia's role in the nuclear fuel cycle. The 1984 ASTEC report recommended not only proceeding with uranium mining, but also becoming involved with other stages of the fuel cycle such as enrichment. It also flagged the *"particular need for international collaboration in developing (high-level) waste management programs"* and the desirability of enabling access to the highest quality geological sites for disposal of those wastes. Later, in 1998, the Synroc Study Group was set up by the Australian government to study the commercial potential for Synroc in a global context. It was conducted by four leading Australian resource companies, assisted by ANSTO and the Australian National University, and advised by SKB Sweden. The study (Synroc Study Group 1991)[15] also considered the option of Australia hosting an international repository. It led on to the Pangea Project described below.

IAEA Expert Groups (1994/95, 2000/01)

The IAEA set up a consultant group on multinational repositories in the early 1990s and this worked until 1995, although the final report, TECDOC 1021, was published only later (IAEA, 1998)[16]. Recently (2001) the topic has taken up again by the IAEA and a new working group, has produced a further report that is awaiting publication (IAEA, 2004)[1].

International Working Group

When the first IAEA Expert Group was wound up in 1995, work continued in an ad hoc group sponsored by the Atomic Energy Corporation of South Africa (AEC) and Germany's Gesellschaft für Nuklear-Service (GNS). The group produced an overview document which can be used by national governments in their own considerations of proposals for regional repositories (International Working Group, 1996)[17]. Included are some basic criteria for identifying potential host countries: a) the country must have an established nuclear and radioactive waste management infrastructure; b) the country must have existing technical and regulatory infrastructures for handling radioactive waste; and c) the country must have a suitable land mass (referring to a preference for a large continental country). The group also published a list of countries it believed would be prime candidates to seek a home for spent fuel inventories (Bredell and Fuchs, 1997)[18].

Pangea (1997-2002)

The project was initiated by individuals who had been involved in the work of the Synroc Study Group in Australia. The technical concept was based on a particular "high isolation" concept (Miller et al., 1999)[19] and various regions of the world possessing especially favourable geological and geographical environments were identified in Australia, Southern Africa, Argentina and China (Black and Chapman, 2001)[20]. The main emphasis was on Australia and a commercial approach to implementing an international repository was developed in detail (McCombie et al., 2001)[21]. The original funders of the project were organisations from Canada, the USA, the UK and Switzerland, with the largest part of the financing coming from BNFL in the UK. The project raised the profile of the global debate on international repositories. It received solid support in scientific and business circles world-wide and in Australia. However, due in part to the premature leaking to the media of an explanatory video on the project, political opposition in Australia and in West Australia was strong from the initial announcement and the project was dropped by its sponsors.

Non Proliferation Trust (NPT)

The US based Non-proliferation Trust and the Minatom Development Trust proposed implementing international storage and disposal facilities in Russia, beginning with 10,000 tonnes of non-US origin fuel. (Cochran, 1998[22]; 2000)[23] The substantial revenues were to be used for remedial action in Russia, for job creation and for charitable purposes. Although the initiative was supported by distinguished persons and groups, there were significant outstanding problems to be solved. The NPT is strongly opposed to reprocessing, whereas Minatom favours this option. US consent would be needed to transfer much of the foreseen inventory to Russia and this will not be granted without conditions being met on reprocessing and on Russia's nuclear cooperation with Iran. The control of the funding is controversial, with the US partners insisting that international confidence will be obtainable only if the funding is controlled by an off-shore USA trust. The motivation for Minatom to pursue the NPT proposal rather than progressing the purely Russian proposals described below does not seem obvious.

The Arius Association

Arius (Association for Regional and International Underground Storage) is a small group of organisations, currently from eight countries, cooperating in an association to support the concept of sharing facilities for storage and disposal of all types of long-lived radioactive wastes. Arius, is an organisation without commercial goals (McCombie and Chapman, 2004)[24]. The mission of the association is to promote concepts for socially acceptable, international and regional solutions for environmentally safe, secure and economic storage and disposal of long-lived radioactive wastes. A key objective is to explore ways of making provision for shared storage and disposal facilities for smaller users, who may not wish to - or may not have the resources to - develop facilities of their own. Consequently, the initial membership of the Arius Association is predominantly from countries with smaller nuclear programmes, although it also includes industrial organisations that are interested in promoting the international disposal concept. One of the initiatives started by Arius is the SAPIERR project, described below.

SAPIERR project

SAPIERR stands for Support Action: Pilot Initiative on European Regional Repositories and is a project within the 6th EC Framework Programme. It is carried out by a consortium of DECOM (Slovakia) and Arius (Stefula and McCombie, 2004)[25]. The project aims to bring together countries with an interest in investigating the possibilities for shared repositories for spent nuclear fuel and high-level radioactive waste, and in particular those countries with small nuclear power programmes that do not have the resources or the full range of expertise to build their own repositories. The prospect of building and operating a single regional repository (or a limited number of such facilities) shared by several European countries was raised in a draft Directive of the European Commission on radioactive waste management (EC 2002)[26] and was encouraged by the related resolution passed by the European Parliament. Practical support for this idea has been demonstrated by the Commission by its selection and funding of the SAPIERR project.

Twenty-one organisations from fourteen countries take part in the SAPIERR working group. At present, the group members are gathering national information on their potential waste inventories for a potential shared repository, as well as on their national legislative backgrounds. These inputs should help DECOM and Arius to produce analytical studies on the waste inventories and legal aspects of the European Regional Repository. The ultimate aim of the two-year study is to propose further actions that could be taken in the EC to move the concept ahead.

Ljubljana Initiative

Following informal discussions during the course of the IAEA Joint Convention Review Meeting in November 2003, representatives from several Central European countries met in Ljubljana to discuss informally possible regional solutions for high-level waste disposal projects. The meeting included experts from waste agencies or government bodies in Austria, Bulgaria, Croatia, the Czech Republic, Hungary, Slovakia and Slovenia. The participants reaffirmed the potential safety, security and economic advantages of shared solutions and discussed actions that could lead to official government commitments being made within the next few years. It was agreed that each representative would go back to their national government and try to get support for pursuing the concept of regional repositories, restricted to the geographical region occupied by these countries.

Members of the group reported back at a second meeting in Dubrovnik in May 2004. There were no negative responses, although there was scepticism about the realism of the proposals. The political figures tended to support the concept, when it was recognised as one of several options. It was agreed that it would be valuable to have a regulatory group, but that the promotional work must be done by a parallel implementing group. The idea agreed was that the regulators among the participants should meet once a year (most likely within the scope of the IAEA General Conference that all attend) and that at this annual meeting, they should review the work which had been done in their countries on

the concept of regional disposal. Meanwhile, the implementers from these countries would try to move ahead with specific initiatives.

Russian proposals

The now superseded Russian ministry, Minatom, was involved in several of the proposals mentioned above. Over the past few years Russia has become increasingly serious about spent fuel import and is the only country publicly supporting this at government level. The currently favoured location for a repository is at Krasnoyarsk-26. Approaches have been made to various countries in parallel with initiation of steps to make the necessary changes in Russian law. The proposal has significant support in the Duma but public reaction is negative in Russia. However, support in US official circles appears to be increasing (Dyer, 2002)[27] and in the IAEA (as described below). This could have an important influence on the chances of success and we comment specifically on how this might be progressed in our conclusions (Sections 7 and 8).

Recent USA discussions on international storage and disposal

At the 2000 Carnegie International Non-Proliferation Conference, the issues influencing US attitudes towards international or regional facilities for storage or disposal were discussed in detail by McGoldrick (McGoldrick, 2000)[28]. His particular interest was in East Asia with its three major nuclear nations, Japan, South Korea and Taiwan. He confirmed the long-standing US interest and support in such concepts, but highlighted the numerous conditions that any country would have to fulfil before the US would exercise its rights to consent to transfer of any of the spent fuel that it controls.

Also in 2000, the CSIS published a report on Managing the Global Nuclear Threat (Nunn et al., 2000)[29] in which the security advantages of regional or international facilities were highlighted, together with other threat reduction proposals. The authors proposed that storage facilities in Russia and, subsequently, in the USA, be put under international rather than national controls and that countries be provided with incentives to use such facilities (again, see Sections 7 and 8 of this article).

Growing support in international organisations

International organisations, such as the IAEA, the NEA and the EC, must try to reflect the views of their member states on issues of common interest. In the nuclear field – and in particular in the waste disposal field – this has often been difficult because of the polarised views that are sometimes held by representatives of Members States. Concerning shared waste disposal facilities, the NEA has been silent for almost twenty years, since producing the early report referred to above. This may be because the OECD countries represented in the NEA are predominantly developed and relatively rich, so that they often have a national waste disposal programme that can feel threatened by multinational initiatives.

The original positive attitude of the IAEA was also tempered in the late 1990s by the reservations expressed by large national programmes concerning the potential disrupting effect of multinational projects. However, driven by non-proliferation concerns, worries

about the security of radioactive materials such as spent sealed sources and the pressure from small member states seeking common, affordable disposal solutions, the Agency has become much more positive. This was evidenced first by the Joint Convention on Radioactive Waste and Spent Nuclear Fuel (IAEA, 2003)[30], which deliberately left the door open for shared facilities. Recent public positions taken by the Director General have strengthened support for FCCs and shared repositories.

In speeches to the 2003 General Conference of the IAEA (El Baradei 2003a)[31] and at the major Waste Management Conference in December 2003 in Stockholm, Director General Mohammed El Baradei pointed out the potential advantages of small countries sharing disposal solutions. Still wider attention to the issue was drawn by an invited article by El Baradei, published in the *Economist* in October 2003 (El Baradei 2003b)[32] , in which he states:

"….. we should consider multinational approaches to the management and disposal of spent fuel and radioactive waste. More than 50 countries have spent fuel stored in temporary sites, awaiting reprocessing or disposal. Not all countries have the right geology to store waste underground and, for many countries with small nuclear programmes for electricity generation or for research, the costs of such a facility are prohibitive. Considerable advantages—in cost, safety, security and non-proliferation—would be gained from international co-operation in these stages of the nuclear fuel cycle. These initiatives would not simply add more non-proliferation controls, to limit access to weapon-usable nuclear material; they would also provide access to the benefits of nuclear technology for more people in more countries."

In a recent speech to the Carnegie International Non-proliferation Conference (El Baradei, 2004)[7], he repeated these sentiments. More specifically, El Baradei advocated limiting the spread of capabilities for production of new nuclear materials by having countries agree to restrict reprocessing and enrichment activities to a limited number of facilities exclusively under multinational controls. This would, of course, require international guarantees of supply to be given to legitimate users.

In the European Union, support for regional repository initiatives was shown by the Commission when it proposed a Directive committing Member States to moving ahead with disposal and pointing out that this could be done in cooperation. A long debate in various EC commissions and committees eventually led to the original Directive being watered down to a recommendation. However, the discussion established the political and legal feasibility of willing States initiating common projects for regional repositories – as well as the legitimacy of individual Member States refusing to accept waste from others.

Enhancing global security through fuel cycle centres for the FC front-end

The arguments for harmonising and integrating front-end activities in FCCs are clear (see, for example, May and Isaacs, 2004)[33]. The drivers are:

- Reduction of the incentive for emerging countries to develop their own fuel cycle capabilities, particularly;
- Halting the spread of spent nuclear fuel in emerging countries pursuing nuclear power;
- Draw-down of the existing inventories of materials of concern as an integral part of shaping a resurgent nuclear power future;
- Reduction of the environmental and non-proliferation burdens, largely through spent fuel take-back and leasing;
- Secure control and storage of fissionable materials and radioactive wastes in a network of national, regional, and/or international facilities.

Several of these arguments point towards front-end FCCs being located in larger countries and, most appropriately, in nuclear weapon states (although smaller countries such as Belgium have also implemented all of the front end technologies). In fact, there are clear commercial attractions in the front-end of the FC and competition to host front-end FCCs may even be arise between candidates with large and mature nuclear power infrastructures, e.g. France, Russia the UK and the USA..

Enhancing global security through shared repositories for the FC back-end

Similarly compelling arguments exist for harmonizing and integrating the fuel cycle back-end. McCombie and Chapman (2004)[24] have identified the benefits:

- Secure disposal of spent fuel and separated excess fissionable materials in state-of-the-art repositories, developed using the best technology and expertise available internationally and preferably operated under an international aegis.
- Availability of a disposal route for all countries with nuclear materials that represent a potential security threat (including other radioactive materials and spent radiation sources that could be used in the fabrication of "dirty bombs").
- Limiting the number of facilities that will need to be secured and safeguarded for long times into the future

Finding countries willing to accept spent fuel and wastes will inevitably be more difficult. The IAEA study pending publication (IAEA, 2004)[1] has defined several scenarios whereby countries might do this. The two most promising approaches are either a partnership between smaller countries in the development of a shared facility in one of them, or the acceptance of foreign wastes into an international repository in a large country. At present, the Russian government is alone in having indicated that it could be willing to fill this second role. Other countries are only likely to come forward if there is a real and well-publicised international desire to fill this major security gap, major incentives provided and credit given for taking on this global responsibility. It is up to the major global players to get behind this issue together and make a clear and common cause.

The way ahead

In this article we have concentrated mainly upon the security advantages of FCCs. These have come to the fore considerably over the last five years. The technical and economic benefits have been apparent from the beginning of the nuclear power era. The principal obstacles to the implementation of FCCs in the past have been:

- political objections to a perceived division of nations into 'haves' and 'have-nots';
- strategic arguments leading some countries to avoid dependence on foreign states which could control their access to nuclear power;
- commercial incentives leading some countries to expand their capabilities independently;
- increasingly negative public opinion concerning transport, storing, treating or disposing of foreign radioactive wastes;
- reluctance of major nuclear nations to transfer powers and responsibilities to international organisations;
- lack of technical and financial resources in smaller nuclear nations, limiting opportunities to initiate specific joint projects;
- the general decline in growth in nuclear energy in the last decades and its perception as a moribund technology.

The rationale behind each of these arguments now looks much less sustainable. For the obstacles to be removed, however, it also requires governments to act for the common good – either independently or in unison. In commenting on the broader international security landscape, El Baradei (2004)[7] observes that:

"….the trend has been towards inaction or late action on the part of the international community, selective invocation of norms and treaties, and unilateral and 'self-help' solutions on the part of individual States or groups of States."

To the authors of this article, much the same seems to be true for the more specific issues of nuclear security and waste management. But the global picture has changed, with increasing concerns about nuclear non-proliferation (e.g. North Korea, Iran) and nuclear terrorism, growing interest in expanding nuclear power programmes (driven by concerns over climate change and oil shortages) and growing awareness of the high costs of national waste disposal programmes. How might the logjam be broken, short of some appalling catastrophe forcing the international community into action? El Baradei has already noted that we are well beyond the point where a few quick fixes will adequately address the threats. Some really significant changes are needed and some major new developments. At present, there seem to be two principal possibilities:

1. Develop comprehensive FCCs in one or more large countries, offering all FC services with full security of supply and of materials handling, at operational scales and economic rates that are attractive to both the providers and the likely large groups of

users. As El Baradei (2004)[7] points out, if FC activities were limited to such facilities, there would need to be both transparency and international guarantees of supply to legitimate users. We noted earlier that integrated FCCs at one location may be difficult to develop if geological and geographical conditions are not suitable for the back-end (repository) component or if societal opposition continues to be most strong towards repositories. Consequently, a second possibility needs to be considered:

2. Separate front-end and back-end FCCs, either in the same countries or in different countries. It is not hard to envisage enrichment, fuel fabrication, reprocessing etc. in one country and spent fuel and waste management in another, where disposal conditions are ideal. Moreover, the back end involves comparatively lower levels of technology and also presents less immediate safeguards and proliferation risks, due to the lower fissile content and the built in protection of the intense radiation fields of HLW and spent fuel. Thus a broader spectrum of potential host countries may be considered.

Neither of these possibilities will be realised unless the international community recognises the need and is willing to provide the necessary technical and financial support.

Specific Proposals

Specifically, where might resources be accessed and be most usefully deployed now on the FCC concept?

For the front end, security concerns have led to intensified efforts to dissuade further countries from developing enrichment facilities and the USA has long discouraged countries from implementing reprocessing facilities for the recovery of plutonium and uranium. As has been suggested by various authors (ElBaradei 2004[7], Bunn 2003[9], MIT 2003[10], Choi and Isaacs 2003[8]), this strategy can succeed only if states are divided into two categories. The MIT authors label these as "fuel cycle" and "privileged" states. The latter would operate nuclear power plants with international support for reactor construction, technical assistance, fresh fuel provision and spent fuel removal. Of course, the states foregoing full fuel cycle facilities would require solid lifetime guarantees from the others that services would continue to be provided. The complex political and economic issues associated with such proposals could be best addressed within the scope of the IAEA.

For concentrating the back-end of the fuel cycle into fewer centres, some progress is being made. The USA has repatriated spent fuel supplied for foreign research reactors. The USA is also supporting Russia in the Global Threat Reduction Initiative to recover Russian-origin fresh and spent HEU fuel from research reactors around the world. For commercial nuclear plants there are greater difficulties, although Russia has accepted returned spent fuel from its earlier satellite countries and may do so in new cases such as from Iran.

In the western world, the topic of international or regional repositories has been controversial at times. However, regional projects such as SAPIERR in Europe are

already taking root, exploring local requirements and feasibility. They need the full support of every country that has a true concern for security and we know that they will take many years and much care if they are to come to fruition. Open recognition of the necessity for shared disposal facilities is also evidenced by the central European countries involved in the Ljubljana initiative, mentioned above. Limited resources for addressing the issues involved have been provided by the IAEA (in its Working Groups) and the EC (for the SAPIERR project). However, specific repository projects involving technical and societal efforts towards siting and constructing a shared repository will need closer coordination, direct involvement of the interested countries and significantly increased resources. In fact, although most of the small countries that must be directly interested in possibilities for shared repositories have accumulated insufficient funds to implement a national repository, there are certainly sufficient resources available in these countries, if pooled, to support a serious joint waste disposal programme aimed at clarifying the options for a shared regional facility. However, more support for backend studies on storage and disposal is needed. The relatively large funding which is proposed for tackling security issues at the front end could be complemented by increased – although still comparatively modest – support for progressing shared repository projects for commercial reactor fuels.

In addition to implementing multinational disposal projects that closely parallel national projects in their structure, siting strategies and timescales, the international community could also support more specific, limited initiatives, e.g. strengthening of on-going efforts to secure all spent sealed sources world wide. More speculative approaches also deserve consideration. For example, technologies specifically targeted at the irrevocable disposal, under international control, of small amounts of excess fissile material need more consideration – for example, using very deep boreholes (Chapman and Gibb, 2003)[34]. Such projects could be progressed to the great benefit of global security, independently of more comprehensive FC developments.

However, today, the biggest, and potentially fully international, initiative that could be grasped and developed immediately is that proposed by Russia, for the back-end of the FC. A combination of fuel leasing allowing take-back of Russian origin fuels and acceptance of foreign fuels requiring USA consent under existing fuel-flagging rules would be a first step. Of course, real interest in sending spent fuel to Russia (or to any other country with an international repository) will be shown by small countries only if existing backlogs of stored spent fuel can also be transferred, since complete avoidance of the need for an expensive deep repository will be the driver. The June 2004 meeting of the IAEA Director General with the Russian President and Foreign Minister included discussion of the development of a spent fuel storage facility in Russia – the first step on the way to a potential back-end FCC.

In our view, the Russian storage initiative will only be acceptable at all if the endpoint of disposal is available – this means actually available or specifically planned and financed, rather than held out as a vague future prospect. If the international community thus wants to make a really useful contribution to global security and safety then this is where it could direct its resources. Specifically, we propose that the IAEA offers to assist Russia to move forward by assembling both the funding and the enormous expertise that exists

internationally to develop, in a timely fashion, a state-of-the-art international HLW repository. In return for this offer, Russia should agree to a new level of transparency and international oversight in the development work. Only in this way can the trust of the international community be enhanced to a level needed for small democratic countries to enter into long-term commitments to transfer fuel to the Russian Federation. This would be a truly worthy project with truly global benefits – it is surely to promote solutions such as this that the IAEA was founded and exists today.

Of course, a single supplier of disposal services could present strategic and economic risks for potential customer countries. Global waste inventories, however, easily justify multiple international repositories and commercial competition could conceivably encourage this. If the international community acknowledges the global value of having international repositories available and is prepared to support their development, then it is not unlikely that other candidates could also appear. These might be other large countries or they might be smaller countries willing to consider hosting a facility implemented with partners.

We need supranational solutions if we are to achieve any of the goals discussed in this article. These solutions need not only the strongest of support from the United Nations and its Member States but they also need to be championed by the major countries, working together. The proposed spent fuel storage conference in Russia in 2005, or the summit on global security proposed, by the IAEA Director General, to be held in parallel with the 2005 NPT Review Conference, could be the fora from which to launch such a project.

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