Date Posted: 18-Feb-2011

Jane's Intelligence Review

Big bank theory - A new approach to nuclear fuel provision

Key Points

A number of countries are planning to launch nuclear power programmes in the next two decades, sparking concerns that weapons-related nuclear fuel cycle technologies will also spread.
To counter this, three international nuclear fuel banks are being established to diversify sources of reactor fuel.
These nuclear fuel banks will be likely to reduce the incentive for, but not fully prevent, the spread of uranium enrichment technologies.

With at least 20 countries expected to launch nuclear power programmes by 2030, there is rising concern about the proliferation risks associated with the potential spread of nuclear fuel cycle technologies. *Pavel Podvig* asks whether fuel bank initiatives can mitigate the problem.

The coming decades are likely to bear witness to the substantial growth of nuclear power generation. Heralded as a 'nuclear renaissance', a notable portion of this growth is to take place in countries which currently do not have nuclear reactors. According to an estimate by the International Atomic Energy Agency (IAEA) in September 2010, some 20 countries are expected to launch nuclear power programmes by 2030, including Indonesia, Jordan and Turkey.

However, the expansion of nuclear power is generating serious international concern that it might lead to an increase in the number of facilities that provide key weapons-related fuel cycle activities, such as uranium enrichment and plutonium separation.

In an attempt to mitigate the proliferation risks associated with the spread of these technologies, a number of recent initiatives have sought to organise fuel cycle technologies multilaterally and provide assurances of fuel supply through the creation of international nuclear fuel banks.

Designed to provide emerging nuclear energy countries with a reliable source of reactor fuel, ínuclear fuel banks are intended to eliminate the need for countries to develop indigenous fuel cycle facilities, thereby reducing the spread of uranium enrichment technologies. However, it remains to be seen whether recent nuclear fuel bank initiatives will prove a viable option for emerging nuclear powers.

Nuclear renaissance risks

According to most international projections, the new nuclear generation capacity will largely come from light-water reactors, the reactor-type that already generates almost 90 per cent of all electricity produced by nuclear power plants. These reactors require fuel comprised of low enriched uranium (LEU), which contains approximately four per cent of the uranium-235 isotope (enriched from the 0.7 per cent U-235 content generally found in natural uranium).

Although LEU cannot be used in a nuclear explosive device, the enrichment technology used to produce LEU from natural uranium poses a significant proliferation risk, as it can also be used to produce weapons-usable highly enriched uranium (HEU) when enriched to around 90 per cent U-235.

The gaseous centrifuge technology that currently dominates the enrichment industry is particularly problematic for non-proliferation efforts, as centrifuge facilities can be easily converted to HEU production. A concealed centrifuge enrichment plant would be extremely difficult to detect, especially if it were to be embedded within a country's wider civilian nuclear programme.

At present, virtually all of the world's commercial enrichment capacity is concentrated in Europe, Russia and the United States, primarily in countries that already possess a nuclear weapons capability. However, this situation is changing, with countries such as Brazil and Iran actively developing their own uranium enrichment programmes, albeit with far less capacity than that of commercial enrichment plants.

The reprocessing of spent reactor fuel is also a proliferation sensitive technology, as the íplutonium separated during the process is potentially usable in weapons. As such, reprocessing could be applied to a dedicated nuclear weapons programme, as it has been in North Korea, for example.

However, as part of the 'back end' of the ínuclear fuel cycle, reprocessing is not as urgent a proliferation risk as uranium enrichment. This is because it will take a considerable amount of time for emerging nuclear energy states to ígenerate enough spent reactor fuel to justify the implementation of indigenous reprocessing facilities.

At present, reprocessing has been deployed almost exclusively in countries that already possess nuclear weapons, with Japan the only exception. This has given the international community time to develop solutions to address the proliferation dangers associated with this technology.

Uranium enrichment poses a more immediate proliferation risk. Because of this, the international community has sought to eliminate the need for new nuclear power-producing countries to fabricate their own reactor fuel. Instead, it aims to enhance their 'energy security' through fuel supply assurances and the establishment of internationally accessible fuel cycle centres.

Emerging nuclear energy countries					
Power reactors under construction	**Contracts signed, legal and regulatory infrastructure well-developed**	**Committed plans, legal and regulatory infastructure developing**	**Well-developed plans but commitment pending**	**Developing plans**	**Discussion as serious policy**
Iran (Bushehr reactor expected to go online in 2011)	Turkey	Italy	Belarus	Bangladesh	Albania
	UAE	Jordan	Egypt	Chile	Algeria
		Vietnam	Indonesia	Israel	Azerbaijan
			Kazakhstan	Kuwait	Croatia
			Lithuania	Malaysia	Estonia
			Poland	Morocco	Kenya
			Thailand	Nigeria	Latvia
				Saudi Arabia	Libya
					Mongolia

					Namibia
					Philippines
					Qatar
					Serbia
					Singapore
					Sri Lanka
					Sudan
					Syria
					Tunisia
					Venezuela
Source: World Nuclear Association					

Evolving concept

The concept of an international fuel bank has evolved from the long-standing operation of multinationally-owned fuel cycle facilities. Two multinational uranium enrichment companies have been operating since the 1970s: the íURENCO consortium of Germany, the Netherlands and the UK; and Eurodif, which is owned and operated by the French government with some international participation. The concept was further developed by Russia when it set up an International Uranium Enrichment Centre at Angarsk in 2007, with Kazakhstan and Ukraine joining as partners. Most of the enrichment plants presently being built in the US could also be described as multinational facilities, as they are controlled by foreign companies and use technology not shared with the US.

Discussion of multinational fuel cycle arrangements generated interest in the concept of a nuclear fuel bank, which is believed to be the easiest way to assure consumer states that they can secure access to fuel for their nuclear reactors in cases of disruption of supply caused by political or other non-commercial reasons.

While offering some of the advantages of multinational arrangements, such as a guarantee of access to fuel, nuclear fuel banks are easier to implement as they can be set up by an individual country or even a non-governmental organisation.

In 2003, Mohamed ElBaradei, then IAEA director general, addressed the international community with a proposal to develop a new approach to the nuclear fuel cycle that would help prevent the proliferation of sensitive technologies while providing all countries with reliable access to the benefits of nuclear power.

The central idea of the new approach was a gradual transfer from the current model of primarily nationally owned nuclear fuel cycle facilities to a system that would be based on international control of the key technologies.

The new structure of the fuel cycle would provide all countries with reliable access to nuclear fuel for their power reactors and protect them from politically motivated disruptions of supply. This guarantee aims to prevent the spread of enrichment technology by removing the incentive for emerging nuclear countries to deploy indigenous uranium enrichment facilities.

Nuclear fuel banks at the implementation stage									
Name of initiative	**Status**	**Role of the IAEA**	**Type of fuel**	**Amount of fuel (tonnes)**	**Fuel bank supplier**	**Conditions for access**	**Price**	**Fuel fabrication**	**Location**
US Reliable Fuel Supply	Offered - (the capacity of the US nuclear complex to provide fuel upon request)	None	LEU (down-blended HEU)	290	US	Recipient country must forego the development of enrichment and reprocessing facilities	N/A	N/A	US-based, but no designated storage within the US required under this initiative
Russian fuel bank	Operational	Material under IAEA safeguards and released on request by the IAEA	LEU (enriched to between two per cent and 4.95 per cent)	120	Guaranteed reserve is created and maintained at the expense of the Russian Federation	Recipient country must be unable to obtain LEU for political reasons and be in compliance with IAEA safeguards	Based on spot market prices published by internationally acknowledged companies	LEU is supplied as uranium hexafluoride and must be transported to another site for fuel fabrication	International Uranium Enrichment Centre, Angarsk, Russian Federation
NTI/IAEA fuel bank	Proposal accepted by the IAEA in December 2010	Owned and managed by the IAEA	LEU (enriched up to 4.95 per cent)	60-80	IAEA to purchase LEU from suppliers as well as accepting donations on a voluntary basis from member states	Recipient country must be unable to obtain LEU from the commercial market or other states (determined at the discretion of the IAEA director-general) and be in compliance with IAEA safeguards	Based on spot prices averaged over a period before delivery and sufficient to cover replenishment	LEU is supplied as uranium hexafluoride and must be transported to another site for fuel fabrication	To be determined, possibly in Kazakhstan

Source: IHS Janes

Fuel bank implementation

Of the 12 fuel supply assurances and fuel bank proposals suggested by individual states and coalitions up until 2008, three have reached the stage of practical implementation: the US Reliable Fuel Supply initiative, the Russian fuel bank in Angarsk and the IAEA fuel bank supported by the Nuclear Threat Initiative (NTI), a US-based non-governmental organisation.

The Reliable Fuel Supply initiative, announced by the US government in September 2005, included a commitment to blend down approximately 17 tonnes of military-origin HEU that had been declared as excess to US national security needs. The US pledged to use the resulting 290 tonnes of LEU to provide fuel supply guarantees, but only to those countries forgoing uranium enrichment or reprocessing technologies. Unlike most other fuel bank initiatives, the material provided under the US plan remains under national (US) control and assigns no role to the IAEA in the decision about recipient eligibility or in managing the delivery.

The second fuel bank initiative that has reached the implementation stage has, like the US initiative, led to the creation of a nationally owned nuclear fuel reserve, this time under the leadership of Russia. The Russian initiative was originally part of a larger proposal made in 2007 that included the establishment of the International Uranium Enrichment Center in Angarsk, a multinational company set up to provide enrichment services to its stakeholders: currently Russia, Kazakhstan and Ukraine, with Armenia, Mongolia and South Africa looking to join. However, the fuel bank is intended to operate independently from the centre, providing access to the fuel stored at the site for all eligible countries.

In practice, the Russian fuel bank consists of around 120 tonnes of LEU stored at the International Uranium Enrichment Centre site. The Russian proposal was approved by the IAEA in November 2009 and, in March 2010, Russia and the IAEA signed an agreement to regulate the fuel bank's operation. All decisions regarding access to the Angarsk fuel bank will be made by the IAEA. In December 2010, the reserve's containers of uranium hexafluoride were placed under IAEA safeguards, allowing Russia to announce that the bank had officially begun operations.

The third proposal that has reached the íimplementation stage is the fuel bank concept promoted by the NTI. In 2006, the NTI received a contribution of USD50 million in funds from private individuals towards the creation of an IAEA-administered fuel bank. Since then, an additional USD100 million has been secured in matching contributions from various governments. The IAEA board formally approved the NTI proposal in December 2010, paving the way for the creation of the physical infrastructure of the uranium reserve. This process is likely to take several years.

According to the IAEA, the NTI fuel bank will include between 60 and 80 tonnes of LEU, enough to manufacture fuel for one complete core of a light-water reactor. In contrast with the arrangements of the US and Russian nuclear fuel banks, the material in this reserve will be owned by the IAEA. While the location of the facility is yet to be finalised, Kazakhstan has offered to host it and bear all associated costs.

Objections and limitations

Although the Russian and NTI fuel bank proposals ultimately got IAEA approval, they had to overcome objections from a number of developing countries that see fuel bank plans as an attempt to limit the right of non-nuclear weapons countries to pursue the peaceful uses of nuclear technology which is an entitlement for all members of the Nuclear Non-Proliferation Treaty (NPT).

To some extent, it was the US proposal that set the stage for debate, despite being a national initiative that did not írequire IAEA approval. The primary source of criticism was that countries must forgo the development of enrichment and reprocessing facilities as a condition of access. With this in mind, Russia and the NTI were careful to emphasise that their proposals did not include this condition, although the very design of fuel reserve arrangements assumes they help reduce the incentive for countries to pursue indigenous fuel cycle technologies and may even actively discourage them from doing so. The impact of this issue was evident when the IAEA withheld approval of the Russian fuel bank proposal when it was first brought up for consideration in June 2009, and a number of countries voted against the proposal in November 2009, when it was eventually approved by the IAEA Board of Governors.

To address concerns that fuel bank arrangements might restrict the legitimate pursuit of nuclear technology, all IAEA documents discussing the banks emphasise that these arrangements would in no way limit the ability of IAEA member countries to develop their own peaceful fuel cycle facilities.

With the IAEA having successfully completed arrangements for the Russian and NTI fuel banks, it is presently facing the more difficult task of ensuring that these reserves provide assurances of guaranteed access to nuclear fuel for countries looking to expand their nuclear programmes. In doing so, the IAEA will need to address the political challenges related to the eligibility criteria, as well as technical hurdles such as licensing and fuel fabrication arrangements.

The IAEA must also face the challenge of assessing the eligibility of countries wishing to access the Russian or NTI fuel reserves. The only formal eligibility requirement for those fuel banks with IAEA participation is that the recipient country must be in compliance with its non-proliferation obligations under the NPT. As the determination of NPT compliance is made by the IAEA based on a set of criteria agreed on in advance, this mechanism should help shield the fuel bank from undue political interference, as no donor country would be able to deny access to the bank as long as the criteria are met.

If a country is fully compliant with its non-proliferation obligations, it is unlikely to find it difficult to access enrichment services on the open market in the ordinary way, with the IAEA-approved reserves available during times of politically motivated disruption to supply.

However, in theory states might also seek to access international fuel reserves when their activity has raised non-proliferation concerns and their access to commercial sources has been denied through sanctions or other restrictions.

Past IAEA operations suggest it could take a considerable amount of time for the agency to reach a formal conclusion on the issue of safeguards compliance. Iran, for example, has been suspected of having a nuclear programme with military ambitions since at least the late 1980s, but it was not until 2003 that the IAEA was able to register its concerns about Iran's implementation of its safeguards agreement.

This pattern might repeat itself in other contentious cases, potentially putting the IAEA under pressure to base its decision on access to fuel bank resources on factors other than a country's formal compliance with its IAEA safeguards agreement. The US administration of President Barack Obama has already expressed its concerns about the narrow interpretation of the eligibility criteria in current fuel bank arrangements adopted by the IAEA, indicating that in some circumstances the US might disagree with an IAEA decision on eligibility and try to influence the outcome of a choice on whether access to the Russian or NTI fuel reserve should be granted.

Technical challenges

In addition to the political challenges to fuel bank implementation, the IAEA and stakeholder countries will also need to address some technical difficulties in the early years of operation.

For recipient countries, gaining access to an international fuel bank would be just the first step in the process of obtaining LEU fuel that can be loaded into a reactor. While fuel manufacturing services are more widely available on the open market than uranium enrichment services, it is not unusual for open market LEU suppliers also to manufacture the material into reactor fuel. This means any disruption to LEU supply would be likely to force the affected country to seek a new fuel manufacturer as well.

At present, both the Russian and NTI fuel banks supply only LEU to eligible countries, so future development of the reserves will need to consider the provision of fuel manufacturing as well as uranium enrichment services. In its resolution of approval for the NTI fuel bank, the IAEA recognised this need and indicated its readiness to work on providing reliable access to fuel manufacturing services in future.

Further complicating the matter, fuel assembly designs differ depending on the reactor type, and before operators can use fuel assemblies produced by an alternate manufacturer they must go through a testing and licensing process. To some extent, this technical challenge could be addressed by advanced planning - a number of countries have already licensed fuel from different manufacturers for use in their reactors - but it certainly does not enhance the fuel supply guarantee provided by nuclear fuel banks.

While not insurmountable, these technical challenges will probably limit the effect that the newly established fuel banks will have on countries presently evaluating their options regarding the pursuit of nuclear fuel cycle technologies.

Conclusion

While it remains too early to determine whether any of the existing fuel bank arrangements could guarantee a reliable and uninterrupted supply of reactor fuel, there is presently no urgent need for them to do so. The provision by Russia's state ínuclear corporation Rosatom of reactor fuel to Iran for use in the Bushehr power plant, expected to go online in 2011, suggests that existing ímarket mechanisms for fuel supply are relatively robust, given that the delivery was made despite a number of outstanding issues regarding íimplementation of the IAEA safeguards agreement in Iran. In this case, the provision of reactor fuel via the open market can be considered as more accessible than any IAEA-administered fuel supply initiative, as the agency would be likely to deny Iran fuel bank services should Tehran request access.

Nevertheless, given that open market provision of LEU reactor fuel relies heavily on positive relations between the supplier and recipient states, there remains a need for fuel supply guarantees to support emerging nuclear energy countries in case they encounter politically motivated or other unforeseeable disruptions of supply.

Fuel bank arrangements, particularly the Russian and NTI reserves undergoing implementation, will be likely to enhance the reliability of LEU supply, and therefore reduce the incentive for emerging nuclear energy states to develop their own uranium enrichment capabilities. íAlthough these initiatives are unlikely to fully curb the spread of enrichment technologies, they represent an important development in non-íproliferation efforts which will ultimately contribute to greater energy and global security.

Furthermore, fuel bank initiatives could ípotentially lead the nuclear industry and IAEA to develop mechanisms to reduce the dependence of nuclear power plant operators on a single supplier of enrichment and fuel manufacturing services. Such diversification could lead to even more favourable consumer conditions within the open market, which still provides the strongest guarantee of uninterrupted fuel supply, thereby ensuring that nuclear fuel banks remain a resource of last resort.

INTERNATIONAL FUEL BANKS: HOW THEY WORK

The basic concept of a nuclear fuel bank is that a certain amount of enriched uranium is set aside in an international reserve, which can then be accessed by countries in need of fuel for their power reactors - without the need for them to develop weapons-usable enrichment technologies indigenously.

Practical arrangements for access to an international fuel bank with International Atomic Energy Agency (IAEA) participation are specified in documents approved by the agency and assume that the fuel reserve will complement existing market mechanisms.

This means a country would ordinarily access the open market to obtain reactor fuel but could turn to the fuel bank if it experienced a disruption to low enriched uranium (LEU) supply. Such disruption is generally envisioned to be the result of political intervention, as opposed to technical or commercial factors such as pricing disagreements.

To qualify for assistance from an IAEA-administered fuel bank, a country must have no outstanding issues with the implementation of its safeguards agreement and be prepared to place the material it receives under safeguards as well. Once the IAEA certifies that all the conditions have been met, the material would be transferred from a physical fuel bank or donor country to IAEA custody.

The agency would then handle the transfer as a normal commercial transaction with the supplied LEU priced to reflect prevailing market conditions. As the LEU would generally be supplied in the form of uranium hexafluoride, the recipient country can arrange for the material to be manufactured into fuel assemblies appropriate for its reactor type.

The amount of material in each of the two fuel banks currently approved by the IAEA should be sufficient to fully reload the core of a light-water reactor. Given that most reactors of this class normally change a third of their core annually during refueling, in theory the Russian or NTI fuel bank could support the operation of one reactor for around three years.

Without replenishment, each of the two IAEA fuel bank initiatives could therefore provide short-term support to a relatively small nuclear power programme, although it might be possible to increase the size of the reserves.

