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How will the implementation of multi-national fuel cycle models impact nonproliferation policy and the verification of compliance with safeguards commitments?

Background

Nuclear power expansion is occurring primarily in Asia. Using IAEA data, eight reactors officially began construction in 2007. Five were in Asia. Ten began in 2008, of which eight were in Asia.

Along with growing support for nuclear power using existing technology, there is growing interest in fast reactors, enrichment, and reprocessing. Examples are in two recent reports.

The 2007 Vision Report of the European Commission's Sustainable Nuclear Energy Technology Platform recommended research on partitioning, i.e., reprocessing, and on fast reactors as a path to improving "uranium and plutonium usage in LWRs."[1]

A presentation to the US National Academies, reporting on an international study, stated "Fuel re-cycling and fast neutron burning of long-lived actinides can dramatically reduce the amount and the lifetime of the nuclear waste." [2]

Interest also is seen in a recent draft bill[3] in the US Congress that provides instructions for a Commission to address nuclear waste issues:

"Recommend measures [the Commission] determines necessary or advisable to support industry efforts to develop the engineering and technical data needed to obtain a license for commercial scale, advanced, proliferation-resistant spent nuclear fuel reprocessing facility from the Nuclear Regulatory Commission."

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[1] Strategic Research Agenda, Sustainable Nuclear Energy Technology Platform, Executive Summary, 30 November 2008.
[2] Lighting the Way: Toward a Sustainable Energy Future, presentation at National Academies Summit on America's Energy Future, Washington, DC, 14 March 2008.
[3] Nuclear Waste Management, draft 1 May 2009.

These interests have lead to examining how to provide fuel assurances while maintaining an effective non-proliferation regime. A National Academies study released last year[4] focused on fuel assurance.

Dr. Lowenthal, the next speaker, was the study director. Dr.Budnitz was a member of the study committee and was principally responsible for the parts of that study relevant to my talk today.

First, I want to define some terms.

1. What is meant by "fuel cycle"? The nuclear fuel cycle includes many operations, not all potential proliferation threats.

Uranium supply: most nuclear reactors, whether research or power, use uranium for fuel. Fast reactors include the use of plutonium. Thorium also can be used and currently there is interest in Norway, Russia, and, especially, in India to use thorium. However, most of the reactors worldwide and all the new reactors in Asian countries use uranium. Although in the past concerns about the resource base for uranium led to support for breeder reactors, current estimates indicate uranium resources would support the continued growth of nuclear power for the rest of this century.

Enrichment: with the exception of the earlier Canadian CANDU reactors, the naturally occurring percentage of about 0.7 U235 must be increased to 3-4 for use in power reactors. This level of enrichment, and even a few percent higher, is not a proliferation risk. However, an enrichment facility can be used to produce HEU, with a U235 percentage of more than 90. There are three uses for such material: research and medical isotope production reactors, ship propulsion (submarines and other naval vessels and icebreakers), and nuclear weapons. Enrichment services are provided in the international market by several consortia and companies (URENCO, EURODIF, USEC, Atomenergoprom).

The US, Russia, and the IAEA have encouraged operators of research reactors to switch to LEU fuel, and many have with the US and Russia taking back the HEU fuel. Similar efforts are being made for isotope production reactors. The ship propulsion reactors are more difficult to change. The third category, use for nuclear weapons, is the primary proliferation concern. These concerns led to the fuel assurance programs that Dr. Lowenthal will discuss.

Fuel fabrication: Uranium enriched to the correct percentage can be used to fabricate nuclear fuel. Fuel fabrication services are available in the international market and can be obtained from facilities in several countries. Fuel fabrication is not a proliferation issue.

The back end: This section of the fuel cycle is less well-defined than the front-end and has the potential to be a serious proliferation risk. What happens after the used fuel[5]

[4] Internationalization of the Nuclear Fuel Cycle, National Academy Press, 2009.

is removed from the reactor has several paths: storage, reprocessing, disposal. All are controversial.

Used fuel storage:

After removal from the core and kept in a pool for thermal cooling, the fuel can be transferred to dry casks for storage. These have been judged by the US Nuclear Regulatory Commission to be safe for at least 50 years and could be repackaged if necessary. Dry cask storage is not a permanent solution but is quite acceptable as an interim solution, even if extended.

A recent international study recommended using such storage:

"Develop safe, retrievable waste management solutions based on dry cask storage as longer-term disposal options are explored. While long-term disposal in stable geological repositories is technically feasible, finding socially acceptable pathways to implement this solution remains a significant challenge."[6]

Spent fuel reprocessing: Countries operating nuclear reactors plan eventually to dispose of the waste. However, before doing so many programs aim to modify the waste to reduce the heat load on the disposal packages, reduce the time of regulatory concern, or recover more of the energy content in the used fuel. Depending on what material is removed, the heat load and the time scale of interest can be reduced significantly. Most of the proliferation concern is in the plutonium that can be obtained by reprocessing spent fuel. Currently not many countries have reprocessing facilities. Japan has recently completed a facility at great cost, estimated to be $25 B, illustrating that cost is one of the obstacles to a spread of reprocessing facilities.

Disposal: disposal in a geologic repository is the method supported by most technical studies for an end point for the fuel cycle. Finding a location acceptable to the interested and affected public has proven to be extraordinarily difficult. Finland appears to have succeeded and Sweden may have. France, the United States, Japan, and perhaps Russia have not.

Depending on what reprocessing is done, disposal may or may not be a proliferation risk. As Professor Peterson has pointed out, if direct disposal is used without reprocessing, after the early high heat load isotopes have decayed, the disposal site can be seen as a plutonium mine.

Options for handling the back end:

(1) Stop nuclear generation. This option is unlikely to be pursued worldwide and would not solve the existing problem of accumulated spent fuel and separated plutonium, the legacy of past and current reactors.

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[5] Terminology has implications. What formerly was referred to as spent fuel now is referred to as used fuel.
[6] Lighting the Way, *op cit.*

(2) Build geologic repositories for spent nuclear fuel. This option has a history of support among technical and scientific communities but strong opposition from some local publics and elected officials.
(3) Store spent fuel at plants in pools or dry casks. This is the current default solution in the United States and many other countries. It is not proposed by anyone as a permanent solution, but done by necessity.
(4) Build off-site storage facilities for spent nuclear fuel. Often discussed but not successfully implemented[7] and also is only a temporary solution (decades to perhaps a century).
(5) Reprocess to separate reusable fissile material from waste. An approach used by France, the United Kingdom, and Russia (for some fuel) and soon by Japan. Reprocessing does not solve the waste problem—a disposal repository is still required, although the waste may occupy less volume and the heat load can be reduced—but reprocessing does postpone when final disposition must be addressed. Reprocessing has fierce opposition from some technical and political groups due to proliferation concerns.

    Several alternative reprocessing methods have been proposed:
    a. PUREX, the current process used in France and Japan.
    b. COEX, a modification of PUREX to keep the plutonium with the uranium.
    c. The suite of UREX-x being developed by the United States.
    d. PUREX-TRUEX, adds extraction of some transuranic elements
    e. Pyroprocessing

Currently, the new US administration has backed off from the previous administration's program to build a commercial scale reprocessing facility but has retained an R&D program for advanced fuel cycles.

In summary, many stages in the fuel cycle pose proliferation risks.

2. What is meant by and implied by "multi-national"?

A multi-national or international center could provide many services to the international market:

Producing LEU for fuel – this would not raise proliferation concerns.
Producing HEU for research or medical isotope reactors – a proliferation concern.
Producing plutonium by reprocessing for use in MOX fuel – a proliferation concern.

From the recent Academies fuel cycle report:

[7] Germany has experienced violent protests when attempting to move waste to a storage site.

"In addition to the question of private versus government ownership, there are many potential variations on concepts for multinational or international ownership and control of fuel cycle facilities. By a multinational center, the joint committees mean a facility whose ownership and management involves an arrangement among several countries. Eurodif, Urenco, and the [Russian] International Uranium Enrichment Center at Angarsk are examples. By an international facility, the joint committees mean a facility whose ownership and management is centered in a fully international organization such as the IAEA. …CERN is arguably a fully international facility (though it could also be considered a multinational facility with a particularly large number of nations participating). There are important differences between CERN and a consortium that operates in the commercial market, but CERN provides a precedent of multinational ownership and governance.

Multinational or international fuel cycle centers might have several nonproliferation benefits…..[S]tates may have more confidence that their fuel supply is assured if they are part owners of such a center and have intergovernmental agreements in place prohibiting any political interference with deliveries. …

In addition, many argue that if enrichment and reprocessing facilities are established in the future in countries that do not have them today, the resulting proliferation risk would be lower if these facilities were owned and staffed under multinational or international auspices. If many countries owned the facility, there would be a higher—though not insuperable—political barrier to the state where the facility was located … seizing it and using it to produce nuclear weapons material. Moreover, such an approach with international staff working regularly with the host country's experts might make it more difficult for those experts to be used to establish covert facilities without any sign of such activity being detected. Furthermore, if such an international facility regime were in place and widely and successfully used, then if a country decided to begin developing and using these sensitive technologies indigenously, that country's motivation for doing so would legitimately be subject to closer scrutiny, focused on whether the real purpose was to develop a nuclear weapons option. On the other hand, approaches involving international staffing would have to be carefully structured to avoid the centers themselves contributing to proliferation of critical knowledge of how to build and operate enrichment or reprocessing facilities."

The recent Academies fuel cycle report addressed issues related to international centers:

"-- A hidden danger of creating such centers is the potential for leakage of sensitive technology. The most damaging leakage of sensitive technology occurred when A. Q. Khan, working as a contractor for Urenco, was able to acquire enough information and contacts to build the supply line for Pakistan's nuclear weapons program.

-- Safeguard arrangements, fuel transfer processes, and return of spent fuel provisions are only a few of the complex legal issues that must be resolved if fuel assurance, fuel take-back, and multinational or international fuel center programs are to be effective.

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-- States should end the accumulation of stockpiles of plutonium separated from spent fuel as soon as practicable, and begin to reduce existing stocks. Spent fuel should only be reprocessed when its constituents are needed for fuel, or when reprocessing is necessary for safety reasons.

--The international community should adopt the philosophy of designing high levels of security and safeguards into new nuclear systems and facilities from the outset."

This was a joint US-Russia study and recommended

"[T]he United States and Russia should work diligently with other nations to ensure that all efforts to establish international centers for enrichment, reprocessing, or other sensitive activities include specific, stringent plans to prevent leakage of sensitive information and technology. Plants with staff from countries that do not have technology of the type used at that plant should maintain the sensitive technology in "black boxes" so that the international staff does not have access to the technologies themselves. Plans to prevent technology leakage should be subject to review by a small group of international experts familiar with such technology controls before the centers are established."

How would a center be coordinated with NPT requirements? IAEA DG ElBaradei is a strong proponent for providing nuclear fuel if a recipient country meets IAEA safeguards criteria. More than 30 non-nuclear countries have indicated interest in going nuclear – that is, for nuclear power, not nuclear weapons. Of course, concerns are that nuclear weapons may be the real goal leading to the many efforts to provide credible fuel assurance. Unfortunately, many proposals, to be addressed by Dr. Lowenthal, do not meet what our study found to be the most important incentive – take back. The Russian proposal does.

3. To address nonproliferation policy and verification requires developing an understanding of who is doing, or suspected of doing, actions that raise proliferation concerns.

Strengthening the nuclear non-proliferation regime requires addressing the drivers of proliferation.

Proliferation drivers are (1) desire to inflict great harm to perceived enemies, (2) build national prestige, and (3) obtain military security. The first leads to terrorist actions, the second requires wide communication of successes, and the third exists in semi-public knowledge. Al Qaeda exemplifies the first, North Korea the second, and Israel the third.

To develop nuclear weapons requires knowledge of designs, a competent workforce, facilities, and, most important, either HEU or plutonium.

Blocking terrorists requires a combination of intelligence information, diplomacy, and military action. Addressing national prestige is sensitive. In the past the US has used carrots and sticks. Although not without problems, the safest method to support building national prestige in the nuclear arena is to help a country develop nuclear research and nuclear power. The problems are (1) nuclear programs can be used as a path to develop nuclear weapons. This is the concern regarding Iran. And, for the US, (2) public anti-nuclear groups and some members of Congress oppose supporting nuclear power anywhere.

To address the third driver, need for military security, the US has provided explicit and implicit nuclear umbrellas. This is extremely important since several of our Asian allies[8] have the finances and the technical capability to develop nuclear weapons in a few years if their governments concluded that were prudent.

Other than stealing or transfer from a friendly nation, the only method to obtain HEU is by enriching LEU. Similarly, obtaining plutonium requires reprocessing used reactor fuel.

Many countries previously not wanting nuclear power have indicated to the IAEA they wish to develop a nuclear power program. Non-proliferation support requires providing incentives to not build enrichment or reprocessing facilities. There now are many proposals to provide assurance of reactor fuel supplies, the front end of the fuel cycle. Missing are proposals to provide incentives for the back-end of the fuel cycle.

Conclusions

With the largest operating nuclear power fleet as well as naval reactors, the US should lead in developing incentives attractive to new nuclear power states.

Strengthening the IAEA is important. The IAEA will have many challenges with multi-national and international fuel cycle centers. International arrangements have major roles in non-proliferation, starting with the NPT requirements. The IAEA has a major role in providing guidelines for the fuel cycle facilities and in inspection to assure IAEA safeguards criteria are being met. Having host countries sign on to the Additional Protocol will be important. The lack of effective enforcement exacerbates concerns – for example, Iran, Israel, and North Korea.

[8] Germany also could do so.