SPENT FUEL MANAGEMENT FOR SMALLER PROGRAMMES AND NEWCOMER STATES

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Chairpersons

A. GONZALEZ
Argentina

K. FU YENG
China

SPENT FUEL CHALLENGES FACING SMALL AND NEW NUCLEAR PROGRAMMES

C. McCOMBIE
Arius Association
Baden
Switzerland

Abstract

In order to ensure that the radioactive wastes in any country are managed safely, it is necessary to have an established legislative and regulatory framework and also to create the necessary organizations for implementation and for oversight of waste management operations and facility development. Guidance on these issues is given in the Joint Convention and a number of other IAEA documents. The IAEA, and also the EC, have in addition published key overarching strategic advisory documents for new nuclear programmes. These tend to imply that all nuclear programmes, however large or small, should be pressing ahead urgently towards early implemention of geological repositories. In practice, however, in small programmes there are neither ecnomic nor technical drivers for early implementation of deep geological repositories; constructing simpler facilities for the disposal of the larger volume of low-lvel wstes has higher priority. Nevertheless, in all countries political decisions have to be taken and policies set in place to ensure that geological disposal will implemented without unjustified delay. This paper distils out a set of key messages for small programmes. Amongst the most critical are the following. Even if disposal is far off, planning and organization should begin at the initiation of the programme; this can help with technical and economic optimization and (importantly) also with public and political acceptance. Important lessons can be learned from advanced programmes — but these must be adapted to allow for the different boundary conditions of new and small programmes. The key differences relate to the timescales involved, and the resources available. There is a range of waste management and waste disposal options open to new programmes. It is not necessary to choose definitive solutions at the outset; options can be kept open, but a minimum level of engagement is required for all open options.

1. INTRODUCTION

In order to ensure that the radioactive wastes in any country are safely managed, so that individuals, society and the environment are adequately protected against radiological and other hazards, it is necessary to have an established legislative and regulatory framework and also to create the necessary organizations for implementation and for oversight of waste management operations and facility development. Guidance on these issues is given in the Joint Convention [1]. The IAEA has also published key overarching strategic advisory documents. The most recent of these with direct impact on small and new nuclear programmes are the 2007 report on issues to be considered when launching a nuclear power programme [2], the expanded version of this with its more specific details on development milestones for nuclear power infrastructure [4], and the 2009 report on policies and strategies for waste management [5]. In the context of the present paper, Annex 1 of Ref [4] is of special interest since it presents a typical strategy for a country with a small amount of radioactive waste.

The rising interest in the use of nuclear power in many European countries has also led the EU to produce waste specific guidance for countries introducing or expanding reactor programmes. The Roadmap [5] recently produced by the waste subgroup of the European Nuclear Energy Forum is focused on the most open waste issue — namely the geological disposal of spent fuel and HLW. The roadmap reaffirms that deep geological disposal should be the endpoint in a national waste management programme for such waste, *"since this is the* *only technically feasible way for the safe long-term management of high level waste and spent fuel, if regarded as waste"*.

In practice, however, there is no huge technical driver in small programmes for early implementation of geological repositories. However, there are important societal reasons for advanced countries showing the way and in all countries political decisions have to be taken to ensure that geological disposal is implemented without undue delay. For small and new nuclear countries, the roadmap recognizes that *"international cooperation is essential to build, exchange and disseminate expertize, identify good practices and optimize the cost of implementation. Joint RD&D programmes will play an important role in this respect. Shared repositories could be an option based on a voluntary agreement between the Member States concerned"*.

The advice given by the international bodies is applicable to all nuclear programmes. To act on the over-arching advice, however, much further detailed planning is needed. This detailed planning is not identical for large and small nuclear programmes.

2. WASTE TYPES TO BE MANAGED

A waste management and disposal strategy must be comprehensive enough to cover all of the waste types arising. Countries contemplating introducing nuclear power should therefore be aware of the diversity of wastes and of the expected volumes arising.

2.1. Wastes from reactor operation

In the operation of nuclear power plants, waste arizes from the processing of cooling water and storage pond water, from equipment decontamination and from routine facility maintenance. The wastes are mainly VLLW or LLW with some small quantities of ILW. LLW makes up around 90% of the volume of all radioactive wastes from nuclear power, but only around 1% of the activity. ILW makes up some 7% of the volume and has 4% of the radioactivity of all radwaste. Since the radionuclides in LLW are maily short lived, final disposal can be in a near surface repository. A 1000 MW(e) reactor will 200–350 m^3 LLW per year.

2.2. Wastes from decommissioning

Although decommissioning of a new nuclear plant will lie 40–60 years into the future, it is prudent from the outset to have a decommissioning strategy and to prepare estimates of the types and volumes of wastes that will arize. The largest volumes of waste from the dismantling of nuclear installations will mainly be VLLW and LLW and can be disposed of like the operational wastes. An exception involves some reactor internals with long-lived nuclides which implies that these must be disposed of in a geological repository. A 1000 MW(e) PWR or BWR produces around 10,000 t or a few thousand m^3 of decommissioning wastes

2.3. Spent fuel

Spent fuel contains most of the radioactive isotpes resulting from nuclear energy production, and these remain radioactive for very long times. For this reason it must be isolated from humans in an environment that will be stable for these long times. Deep geological formations represent the only accessible environment where stability over many thousands of years can be expected, based on our knowledge of their evolution over far longer times. The quantities of spent fuel that are produced by modern nuclear reactors depend upon the reactor type and size and upon the burnup level of the fuel. Modern light water reactors of 1000 MW(e) capacity, with an availability of 90%, an efficiency of 35% and a burnup of around 45 GWd/tU, will generate only around 25t of spent fuel per year. Heavy water reactors that can use natural uranium generate larger volumes of spent fuel. Per 1000 MW(e), a Canadian Candu reactor produces in a year around 125t of spent fuel with a volume of 25m3.

2.4. Wastes from reprocessing and recycling

Vitrified HLW accounts for over 90% of the total radioactivity produced in electricity generation if a reprocessing policy is followed. The most important of the numerous other waste streams produced in reprocessing spent fuel is the long-lived ILW composed of the hulls and endcaps of the metal tubes that contained the fuel, and other parts of fuel elements. The reprocessing step reduces the volume of highly radioactive wastes. The total radioactivity is of course unchanged, but is distributed in a very different way. The fuel assemblies comprising the 25 tonnes of spent fuel emerging in one year from a 1000 MW(e) reactor have a volume of around $10m^3$. Reprocessing these results in only around 2–3 m^3 of vitrified HLW; this corresponds to 12 standard waste canisters. The packaged volume for disposal would then be around 16 m^3 (assuming cylinders are individually encapsulated) which is less than the 40 m^3 or so which would be the volume of the fuel after similar encapsulation for disposal. The ILW which is also produced, however, gives additional waste packages. These will also take up space in a repository, although they can be more closely packed than the HLW canisters since they generate little heat.

2.5. Other wastes

It is useful to remind countries contemplating introducing nuclear programmes that, even without nuclear power, there will likely be radioactive wastes to be managed in their country. In fact, a comprehensive waste management and disposal programme should take all radioactive wastes in the country into consideration. Typical non-nuclear-power wastes include:

Medical wastes: The use of isotopes for medical diagnosis and treatment results in the generation of mainly short lived wastes.

Industrial wastes: Industry utilizes radioactive sources for a wide range of applications. The majority are short lived but some, including thousands of Am-241 smoke detector sources compacted into steel tubes are classified as long-lived. Other industrial wastes are "naturally occurring radioactive materials (NORM)" which result from the concentration of naturally occurring radioactivity via industrial processes.

Research wastes: Generally sources utilized at research establishments are disposed of as short-lived wastes but Ra-226 and Am-241 sources used in biological and agricultural research are long-lived. Research reactors produce the same wastes (spent fuel, operational, decommissioning) as commercial reactors but on a much smaller scale. In accelerators, leakage of proton beam causes not only a cascade of radionuclides from spallation reactions but also a significant amount of neutrons. A large accelerator gives decommissioning wastes volumes similar to NPP (but less concentrated).

3. THE NEED FOR AN INTEGRATED WASTE MANAGEMENT STRATEGY AND PROGRAMME

In the early days of nuclear power, waste management was approached in a pragmatic, ad-hoc manner with attention focussed on ensuring the safety and controlling the costs of operations involving waste handling and treatment. Less attention was paid to the longer term issues related to the ultimate disposal of the wastes. This was understandable, given that all of the waste volumes arising were modest, the highly radioactive wastes or spent fuel require decades of cooled storage, the low-level wastes could often be disposed of in relatively simple near-surface facilities and storage capacity for all wastes was easy to arrange. Today, however, it is recognized that developing from the outset an integrated strategy for introducing nuclear power can in the future avoid technical problems, reduce economic problems and enhance societal acceptance. Small and new nuclear programmes can learn from the experience of older mature programmes — not, however, by slavishly copying but rather by thoughtful adaptation to the different boundary conditions.

The starting point is to develop on a scenario for the future nuclear programme (or more often a range of conceivable scenarios) and to estimate the waste types and volumes arising over time. Next, the policy and technical waste management strategies to be considered must be identified and their repercussions examined, including infrastructural, human and financial requirements. The choices will be determined by the scope of nuclear activities foreseen for the future, the scale of the power programme, the relative merits of technology imports versus build-up of autonomous know-how, etc. A prudent strategy implies arriving at a suitable balance between keeping options open and establishing a sufficiently concrete planning base.

The timescale on which all actions must be taken is a crucial issue for new programmes. The most urgent task is the build up of the necessary knowledge base. By the time the first nuclear plant comes on line, a country should have a core body of waste management experts who can ensure that no critical issues are neglected. This body may be very small, especially if full use is made of external expertize and established networks, but core competence is essential. Another aspect to be addressed early is the financial structure set up to ensure that sufficient funding will be available for the necessary "cradle to grave" safe management of nuclear materials including wastes. This is crucial since the incomes from power production are generated very long before the larger part of the costs for waste and SFM occur. Various countries in the past have neglected this point by not diverting from the start an adequate flow of funding not only to ensure safe operational waste management but also to build up reserves for further down the line when costly storage and disposal facilities will be needed.

The following figures illustrate the importance of back end costs in the fuel cycle. Nuclear-fuel costs consist of front-end and back-end costs. The front-end costs are the cost of uranium (about 25% of the total fuel cost), its conversion (5%), enrichment for light water reactors (30%) and fabrication into fuel assemblies (15%). The back-end costs (roughly 25% of the total fuel cost) include direct disposal or, alternatively, reprocessing followed by recycling of the fissile material for reuse, whereby cost estimates for the direct disposal route are today significantly lower than for the alternative.

4. A CREDIBLE WASTE MANAGEMENT STRATEGY REQUIRES DISPOSAL PLANS

A credible waste management strategy must include all waste types and must cover all of the long time scales between waste production and ultimate disposal. The most immediate issues concern handling, treatment, storage and disposal of the LLW and ILW that will start to be produced as soon as the reactor commences operation. These are tasks that have been tackled in the hundreds of nuclear power plants world wide for decades. Therefore, the challenges for new nuclear programmes are centred on ensuring that the know-how, the technologies, the facilities and the human and financial resources required are all available at the outset.

A much more problematic and controversial part of the waste management planning concerns the establishment of a credible programme and timescale leading to the implementation of final disposal facilities — especially of a final deep geological repository. Currently, there are no such repositories in operation for the disposal of spent fuel or high level wastes and this has led to much criticism from opponents of nuclear power. Accordingly, international organizations, most notably the EC, have been encouraging rapid progress towards this goal and some of the advanced programmes (e.g. in Finland, Sweden, Germany and France) are striving to achieve it in the next 10–15 years. It will be beneficial to nuclear programmes in all countries when these advanced projects begin disposal and thereby illustrate directly the feasibility. For small and new nuclear programmes, however, it is infeasible, or at least impractical, and also unnecessary to implement geological disposal on anything like these timescales. It will be many decades before the volumes of HLW from the first reactors are sufficiently large and the heat emission sufficiently low to allow disposal. Nevertheless, the public and politicians in new nuclear countries will expect to see a credible disposal strategy. Pointing to the few deep repositories that may by then exist somewhere else in the world may not be sufficiently convincing.

A new nuclear programme can go further towards establishing a credible disposal strategy by taking the following steps, which are expanded upon in the IAEA documents referenced:

(a) Allocate responsibility for long-term management of all waste arising and establish relevant infrastructure;
(b) Establish a funding mechanism by which the necessary financial resources are set aside, most usefully in a segregated fund, to cover all future costs;
(c) Develop (probably in cooperation with foreign service-providers) a sound engineering concept for disposal of the types and quantities of wastes expected to arise;
(d) Define a practicable storage strategy ensuring the safety and security is guaranteed for all accumulated wastes through to the final disposal step, even if this is many decades into the future;
(e) Initiate a modestly sized programme to study the availability of potentially suitable repository sites. As discussed later, this can be a totally national programme or else a dual track approach in which the possibility of sharing a repository with other national programmes is also considered;
(f) Ensure that the necessary core competence in waste management is built up and then maintained at the national level. This can be done most efficiently by creating an appropriate organizational structure with an independent waste agency whose members are offered training and education opportunities and subsequently fully integrated into the appropriate regional and global networks.

5. NATIONAL VERSUS MULTILATERAL SOLUTIONS

As mentioned above, key decisions concern the level of fuel cycle autonomy aimed at in new or small nuclear programmes. National solutions may be preferred by a country if they reduce dependence of foreign suppliers or help build a new advanced technology base in a country. Multinational solutions may be preferred by a country if economies of scale lead to lower costs, if technical or societal siting problems are reduced, or if insufficient national capacity for nuclear activities exists. Increasingly, multinational solutions are being advocated by the international community for those back-end technologies, such as reprocessing or long term spent fuel storage, that bring with them increased risks of nuclear proliferation of terrorist activities.

The current situation concerning multinational back-end solutions is summarized below.

5.1. Spent fuel storage

There have been proposals that large nuclear countries such as Russia could store spent fuel from any country that is short of storage space. These have not progressed, however, since the acceptance of spent fuel with no firm commitment on its return has been regarded as waste import, which is not welcomed at present by any country. Multinational storage of spent fuel could, in principle, be attractive for small and new nuclear programmes since this could ease the problems of maintaining safety and security at national spent fuel stores over long times. However, by ensuring that new reactors have pool storage capacity for decades — or even for the whole reactor lifetime –new nuclear programmes can postpone this storage issue for many years.

5.2. Reprocessing

National reprocessing is certainly not economic for small programmes and will, therefore, be a goal only for those with overarching political or strategic objectives. Reprocessing by a foreign service-provider is, however, an option. This service is currently offered by France, Russia and the UK — but the costs are high and the value of fissile plutonium recovered from recycling is low or negative, given the high cost of MOX fuel relative to fresh fuel. For small programmes, the possible reprocessing incentives today are to be able to move spent fuel off site or to receive back HLW that is a quality assured vitrified form and is smaller in volume that the spent fuel.

5.3. Disposal

Multilateral options that remove the need for implementation of many small deep geological repositories could be much more economical than each counttry implementing a small national repository. They are potentially of particular value for new and small nuclear programmes. The existence of a large multinational repository could also mean that their spent fuel or HLW could go to final disposal at a much earlier date than would otherwise be possible. One possible approach that could achieve this is fuel leasing, where the supplier retains ownership of the fuel and accepts it back into his country after its removal from the customer country reactors. Unfortunately, fuel leasing has been offered only on a very limited scale (by Russia) and no commercial services for acceptance of foreign spent fuel have been established.

There has, however, over the past ten years been increasing interest in the concept of multinational or regional disposal. It is universally accepted (and anchored in the Joint Convention) that each country has responsibility for its own wastes — but this does not a priori exclude responsible transfer agreements between willing nations, if safety is assured. Cooperation among geographically contiguous or close nations to develop shared regional repository projects may be the most credible approach. The issue of import of radioactive wastes remains very sensitive, however, and several countries currently have laws that forbid this and would have to be amended before any country could volunteer to host a multinational disposal facility. This has been discussed at length in IAEA documentation in which a range of conceivable scenarios for mulktinationalrepositories was described [6].

If experience with the first generation spent fuel or HLW repositories leads to cost effective, standardized technologies that make even small repositories economic and if the societal acceptance problems drastically abate due to the positive example shown by the leading repository countries, then the implementation of many small repositories across the globe may become a less daunting prospect than it currently is. If this is not the case, then the likelihood of multinational disposal may rize. However, even if options for multinational disposal of spent fuel and HLW become available, they will not be fully adequate unless the waste accepting country also is prepared to take in other long-lived wastes that need to go to geological repositories since this extended service is required if small countries are to avoid the need for a national geological repository.

The public and political acceptance of shared multinational or regional repository concepts has increased somewhat over the past years, although opposition is still apparent in many countries and no implementation project has yet emerged. The SAPIERR projects and the European Repository Development Organization Working Group (ERDO-WG) could perhaps act as a role model for regional groupings elsewhere in the world. . Both the EC and the IAEA have indicated that they would support countries selecting a multinational option.

6. FUNDAMENTAL STRATEGIC WASTE MANAGEMENT OPTIONS

In an IAEA document, Options for Management of Spent Fuel and Radioactive Waste for Countries Developing New Nuclear Power Programmes [7], the fundamental strategic waste management options facing new and small nuclear countries are categorized under the following headings.

For spent fuel:

(a) National storage and disposal (early or late);
(b) Reprocessing abroad. Recycling and waste disposal nationally;
(c) Reprocessing, recycling and waste disposal abroad;
(d) National storage; disposal in a shared repository;
(e) Fuel leasing (similar to point above);
(f) Retention of spent fuel as a valuable commodity.

For operational and decommissioning waste:

(a) National storage and disposal;
(b) Multilateral disposal.

These strategies are then considered by examining their repercussions on the following aspects of a nuclear programme:

(a) Safety;
(b) Security;
(c) Feasibility;
(d) Economics;
(e) Political;
(f) Legal;
(g) Societal.

This logical and transparent approach to developing one or more long-term waste management strategies to be kept open can be applied by any new nuclear programme. However, the weightings given to the various issues will be dependent on the national characteristics and hence the answers will not be the same for all countries.

7. CONCLUSIONS AND RECOMMENDATIONS TO SMALL COUNTRIES ON WASTE MANAGEMENT AND DISPOSAL

It is possible, however, to distill out a set of common key messages concerning waste management and disposal strategies for new or small programmes. These include the following:

(a) A responsible NPP programme needs to consider the lifecycle of all nuclear facilities and all radioactive materials from the outset; a holistic approach is most effective. (What facilities will be needed? At which times?? What are end points for all materials?);
(b) Even if disposal is far off, planning and organization should begin at the initiation of the programme; this can help with technical and economic optimization and (importantly) also with public and political acceptance;
(c) Resources (human and financial) must be made available for planning and implementing the policy and strategy on waste management;
(d) Important lessons can be learned from advanced programmes — but these must be adapted to allow for the different boundary conditions of new and small programmes. The key differences relate to the size of the programme, scope of nuclear activities, timescales involved, and the resources available;
(e) A "wait and see" policy - if this implies that no actions are being taken or planning being initiated - should not be an option. There are minimum steps that any programme should initiate — even if only one or few reactors are foreseen;
(f) At a minimum a new programme should allocate responsibilities, educate and train personnel; develop reference options (plan facilities, timescales etc); organize funding mechanisms; start consideration of the feasibility of national repository siting options; consider all siting issues for all facilities in order to assess co-siting possibilities and engage in international networks;
(g) The most urgent tasks are:
    - Establishing a know-how base,
    - Ensuring that all at-reactor facilities needed for safe handling and treatment of operational wastes will be available from day one,
    - Ensuring sufficient storage capacity will be available at ALL future times,
    - Establishing **credible** disposal options;
(h) There is a range of options open to new programmes depending on the allocation of responsibilities for planning, execution and funding, the timing chosen for storage and disposal, the storage and disposal technologies chosen, the fuel cycle options and the degree of self-sufficiency aimed at. It is not necessary to choose definitive solutions at the outset; options can be kept open, but a minimum level of engagement is required for all open options.

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SPENT FUEL IN CHILE

F. LÓPEZ LIZANA
Chilean Nuclear Energy Commission
Santiago
Chile

Abstract

The government has made a complete and serious study of many different aspects and possible road maps for nuclear electric power with strong emphasis on safety and energy independence. In the study, the chapter of SFM has not been a relevant issue at this early stage due to the fact that it has been left for later implementation stage. This paper deals with the options Chile might consider in managing its Spent Fuel taking into account foreign experience and factors related to safety, economics, public acceptance and possible novel approaches in spent fuel treatment. The country's distinctiveness and past experience in this area taking into account that Chile has two research reactors which will have an influence in the design of the Spent Fuel option.

1. INTRODUCTION

Chile has been considering the nuclear option for the future energy needs of the country. Presently, the country obtains its electrical energy from hydroelectric, thermal and gas power plants. However, drought has lowered the hydroelectric output, the prices of oil are increasing and Argentina, the main supplier of natural gas to Chile, has stopped delivery. A high level expert committee was convened with the mission to study the subject and make a report. The report does not exclude a nuclear power program. Its main message is that a thorough study had to be made, with solid facts in the hand, before the country decides to proceed or not. This study is in an advanced stage and nearly all specialized reports have been delivered to the Ministry of Energy. The recently elected government has made public its interest in continuing with specialized studies, strengthening the institutional organizations, and the establishment of a fully independent and efficient Regulatory body within the next four years.

Chile has an on-going collaboration with the International Atomic Energy Agency in nuclear energy matters which are implemented through technical cooperation projects which include support for international know how on SFM [1].

In many countries, the preferred technological approach would be to dispose the spent fuel as waste in repositories constructed in rock formations hundreds of meters below the earth's surface. Although several experimental and pilot facilities have been built, there are no operating high-level waste repositories yet, and all countries have encountered difficulties with their programs. Chile as a seismic country would have to adequate technical setup for disposal in a deep geological repository.

Presently, there are a number of countries planning to expand their nuclear power programs as well as some "newcomers" that are considering the introduction of nuclear power in the near future, Chile being one of them. This growth of nuclear power after years of stagnation will bring stronger research and development of spent fuel handling and disposal. This R&D will surely be done in countries that have large stocks of cooled-down SF and whose interim storage capacities are nearly complete. Newcomers have a few decades in which their SF stockpiles will grow and can benefit from the results of new developments in this field.

2. THE CHILEAN PLAN FOR NUCLEAR POWER REACTORS

2.1. A modest nuclear program

The Ministry of Energy with the support of the National Energy Commission (CNE) and the Chilean Nuclear Energy Commission (CCHEN) has produced a document that describes the Chilean nuclear program in a clear and brief manner. The report “Nuclear Electricity in Chile: possibilities, gaps and challenges” was submitted to the government in March 2010 [2]. Based on this paper, the requirements and setup of SF management can be planned in a reliable way.

FIG. 1. Schedule of NPP implementation.

The power reactors could be “turn-key” units, where the supplier will design, build and manage the construction until the NPP is delivered. It is expected to buy the fuel on the world market and there are no plans to fabricate fuel assemblies locally. This policy will have an impact on the waste management programme reducing it to the usual medium and low waste of plant Operation and Maintenance (O&M) as well as the management of the spent fuel. The substantial waste streams that are usual for the front- and back-end operations of nuclear chemical facilities will be avoided. We recall that most of the international debate on waste management applies greatly to activities of countries with large nuclear programs that have enrichment facilities, reprocessing and advanced fuels production.

The study also takes into account the future rise in costs of fossil fuels and the growing demand for electricity that will lead to energy bottlenecks at the beginning of the twenties. If the nuclear option is not implemented, most probably, the demand for more electricity will have to be covered with coal fired plants which will result in massive emissions of CO_2. This would have a negative impact on Chile’s clean emission history. Experts proposes the construction of up to five 1100 MWe plants by 2035, the first reactor being connected to the electrical grid by 2024. The Chilean study points to Generation III+ PWR’s, which would have high passive and active safety standards, eventually allow operation for 60 years, use LEU and MOX fuel and allow high fuel burnup among other advantages.

Although this is the frame in which the options for nuclear power and SF management are being discussed, Chile will maintain open the option to develop later more advanced parts of the fuel cycle in the far future. The article 4 of the Nuclear Proliferation Treaty, NPT, states that signatory states while complying with their safeguards obligations will not be hindered in developing all types of peaceful nuclear options. Chile has repeatedly made this statement at the annual IAEA General Conference. The reasoning here is that future world fuel supply may change substantially and that the improvement in national know-how in fuel technology could make a local or regional development of reactor fuel or parts of the U-cycle, a course to be considered. For example the use of MOX or Thorium might become common standards in energy production elsewhere and Chile could think about the way to use it in its energy mix [3]. Pooling advanced nuclear efforts with other countries and multilateral solutions will also be possible future options.

2.2. Quantities

How much material can the proposed plan generate? An estimation of the SF generated by PWRs can be made considering units of 1100 MWe. Each NPP will recharge with about 25 Tons of Heavy Metal (finally encapsulated in about 75 m^3) for interim storage.

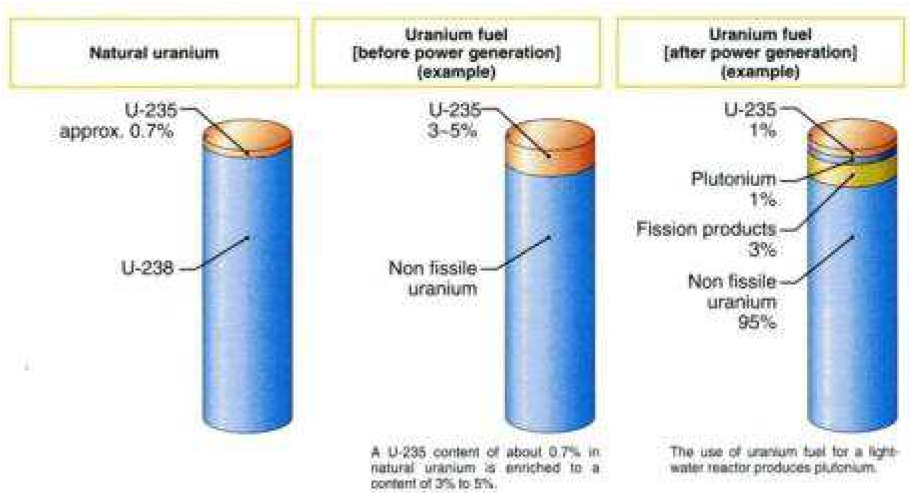

FIG. 2. NU, LEU and SF: gross elemental isotopic composition.

This would mean that at the end of the useful life (60 years) of five NPP's an amount of about 7500 tHM would be stored.

If a conservative fuel policy is implemented, it would mean that the initially 3.5% enriched fuel would be burnt and there would have an inventory of 7200 t of LEU, 75 t of Pu and 225 t of FP (at 35- to 50 GWd/MtU). Burnt fuel is considered waste although substantial part of the SF is uranium and plutonium, both which are fissile elements that could be used again as fuel, provided the minor actinides and fission products are separated from it.

3. THE PRESENT WASTE AND SPENT FUEL MANAGEMENT IN CHILE

All radioactive material generated which has no further practical use, is defined as radioactive waste. It has to be managed to ensure human health protection and to preserve the environment. This is assured by effective and systematic approaches within a legal framework that each country defines.

There is a range of waste materials, solid, liquid and gaseous including the products of the operation of nuclear reactors. Spent Fuel is treated as waste if has to be disposed of without prior treatment. In closed fuel cycles it is also considered as a valuable resource because it still contains great amounts of uranium and plutonium that could be re-used as fissionable fuel. The SF's high activity will depend on the radionuclides present in it. Depending on these features, the radioactive waste management shall be developed to guarantee its confinement and to contain the dispersion of radioactive material.

3. 1. Radioactive waste in Chile

Radioactive waste in Chile is generated from applications of the nuclear energy in health, industry and research sectors. About 10 m^3 per year of radioactive waste is produced in the country, which classify in the very low level, low level and intermediate activity level.

The management of nuclear waste and reactor spent fuel is responsibility of the CCHEN. This is the only organization in the country that has the appropriate and authorized technical infrastructure to give treatment, conditioning and storage to these wastes. According to the present legislation, the waste generator is responsible to provide the safe management for its own radioactive waste; under these conditions, waste generators request CCHEN to manage the waste under the necessary safe and security conditions.

From both nuclear research centres, CEN La Reina and CEN Lo Aguirre, and also universities, a large amount of gaseous, liquid and solid radioactive waste are generated, which include radionuclide's of different types and concentrations from very low to high activity, being these last corresponding to the spent fuel from the RECH-1 research reactor. Main waste from the health and industrial sector that are received in CCHEN correspond to the type "spent sealed source" in amounts of 100 units/year with activities reaching Tera Becquerel ranges (from Cobalt therapy devices). This waste comes from an average of 20 radioactive facilities which are assisted each year by CCHEN. To give sustainability to the system of radioactive waste management in the country, a national policy and strategy will be established, and the draft report on the study has been prepared with the technical assistance of the IAEA. This report is being discussed by an ad-hoc group and will be presented to high level authorities for discussion and approval [4].

3. 2. Research reactors

CCHEN operates two nuclear research reactors; RECH-1 and RECH-2, both of them are pool type. The RECH-1 research reactor is located at La Reina Nuclear Centre in Santiago and the RECH-2 reactor which is located at Lo Aguirre Nuclear Centre near to Santiago.

The first criticality of RECH-1 was achieved on 13th October 1974 using high enriched uranium (HEU) fuel assemblies. The reactor uses light water as moderator and coolant and beryllium as reflector. For most of the time the reactor has been operated at the nominal power of 5 MW in a continuous shift of 24 hours a week, 48 weeks a year. The reactor has an annual shutdown period of 3–4 weeks for maintenance, usually during the early summer. The reactor is used mainly for radioisotopes production, neutron activation analysis, beam experiments, in core experiments, neutron irradiation, and neutron radiography.

RECH-2 is moderated and cooled by light water and it utilizes graphite as reflector. The first criticality was achieved in February 1977. The reactor has a license to operate at the power level of 2 MW using HEU fuel assemblies; however, due to lack of a utilization program the reactor is in extended shut down.

Both reactors, RECH-1 and RECH-2, utilized MTR type fuel assemblies with HEU (80–90% 235U) in the initial years. Later the fuel was gradually lowered in its enrichment until reaching the actual LEU fuel of 19.75% in 235U. CCHEN has developed the capability to produce its own U_3Si_2-Al MTR type fuel.

The HEU spent fuel assemblies from the RECH-1and RECH-2 reactors have been sent in various shipments to the Savannah River Site, South Carolina; all within the framework of the

U. S. Foreign Research Reactor Spent Nuclear Fuel (US FRRSNF) acceptance program. This could also be seen as the first successful "disposal" of Chilean Spent fuel.

Research Reactor Spent Fuel is managed under strict technical and safety norms. The IAEA has supported CCHEN with continuous advice and training of qualified personnel. They were partly developed in the frame of the IAEA Technical Cooperation Regional Project RLA/4/018: Management of Spent Fuel from Research Reactors in Latin America. To date there have been no incidents in the safety record. Detailed reports of Chile's SF activities have been published elsewhere [5].

4. SPENT FUEL AND CHILE'S FUTURE NUCLEAR POWER REACTORS

4. 1. Management and long-term responsibilities

If Chile's plan to introduce nuclear power is implemented, nuclear waste management efforts will have to be incremented substantially, especially in defining responsibilities for the near and far future.

Developed nations with open fuel cycles are handling their SF for more than 40 years with obvious success, and the handling for the next five decades or more doesn't seem to pose major challenges. Chile will benefit from this previous experience and make use of the most suitable cases for its own program. There are two aspects that must be addressed: the managerial and the technical.

In the managerial aspect it will be of great importance to discuss the assignment of responsibilities in waste and SF management for the near and far future. For example, Who should be liable for the spent fuel after the reactor has been decommissioned? The operator or the state? Final disposal will be implemented long after the present actors have changed, so organizational and financial responsibilities should be addressed soon. Although there might be no decisive answer to these questions today, pointing them out and discussing the options would greatly improve our perception of SF management at the moment of taking decisions.

Although Chile has a legal structure that regulates nuclear activities, it has some shortcomings of which the authorities are aware. Presently the regulator and the promotional activities are both under the mandate of the CCHEN. In this sense the CCHEN has prepared a new set of legal measures and is advising the government in its implementation. The present administration is pursuing the establishment of an independent regulatory body that would be in condition to manage nuclear activities and eventually the setup and licensing of a nuclear power program, should the political decision be made in this direction.

Several possible aspects should be discussed in order to facilitate the successful implementation of waste management and disposal. For this, the measures have to contribute significantly to one or more of the following goals:

- Control of the risks to public health and safety and the environment from waste management and disposal activities in the short and/or long term;
- Study and estimate of the economic costs of achieving an acceptable level of performance with respect to short and long-term risk;
- Reach general public confidence in the technical and organizational effectiveness of the proposed waste management and disposal activities.
- An advanced technical setup in handling spent fuel through the fuel cycle.
- An efficient institutional and organizational setup for SF management.

Each of these measures should be evaluated in terms of its impact on the entire waste management system, including not only final disposal but also pre-disposal processing, transportation, and storage operations.

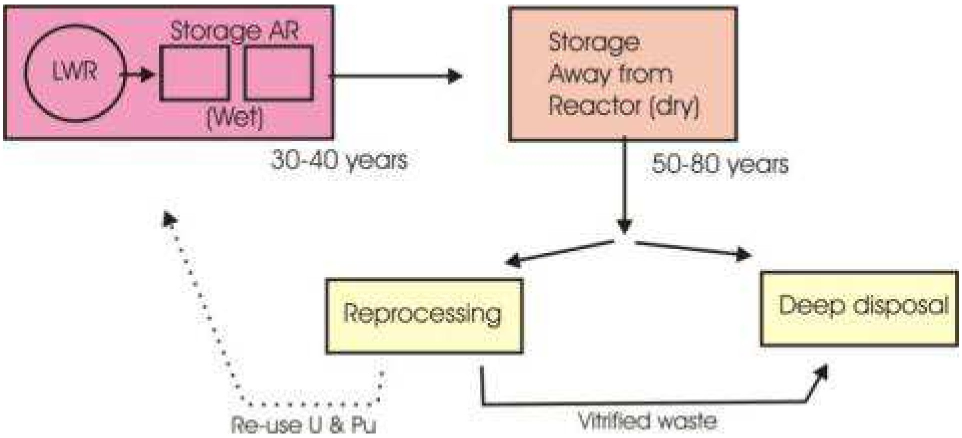

FIG. 3. Pathway of spent fuel, from the core to final disposal.

Basically, there are three storage steps for SF management simplified in the figure above. After the assemblies are withdrawn from the reactor core, they are moved underwater to storage racks in pools within the reactor building. After a long cooling period, they are loaded in special casks and transported by land to the dry interim storage Away From the Reactor (AFR) and kept preferably in a dry atmosphere. Prior to final disposal, a decision should be made as if the whole fuel assembly will be disposed or if only the separated fission products will be sent to the final depositary.

4. 2. Storage at the reactor

Storage at the reactor begins with the discharge of spent fuel from the core of a power or a research reactor and its transfer to wet storage at the reactors pool. The once-through cycle in the Chilean study does not specify the direct disposal of the spent fuel after a period of cooling. Although disposal is clearly an option, there could be other ways of handling the assemblies such as reprocessing of the spent fuel and recycling of plutonium and uranium for new mixed oxide fuels or transmutation techniques for fission products that might become operational in the next future. This approach could be considered as a “wait and see" option, while the SFM program is still being evaluated.

The first place where the SF is stored is At the Reactor (AR). Typically, the reactor has a pool capable of holding about 1300 assemblies. This allows for ~30 years of SF cooling and decay after which a transfer to dedicated storage area for SF, Away From the Reactor is made [6].

Keeping the SF for long periods AR has various benefits as:

- Physical control and Safeguards occur in one place;
- Transportation technology is postponed or avoided;
- Initial human resources are available on-site;
- Licensing is done together with the reactor.

There is also the financial dimension: if the decision to build an AFR storage facility will be made in the next future, economic resources can be used once the power plants have built up capital for an improved solution. For these reasons, it would be an advantage to design the pools AR of the largest practical size possible as an integral part of the system architecture. Keeping the greatest number of fuel rods AR would be an advantage for a once-through cycle like Chile's.

The realization of this important step will depend on many factors, mainly safety, safeguarding and criticality studies and in agreement with the SF management setup.

4. 3. Storage away from the reactor

Most of the SF intended for final disposal will have to be stored above ground for some decades in the "wait and see" process of learning from developments in SF processing and high level waste repositories techniques. An interim storage at a centralized dry storage away from the reactor should be part of the design of the SFM system for a period of several decades. Such a storage capability would:

- Provide greater flexibility in the event of delays in final repository development;
- Allow a deliberate delayed approach to disposal and create opportunities to benefit from future advances in relevant science and technology;
- Provide greater logistical flexibility, with a centralized buffer storage capacity facilitating the balancing of short and long-term storage requirements, and enabling the optimization of logistics, pre- processing, and packaging operations;
- Allow Chile to keep open the option to reprocess their spent fuel without actually having to do so;
- Create additional flexibility in repository design, since the spent fuel would be older and cooler at the time of emplacement in the final repository; and
- Potentially reduce the size of the final repository required.

At-Reactor storage will be feasible for some spent fuel, hopefully for a great amount of Heavy Metal (HM) for the lifetime of the NPP. For the remainder, centralized storage facilities, away from the reactor will be required [7].

The storage AFR will have to be a safeguarded, well-protected central storage facility which will also have non-proliferation benefits [8]. The sitting of the AFR storage facility will be rather complex due to Chile's seismic condition, but this technical issue will be more straightforward than for a geologic repository. Finding an adequate site, while still be a challenge, might be easier than in other countries because Chile has great extensions of inhabited desertic land. The desert of Atacama is known to be the driest desert on earth which is an adequate environment for air cooled casks. The dry air of the desert is a major asset in designing a centralized dry storage facility AFR. The SF assemblies in their casks, cooled by a passive flow of air, would be protected from further corrosion by the dry and reducing environment, which would allow safe storage for a considerable period at the site. Additionally, the task of persuading the small neighbouring communities to accept such facilities might be possible.

Therefore, making provision for several decades of temporary spent fuel storage would make for a more robust waste management system overall, and could be cost effective too, if the result was to postpone the onset of major spending on the final disposal repository construction and operation.

4. 4. Final disposal

Final disposal is generally understood as the disposal of the spent fuel rods in a location and under conditions that do not allow for its later retrieval. This is also referred to as the Direct Disposal of SF. The same can be the case if only the fission products, separated and encapsulated in whatever way, are also disposed forever.

The concept of deep geologic disposal has been studied extensively during several decades, and there is a high level of confidence within the experts, scientific and technical community that this approach is capable of safely isolating the waste from the biosphere for as long as it poses significant risks. This assessment is based on: (1) an understanding of the processes and events that could transport radionuclides from the repository to the biosphere; (2) mathematical models which, when combined with information about specific sites and repository designs, enable the long-term environmental impact of repositories to be quantified; and (3) natural analogue studies which help to build confidence that the analytical models can be reliably extrapolated to the very long time-scales required for waste isolation.

Before the spent fuel is emplaced in a deep repository it must be encapsulated in a durable canister. The residual heat of the fuel is an important factor that has to be considered for the final canister disposal. The residual heat influences the distance between the canisters in the final repository and even the quantity of fuel assemblies that can be accepted per canister. In the case of higher burnup fuel, this also means that it would lead to fewer fuel assemblies and at the same time “level off” at a higher back-end cost per assembly.

Although there is sufficient knowledge for a safe final disposal strategy, no country has yet a deep geologic repository in operation. Finland, France and Sweden have taken the decision to build such a repository and the final repository of Olkiluoto in Finland that will have a capacity for 12000 Mt of HM is already in progress.

Chile, together with many other countries is observing these and other developments for final disposal. We are confident that in 100 years from now, improved solutions for final disposal will be operational and the choices will be environmentally safer and applicable to the particular situation of Chile. Following this reason, the USA has stopped its plans of final disposal at Yucca Flats and wants to follow a similar strategy [9].

4. 5. Long lives

Spent nuclear fuel discharged from the nuclear reactors will remain highly radioactive for many thousands of years. The primary goal of nuclear waste management will be to ensure that the health risks of exposure to radiation from this material are reduced to an acceptably low level for as long as it poses a significant hazard. Protection against the risk of malevolent intervention and misuse of the material is also essential.

Because of the very long toxic lifetime of the waste, the primary technical challenge is that of long-term isolation. However, shorter-term risks must also be addressed. Prior to final disposition, the waste will pass through several intermediate stages or operations, including temporary storage, transportation, conditioning, packaging, and, probably, intermediate processing and treatment steps. There are several possible choices at each stage, and the design of the overall waste management system, including the specific technical characteristics and the physical location of each stage will importantly affect the overall level of risk and its distribution over time [10].

Most of the high active isotopes will have decayed to lower levels after about 120 years which will make the SF easier to handle. But due to the toxicity of the very long life isotopes, it will have to be treated for many centuries as HLW.

4. 6. Future developments

There are a good number of innovative options for new type of reactors and fuel cycles that will obviously have an impact on the way SF is handled worldwide. Many of these innovative solutions result in a reduction of waste, radioactivity and decay time. Some produce SF that is more resistant to chemical changes. The thorium fuel cycle, accelerator driven reactors and fast reactors are examples that have been studied in other countries and some have been put into practice.

Another technical improvement that allows the reduction of the HLW generated is High burnup fuel [10]. The burnup of spent fuel — the amount of energy that has been extracted from a unit of fuel at the time of its discharge from the reactor — is a design choice for reactor operators. In the past, the burnup of LWR fuel averaged about 33 GWd/MTU. An increase to 100 GWd/MTU is within technical reach, and even greater increases are potentially achievable. Increasing the burnup to 100 GWd/MTU would yield a threefold reduction in the volume of spent fuel to be stored, conditioned, packaged, transported, and disposed of per unit of electricity generated. But the corresponding reduction in the required repository storage volume would not be significant; the individual fuel assemblies, although there would be fewer of them, would generate more decay heat and would therefore have to be spaced farther apart in the repository. The amount of plutonium and other actinides, which are the dominant contributors to the radiotoxicity of the spent fuel after the first hundred years or so, would also be reduced somewhat per unit of electricity generated. A further benefit of higher burnup is that the isotopic composition of the discharged plutonium would make it practically unsuitable for use in nuclear explosives.

Some of these strategies are very promising and Chile will remain interested in these developments although its main target today is to solve its pressing energy needs and these can only be achieved with proven technologies such as LWR’s and the uranium fuel cycle. LWR’s have had a long experience with fuel availability, safety, reliability and safeguards.

4. 7. Earthquakes

On 27th of February 2010, a severe 8.8 earthquake on the Richter scale shocked Chile and brought it on the front pages of the media as a country with high seismic risks. By coincidence, it is fifty years since the strongest measured earthquake worldwide hit Valdivia, Chile with a force of 9.5 Richter. Both events were followed by devastating Tsunamis. Chile will have to make greater efforts in anti-seismic measures before embarking in any nuclear power programme as compared to those made elsewhere. This is valid for building the power plants as well as for all additional installations including the SF storage sites. Japan for example is a country with a significant seismic history and has developed at the same time a vast nuclear infrastructure. The excellent operational safety record under such events make countries like Japan a model from which Chile can acquire substantial experience.

When designing SF storage facilities in Chile, similar standards of earthquake resistance that apply for the construction of power reactors will be used. The first storage stage, the pools AR will be given special consideration. The containment will have to resist strong earthquakes without rupture of the pool or spills of the coolant water over the rims. The strong earthquake that shocked Kashiwasaki, Japan in 2007 caused spilling of some water but the stainless steel coated pools held the event without issues [11]. Although the spilled water was insignificantly contaminated, it was enough for the media to criticize the NPP as a whole. Therefore for such a case, it will be of uttermost importance to keep the pool water clean as possible, encasing any damaged assemblies immediately.

4. 8. Human resources

Presently, Chile has an efficient working system for spent fuel handling at its research reactors. As described above, SEGEDRA is proficient in all institutional and technical aspects of waste management. These technicians and experts can be the source on which a greater SF management group is built as it is clear that the human resources for a nuclear power program will be of greater order of magnitude. In the immediate future, Chile will concentrate on the build-up of human resources that will be experts in advising the government in nuclear maters and implementing an independent regulatory body.

A great number of professionals will be needed in this area as the same those who will be needed as operators and regulators. Chile will have to invest in this build-up of human resources which will have to be trained in many special techniques in the frame of a solid safety culture. Basically there should be no problem in this effort because the country has a good educational system for higher graduates in science and technology. There is enough time for this build-up once the decision for nuclear power in made.

4. 9. Public acceptance

The way spent fuel will be managed is one of the main concerns the public has. In fact it has a central role in society's acceptance of the whole nuclear power program.

The public is aware of some unacceptable behaviour on part of operators with high active waste handling and disposal in the past. These misdoings have been reported from waste handling in military programs in nuclear weapons countries and have damaged the image of the nuclear industry as a whole [12]. Contrary to this, it is also true that the waste and spent fuel handling by the civilian nuclear operators has been excellent. With support of the IAEA, the civilian operators have implemented protocols of high safety standards and taken precautions to manage the HLW and spent fuel in a safe and responsible manner. This brilliant record has had a positive impact on the public opinion and should be continued and enhanced.

The public opinion has been part of the comprehensive study made by the Chilean Ministry of Energy [2]. The study shows that 68% of the public is against NP and 27% in favour with 5% with no answer. A number of other questions were made in the survey and it shows that much disinformation is the cause for this adverse position.

As in the successful case of public acceptance in Sweden, where once a population against nuclear changed its opinion after a transparent and solid information program, Chile will have to make efforts in this sense if the nuclear power program is to become a reality.

5. CONCLUSIONS

The most important chapter of SFM in Chile will be the safety setup of the locations, the installations and the material handling. The institutional control will be designed to fulfil this purpose in the best possible way.

Technically the handling could follow these three steps: First, an interim wet storage at the reactor where they can be kept for 30–40 years. Second, a centralized interim dry storage away from the reactor, probably at an isolated dry location in the north Chilean desert for another 40 years or more. And third, at the beginning the next century, Chile would have to decide for one of these two ways to proceed: Final disposal of the fuel assemblies or recovery of the fissile elements and final disposal of the fission products.

An early decision on final disposal would rather be a disadvantage than an asset. New final nuclear fuel disposal techniques; safe, clean and economical will be available by 2100 and therefore it is advisable to defer the decision of final disposal to a later stage, when these new solutions have been developed and proved by more advanced nuclear programs.

In brief, a successful NPP program in Chile will have to focus in designing the best option for interim storage for nuclear fuel for the first eight decades, beginning from the date the first NPP goes operational.

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EGYPTIAN PROPOSED STRATEGY OF SPENT FUEL MANAGEMENT FROM NUCLEAR POWER REACTORS

M.M.A. IBRAHIM
Nuclear Power Plants Authority
Cairo
Egypt

Abstract

This paper presents a proposed policy and strategy of the Arab Republic of Egypt towards the management of spent fuel from the nuclear power reactors. The proposed Egyptian strategy supports the free international trade of nuclear materials and services and adheres to Non Proliferation Treaty (NPT) and other institutional frameworks aimed at promoting the peaceful use of nuclear power in all countries. Considering the spent fuel is a main part of nuclear fuel cycle, therefore the Nuclear Power Plants Authority (NPPA) is responsible for the assurance, safety, secured and stable supply of all services and materials of nuclear fuel cycle within a long term contracts. Egypt has taken the decision to adopt an open fuel cycle for the first nuclear power plant, i.e. no reprocessing of spent fuel. NPPA would develop at an early stage a conceptual plan describing all important steps leading to the final disposal of spent fuel and radioactive waste in Egypt utilizing fully the national and international experience and the capabilities of international cooperation.

1. INTRODUCTION

The management and disposal of radioactive waste from the nuclear fuel cycle is one of the most difficult problems currently facing the nuclear power industry. Today, more than forty years after the first commercial nuclear power plant entered service, no country has yet succeeded in disposing of high level nuclear waste — the longest — lived, most technologically challenging of the waste streams generated by the nuclear industry. Therefore, the Egyptian proposed strategy considered the SFM is very important area that need technical, scientific, and management support on all scales.

2. NUCLEAR FUEL SUPPLY

The methodology presents the general fuel strategy elements that depend upon:

- A strategic stockpile shall be kept in Egypt, large enough to guarantees several years for operation even in the case of interrupted supply;
- Long term contracts would be distributed among different suppliers and countries to increase and countries to increase supply reliability;
- Market development would be studied and projections made of supply, demand and prices in all areas of the nuclear fuel cycles as a continious and high priority task within the Nuclear Fuel Sector.

3. SPENT FUEL AND RADIOACTIVE WASTE

NPPA would develop and propose a plan describing all important steps leading to the long term interim storage of spent fuel and radioactive waste in Egypt utilizing fully the international experience and the possibilities of international cooperation.

The proposed strategy for spent fuel and waste management can be determined through a review of the current commercially available interim spent fuel storage technologies and the disposal strategy can be developed over a longer period based on technologies under development in several countries around the world.

3.1. Spent fuel

NPPA should develop and propose the policy and strategy covers the methodologies within the framework of cooperation with consultant and IAEA to plan, implement, and manage the spent fuel as following:

- The nuclear power plants would have the large capacity to store the production of spent fuel in wet pools;
- An intermediate retrievable storage for spent fuel should be built with a sufficient capacity to give enough time for the prudent development of an Egyptian final disposal method for spent fuel;
- The methods and sites for final disposal of spent fuel within Egypt would be developed utilizing the fact that the intermediate storage will allow for a long time period and large flexibility for this development.

3.2. Radioactive waste

Low and intermediate radioactive waste are to be stored by minimizing the space required and in a manner that will allow an easy transfer to disposal sites in the future. The safe storage of this material will provide sufficient time for the utility and the government to select and apply the most appropriate disposal approach and technology. National laws and specific agreements with the government, which are independent of changes to the owners and operator of the plant, should ensure operational stability and safety of the waste management facilities.

4. SPENT FUEL MANAGEMENT STRATEGY REQUIREMENTS

4.1. Safety and quality requirements

Spent fuel and radioactive waste management would follow the safety regulations gradually developed and set up by the Egyptian Nuclear Regulatory and Safety Body. Therefore, Safety objectives require that nuclear fuel installations are designed and operated so as to keep all sources of radiation exposure under strict technical and administrative control. The design for safety of a nuclear facility should follow the principle that plant states that could result in high radiation doses or radionuclide releases are of very low probability of occurrence, and plant states with significant probability of occurrence have only minor or no potential radiological consequences. The safety approach should ensure that the need for external intervention measures is limited or even eliminated in technical terms, although authorities, for emergency preparedness, would still require such measures.

Back end of Nuclear fuel cycle should be met the requirements of quality assurance and control program during contracting, procuring, designing, manufacturing, inspection, and testing. In addition to the control procedures should be applied on transportation, handling, and storing of fresh and spent fuel. Quality assurance codes and standards should be applied on selected sites of temporary and final storage.

4.2. Human resources development

Egypt opted for turn-key contract approach for its first nuclear power plant project. In that regard, Egypt is working in close cooperation with the IAEA and will be working with the support of the project international Consultant to ensure that business and technical expertise would be available for fuel cycle procurement and spent fuel storage management. The IAEA is also providing technical assistance in developing local expertise to conduct training programmes for construction project management and the management system, as well as in developing plans to fully staff and train the regulatory body

4.3. National position

Nuclear Law has been established by a Presidential Decree No.7 for year 2010 (Law of Regulating the Nuclear and Radioactive Activities). State' System of Accounting for & Control of Nuclear Materials (SSAC) has been established by a Presidential Decree No. 152 of 2006 and its executive Ministerial Decrees (No. 419, 420 and 421, 2006) concerning the Egyptian System of Accounting for & Control of Nuclear Materials.

Specific legislation has been established in the nuclear law to: identify responsibility for safety, security and safeguards, specify allowable ownership of NPPs and associated rights and obligations, and provide funding for NPP programme. Specific legislation has been established in the nuclear law to: identify responsibility for safety, security and management of spent fuel and radioactive waste (transportation, handling, and storage).

4.4. Research and development requirements

Nuclear fuel staff in NPPA would be aware of research and development of interested areas concerning the open nuclear fuel cycle.

4.5. Financial costs requirements:

The Nuclear fuel cycle costs include:

- Front end costs;
- Back end costs;
- SFM and storage costs.

5. ACTION PLAN

The general guidelines of this policy would be followed and implemented into working procedures, special instructions and rules. The policy should be reviewed each year, or on the initiative of the NPPA staff. Any changes proposed should be justified by the Nuclear Fuel Division.

6. CONCLUSIONS

Consideration of nuclear energy as an option for electricity generation was revived in 2006, and in October 2007 the strategic decision to start a programme to construct Nuclear Power Plants for electricity generation was taken by the President.

NPPA starts the implementation of the necessary steps to construct the first Nuclear Power Plant for electricity generation by hiring an International Consultant.

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