Nuclear renaissance

Security challenges of atomic power

Global nuclear energy production is projected to triple over the next 50 years, raising concerns about the risk of proliferation. ***Pavel Podvig*** *explores the security challenges associated with nuclear power and considers options for regulating the industry.*

KEY POINTS

- The expansion of nuclear power is likely to lead to an increase in the number of facilities that provide key weapons-related fuel cycle activities, such as uranium enrichment and plutonium separation.
- Nuclear fuel banks and supply guarantees are unlikely to contain the spread of uranium enrichment technologies.
- The risks associated with separating plutonium could be reduced by a moratorium on further civilian reprocessing and 'lease and take-back' arrangements for reactor fuel.

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More than 30 countries are currently considering establishing their own nuclear power programmes. The growing popularity of nuclear power could be likened to a 'nuclear renaissance', as concerns about climate change, increasing energy demands and the desire to secure energy supplies and break dependencies on fossil fuels continues to drive nuclear power up the policy agenda.

While nuclear power may present some countries with a viable alternative for energy production, the spread of nuclear technology, material and expertise may pose a new range of challenges to the already stretched non-proliferation regime. Indicative of these concerns, in a speech at the UN General Assembly in New York on 23 September, United States President Barack Obama stated that the nuclear non-proliferation treaty (NPT) says "all nations have the right to peaceful nuclear energy" but also warned that "the threat of proliferation is growing in scope and complexity".

Despite the risks, the potential contribution of nuclear power is gaining recognition. According to the US Energy Information Administration's *International energy outlook 2009*, the demand for electricity is set to grow by about 77 per cent by 2030. Nuclear power is seen by many countries as a favourable option for meeting this demand because of its relatively low operating costs and reduced carbon emissions. In their book, *Nuclear power and climate change*, Robert Socolow and Alex Glaser estimate that lifecycle emissions per kilowatt-hour generated by a nuclear power plant are about 20 times lower than those generated by burning coal. The nuclear industry has managed to significantly improve the efficiency of plant operations since the first wave of expansion in the 1970s and 1980s and has demonstrated a commitment to safety that has led the industry to recover its reputation following the Three Mile Island and Chernobyl incidents (in 1979 and 1986 respectively). Despite these advances, it is not yet clear whether the nuclear industry will be able to garner sufficient public support to proceed with planned expansions. The industry will, in all likelihood, continue to be highly capital intensive and the possibility remains that a single serious safety incident might negatively affect the entire industry. Furthermore, there is still no widely accepted long-term solution for nuclear waste management and disposal.

Unlike other sources of energy, nuclear power is intrinsically linked to technologies that can be used to obtain material for nuclear weapons. The expansion of nuclear power is likely to lead to sensitive technologies and expertise proliferating, with potentially serious security implications. To a large extent this process has already begun, putting a noticeable strain on the current nuclear non-proliferation regime maintained by the International Atomic Energy Agency (IAEA).

Sensitive technologies

The impact of nuclear power on the international security environment is likely to be determined by two key developments: a shift in the pattern of nuclear reactor deployment to non-Western countries and technological advances that will allow more countries to develop their own nuclear fuel cycle technologies.

These trends are already visible. Most of the projected new reactor construction will concentrate in the Asian region, particularly in China, India and South Korea. The list of countries that do not have nuclear power but have expressed an interested in acquiring it includes more than a dozen countries, ranging from Turkey to Nigeria and the United Arab Emirates to Venezuela. From a technological and economic perspective, for the next several decades the nuclear industry is likely to continue to be dominated by a small number of established suppliers based in Western Europe, North America, Russia and Japan. However, this has not prevented other countries, such as India, Brazil and Iran, from pursuing their own nuclear technologies, even if they are unable to compete on the international market.

The two nuclear fuel cycle technologies that are of particular proliferation concern are uranium enrichment and the separation of plutonium in the chemical reprocessing of spent fuel. Uranium enrichment is a necessary component of the fuel cycle of light water reactors, which use fuel with uranium enriched to between 3.5 and five per cent U235 (from approximately 0.7 per cent U235 in natural uranium ore). The key security problem posed by uranium enrichment is that almost all enrichment facilities have the potential to be configured easily to produce weapons-grade uranium (enriched to at least 90 per cent U235). The amount of separative work (the separation done by an enrichment process) required to supply one reactor with fuel for one year, would also be sufficient to produce enough material for more than 10 nuclear weapons.

Chemical reprocessing of spent reactor fuel also poses a significant security risk, as it involves handling large quantities of separated weapons-usable plutonium. The primary proliferation concern is that the enrichment or reprocessing technologies and facilities that are developed to support the operation of nuclear power plants can also be used to produce fissile material for weapons. A country with access to these technologies would essentially possess a latent nuclear capability, with some countries likely to consider this an important benefit of their nuclear power programme. As illustrated by Iran, the issue of intent in developing a nuclear energy capability can become a source of serious international tension.

Until recently, the proliferation risks associated with the nuclear fuel cycle have been largely contained by the fact that most commercial facilities have been concentrated in recognised nuclear weapon states (US, Russia, UK, France and China) or their close allies. Sensitive technologies such as uranium enrichment and nuclear reprocessing have also been largely under the control of nuclear weapon states, which are able to use their status to offer a range of nuclear services, including providing reactors. The present concentration of commercial fuel cycle facilities in a limited number of countries has also placed fewer demands on IAEA resources, since the NPT does not normally require safeguards in NPT-recognised nuclear weapons states.

The existing pattern of nuclear fuel cycle facility deployment is unlikely to hold in the short to medium term, as the planned expansion of nuclear power will almost certainly be followed by fuel cycle facilities and technologies spreading. Brazil has already built an enrichment plant in Resende to support its nuclear power reactors, while South Korea has been actively pursuing reprocessing technologies to deal with its spent fuel. Countries with significant natural uranium resources are attracted by the commercial opportunities of uranium enrichment, as in the case of Canada and Australia, which have been discussing the possibility of a greater role in enriching the uranium they supply to the world market.

Enrichment risk management

The security risks and uncertainties associated with the spread of fuel cycle technologies have been widely acknowledged, although finding ways to address these issues have proved difficult.

Various countries have developed several policy proposals, most of which are directed at the front end of the nuclear fuel cycle (uranium mining, enrichment and fuel fabrication), with a particular focus on centrifuge enrichment technology, which has emerged as a major proliferation concern. Other elements of the fuel cycle, such as reprocessing, are also considered, especially in the context of waste disposal or advanced breeder reactors.

Strictly speaking, increased demand in enrichment services does not have to lead to an increase in the number of enrichment facilities. The leading existing providers, Urenco, Areva and Tenex, would most certainly be able to scale up their operations to meet any increase in demand. Still, in order to protect their investment and secure the supply of reactor fuel, it is likely that small national enrichment facilities would also be sought by new nuclear power countries, even if they were unable to compete with the large providers. Although any serious disruption of nuclear fuel supply is largely a hypothetical scenario, countries as wide-ranging as the US and Iran are building uranium enrichment facilities on their territories, at least in part because they need to achieve independence from foreign suppliers. Countries are generally reluctant to accept limits on the kind of technology they can develop (evident in the cases of Brazil, India and South Korea), with non-nuclear weapon countries in particular often viewing such limits an infringement of their right to peaceful nuclear technologies guaranteed by the NPT.

> 'The spread of nuclear technology, material and expertise may challenge the already stretched non-proliferation regime'

Purported solutions

As new legal restrictions on the spread of enrichment technology have met resistance from non-nuclear weapon countries, most proposals that try to address the proliferation risks associated with the expansion of nuclear energy are based on policies that would provide countries with certain guarantees of access to fuel cycle technologies and voluntary arrangements to establish tighter control over sensitive technologies.

The US administration of former president George W Bush sought to combine these two approaches by advocating a Global Nuclear Energy Partnership (GNEP) for "the safe, secure and peaceful use of nuclear energy while reducing the risk of nuclear proliferation". Announced by the US Department of Energy in 2006, the GNEP proposed dividing countries into supplier "fuel cycle states", which would enrich uranium into reactor fuel and take back spent fuel, and "nuclear reactor states", which would forgo fuel cycle technologies in exchange for guaranteed access to the service.

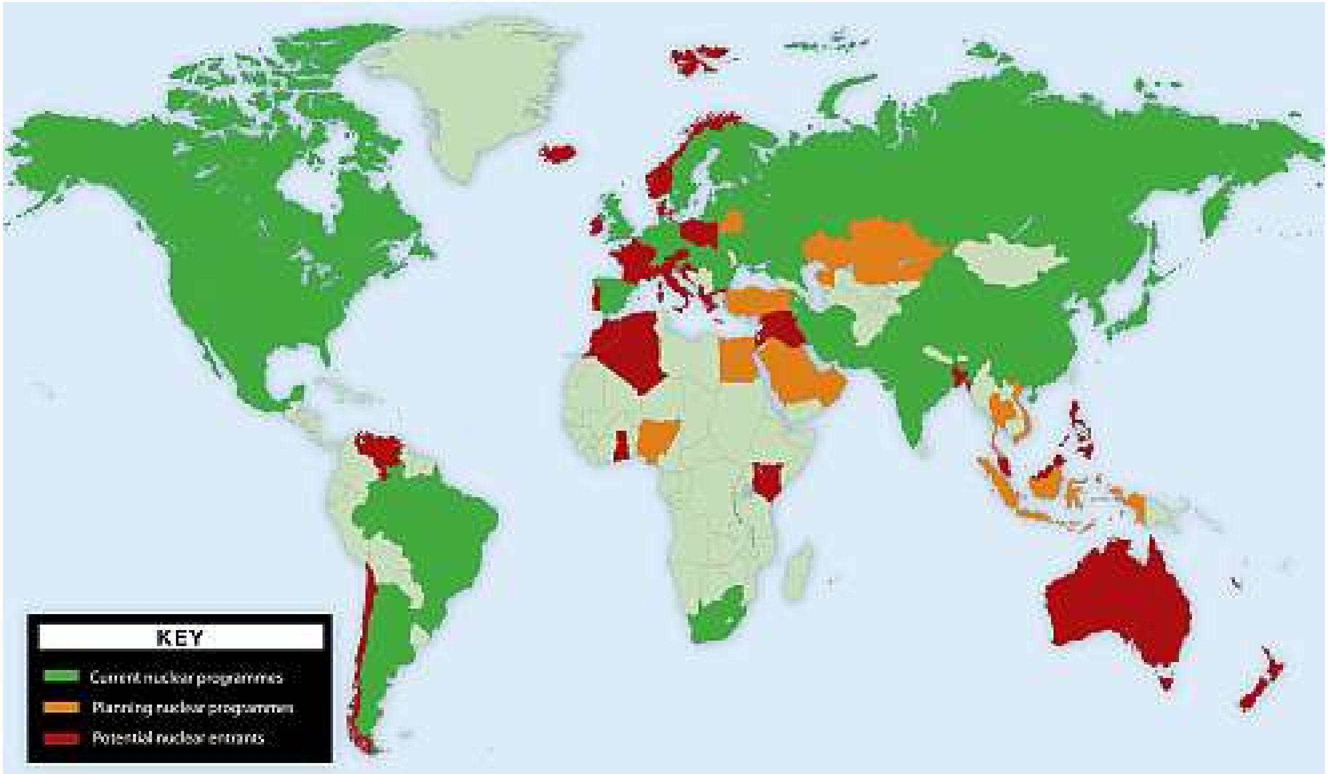
The basic principle of the GNEP was embraced by the 25 countries that signed its statement of principles, reflecting a willingness to accept restrictions on fuel cycle technologies in exchange for nuclear power. Yet, the programme failed to generate wider support and most of its elements were discontinued as it became clear that the new division into fuel-cycle and nuclear-reactor states was unlikely to be universally accepted – precisely because the division reinforces the inequality of nuclear 'haves' and 'have-nots' implicit in the NPT.

Another approach that has received significant attention in recent years calls for a mechanism to guarantee supply of nuclear reactor fuel to be established, either as a physical fuel bank or as binding or contractual obligations. These mechanisms would be used to sustain the operation of nuclear reactors if a country were faced with a politically motivated interruption in fuel deliveries.

Some concrete steps towards realising these proposals have already been made: the US committed 17 tonnes of highly enriched uranium (HEU) in September 2005 and Russia committed 120 tonnes of low-enriched uranium (LEU) in June 2007 towards stand-by reserves. Similarly, the Nuclear Threat Initiative (NTI), a US-based non-governmental organisation, collected more than USD150 million in private and governmental contributions towards establishing a fuel bank under IAEA control. A number of countries that supply reactor fuel have proposed legal and contractual arrangements that would ensure uninterrupted access to enrichment services, such as enrichment bonds.

However, these proposals were met with a great deal of scepticism by potential consumer states in the developing world, which expressed little interest in participating in these arrangements. In June 2009, opposition from a group of developing countries led the IAEA board to delay approving the fuel bank project initiated by NTI. In addition, all fuel bank arrangements would need to address issues of physical control over the material, available production capacity and fuel fabrication and licensing, all of which would seriously complicate their implementation and in most cases render the arrangements impractical. While creating a fuel reserve would probably serve as a stabilising factor for the uranium enrichment and reactor fuel markets, it appears that its existence is unlikely to help contain the spread of enrichment facilities because of the general impracticality of fuel bank arrangements.

Yet another set of proposals aimed at preventing sensitive technologies proliferation suggests fuel cycle facilities should be placed under in-



Wayne Sudbury/IHS Janes/1333912

Map showing countries with current, planned and potential nuclear capability. The expansion of nuclear power programmes around the world poses challenges for the nuclear non-proliferation regime as technology on uranium enrichment and plutonium separation becomes more widespread.

ternational control. It is usually assumed during such discussions that customer countries would have a stake in ownership and management of a multinational facility, which would ensure reliable access to its services. However, because they would not have access to the technology, operation of the facility would be proliferation-resistant.

The concept of multinational fuel cycle facilities has been around for some time, with several arrangements of this kind already in existence. The Urenco consortium, founded in 1971, provides one example, with shares held by the UK government, the Dutch government and German utilities. Eurodif, created in 1973, also reflects this model with the French operator sharing ownership with Italy, Spain, Belgium and Iran. The most recent example of a multinational fuel bank is the International Uranium Enrichment Center (IUEC) in Angarsk, in Russia's Irkutsk province, incorporated in September 2007 and operated by Russia with Kazakhstan and Armenia (and potentially Ukraine) as shareholders.

The experience of such existing multinational enterprises suggests that, although they can often provide countries with an attractive option for participating in enrichment activities, they may not prevent individual countries from pursuing their own enrichment programmes. For example, Iran refused to accept Russia's offer to participate in an arrangement that would provide it with access to the output of Russian enrichment facilities. One way of addressing this problem is to require all fuel-cycle facilities to be converted to multinational ownership and control. This approach would offer a degree of guaranteed access to the services, but more importantly would provide a basis for greater openness and transparency and would add a layer of contractual obligations to existing non-proliferation commitments.

In practice, converting fuel-cycle facilities into multinational enterprises would be a difficult task. If the multinational requirement were applied universally, nuclear weapons countries would have to lead the charge by opening their facilities to international participation and control while providing strong political leadership. Otherwise, owners and operators would have few incentives to participate in multinational arrangements, especially if they would involve greater transparency and additional safeguards. There is currently no mechanism that could provide the legal framework for operating these facilities or enforce the multinational requirement.

Plutonium proliferation

The back end of the fuel cycle, which involves managing and reprocessing spent fuel, also poses a serious proliferation risk. All power reactors currently in operation discharge spent fuel, which can be reprocessed to produce plutonium, a key fissile component of nuclear weapons.

Nuclear power reactors currently in operation worldwide produce approximately 75 tonnes of plutonium annually, although most of the plutonium remains a component of spent reactor fuel and is not separated for further use. The chemical process used to separate plutonium from spent reactor fuel was originally invented to produce plutonium for nuclear weapons programmes, but has now been adopted by commercial reprocessing facilities.

While spent fuel reprocessing is by no means a simple technology, it is a well-known chemical process that does not present as many technical challenges as the technology involved in uranium enrichment.

The greater accessibility of spent fuel reprocessing technology compared to that of uranium enrichment is evident in North Korea's nuclear programme, which has so far relied on chemical reprocessing to extract plutonium for its nuclear weapons, having not yet achieved a uranium enrichment capability.

Reprocessing spent fuel does not have to be a part of the civilian (as opposed to military) fuel cycle. A number of countries, including the

US, have chosen to maintain an 'open' or 'once-through' civilian fuel cycle in which spent fuel is not reprocessed but disposed of upon removal from a reactor. In contrast, a 'closed' fuel cycle uses the appreciable quantities of fissile material contained in spent fuel; plutonium is separated from spent fuel through reprocessing and blended with uranium to create mixed oxide (MOX) fuel suitable for light-water reactors.

Despite the proliferation risks posed by including plutonium in civilian energy programmes, a number of countries argue that the plutonium contained in spent fuel is a valuable source of energy that should be recovered. The World Nuclear Association says on its website: "A single recycle of plutonium in the form of MOX fuel increases the energy derived from the original uranium by some 12 per cent, and if the uranium is also recycled this becomes approximately 22 per cent (based on light water reactor fuel with burn-up of 45 GWd/tU)."

MOX fuel is widely used across Europe and comprises a portion of the fuel used in more than 30 reactors, with Japan planning to employ the technology in the near future. While MOX fuel technology provides a useful means of converting surplus military plutonium into usable energy, so far the economics of nuclear reprocessing in a closed civilian fuel cycle for use in light-water or breeder reactors appears unfavourable. If used in light-water reactors, the cost of plutonium-based fuel cannot compete with that of uranium-based fuels.

Another option on the horizon, which would offer a truly closed fuel cycle, is usingplutonium-based fuel in breeder reactors. Currently under development, breeder reactors generate more fissile material than they consume, potentially creating a self-sustainable fuel cycle. However, there are no commercial plutonium breeder reactors in current operation and even if the technology is matured, it would take at least several decades for breeder reactors to be deployed on a large scale.

The supply of separated civilian plutonium has far outpaced demand, resulting in an accumulation of more than 250 tonnes of the material worldwide, while global military stockpiles are estimated by *Jane's* to include another 250 tonnes of plutonium. Nevertheless, a number of countries maintain active civilian reprocessing programmes, including France, India, Japan, Russia and the UK.

It is conceivable that newly emerging nuclear energy countries might choose to use nuclear reprocessing as part of a spent fuel management strategy or even reuse plutonium for further reactor fuel. It is also likely that some of these countries will look to acquire reprocessing technology as a step towards achieving a virtual or actual nuclear weapons capability. Stocks of separated plutonium present another security threat given the risk that insurgent or other violent groups might obtain such material.

Reducing the plutonium risk

Managing the security risks at the back end of the fuel cycle presents a serious challenge. In contrast to the situation at the front end, there are currently no established strategies or plans of action that can address the demand for spent fuel management services.

In most cases, countries that operate reactors own the spent fuel they produce and therefore have considerable freedom in strategies for its disposal. Most countries are reluctant to accept spent fuel from other countries, which seriously complicates efforts to develop workable multinational arrangements.

To a certain degree, the risks associated with reprocessing can be managed by instituting a norm that would require suppliers of fresh reactor fuel to take back the irradiated spent fuel removed from the reactor.

These 'lease and take-back' arrangements were in place between the Soviet Union and its allies. The Soviet Union assumed full responsibility for all elements of the fuel cycle by supplying fuel for nuclear reactors and taking back spent fuel for reprocessing and storage. Russia generally continues to honour these arrangements and in 2003 reached a similar agreement with Iran, having pledged to take back the spent fuel from Iran's Bushehr reactor. Russia appears to be the only country that has expressed a readiness to accept irradiated fuel, and this policy remains highly controversial with the Russian public.

A more successful option, at least over the next several decades, might be to suspend all civilian plutonium separation activities; most military reprocessing has stopped already. Even if the closed fuel cycle could efficiently and safely reuse plutonium in breeder reactors, enough separated plutonium already exists to initiate breeder reactor operations. A moratorium on nuclear reprocessing would give the international community time to devise measures to help mitigate the risks associated with reprocessing. Meanwhile, spent fuel generated by reactors could be placed in interim storage where it would be available for either further reuse or disposal in future.

CONCLUSION

While it is difficult to foresee all consequences of a major expansion of nuclear power, the 'nuclear renaissance' will almost certainly increase the number of countries with access to weapons-related nuclear technologies.

The combination of measures that helped to contain the proliferation risks associated with nuclear power so far – concentration of nuclear facilities in a small number of countries and restrictions on transfers of sensitive technologies – will be less effective as the industry expands. Although the NPT regime will continue to provide a valuable legal and institutional framework for the international nuclear order, this framework may not be well suited for containing the kind of latent nuclear capability that nuclear energy generation often entails. The IAEA will certainly face serious safeguarding challenges in dealing with new technologies and the increased size of the nuclear complex.

There is therefore a strong possibility that nuclear energy could give rise to further proliferation over the next few decades, with countries such as Iran, Venezuela, Saudi Arabia, Syria, Egypt, Myanmar and South Korea currently the most likely proliferants. It is impossible to gauge how many countries will go nuclear, as it depends not only on intent but also the reactions of the international and regional communities. Moreover, preventing countries with full nuclear fuel cycles or autonomous nuclear power industries from transferring the technology to military means is a process fraught with difficulty, as demonstrated by the example of North Korea.

Some of the proliferation risks associated with the growth of nuclear power can be minimised in the short term by strengthening the NPT, improving safeguard and detection technologies and promoting universal acceptance of the IAEA Additional Protocol, a voluntary and more stringent safeguards regime, all of which would enhance the IAEA's ability to detect undeclared nuclear activities. Promoting multinational arrangements in enrichment and a moratorium on reprocessing could also help deal with some of the immediate dangers.

However, in the longer term, managing the risks associated with nuclear power is likely to necessitate serious changes to the international security environment. This will require strong leadership on the part of nuclear weapon countries in promoting new institutional arrangements and co-operation from all countries in accepting principles of universal transparency and accountability, factors that cannot be guaranteed given the political difficulties in implementing them. ■