

# Nuclear Power and Fuel Cycle

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## ABSTRACT

Due to rising energy cost and climate concerns, nuclear power is once again being seriously considered as an energy source by several countries. This revival of nuclear power is closely linked with the choice of fuel cycles available, and the intentions of nuclear power pursuing countries are likely to be, correctly or incorrectly, judged by the choice of fuel cycle they make. The needs and constraints of the emerging nuclear powers may however be different from the expectations of a segment of the world community. If this potential growth in nuclear power is not to be stifled, it is imperative that a climate of mutual trust is developed respecting every country's right to develop peaceful uses of nuclear power without leading to an atmosphere of mistrust regarding the "intentions" behind the pursuit of peaceful nuclear power. While it will be a near impossibility to completely decouple the peaceful uses of nuclear power from its more destructive applications, it is important that aspiring countries develop a clear and transparent process. Technology supplier countries also need to develop and follow clear and consistent treaties and national policies, avoiding ad hoc country specific arrangements. We here review the state of interest in nuclear power, current policies, and discuss fuel cycle options that may pave the way for the future growth of nuclear power.

## 1. INTRODUCTION

Several countries have plans to explore the nuclear option for power or desalination purposes. These include: Egypt, GCC member countries, Indonesia, Iran, Jordan, Malaysia, Morocco, South Africa, Thailand, Turkey, etc. As much as they depend upon energy supply/demand and global warming, the prospects for peaceful use of nuclear power are closely tied to perceptions and geo-political conditions as well. To make sure that peaceful and legitimate uses of nuclear energy are not stifled inadvertently due to unnecessary restrictions, bad policies and due to decisions on the part of some governments and international agencies, it is necessary to help countries and international agencies formulate policies that are consistent with the desire to improve world security and long term potential of nuclear power.

For economic as well as political reasons, selection of fuel cycle option plays a very important role toward the development of nuclear power. A country's decision based on a desire for energy independence and national security can be very easily perceived or portrayed as an ill-intentioned move. However, it may be possible to convince the countries that are in the very early stages of a nuclear power program of the economic inefficiency of a completely indigenous fuel cycle.

Fuel cycle refers to the origin of the fuel, its final destination, and the life in between. While the utility of a closed fuel cycle, in which left over or unused fuel would be reused or recycled, was recognized early in the nuclear age, political and non-proliferation considerations led some countries to opt for an open fuel cycle. [Since re-cycling allows the possibility of diversion of bomb grade material, an open cycle is considered better from non-proliferation perspective.] However, with rising

cost of fuel and no permanent solution for storage or disposal of used fuel at hand, open fuel cycle is increasingly being questioned. United Kingdom, France and some other countries already recycle. USA has been considering a revision of its open fuel cycle policy to allow recycling which is expected to reduce pressure on waste storage sites. India, Japan and South Korea are developing their own fuel cycle options. While countries that already have nuclear power discuss and evolve fuel cycles appropriate for their needs, desire for nuclear power shown by a large number of countries that currently have no nuclear power is raising the prospect of a global nuclear fuel cycle. Tension between national aspirations on one hand and proliferation concerns on the other are likely to color the debate over any "global" fuel cycle.

In addition to the development of capabilities that will allow re-processing of used fuel, decision whether to develop capability to manufacture virgin fuel, say from yellow cake, is also loaded with economic and geo-political concerns. From availability of indigenous Uranium (or Thorium) to the number of NPPs operating, planned or in the pipeline significantly affect the economics of this end of the fuel cycle. While countries newly embarking on a nuclear power plan may decide to forgo manufacturing their own fuel, as number of NPPs grows and regional alliances are formed, they may decide to move toward national or regional fuel manufacturing capabilities.

## 2. CURRENT EFFORTS

In this regard, US National Academies and Russian Academy of Sciences have jointly commissioned a two-year study, to be completed in spring of 2008, to assess the "technical, economic, legal/regulatory, and non-proliferation criteria

necessary for the implementation of an international civilian nuclear fuel cycle.” The committee is looking at the following questions related to light water reactor fuel services to countries that may not have their own fuel processing facility [1]:

- Feasibility and effectiveness of establishing international fuel supply centers as an incentive for countries not to develop indigenous enrichment facilities.
- Advantages and disadvantages (if any) of establishing international centers for: Sending and receiving back fuel? Training personnel? Manufacturing fuel?
- Ownership question of the nuclear material and the fuel in such arrangements.
- Should the international facilities be owned by governments or could private companies own some or all of the facilities?

More important from the fuel receiving country’s point of view are the following secondary questions that are to be addressed by the committee if “time and budget permit.”

- What regulatory requirements should be in place in the receiving country to provide assurance of safety and safeguards?
- What level of technical personnel are needed, in terms of training and in terms of numbers, to provide adequate confidence that the countries receiving fuel can safely and securely operate their reactor(s)?
- What should be the role of the International Atomic Energy Agency (IAEA) in overseeing the transfer, use, and/or return of fuel?
- What changes in laws and regulations in the countries sending, consuming, and receiving spent fuel would be required to implement this concept?

A second set of questions for the committee relates to the feasibility of different fuel recycle options. These include:

- Compare the uranium recovery by extraction plus (UREX+), the plutonium and uranium recovery by extraction (PUREX) process, and other processes being considered by the Russian Federal Agency for Atomic Energy for separation of fissile and other materials from spent or irradiated nuclear fuel. Consider the resulting waste streams and what can and should be done with these waste streams.
- Compare the burn up and the number of cycles needed to reach an acceptable level of destruction of actinides in the conceptual advanced burner reactor proposed in the U.S. Global Nuclear Energy Partnership (GNEP) and in the Russian BN-600 and BN-800 reactors.
- What impact could new technologies have on these proposals?
- Compare the fuel to be produced from the processes examined in (1) for use in appropriate reactors (LWRs, High Temperature Gas Cooled Reactors, and fast

reactors). What are the advantages and disadvantages of each type of fuel?

- Compare the repository requirements for the waste produced by the processes proposed in the GNEP concept with that from a system based on PUREX and one based on Russian plans.
- Are new laws and/or regulations required for either the U.S. or the Russian approach to the internationalization of the fuel cycle? Will either approach require any existing laws or regulations to be repealed or changed?

As the questions raised in the list above (copied from the charge given to the committee) suggest, there are several fuel cycle options for the front as well as the tail end being considered. Some of these are directly relevant to countries or group of countries such as the GCC that are aspiring nuclear power. Given the technical base of most of these countries, it is very likely that introduction of nuclear power in these countries will be based on turn-key projects provided by major nuclear powers of the world. Therefore, most likely scenario for the fuel cycle for these countries will be, at least in the initial stages of their entry into the nuclear world, the open cycle. However, as the decisions are made, it is important that similar committees are formed by the nuclear-aspiring nations to address these and other relevant questions from their point of view. It will then be possible to help the decision makers to make informed decisions based on answers provided by such committees. Suggestions for a unified global nuclear policy and steps to start a new nuclear energy program are given in the next section.

### 3. PATH FORWARD

To move forward toward a relatively stable nuclear regime, immediate international focus should be on:

1. A meaningful commitment on the part of weapons states to not threaten or use nuclear weapons against non-weapons states.
2. Eliminating non-signatories of NPT by either including them in existing categories in NPT or creating new categories of countries.
3. Restrict the development of new weapons systems.
4. A serious attempt on the part of the nuclear weapons state to reduce and eventually eliminate all nuclear weapons and move toward a nuclear weapon free world.

Though until recently it seemed unlikely that the weapons states in the near future will willingly move toward a complete disarmament in any meaningful way, recent efforts by some prominent and influential players suggest that this may not be as farfetched as it appeared only a few months ago. An article in the Wall Street Journal by Shultz, Perry, Kissinger and Nunn [2] argues in favour of a nuclear weapon free world, and how such a development is likely to actually increase the safety of even the weapon-countries in the long run. Given the existence of such a movement in the United States and supported by at least some players in other nuclear weapon states, it is probably reasonable to expect that an agreement on the future of nuclear fuel cycle

may be used to further pressure the nuclear weapons states to move more aggressively toward a weapons free world in exchange for non-exercising the right to enrich and recycle by the countries aspiring to start a new nuclear power program.

Nuclear weapons states must not hamper development of peaceful uses of nuclear power simply because of geo-political considerations. Such efforts are counter productive and in fact the non-weapons states because of such measures may either take their nuclear activities underground or may even consider leaving the NPT. There are risks and benefits to an expansion of nuclear technology around the world. As perceived threat to our planet from increased CO2 emission becomes even more significant and urgent, and larger than the threat from a nuclear confrontation, a slight potential increase in likelihood of proliferation may be an acceptable price for allowing countries to develop their own fuel cycle if that is what it would take to convince them to seriously consider the nuclear option.

#### **4. STARTING NEW NUCLEAR PROGRAMS**

A single nuclear power plant in a country may be good for the prestige of the country, but as is made abundantly clear by the consolidation of nuclear power plants in the hand of a few utilities in the United States of America and in many other countries with substantial nuclear power, such units are likely to be inefficient, and moreover unlikely to make a major impact on the energy scene. Hence, in order for nuclear power to play a significant role, countries that decide to “go nuclear,” would most likely want to diversify a significant fraction of their electricity generating capacity (and possibly heating and, in the future, hydrogen production) to nuclear, possibly requiring at least few and possibly many nuclear power plants. Another option, especially for some of the smaller countries, would be to join hands and form nuclear consortia and thus build a large enough nuclear program to be economically feasible.

In order to proceed with the nuclear option, these countries would expect a certain level of long term assurance on the fuel supply. Nuclear power plants (NPP) and fuel options available to countries for their nuclear programs can be categorized as follows.

- A. Fully indigenous program with complete development of power plants and fuel cycle.
- B. Fully or partly indigenous program for power plant development; while depending on an international consortium for fuel supply and waste treatment.
- C. Rely on international consortia to build and operate all aspects of nuclear power plants (with local manpower).

A total of around fifty to seventy five countries are likely to be interested in nuclear power in the next fifty years. As they choose their options (A through C), it is likely that, with time, there will be some expectation that a country will move to higher levels (C to B and B to A). Note that under the current NPT, signatories have an “inalienable right ... to develop research, production, and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II.” Moreover, paragraph 2 of Article IV further underscores that each

NPT state-party “undertake[s] to facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy.” Fuel cycle is clearly an important part of nuclear power, and few would argue that non-weapons states do not have the right to develop their own fuel cycles. However, proliferation concerns are also real, and must be adequately addressed.

Future fuel cycles are still being debated even in countries with established nuclear power programs. It is far too early for non-nuclear states in early stages of their programs to lock in to a fuel cycle. Fuel cycles may change dramatically in years to come, and the technology is expensive. Best path for new states now considering the nuclear power option may be to simply insist on their right to have a complete indigenous fuel cycle option but not exercise it. They will have a much stronger argument for an indigenous fuel cycle once they have an established nuclear power program with few to several nuclear power plants running. On the other hand, proposals to develop fuel cycles that concentrate all fuel processing in few fuel-suppliers states and deny the technology associated with this aspect of nuclear power to the end user actually contributes to the atmosphere of mistrust and hence leads to pressure on the NPT.

#### **5. SUMMARY**

As difficult as it may be, if nuclear power is to play its useful role, technology, treaties and policies must be developed that: 1) allow nations to freely pursue the development and use of nuclear power for peaceful purposes; 2) provide disincentives to develop nuclear weapons; and, 3) establish a universal verification regime that detects a country’s move toward acquiring nuclear weapons. At the same time, countries embarking on the nuclear power path, while retaining their theoretical right, should, in the short run, not insist on exercising that right for fuel development and processing. The weapons states in return should actively move toward a nuclear weapons free world.

#### **6. REFERENCES**

- [1] GEORGE P. SHULTZ, WILLIAM J. PERRY, HENRY A. KISSINGER and SAM NUNN, Toward a Nuclear Free World, Wall Street Journal, January 15, 2008.
- [2] <http://online.wsj.com/article/SB120036422673589947.html>
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