# Multinational Repositories

past, present and future

Charles McCOMBIE

Arius Association, Switzerland

Email: charles.mccombie@arius-world.org

Neil CHAPMAN

Arius Association, Switzerland

Email: neil.chapman@arius-world.org

**Abstract**

Since the beginnings of commercial nuclear power production, and especially over the past 25 years, there have been numerous initiatives assessing the potential role of multinational repositories (MNRs) in enhancing global safety, security and environmental protection. Increasingly, it has also been realized that an MNR would also enormously benefit countries with no nuclear power but with nuclear technology applications in research medicine and industry that also generate radioactive wastes for which geological disposal is the only safe solution. The paper looks back over these studies highlighting the key issues they brought forward and commenting on the reception these received in the nuclear community. It identifies milestones in the international legislation related to multinational disposal and in radioactive waste management policy decisions taken by individual States. Important issues that have proven contentious are discussed. These include ethical debates regarding MNRs, impacts of MNRs on national geological disposal programs, economic benefits and risks associated with hosting an MNR, and the big question of siting strategy. The paper also summarizes current MNR activities being worked on by organizations such as the IAEA, EC, IFNEC, and the Arius and ERDO Associations. Finally, suggestions are put forward on progress that might be made on MNRs in the coming one or two decades, during which the vast majority of States requiring access to safe geological disposal will not yet have implemented any national repository.

## INTRODUCTION

It is almost 20 years since the Arius Association was formed at the turn of the century, at a time when multinational repositories (MNRs) were a controversial concept. Since then, progress with MNRs has been slow, as it has also been in national deep geologic repository (DGR) programs, with very few exceptions. But interest has increased continuously, with more international studies (European Commission, IAEA, IFNEC) undertaken, more countries getting involved directly, and, most recently, establishment of the ERDO Association, which is described in another paper to this conference.

The present paper looks briefly at the background and history of the MNR concept and points out the contributions that Arius has made to many of the key developments. It then highlights discussions of the most contentious MNR issues that have arisen and concludes with an optimistic look ahead to a phase when one or more MNRs will be operating in parallel with ‘sister’ national DGRs. Together, these facilities can provide a safe solution to the long-term management of all radioactive wastes that must be emplaced in a geologic disposal facility. These developments will remove a key perceived obstacle to the expansion of nuclear power, which is a key element in combating the potentially disastrous impacts of CO2 emissions on Earth’s climate and will also ensure that non-nuclear power countries that employ other nuclear technologies also have access to a repository for the long-lived radioactive wastes that they produce.

## The benefits of a multinational repository

The most obvious benefits of a multinational repository (MNR) are economic. MNR users can expect unit disposal costs for all types of waste that are below those that would arise from implementing a small-scale national DGR. The provider of an MNR could also enjoy additional economic benefits. A multi-year DGR project could bring in a very large revenue stream (see Section 4.3) that could be used to benefit not only the DGR operator but also the host region and country in which the MNR is located. But the benefits are not only economic. The following summary of potential benefits is based on a comprehensive list that has been developed in earlier studies and in a project currently underway in the INPRO project at the IAEA [10]:

* Economic.
* Sustainable revenue flow over the long lifetime of an MNR project;
* Direct economic benefits for distribution to the community, region and/or nation;
* Reduction in national disposal costs, resulting from large economies of scale;
* Sharing costs should make finding the funding for long-term disposal projects easier.
* Social.
* Short- and long-term employment opportunities;
* Infrastructure improvements and development of spin-off industries and services.
* Ethical.
* Participant/user countries, independent of their waste inventories, can fulfil their obligation to ensure safe final disposal;
* Avoids indefinite spent fuel storage by countries unable to develop a national DGR.
* Global safety, security and non-proliferation.
* Limited numbers of facilities to be secured, thus enhancing global security;
* Earlier removal of hazardous materials from the surface to the deep underground;
* Enhanced levels of international oversight, ensuring that safeguards are maintained;
* Shared costs should result in closer financial control and oversight.
* Environmental.
* Concentration of conventional large project impacts at one site, instead of multiple sites;
* Remove obstacle to new nuclear reactor developments that can or must contribute to low CO2 emission scenarios.
* International Influence.
* Service provider strengthens its ties to the international community and may become major actor in the global nuclear industry.

## The extensive baseline of studies and initiatives

Table 1 summarizes significant developments over the last 20 years that have helped expand awareness of the potential benefits of MNRs and contributed to advancing recognition and approval of the concept.

TABLE 1 Summary of MNR Developments

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| --- | --- | --- |
| Development | Comments | References |
| International studiesPre-2000 | Mostly aimed at reducing safety and security risks by centralising management of fissile materials in regional nuclear fuel centers  | Summarized in [10][11] |
| Pangea1998-2002 | Commercial model for an Australian MNR, proposed by private investor group. Showed potentially huge economic benefits, but failed to win political support | [15] |
| Arius2002 - present | Association with mix of member organizations. Developed detailed partnering model for shared MNRs. Undertook studies for Europe, MENA regions |  |
| SAPIERR I and II2006-2009 | European Commission funded studies on shared repositories. Covered economic, safety, security, business and public acceptance aspects. Participants from 14 countries. Led to establishment of the ERDO-WG in 2009 | [1] |
| EC Waste Directive2011 | Recognition in EU legislation that Member States may make use of a shared European MNR | [6][7] |
| IAEA1996 - 2021 | Several TECDOCS on MNR concepts, focused on partnering approach; key 2005 positive Expert Report to IAEA Director General; current INPRO study | [11][12][13][14] |
| South Australia2016-2018 | Royal Commission established by South Australian Government to assess advantages of hosting a commercial MNR. Positive conclusions drawn, but challenges to business case and lack of political support led to suspension | [19] |
| IFNEC2015 - present | Reports and meetings on benefits and challenges of MNR; focus on commercial models; studies on financing options | [8][9][21] |
| ERDO-WG2009 - 2020 | Self-funded Group of Government nominated representatives from 10 European countries studying shared repository concept  | [16] |
| ERDO Association2021 - present | New Association promoting European MNR as part of a dual track repository program; initiated wider multinational cooperation topics; studying siting approaches  |  |

One of the key developments to emerge internationally over the last decade has been the concept of the ‘dual track’ approach to geological disposal. A dual track disposal policy involves developing a national disposal program in parallel with promoting and evaluating, in cooperation with like-minded countries, the potential for a multinational disposal solution. A dual track policy has already been adopted formally by several European countries (e.g., Denmark, the Netherlands, Norway, Slovenia) and is being considered by several others, as well as countries in other regions of the world (e.g., Jordan, the UAE). A fundamental requirement is that a nation with a dual track policy must have an active and credible national program that could lead to geological disposal of all relevant wastes within its own DGR. This is critical, because a multinational solution that meets that country’s requirements might not be found. In the dual track approach, a national solution must remain an option up to the point where an implementable MNR solution has been developed.

The other key development has been the preference among many of the most active countries and organisations working in the field of MNRs for exploring shared solutions. While a commercial, third-party MNR might eventually emerge that can offer disposal services globally, sharing in all the stages of radioactive waste management, up to and including MNR implementation, on a cost-sharing basis, is being seen as the most attractive way forward at present.

## The BIG QUestions

Certain issues have cropped up repeatedly over the years as interest in the MNR concept has grown. Some of the most prominent of these are summarized in the present section, together with counter-arguments that have been put forward by organizations supportive of this advanced level of multinational cooperation, in particular between countries with modest radioactive waste inventories.

### Is disposal in another country ethical?

Ethics specialists have examined the question of MNR development. For example, it has been pointed out [20] that, ethically speaking, each country has responsibility for its own wastes, but there could be good reasons for wanting a multinational solution: for example, lack of suitable rock formation, or safety and economic benefits. The questions are who exports to whom and under what ethical conditions? In the view of the numerous countries considering the option and of international organisations like the IAEA and the European Commission, freely agreed transfer of radioactive wastes between willing sovereign states (as would be required in all responsible multinational initiatives) is an ethical approach. Nevertheless, in the early days of MNR considerations, the concept of one country accepting wastes for disposal from another was criticized by some national waste management programs. Claims were made that any such proposals might seriously hinder these programs by causing alarm among the public and politicians about the possible import of ‘foreign’ radioactive wastes, even when this was not permitted by national laws. In Europe in particular, the concept of regional repositories became highly controversial. Some advanced programs advocated publicly that all discussion of this ‘sensitive topic’ should be stopped [17]. It was argued that the prospect of shared solutions might have negative impacts on national endeavors, for political, strategic or ethical reasons. Most worries were related to the risk of local rejection of a national GDF.

Two major arguments against multinational repositories, as put forward by the head of a major national disposal program [18], were that they are:

* “unethical” since each country using nuclear technologies should dispose of wastes on its own territory, or;
* “academic” because there are currently no specific host countries identified.

The opposing view is that it is certainly unethical for major nuclear nations to try to impose upon small countries their own interpretation of ethics. The large nuclear nations were happy to export nuclear fuel cycle products and services (including reactors, fuel fabrication, reprocessing etc.) to any who would purchase these. To single out disposal as the one part of the nuclear fuel cycle that may not be internationalized is self-serving and inconsistent. The arguments for national nuclear self-sufficiency ring rather hollow in nuclear countries that depend upon imported uranium and thus avoid all problems associated with mining – the fuel cycle step that has the most environmental impact.

The second argument – that multinational schemes are “academic” because no site has been identified at present – is perhaps even harder to accept. If this is to be a criterion for credibility, then virtually all national HLW geologic disposal programs are also academic, since very few have identified DGR sites. In reality, no site or country is currently nominated for an MNR for exactly the same reason that national programs do not nominate a DGR site at the very beginning of their efforts. Both national and multinational programs must fulfil some important prerequisites before taking the important step of selecting preferred sites. Not least of these are recognition of a common need for a disposal facility and building trust in the organisations that are charged with identifying and developing the site. Only then should one move to discussion of specific siting options. This is the gradual process envisioned by the Arius Association and the newly formed ERDO Association.

### How might MNR developments impact on national repository programs?

In the past, concerns have been expressed by some national disposal programs that the prospect of shared solutions may have negative impacts on their own endeavors, for political, strategic or ethical reasons, with most worries being related to the possible risk of reduction of local acceptance of a national DGR (especially when local acceptance has already been gained). Some of these concerns are understandable. The fears are that the prospect of importing waste could increase local opposition to a national repository, or that the prospect of being able to export waste might reduce political support for a national solution – or even deflect funding from national disposal organisations. The fear of a country being compelled against its will to accept waste from other countries is, however, unwarranted, when one considers the firm commitments at all levels to the principle that this is not permissible – as expressed, for example, in the IAEA Joint Convention and in the EU’s Waste Directive. The concern that effort or attention might be diverted is not realistic, since the modest resource requirements of multinational initiatives in the current phase mean that a national program could easily examine both options in parallel, as in the "dual track" approach described above, which is already being followed by several countries.

MNRs can only be sited in willing communities and nations, and in host countries that are able to provide the technical and regulatory framework that is necessary to ensure safety and security. MNR programs must be based on a clear, a priori, formal and open agreement between the countries involved. This agreement must set up adequate rules, organizational frameworks, financial schemes, R&D programs etc. Only when all concerned countries have a credible repository program will fears, rational or otherwise, about imposition of unwanted wastes on successful national programs cease to be of concern. National and multinational programs need to work together to achieve this objective as soon as is feasible.

### How robust is the business case for commercial MNRs?

Whilst a financial model for a shared MNR will largely be concerned with covering the costs of disposal and sharing them equitably among the partners, a commercial MNR will also need a business case to attract investors. At some stage, a successful shared MNR might decide to offer commercial services to non-partners, using any profits to defray the costs of the original participants.

Both the Pangea and South Australia projects mentioned above began to set out frameworks for business cases and both drew highly positive conclusions on the commercial viability and attraction of an MNR. However, the former was never reviewed in detail and the latter was criticized for not being sufficiently detailed and not fully assessing market uncertainties. The criticism was unfounded at the present stage, as the project was only intended to scope the commercial possibilities. Furthermore, conservative estimates of the potential market were employed, neglecting countries that have decided on a national solution and allowing for only a share of the remaining potential market for an MNR.

An example of the commercial scale of a large MNR can be seen in the turnover that might be associated with disposal of SNF. A range of national cost estimates give a working figure of about one million USD/tHM for geological disposal – typically plus or minus a quarter of a million USD [3]. The South Australia project developed a ‘willingness to pay’ estimate for countries that might not be able to develop their own DGR, from which a baseline reference ‘price to charge’ of 1.25 million USD/tHM was suggested as a working value [5]. It was postulated that some countries could be willing to pay considerably more for the convenience of having their SNF (and other waste) problems solved. With around half a billion tHM of SNF awaiting disposition around the world, the scale of potential revenue streams arising from dealing with only a fraction of this are in the hundreds of billions of USD. Clearly, a convincing and attractive business case would need to be built on taking a credible project proposal from a host country to potential users, negotiating prices and financing models, and establishing the minimum size of the market. The lesson that can be learned from the South Australian project is that prior discussions with potential MNR user countries could increase confidence in business case predictions simply by demonstrating definitively that there are potential users of the service.

The other concern of critics of the business case for an MNR is that high up-front investments are required and that these represent risk capital that might be lost. For investors, who might include government agencies as well as private financing sources, the vast revenue potential has indeed to be set against the front-end costs of developing an MNR, the possibility of cost overruns (which beset NPP construction and would be suspected to attach to other commercial nuclear projects) and the likelihood of project failure. Experience from national DGR programs suggest that the front-end costs (up to the point of operation) are likely to be only around 1 or 2 billion USD, including implementing an interim/buffer storage facility that could bring in early revenue. Front-end costs could expand if major new transport systems (hundreds of km of railway, for example) need to be constructed. With state-of-the-art DGR solutions now coming close to operation, we are well past the point of needing extensive R&D programs and decades of development work, so the step from concept selection to implementation will, in future be much shorter. These front-end costs are a very small fraction of a potential eventual revenue stream but are still large numbers. A business model that establishes a core group of first customer countries and offers them preferential disposal prices based on sharing some portion of front-end costs and risks is an obvious approach.

The risk of project failure will be a key interest for potential investors. Technical problems are considered an unlikely cause of failure: uncertainties associated with site characteristics and repository concept and design are readily identifiable and manageable, based on decades of international experience, and are highly unlikely to lead to abandoning a project. Rather, the credibility of any proposed MNR project will hinge on the strength of sustained political support from the host country government and evidence for a willing and engaged host community. Unfortunately, political reactions in both the Pangea and the South Australian case prevented the projects moving on to a phase of information and dialogue exchange with potential host communities. .

The conclusion is that an attractive business case should be readily attainable, but its credibility will be entirely dependent on political considerations. The business case must be backed enthusiastically be cross-party government support in the host country and a guarantee of compensation if the project is subsequently cancelled for political reasons.

### Will there be a willing MNR host country?

The core question most often put to proponents of the MNR concept is ‘who will host the repository?’

In response, it is correctly asserted that the question is no different in nature to the problem of finding a host community for a national DGR. A range of options needs to be identified and a choice made. But failure to implement an acceptable process for siting has been the downfall of most national DGR projects over the last four decades. Today, however, it is widely recognised that the only solution in a democratic society is to explain the issues involved and describe what is being sought technically, engage with communities that then understand these issues and think they might be interested in helping to find a solution, assess whether they are able technically to act as hosts for a DGR and then ask for a democratically based statement that they want to take on the task. The whole process is highly sensitive, contains checks and balances – especially associated with financial and other benefits – and needs to have both guarantees for those investing time and money in the project, as well as escape routes until commitments become certain. In a somewhat over-simplified fashion, this complex process is referred to as ‘the volunteer approach’ to repository siting.

It takes many years to go through such a process and, for an MNR, there is an extra layer of decision-making involved, given the involvement of multiple national governments. For partnering MNR projects, a key question is whether there is a minimum timescale for some countries before they need access to a DGR. Some can implement state-of-the art storage facilities and thus have relaxed timescales (e.g., the Netherlands, at 100 years) while others may prefer a much earlier solution that removes sensitive nuclear materials as soon as possible from their country. For a group of partner countries to agree a common MNR time scale is a very useful first step, as this will frame the siting program. If the agreed timescale postpones disposal target dates for some countries, then the importance of establishing the feasibility of an MNR becomes central to the credibility (and management) of their RWM programs. Today, it is a reasonable assumption that no shared MNR siting program is likely to develop significantly until well after the first purpose-built national DGRs are operational, by which time attitudes, opinions and drivers for DGR siting projects will likely have evolved.

A 2008 paper [2] sketched a possible ‘volunteer’ approach to MNR siting that is based on the application of consensual, staged and adaptive siting, with appropriate public engagement programs in each of the participating nations. The key aspect is that it is driven by the interests of communities in hosting a repository. National governments must agree that acting as host is not forbidden and, ideally, would provide the framework for discussions to take place (perhaps facilitated by a multinational WMO formed by the partner countries) but they need not drive the process once this agreement has been reached. Having established intergovernmental agreements to proceed with a shared siting program, each national government need take only a secondary role in the early stage of the siting process until concrete possibilities emerge and, of course, national governments will retain the ultimate right of approval. Effectively, the communities themselves take a much more proactive role in the international arena, with a range of benefits consequently accruing to them. The essence of the model approach is that it takes the burden of leadership of a highly sensitive project off national governments that may not wish to be in the vanguard of such a program.

This, of course, is just one approach that might be considered – perhaps the more promising approach would be for the national governments of potential host countries to act as champions and proponents. In this respect, all those organisations currently involved in promoting the MNR concept tend to agree that the first step is to get government representatives talking to each other. MNR siting, whilst constrained and guided by technical requirements, is not a technical issue, where the first moves are made by technical organisations such as WMOs. The first steps must be made at the level of government ministers. Facilitating such interactions is a primary strand of the future work program of the new ERDO Association.

## Reasons for optimism

As for the case of national repositories, the rate of progress towards MNRs has been much slower than proponents had hoped or planned for. Nevertheless, there are reasons for being optimistic that MNRs will become a reality, in parallel with operation of the national DGRs that are reaching the stage of implementation.

### Growth of nuclear power

One clear reason for optimism is connected to the growing societal and political acceptance of a need for increased nuclear power. It is clear that, in principle, renewables (solar, wind and hydropower), could in many cases provide enough energy to supply a whole country. But the output from these new renewables fluctuates with time to such a huge extent that it cannot be coped with by current storage and grid technologies. A stable base load is required and nuclear is the only clean option for this at present. It is also acknowledged that a credible path towards safe geologic disposal is an essential element for the necessary expansion of nuclear power (and other nuclear technologies that produce long-lived wastes) and that this path cannot easily be followed by countries with small waste inventories. Access to geologic disposal is essential for all countries and will only realistically be provided for many if MNR solutions are available.

### Advent of small modular reactors (SMRs)

There are many diverse projects underway to develop SMRs that can be flexibly and cost effectively deployed in new and existing national nuclear power programs. Some of these will operate for decades before fresh fuel is required and the refueling or replacement of the SMRs will take place back at the factory where they were produced. Retention of the spent fuel by the provider is clearly a simplified option for management of the back-end of the SMR fuel cycle. Thus, a country supplying SMR technology might also find it appropriate to provide its customer countries with a disposal service in an MNR. An alternative would be that a third country provides a commercial service for disposal or refurbishing of SMRs from various countries and, again, common disposal in an MNR would be the simplest solution.

### Progress with national DGRs

Many of the criticisms correctly levelled at national DGR programs over the past two to three decades are beginning to be answered by the most advanced disposal programs. Finland expects to operate a spent fuel repository in the near future and Sweden and France will likely be the next national programs to reach this milestone, which will demonstrate the feasibility of successful geologic disposal. As these programs move into a sustained, low-key operational phase, public fears about disposal safety should diminish. Moreover, MNR projects are learning from the experience gained in the successful national programs – both technically and in stakeholder participation processes. MNR initiatives have often been belittled with the argument that no country will ever be prepared to act as host. The advanced national programs mentioned, and others such as that of Canada, have shown that, when stakeholders (regions or communities) agree that there is a common need for a repository that will serve all of them, positive engagement and voluntary siting become feasible.

### Increasingly open recognition by countries of the benefits of an MNR

The initiatives summarized in Table 1 illustrate clearly that national programs are increasingly open in their desire to see an MNR being implemented. The studies mentioned have involved dozens of countries and the European Waste Directive reports submitted by EU Member States indicate that around half are directly interested in the MNR concept. Work by Arius and ERDO has stressed that at present an MNR strategy should be coupled with a national strategy in a dual track approach, and this has, to some extent, allayed concerns of international bodies such as the IAEA and the EC that the possibility of an MNR option being offered could lead to countries adopting a ‘wait and see’ attitude to disposal planning.

## CONCLUSIONS

Over the past two decades gradual progress has been made towards acceptance of the benefits and of the feasibility of establishing an MNR that would, in particular, allow countries with limited radioactive waste inventories to access a state-of-the-art geologic repository. The Arius Association, as the only entity dedicated fully to promoting MNRs, has played an important role in many of the developments noted in Table 1. The partnering option for repositories championed by Arius was developed in part as a reaction to the stalling of the commercially based Pangea project.

Since then, Arius has been a major contributor to the numerous IAEA publications on the topic and was the chosen advisor on disposal issues to the expert group that submitted the seminal report on multinational back-end cooperation to the Director General in 2005. In the first decade of the century, Arius also interacted with relevant organisations not only in Europe but also in the MENA region and in Asia, with its activities supported by its European members and by US Foundations and think-tanks. A strong focus was on Europe, however, where the common interests of neighboring countries in the European Union gave provided a firm framework. The led to the SAPIERR projects that produced the most comprehensive analyses to date of the benefits and challenges of an MNR. From SAPPIER there emerged the ERDO Working Group, whose secretariat for its 10-year lifetime was provided by Arius. Providing input to the South Australian Royal Commission and IFNEC work on the commercial service provider approach to an MNR has also been an important Arius activity.

But Arius was always envisioned, not as an implementer of an MNR, but rather as a global promoter of the concepts. Concrete progress towards a future facility will require direct involvement of representatives of national governments. This is why representatives in the ERDO Working Group that Arius helped to create were required to be nominated by the appropriate ministerial level body, even though the Group was not established as a legal entity. With the recent establishment of the ERDO Association, which is described in another paper to this conference, a further key step has been taken.

Having laid the foundations for developing feasible MNR projects and having established the interest and ambition of many countries to move towards MNR solutions, the next steps are now acknowledged to involve bringing together decision makers in like-minded governments to give the authority for shared projects to move forward.

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