The Advanced Nuclear Fuel Cycle System in Korea
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In Focus

Nuclear Renaissance and Its Nonproliferation Implications

Recently, a great interest in nuclear energy has been renewed around the world; many countries, both industrialized and developing, believe that nuclear power is the most reliable energy source capable of meeting their increasing energy demands for the future. They are also confident that nuclear energy can be used in the future, safely and economically, with the certainty of long-term supply and without adverse environmental impacts. For these reasons, numerous countries, particularly those in Asia, are considering or have already decided to introduce nuclear energy to their energy mix, while countries with established programs are seeking to expand their generating capacity. With 30 new reactors under construction and over 200 reactors planned or proposed, there is no doubt that a nuclear “renaissance” will soon materialize.

Such a nuclear “renaissance” or revival, however, will surely be accompanied by the question of nuclear proliferation, namely, that of how we can prevent the proliferation of nuclear material and technology. Nuclear weapons have been preceded by civilian nuclear power; the issue of nuclear proliferation has been prominent in discussions on nuclear power since its earliest days. The recent surge of enthusiasm toward nuclear energy certainly has not reduced its magnitude.

In this issue of *The Nuclearancy*, two energy experts, Steve Kidd and Sharon Squassoni, discuss the nonproliferation implications of this recently emerged nuclear renaissance. Steve Kidd is the Director of Strategy and Research at the World Nuclear Association, the international association for nuclear energy based in London, and Sharon Squassoni is a senior associate in the Nonproliferation Program at the Carnegie Endowment for International Peace, a private, nonprofit research organization based in Washington, D.C. Please note that the views of both these individuals do not necessarily represent those of the Korea Atomic Energy Research Institute (KAERI).

NUCLEAR PROLIFERATION: A Barrier to New Build?

Written by Steve Kidd

For

With all the attention in the media being granted to North Korea’s nuclear tests and Iran’s alleged intention to pursue a nuclear weapons program, a fear has emerged that nuclear proliferation may cast a shadow over the recently emerged nuclear renaissance. Critics allege that nuclear energy and nuclear bombs are merely two sides of the same coin. This is because nuclear material could conceivably be diverted from a civil nuclear power program to the production of nuclear weapons.

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PROLIFERATION RISKS: Realities of Nuclear Revival

Written by Sharon Squassoni

Against

“Energy,” to quote John Turner of the US National Renewable Energy Laboratory, “is as important to modern society as food and water. Securing our energy future is critical for the viability of our society. Time is the essence and money and energy are in short supply.” Clearly, choices need to be made among energy sources, and obviously, no two energy sources are equal across all states. Some are cheaper but dirtier; others require natural resources, which, if not available domestically, must be

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Alternatively, major fuel cycle processes could be employed to produce weapons rather than fuel for civil reactors. A related concern pertains to the security of civil nuclear facilities, a concern that has multiplied since the 9/11 terrorist attacks in New York City. The possibility of aircrafts similarly crashing into such plants has been raised, as has that of terrorist incursions into plants to either acquire material for weapons or misuse the facility to trigger an explosion or a major radioactive release.

The entire 50-yr. history of civil nuclear power contains nothing to suggest that the risks are other than very remote.

Such security issues have been addressed through the implementation of specific measures, for example, the deployment of additional armed personnel at facilities to prevent incursions. Moreover, new nuclear plants will be designed keeping in mind the possibility of an aircraft impact. Although such events are clearly not impossible, the entire 50-year history of civil nuclear power contains nothing to suggest that the risks are other than very remote. Little can be done apart from what has been accomplished already, and the risks involved should certainly not be allowed to determine future actions. To view things in perspective, consider the following: Should the new Wembley Stadium not be licensed to accommodate 80,000 football fans simply because a direct aircraft strike during a game could conceivably kill thousands?

The proliferation of nuclear material and technology misuse is clearly a more substantive risk, particularly since it will likely involve sovereign states with greater resources than those available to terrorist organizations. The critics of nuclear power emphasize that designing a nuclear bomb is not particularly difficult. This, in itself, does not create a great risk, provided that neither the necessary plutonium nor highly enriched uranium is available by diversion from civil uses or production at a local facility. It is therefore necessary for the anti-nuclear forces to also focus on the alleged weaknesses in the international nuclear safeguards regime, stories of illicit material trafficking, alleged weaknesses in security with regard to the transportation of nuclear material, and the possible spread of enrichment and reprocessing technologies to countries that may be interested in using them beyond the sphere of normal civil use. Probably the greatest weakness of the anti-nuclear forces' case is that "it hasn't happened yet," despite the considerably slack arrangements that were in place in the past as compared to the present. While there is no room for complacency and the further strengthening of arrangements is fully warranted, the real risks are, in reality, as remote as those associated with the security for nuclear facilities.

Over the past 35 years, the IAEA safeguards system under the NPT has been a conspicuous international success in terms of curbing the diversion of civil uranium for military uses.

This has involved the International Atomic Energy Agency (IAEA) promoting cooperation among states for developing nuclear energy while ensuring that civil uranium and plutonium and the associated plants are used only for peaceful purposes and do not contribute in any way to the proliferation of the nuclear weapons programs. In 1995, the Nuclear Non-proliferation Treaty (NPT) was extended indefinitely. Its scope is also being widened to include undeclared nuclear activities.

Most countries have renounced nuclear weapons, recognizing that the possession of such weapons would threaten rather than enhance their national security. They have, therefore, embraced the NPT as a public commitment to use nuclear material and technology for peaceful purposes only. The NPT's main objectives are as follows: stop the proliferation of nuclear weapons, ensure security for the non-nuclear-weapon states that have relinquished the nuclear option, encourage international cooperation for peaceful uses of nuclear energy, and pursue negotiations in good faith toward nuclear disarmament with the aim of eventually eliminating all nuclear weapons. It is clearly the last objective toward which the least progress has been made, since the five nuclear-weapon states (China, France, Russia, the UK, and the US) have arguably failed to keep to their side of the bargain, as is evident from the current slow progress toward disarmament.

The IAEA undertakes regular inspections of civil nuclear facilities to verify the accuracy of the documentation supplied to it. Specifically, the agency examines inventories and conducts sampling and analyses of materials. The safeguards are designed to increase the risk of early detection in order to deter the diversion of nuclear material. These safeguards are complemented by the implementation of controls through voluntary bodies such as the Nuclear Suppliers Group (NSG) on the export of sensitive technology from countries such as the UK and the US.

The signatories to the NPT have agreed to accept the technical safeguard measures applied by the IAEA. These require that the operators of nuclear facilities maintain and declare detailed accounting records of all movements and transactions involving nuclear material. Over 550 facilities and several hundred other locations are subject to regular inspection and the auditing of their records and nuclear material. In addition, the IAEA's inspections are complemented by other measures such as the installation of surveillance cameras and instrumentation at such facilities.

The aim of the traditional IAEA safeguards is to deter the diversion of nuclear material from peaceful uses by maximizing the risk of early detection. At a broader level, these safeguards provide assurance to the international community that countries are honoring their treaty commitments to use their nuclear material and facilities exclusively for peaceful purposes. In this regard, the safeguards are beneficial to both the international community and individual states that recognize that it is in their own interest to demonstrate compliance with these commitments. All the NPT non-nuclear-weapon states must accept these full-scope safeguards. In the five nuclear-weapon states plus the non-NPT states (namely, India, Pakistan, and Israel), facility-specific safeguards are applied. IAEA inspectors regularly visit these facilities to verify the completeness and accuracy of their records.

Neither can the terms of the NPT be enforced by the IAEA alone nor can nations be forced to sign the treaty. In reality, as seen in the cases of Iran and North Korea, the safeguards should be backed by diplomatic, political, and economic measures. Moreover, the situations in these two countries illustrate both the strengths and weaknesses of the existing international safeguards. For example, while accepting the safeguards at its declared facilities, Iran has allegedly set up equipment elsewhere in an attempt to enrich uranium to weapons grade. On the other hand, North Korea used research reactors (not commercial electricity-generating reactors) and a reprocessing plant to produce some weapons-grade plutonium. The weakness of the NPT regime lies in the fact that these cases did not involve any obvious diversion of nuclear material. The uranium used as fuel probably came from indigenous sources, and the countries themselves built the nuclear facilities concerned without declaring them or placing them under the safeguards arrangements.

In 1993, a program was initiated to strengthen and extend the classical safeguards system, and a model protocol was approved by the IAEA Board of Governors in 1997. The measures boosted the IAEA's ability to detect undeclared nuclear activities, including those that appear to have no connection to the civil fuel cycle. The so-called Additional Protocol enables the IAEA to obtain considerably more information on nuclear and nuclear-related activities including information on the related R&D, production of uranium and thorium (regardless of whether it is traded), and nuclear-related imports and exports. Inspectors also have greater rights of access to any suspect location. Visits can be paid at short notice (that is, only a two-hour notice period is required), and the IAEA can deploy environmental sampling and remote monitoring techniques to detect illicit activities. As of mid-2006, 76 countries and Taiwan had implemented the IAEA's Additional Protocol, and a further 38 had approved and signed it.

The greatest risk of nuclear weapons proliferation has traditionally rested with the countries that have not joined the NPT while conducting significant unsafeguarded nuclear activities. India, Pakistan, and Israel fall in this category. Although safeguards are applied to some of their activities, others remain beyond scrutiny.

An additional concern is that countries may develop various sensitive nuclear fuel cycle facilities and research reactors under the full scope of the safeguards and subsequently opt out of the NPT.

This suggests that this is a good time to introduce some type of intrinsic proliferation resistance in the fuel cycle itself. There are a number of ideas, which were floated many years ago, that have been recalled and revamped. One key principle is that the assurance of nonproliferation must be linked with the assurance of supply and services within the nuclear fuel cycle to any country embracing nuclear power. The Global Nuclear Energy Partnership (GNEP) program announced by the US and the complementary initiatives discussed by Russia and the IAEA might guarantee the supply of nuclear fuel and services for bona fide uses, thereby eliminating the incentive for countries to develop indigenous fuel cycle capabilities. One concept involves the creation of new multinational, and possibly regional, fuel cycle facilities for the enrichment, reprocessing, and used fuel management processes based on joint ownership. Another concept involves the establishment of measures to reinforce the existing commercial market mechanisms of long-term fuel supply contracts, possibly through fuel leasing and the take-back of used fuel by the original supplier, thus obviating the need for fuel cycle facilities in most countries. Yet, this concept clearly involves a risk of dividing the world into "good guys and bad guys" in a politically discriminatory manner.

One stimulus for rejiggering the old rules may be the new arrangements on nuclear trade that the US is in the process of finalizing with India, which was stalled for many years owing to the latter's nuclear weapons program. There remain substantial challenges in implementing this strategy, particularly with regard to the NSG arrangements. However, definitive action needs to be taken, since categorizing the second most populous nation in the world as a "nuclear outlaw" was never helpful; moreover, it hardened India's stance.

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imported; still others are renewable but may be costly to install; and others await technology development.

At present, there appear to be two major drivers in assessing energy sources for electricity—global climate change and energy security. In this context, the enthusiasm for nuclear power has risen dramatically in the last few years. For many reasons, the revival of nuclear energy on the scale necessary to mitigate global climate change in the critical timeframe is unlikely.[1] Nonetheless, several elements of the current nuclear euphoria may shape nuclear power expansion in ways that magnify the risks of nuclear proliferation.

These elements include the expansion of nuclear expertise in many more countries, particularly in politically volatile regions; increased pressure on the International Atomic Energy Agency (IAEA) safeguards system, particularly if enrichment and reprocessing capabilities expand to additional countries; and a renewed interest in reprocessing capabilities and plutonium-fueled reactors, all within the context of a heightened sensitivity to the discriminatory nature of the international system for regulating nuclear trade.

In some respects, the current proliferation crises of Iran and North Korea are a sideshow to the potential development of latent nuclear weapon capabilities in a much wider range of nations. The international system for regulating nuclear trade that has evolved over time to minimize the inherent risks of proliferation—the Nuclear Non-proliferation Treaty (NPT); the IAEA, which implements safeguards to ensure that nuclear energy is used for peaceful purposes; the Nuclear Suppliers Group (NSG); and the UN Security Council resolutions—is imperfect, but efforts continue to strengthen it.

Yet, efforts to promote nuclear power threaten to outpace those to manage it. Last year, the US and Russia embarked on an initiative to promote nuclear energy worldwide. The US has lifted many of its own previous restrictions on technology cooperation and transfer, including those within and outside the NPT, and France appears to be deploying a new kind of “nuclear diplomacy” in the Middle East. All this has resulted in a record number of countries, where no nuclear power reactors are currently installed, expressing interest in developing nuclear power.

Risk Assessments

A defining feature of nuclear energy in contrast to other energy sources is the risk that fissile material, equipment, facilities, and expertise can be misused for the purpose of developing weapons. The only question is regarding where to draw the line to mitigate the risk. Although all reactors—production, research, and power reactors—produce fissile material that could be used in weapons, there tends to be greater concern about uranium enrichment and spent fuel reprocessing because these separation processes can result in weapons-usable material without radiation barriers. Regardless of the views on the efficacy of international safeguards, no one disagrees that nuclear energy carries an inherent risk of a weapons “breakout” capability in the case that a state withdraws from the NPT. If a country already possesses enrichment and reprocessing capabilities or its weapons-usable fissile material has already been stockpiled, the time required to produce a bomb reduces significantly.

Geography

Since 2005, more than 20 states that do not currently possess nuclear power generating facilities have expressed interest in installing them, and over half of these states belong to the Middle East. Some of these countries are oil- and gas-rich, but are looking to hedge their energy bets; others appear to be making a national statement about their capabilities. Few states in the Middle East need to worry about their carbon dioxide emissions from a global warming perspective or about potential taxes levied upon emissions. The current encouraging climate for nuclear energy—evidenced by new cooperation agreements between Algeria and Libya, France and the United Arab Emirates (UAE), and between the US and Jordan, Turkey, and potentially Bahrain—suggests that some states in the Middle East will develop nuclear energy even if a nuclear renaissance does not materialize. These states will acquire the nuclear expertise that they are currently lacking.

Will some new nuclear states raise proliferation concerns by virtue of their geographic location, the existence of terrorist groups on their soil, or other sources of political instability? Some might argue that profitability will steer reactor vendors toward safer investments, but it may be difficult to argue that “new nuclear states” that have newly implemented all the recommendations for safety, physical protection, and regulatory infrastructure should be avoided. It will take time, however, for some states to develop nuclear safety and security cultures. However, regional dynamics may lead the neighbors of such countries as Egypt, Indonesia, Jordan, Malaysia, Morocco, Nigeria, Vietnam, and the Gulf Cooperation Council (GCC) countries to worry about and respond to the possibility that these countries will develop nuclear weapons. Leaving aside the question of whether new nuclear reactors in the Middle East would result in new enrichment or reprocessing plants in that region, it is clear that the proliferation potential of a country with no nuclear expertise is lower than that of a country that possesses nuclear power and its associated infrastructure.

Of course, a critical implication of the doubling or tripling of the number of reactors would be its impact on uranium enrichment. If all projected plans for power reactors by 2030 are realized, production of twice the present amount of enriched uranium would be required. Where will all that uranium be enriched? Although since 2004, the US has proposed that no new countries should develop enrichment and reprocessing facilities, this policy appears to be failing. From the G-8 moratorium to the potential adoption of essential criteria by the NSG, efforts to limit enrichment to the current technology holders are on the verge of failing. Some countries may foreswear capabilities publicly as a way to build trust in their intentions. For example, the UAE's recent statement on nuclear energy is a positive step, but it is not clear whether all the other states in the region will follow suit. Until now, the GCC has been considering an enrichment facility outside the region, partly as an incentive for Iran to give up its national enrichment program. What this GCC proposal will lead to if Iran continues on its path toward achieving a commercial enrichment capability is uncertain. Should the NSG adopt the draft criteria currently under consideration, states might have incentives to not foreswear such capabilities.

The Nonproliferation Regime

There are several different risks implicit in the recent surge of enthusiasm for the nonproliferation regime. The first risk is that managing the nuclear supply of reactors, enrichment, and possibly reprocessing projects will heighten existing frustrations about discrimination in the regime. One concern is a natural outcome of market forces. Should the demand for reactors exceed the nuclear industry's capability to supply them, vendors may focus on the more advanced states, leaving expectations in other states unmet. Further, frustration about discrimination could have ripple effects in the NPT fora, possibly including reluctance to provide the IAEA with the resources it requires, or slower implementation of the safeguards-strengthening measures outlined in the 1997 Model Additional Protocol. Alternatively, new suppliers such as China and India could step in to meet the increased demand for reactors. A short-term implication may be lower quality of components.② A longer term implication could be India and other countries' export of more pressurized heavy water reactors, which many consider to be less proliferation-resistant than light water reactors.

Another facet to this general concern is the impact of recent proposals to limit enrichment and reprocessing capabilities. In part, the US approach to clamp down on enrichment and reprocessing has been widely perceived as an additional effort to discriminate between the "haves" and "have-nots" within the NPT. The prospect of being refused the opportunity to acquire certain capabilities in the future has sparked interest to obtain enrichment capabilities in countries where, to a large extent, there was no interest before. These countries include Canada, South Africa, Ukraine, and, at times, Australia. (Ukraine is seeking cooperation with foreign partners "to obtain the full cycle of enrichment and production of nuclear fuel" to counter uncertain gas supplies from Russia.) Additional capacity in these states may not be a cause for alarm, but it will make it increasingly difficult to justify why other states should not develop such capabilities.

Since 2004, the NSG has discussed criteria restricting enrichment and reprocessing transfers, which the Bush administration reportedly objected to because it would not entail the complete restriction of transfers to non-technology holders. Yet, the May 2008 NSG plenary could adopt more detailed criteria for sensitive nuclear transfers, which could make it easier for some states to present their nonproliferation criteria in support of indigenous enrichment or reprocessing. This raises the question of whether the new criteria actually improve the prospects for the successful restriction of such technology transfers or whether the current policy is best left untouched. After all, the NSG members have, to a large extent, not transferred sensitive nuclear technology since the late 1970s. The Iranian and North Korean enrichment technology acquisitions came from Pakistan—a non-party to the NPT and NSG.

A second risk is the potential strain on the IAEA safeguards system. Additional facilities will imply additional safeguarding efforts by the IAEA inspectors. Although relatively fewer days are required for conducting inspections at reactors, there is significant work in terms of helping to prepare new nuclear states for nuclear power programs. The IAEA has already conducted workshops on infrastructure requirements, including energy needs and planning considerations; nuclear security and safeguards; physical infrastructure; current and future reactor technology; experience in developing nuclear programs; human resource requirements; and public perceptions. States must also develop their state systems of accounting and control (SSAC). For states that may consider regional approaches to nuclear energy, including integrating electricity grids, there is additional work to be done.

A nuclear expansion that yields more states with bulk-handling facilities (i.e., enrichment and reprocessing) could also place significant strain on the IAEA and the safeguards system. Some critics of the IAEA suggest that the current methods of inspection cannot provide timely warnings on the diversion of a significant quantity of special nuclear material. Yet, at present, the largest enrichment and reprocessing plants under safeguards are under the European Atomic Energy Community (EURATOM) safeguards; the IAEA's role in verifying material balances in these plants is limited by the IAEA-EURATOM agreement. The only country with experience in safeguarding commercial-scale enrichment and reprocessing plants outside EURATOM in a non-nuclear-weapon state is Japan, where incidents with significant material losses have raised questions.

US Policies

The US announced the Global Nuclear Energy Partnership (GNEP) program in 2006, partly to make nuclear power "safe" for all states. The domestic component of the GNEP involves the "advanced recycling" of spent fuel, which overturns the 1970s-era US policy of discouraging the use of plutonium in the civil nuclear fuel cycle. The international component of the GNEP envisions a consortium of nations with advanced nuclear technology that would provide fuel services and reactors to countries that "agree to refrain from fuel-cycle activities" such as enrichment and reprocessing. This is essentially a fuel leasing approach, wherein the supplier accepts responsibility for the final disposition of the spent fuel. It is not clear if or how states would agree to refrain from fuel cycle activities, but the two components of the GNEP together send a mixed message that recycling is valuable for some states but not for others.

A nuclear renaissance that embraces reprocessing as necessary to reduce spent fuel accumulation could result in more plutonium in transit, providing more potential targets for diversion. A renaissance that includes the widespread installation of fast reactors would similarly increase targets for diversion. Yet, there are few assurances thus far that new techniques for spent fuel "conditioning" are any more proliferation-resistant than PUREX. As opponents like to point out, no future fuel conditioning technique in the US will be more proliferation-resistant than storing spent fuel. Moreover, while most countries are probably interested in having someone else to solve the problems of the storage of spent fuel or high-level waste, at present, no commercial reprocessing service will store high-level waste. None of the countries from among France, Russia, and the US have committed to taking back spent fuel under the GNEP.

Finally, the July 2005 agreement between India and the US to engage in civilian nuclear cooperation will have far-reaching implications for the nuclear nonproliferation regime, particularly if the peaceful nuclear cooperation agreement is approved as is, and the NSG considers India as an exception to its rules without conditions. The so-called 123 agreement now permits, in principle, the Indian reprocessing of US spent fuel and cooperation with regard to sensitive nuclear technology (i.e., enrichment and reprocessing). Countries other than India raise the question of why the US cannot make exceptions for other states—particularly those in good standing as the NPT members—as well as suggest a relaxation in the rules of nuclear commerce.

Summary

It is unlikely that the current enthusiasm for nuclear energy—stemming from concerns about global climate change and energy security—will result in the kind of nuclear expansion that some envision. Yet, the widespread acceptability of nuclear energy may imply that growth occurs in more developing, rather than developed nations, within the context of difficulties faced in reigning in sensitive nuclear technologies.

The proliferation risks clearly depend on the form taken by nuclear expansion. Essentially, more light water reactors pose no new technical challenges to the safeguards system, but additional enrichment or reprocessing capabilities in non-nuclear-weapon states could easily strain the system. A shift to fast reactors with reprocessing will likely introduce further strains on the nuclear nonproliferation regime. The provision of "cradle to grave" fuel services, as foreseen by the GNEP, could go a long way toward limiting the spread of sensitive fuel-cycle technologies; however, unless the US, Russia, and other nations take bold decisions to shoulder the burden of storing or reprocessing foreign spent fuel, the GNEP could have exactly the opposite effect, thereby dramatically increasing the risks of proliferation.

More importantly, planned technological developments threaten to outpace nonproliferation initiatives, including fuel supply assurances, multinational fuel-cycle centers, voluntary export guidelines, and further restrictions within the NSG. Moreover, in the efforts to manage the expansion of the front- and back-end fuel cycles, formal restraints have been abandoned in favor of incentives. However, it will take some time before we know how compelling these incentives are.

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[1] *Sharon Squassoni, Testimony before House Select Committee on Energy Independence and Global Warming, "Nuclear Power in a Warming Climate: Solution or Illusion?" March 12, 2008. Available at http://www.carnegieendowment.org/files/3-12-08_squassoni_testimony1.pdf*

[2] *"Utilities Fret as Reactor-Parts Suppliers Shrink," Wall Street Journal, April 11, 2008.*

Research Notes

Spent Fuel Management with Pyroprocessing: Is It the Way to Go?

Nuclear power generation inevitably produces significant quantities of spent fuel. At the end of 2006, the total amount of spent fuel accumulated in the world was approximately 270,000 MtHM and is increasing by about 12,000 MtHM every year. Considering the fact that nuclear energy is currently drawing considerable attention as an alternative energy source to fossil fuels—worldwide, there are currently 439 nuclear power plants operating in 30 countries and 39 new reactors under construction, while 90 more reactors are planned and 218 proposed (http://www.world-nuclaer.org)—there is no doubt that these numbers will surge.

The effective management of this spent fuel certainly imposes a heavy burden on mankind; the manner in which this spent fuel is dealt with will definitely decide the future role of nuclear energy in the world energy mix. Against this backdrop, many countries, particularly those with active nuclear power programs, have been exploring the possibility of recycling their accumulated spent fuel. According to reports, countries with nuclear capacities over 20 GWe, such as the US, France, Japan, and Russia, as well as countries that are expected to exceed 20 GWe in their nuclear capacity by 2020, such as China and India, are considering recycling their spent fuel. The only exception is Germany, wherein additional nuclear power plants will not be built after all the existing plants have been phased out.

As introduced in the previous issue of *The Nuclearancy*, the Korea Atomic Energy Research Institute (KAERI) is also developing a strategy for implementing an SFR fuel cycle with pyroprocessing, through which spent PWR fuel can be reused in the SFRs. However, it should be noted that this initiative is the outcome of the efforts of the KAERI in its capacity as a nuclear research institute and not the result of the Korean government's decision to adopt a spent fuel recycling approach. To verify this strategy being developed by the KAERI, Kun Jai Lee, a professor in the Nuclear Engineering Department at the Korea Advanced Institute of Science and Technology (KAIST), has conducted a feasibility analysis, the excerpts of which are provided in this issue of *The Nuclearancy*.

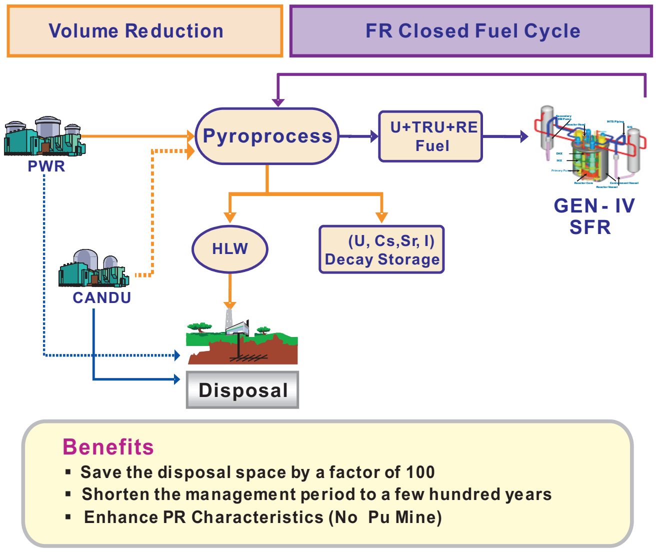

Fig 1. SFR Fuel Cycle with Pyroprocessing

Country	No. of Nuclear Reactors	Capacity (MWe)	Policy
US	104	99,049	Direct Disposal → Recycling (?)
France	59	63,473	Recycling
Japan	55	47,577	Recycling
Russia	31	21,743	Recycling
Germany	17	20,339	Direct Disposal
Korea	20	17,533	Wait and See
China	11	8,587	Recycling
India	17	3,779	Recycling

🟥 Countries with nuclear capacities over 20 Gwe
🟩 Countries that are expected to exceed 20 GWe in nuclear capacity by 2020

Table 1. Waste Management for Spent Fuel

Spent Fuel Management with Pyroprocessing

“ The Advantages of
the Pyroprocessing Option from
the Perspective
of Waste Management ”

Written by Kun Jai Lee

1. Introduction: Direct Disposal vs. Recycling

The options for managing spent fuel are generally regarded as twofold: direct disposal and the recycling of the spent fuel. The former considers spent fuel to be a waste, while the latter, a valuable resource. The decision regarding which option to adopt depends on various factors including the national energy policy, economics, environmental effects, public acceptance as well as issues related to international politics, such as nonproliferation.

In this study, the two options for managing spent fuel were evaluated with respect to the two vital elements that determine the sustainability of nuclear power generation: resource utilization and waste management. In the process, the study conducted analyses on the disposable quantities of spent fuel, the decay heat and radiotoxicity, and the natural uranium savings from recycling the spent fuel.

The first option entails the storage of the spent PWR fuel in an interim facility before being permanently discarded. The second option of the SFR fuel cycle with pyroprocessing entails the conversion of the spent PWR fuel into a metal fuel and recycling it into the SFRs, while the uranium separated from the spent PWR fuel is stored in order to be reused in the SFRs and/or CANDU reactors. The spent SFR fuel is again pyroprocessed and recycled into the SFRs, while the Cs and Sr contained in the high-level radioactive waste (HLW) are managed separately until they become low-level radioactive waste (LLW).

2. Assumption: Electricity Generation Scenario

Every two years, the Korean government announces a Basic Plan of Electricity Supply and Demand (BPE) that stipulates electricity policy directions with respect to the long-term outlook on supply and demand, the construction plan, the Demand Side Management (DSM), and so on.

According to the third BPE that covers the years 2006–2020, the average growth rate of the national electricity generation is expected to be 2.5% per annum during this period (3,531 TWh in 2006→4,786 TWh in 2020). However, the industry is expected to evolve gradually into a low electricity-consuming segment and the annual average growth rate is expected to be approximately 1% after 2013. Meanwhile, nuclear power generation is expected to constitute 43.4% of the total energy supply in 2020.

Since the third BPE only covers up to 2020, the study made several assumptions in order to chart Korea’s nuclear power generation till the year 2100; this study assumed the average growth rate of the total electricity generation to follow the third BPE until 2020, increase by 0.84%/yr in 2021–2050, and decrease gradually after 2051 until the growth rate reaches 0% in 2100. The nuclear electricity generation is calculated to be 350 TWh in 2100, on the basis of these assumptions.

3. Management of the Disposable Spent Fuel

On the basis of the above scenario regarding long-term electricity generation, the study first assessed the two options for spent fuel management with respect to the quantity of the PWR spent fuel that is generated and discarded. As shown in Figure 1, the once-through cycle is expected to generate approximately 70,000 tHM of the PWR spent fuel by 2100. In order to discard this quantity of spent fuel, approximately 14 km^2 of stable bedrock is required. Considering the geography of Korea, it is nearly impossible to find and secure a place possessing the requisite storage capacity.

In the SFR fuel cycle with pyroprocessing, most of the PWR spent fuel is reused in the cycle. Moreover, Cs and Sr, which generate most of the heat in the spent fuel, are removed and managed separately. Therefore, although HLW is produced in this cycle when the spent fuel is treated, the size of the final repository required is considerably less than that required in the once-through cycle.

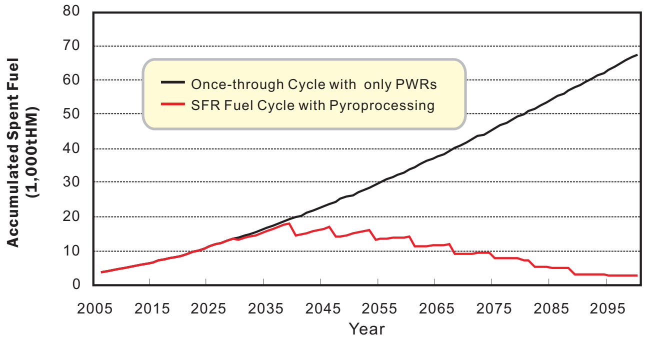

Fig 1. Management of the Disposable Spent Fuel

4. Natural Uranium Savings from Recycling of the Spent Fuel

Although nuclear energy is more technology-intensive in comparison with other fossil fuels, it still needs uranium to produce electricity, which is also a scarce resource. Consequently, the uranium resource utilization plays an important role in evaluating nuclear fuel cycles; the quantity of uranium needed for power generation affects the sustainability of nuclear power.

In this study, the uranium resource utilization with respect to the two options for spent fuel management were evaluated in the following ways: 1) the recycling value of the spent fuel accumulated in Korea by the end of 2007 and 2) the monetary value of the natural uranium that Korea needs to import in order to support the nuclear generation.

Assuming that 97% of the nuclear material in the PWR spent fuel can be burned in the SFRs, the total quantity, which stood at 4,328 MtHM by the end of 2007, can be operated in 20 SFRs with 1,000 MWe for about 150 years. This is equivalent to 73 billion dollars that Korea needs to spend on importing natural uranium in order to actualize the same amount of nuclear generation in the PWR once-through cycle.❶

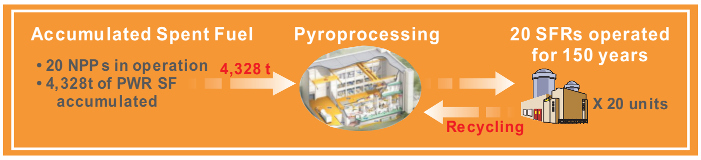

Fig 2. Recycling Value of Spent Fuel in Korea

5. Decay Heat of the Spent Fuel

The decay heat of the spent fuel is also an important factor that determines the size of the final repository. It is known that if Cs and Sr, which generate most of the heat in the spent fuel and actinides, are removed, the final repository will be rendered considerably more effective. Roald A. Wigeland et al. established that the potential repository drift loading increase as a function of the separation efficiency of the spent fuel. The result showed that the repository is 225 times more effective when 99.9% of Cs and Sr are removed and 99.9% of Pu and minor actinides (MA) are transmuted.❷

In this study, the composition and decay heat of the spent fuel with 50 GWd/tHM and 4.3% of U-235 were calculated using the Origen Code. The study then compared these values with those in cases wherein 99.9 % of the actinides are separated and transmuted and 99.9% of Cs and Sr are separately managed.

(Unit: W/tHM)

Cooling (Year)		30	50	100	1,000
Actinides	U	0.1	0.1	0.1	0.1
	Pu	224.7	196.8	144.3	34.1
	MA	229.5	203.8	170.2	40.0
	Total	454.4	400.7	314.7	74.3
Fission Products	Cs/Sr	722.7	452.2	140.1	0.0
	Total	740.3	455.9	140.2	0.0
Total Decay Heat		1,194.7	856.7	454.9	74.3
Pu/MA 99% of Removal Cs/Sr 99% of Removal	Decay Heat of (Cs+Sr+Pu+MA)	1,165.1	844.2	450.1	73.4
	Ratio (Decay Heat of (Cs+Sr+Pu+MA) /Total Decay Heat)	97.53%	98.55%	98.93%	98.74%
	Decrease in Decay Heat	1/40	1/69	1/94	1/79
Pu/MA 99.9% of Removal Cs/Sr 99.9% of Removal	Decay Heat of (Cs+Sr+Pu+MA)	1,175.7	851.9	454.2	74.1
	Ratio (Decay Heat of (Cs+Sr+Pu+MA) /Total Decay Heat)	98.41%	99.44%	99.83%	99.64%
	Decrease in Decay Heat	1/63	1/180	1/596	1/275

Table 1. Decay Heat of the Spent Fuel

Nuclear Energy in Korea

The Republic of Korea (ROK, Korea) is an energy resource-poor country. It is not endowed with significant fossil fuel reserves such as oil and gas. However, the country's energy consumption has steadily grown, owing largely to its rapid demographic and economic growth. This has rendered Korea exceedingly dependent on foreign energy resources, which predictably instigated two disastrous oil crises in the country in the 1970s.

Having undergone several hardships during the crises, Korea considers nuclear power to be the most reliable energy source capable of meeting the increasing energy requirements for its economic development. Consequently, Korea has chosen nuclear power as one of its major sources of energy for the future.

Since the first commercial operation of the Kori Unit 1 in 1978, the nuclear energy program in Korea has steadily expanded. As of April 2008, a total of 20 nuclear power units are in operation. Their generating capacity is about 17,700 MWe, which constitutes about 36 percent of the total production of electricity in Korea. According to the third Basic Plan of Electricity Supply and Demand (BPE) in Korea, announced by the Ministry of Commerce, Industry, and Energy (MOICE) in 2006, 8 new nuclear power units will be constructed by 2020, taking the total number of units to 28. Their total generating capacity will be increased to 27,320 MWe, which will account for about 43 percent of the total production of electricity.

However, such an active nuclear energy program in any country inevitably results in the production of significant quantities of spent fuel. By the end of 2007, the spent fuel generated in Korea amounted to about 9,500 MtHM, which is expected to increase to about 27,000 MtHM by 2030. At present, it is stored in temporary storage pools at plant sites, while a portion of the CANDU spent fuel is dry-stored in concrete canisters. All the storage pools currently in operation are expected to reach their full capacity in the near future.

While the Korean government has adopted a "wait and see" attitude toward the management of spent fuel, the Korea Atomic Energy Research Institute (KAERI) has been developing a strategy for implementing an SFR fuel cycle with pyroprocessing and conducting vigorous research activities to support the initiative. In this SFR fuel cycle, the spent PWR fuel is converted into a metal fuel and recycled back into the SFRs, while the uranium removed from the spent PWR fuel is reused in SFRs and/or CANDU reactors. The spent SFR fuel is pyroprocessed and recycled again into the SFRs, while the Cs- and Sr-containing high-level radioactive wastes (HLW) are managed separately.

As shown in Table 1, the decay heat of the spent fuel decreases 1/60~1/600 when 99.9% of the actinides and 99.9% of Cs and Sr are separated and removed. Consequently, the size of the final repository is significantly reduced.

6. Time Required for Radioactive Waste Management

In order to evaluate the time required for waste management, the long-term radiotoxicity of the disposable spent fuel was calculated and compared with that of natural uranium, since it indicates the time required to reduce the level of radiotoxicity of the spent fuel to that of natural uranium. As shown as in Figure 3, it takes approximately 300,000 years for the level of the radiotoxicity of the spent fuel to decrease to that of natural uranium in the once-through cycle, after it is directly discarded. In the SFR fuel cycle with pyroprocessing, the time is substantially reduced to approximately 300 years.

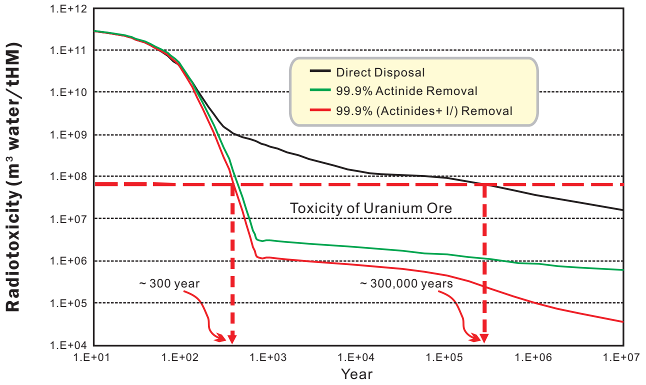

Fig 3. Radiotoxicity of the Spent Fuel

7. Long-term Safety of the Underground Repository

The total radiotoxicity of the disposal waste is widely used as an indirect indicator for the long-term stability of an underground repository. Table 2 shows the results of the radiotoxicity of the spent fuel with respect to the two options for spent fuel management: direct disposal and recycling. In order to compute the radiotoxicity, the spent fuel was assumed to be 50,000 MWd/tU and 4.3 U-235 of the initial enrichment.

As shown in Table 2, the radiotoxicity of the spent fuel is reduced by 1/43~1/247 when 99.9% of actinides are removed and by 1/170~1/360 when I-129 and Tc-99 are removed.

Cooling (Year)	10	700	1,000	10,000	100,000	1,000,000
Direct Disposal of Spent Fuel	5.36E+12	1.29E+10	9.48E+09	2.46E+09	1.76E+09	6.65E+08
99.9% of Actinides Removal	5.30E+12	4.23E+07	3.84E+07	3.05E+07	2.37E+07	1.54E+07
Decrease in Radiotoxicity	1	1/306	1/247	1/81	1/74	1/43
99.9% of Actinides and I/Tc Removal	5.30E+12	2.64E+07	2.25E+07	1.47E+07	8.42E+06	1.83E+06
Decrease in Radiotoxicity	1	1/490	1/421	1/168	1/210	1/364

Table 2. Radiotoxicity of the Spent Fuel

8. Conclusion

According to this analysis, the SFR fuel cycle with pyroprocessing entails certain advantages in regard to the perspective of both resource utilization and waste generation. While it saves Korea 73 billion dollars against the import of uranium resources, the SFR fuel cycle with pyroprocessing reduces the quantity of the disposable spent fuel, by recycling it to fast reactors and minimizing the decay heat and radiotoxicity, thus reducing the time required in the management of the final repository and maximizing the repository utilization.

From the perspective of Korea, which lacks natural resources and space for a final repository, these are particularly important elements that should be taken into consideration when evaluating the competitiveness of the nuclear fuel cycle. Consequently, the SFR fuel cycle with pyroprocessing is expected to be beneficial to Korea.

[1] *160tU$_{nat}$/(reactor x year) x 20 reactors x 153 \$/kgU* x 1,000kg/t X 150 years = \$73B, * Spot market price as of June 3, 2008.*

[2] *Roald A. Wigeland, et al., "Separations and Transmutation Criteria to Improve Utilization of a Geologic Repository," Nuclear Technology, 154, 1, 2006.*

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/ Continued from page 01

To summarize, although much remains to be achieved to strengthen the nonproliferation arrangements, progress is slowly being made. The possible diversion of fissile material for illicit purposes is likely to emerge as an issue whenever any new nuclear build program is proposed, although the risks are, in reality, low and tolerable. It is unclear why building numerous nuclear power plants will markedly increase any of these risks, particularly if they are built in countries that already have well-established nuclear facilities. The number of new countries likely to build nuclear plants by 2020 is, in any case, quite small, and they will be expected to embrace the best international practices. To provide a parallel example, the small risks involved in international air transportation do not prevent passengers from cheerfully travelling by flight, since the risks are considered to be low and well-managed. Nuclear power must be viewed in the same light.

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The Decommissioning Project of KRR-1 & 2

Written by Seung-kook Park and Un-soo Chung

1. Introduction

The term "decommissioning" refers to the isolation and permanent removal of a nuclear facility that has lost its utility value, in order to maintain the safety of the surrounding environment. Thus, decommissioning could ensure that a nuclear facility that has been dismantled does not release radioactive or contaminated materials. In Korea, as in other developed countries, a user of such a facility is legally responsible for decommissioning a nuclear facility that has closed down. Consequently, the Division of Decommissioning Technology Development at the Korea Atomic Energy Research Institute (KAERI) has advanced the decommissioning project for Korea Research Reactors (KRR)-1 & 2 in Seoul. The aim of this project is to eliminate the contaminated and activated materials from the structures, components, and the equipment at the facility and safely manage the dismantled waste. The next aim is to enable the unrestricted use of the sites and the buildings at these facilities for other general purposes.

2. The Decommissioning Project

The operations at KRR-1 & 2 were permanently phased out in 1995, the decommissioning project begun in 1997, and its completion envisioned at the end of 2008. The estimated governmental budget for this project is USD 19.7 million, which includes the expenses related to the development of technology. The KAERI submitted a decommissioning plan and environmental impact assessment reports to the Korean Ministry of Science and Technology (MOST) for obtaining a license in December 1998, which was approved in November 2000. The approved clearance level of waste treatment for this project was fixed at 0.4 Bq/g (or Bq/cm^2) for β-γ emitters and 0.04 Bq/g (or Bq/cm^2) for α emitters. The individual annual target level of dosage for the project was established at 15 mSv/yr. The external and internal levels of dosage are being maintained in accordance with the concept of as low as reasonably achievable (ALARA).

The project has four phases that have been planned according to the characteristics of each facility; the four facilities are the KRR-2 radio isotope production facility (RIPF), KRR-2 reactor and its hall, KRR-1 RIPF, and the KRR-1 reactor and yard facilities. The KRR-2 RIPF comprises 12 laboratories, 10 lead hot cells, and 2 concrete hot cells. Most of the objects being decommissioned, such as the experimental tables, sink, and fume hood, were removed using hands-on tools. However, the hot cells were removed and dismantled using hydraulic and electric power equipments.

The second object, the KRR-2 reactor and its components—the core, tubes, and rotary specimen rack (RSR)—as well as the internal structures in the reactor pool were cut and removed by means of remote-controlled devices that can be operated underwater. The core structure of KRR-2 was also dismantled, cut into small pieces, and packed into a shielded waste cask underwater. The RSR, which was installed in the ring-shaped reactor core, was separated and transferred to the experimental pool of KRR-1 in order to dismantle it by means of a remote-controlled cutting machine, developed by the KAERI for removing highly activated metal objects. The highly radioactive parts of the pipes were separated underwater and the less active parts were extracted from the water and cut into small pieces in a temporary shielding apparatus.

The dismantling of KRR-2's bio-shielding concrete commenced in May 2005 and was completed at the end of November 2005. Since all the facilities embedded in the concrete, such as the thermal columns and beam port tubes, were highly activated, they were dismantled before the main cutting procedure for the bio-shielding concrete was performed. The graphite blocks located near the core were removed from the thermal columns as they were considerably more activated than expected. A remotely operated gripping tool was developed and used to extract the graphite blocks. Since the stainless steel pipes of the beam ports and their surrounding concrete were highly activated by neutrons, a hydraulic drilling machine was used to remove them.

The first step involved the characterization of the bio-shielding concrete to determine its exact shape and size and the second step, the measurement of its physical properties such as its density. Finally, a matrix sampling was conducted on the surface and along the depth of the concrete, in order to obtain information on the radiological condition. The surface radioactivity was mapped on the basis of the measured radioactivity of the samples, which was extended to three-dimensional diagrams with respect to the general trend of radioactivity along the depth. The sequence in which the equipment would be cut and dismantled was determined on the basis of the results of the pre-works and the characterization procedure. Furthermore, the cutting lines were delineated with respect to the capabilities of the handling devices, e.g., the existing crane and fork lift, accessibility to a diamond wire cutting saw and transportation vehicles, and the margins for the separation of an activated part from a nonradioactive part.

After removing all the nonradioactive parts of the concrete, a green house constructed using plastic sheets was installed to cover all the activated parts and a hydraulic jackhammer and crusher were used to dismantle the activated concrete. Yard facilities such as solid waste storage, several liquid waste collection tanks, a liquid waste treatment facility, an evaporation facility, and three stacks outside the ventilation duct were all decontaminated and decommissioned.

As per the demands of the senior scholars in the field of nuclear science in Korea, it has been decided that the KRR-1 reactor will be converted to a monument to commemorate Korea's first nuclear reactor.

3. Conclusion

By the end of 2007, a total of 2,280 tons of dismantled waste had been generated. All dismantled materials were classified into three categories: noncontaminated material, radioactive material below the clearance level, and radioactive material above the clearance level. The noncontaminated waste was discarded in a similar manner to the normal industrial waste. Till date, 1,561.6 tons of concrete have been removed for industrial reuse such as the construction of road pavements. The rest of the concrete, temporarily stored on-site, will be discarded after the permission to do so is granted, which depends on achieving the individual and collective dosage targets of 10μSv/yr and 1man-Sv/yr, respectively, by means of a scenario assessment. The radioactive waste amounting to 306.5 tons was placed in 4 m^3 containers or 200-liter drums for temporary storage in the KRR-2 reactor hall. These containers will be transported to the national low- and intermediate-level radioactive waste (LILW) storage facility in Gyeongju, scheduled to open in 2009. This radioactive waste, which constitutes only 13.44% of the total waste, is the result of secondary decontamination activities and the volume reduction system.

In conjunction with the implementation of this project, several technologies concerning decommissioning have been developed and employed. The steps involved in the decommissioning project were as follows: the planning for the decommissioning; environmental impact assessment; development of a radiation protection program, related systems and procedures, decontamination methodologies, and cutting technologies; classification and treatment of radioactive waste; the application of a project management system using a database system called DECOMMIS (Decommissioning Information System); and the restoration of the site and buildings. It is expected that such knowledge and technologies are indispensable to future decommissioning activities of nuclear facilities and ultimately, for the effective functioning of nuclear power generation plants.

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Calendar

2008

AUG 18~20

4th Annual Nuclear Energy Nonproliferation in East Asia
Busan, South Korea
Organized by High Level Waste Disposal Research Division
Contact : Yong-soo Hwang
Tel. +82-42-868-2034
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AUG 24~27

2nd International Pyroprocessing Research Conference
Jeju Island, South Korea
Organized by Nuclear Fuel Cycle Technology Development Department
Contact : Do-hee Ahn
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Fax. +82-42-868-2990
Email. dhahn2@kaeri.re.kr

SEPT 18~19

8th Korea-China Joint Workshop on Radioactive Waste Management
Jeju Island, South Korea
Organized by Nuclear Fuel Cycle Technology Development Department
Contact : Heui-joo Choi
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Fax. +82-42-868-8198
Email. hjchoi@kaeri.re.kr

OCT 6~10

18th GEN-IV PR&PP Working Group Meeting and Seminar on Korean Nuclear Fuel Cycle and Safeguards
Seoul, South Korea
Organized by Nuclear Fuel Cycle Development Strategy Research Division
Contact : Jung-won Lee
Tel. +82-42-868-8268
Fax. +82-42-868-8679
Email. jwlee3@kaeri.re.kr

JAN. 2009

4th Workshop on Nuclear Energy and Nonproliferation
Seoul, South Korea
Organized by Nuclear Fuel Cycle Development Strategy Research Division
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KAERI in Brief

KAERI Holds the 2nd Workshop on Nuclear Energy and Nonproliferation

The Korea Atomic Energy Research Institute (KAERI) held the 2nd Workshop on Nuclear Energy and Nonproliferation on January 21, 2008, in Seoul, South Korea.

KAERI invited two keynote speakers—Yung-woo Chun, Special Representative for Korean Peninsula Peace and Security Affairs of the ROK Ministry of Foreign Affairs and Trade, and Soon-heung Chang, Vice President of the Korea Advanced Institute of Science and Technology (KAIST)—to speak on the theme "The Future of Korean Nuclear Diplomacy." In their speeches, Chun informed the audience of the ongoing Six-Party Talks on the North Korean nuclear crisis and shared his views on how it would affect the nuclear activities in South Korea, and Chang discussed the 3rd Comprehensive Nuclear Energy Promotion Plan (CNEPP) of the Korean government and the direction of nuclear diplomacy within the plan.

After these two keynote speeches, five nonproliferation experts—including Jae-seong Jeon (Professor, Seoul National University), Jin-ho Jeon (Professor, Kwangwoon University), Bong-geun Jun (Professor, Institute of Foreign Affairs and National Security), Tae-woo Kim (Researcher, Korea Institute for Defense Analyses), and Seong-ho Shin (Professor, Seoul National University)—delivered their presentations on the theme.

The Workshop on Nuclear Energy and Nonproliferation, organized by KAERI, is held biannually in order to provide a forum for experts in the two fields of "nuclear technology" and "nonproliferation politics" to network and exchange views.

KAERI Announces an Institute Reorganization Plan

Myung-seung Yang, the president of the Korea Atomic Energy Research Institute (KAERI), announced an institute reorganization plan on January 16, 2008. "In the pursuit of a small but efficient institute," said Yang, "six departments were reshuffled according to their research functions, whereby the number of research divisions was reduced from 51 to 37. I believe that such a change will increase the competence and efficiency of individual researchers at KAERI."

According to the plan, the Department of Sustainable Nuclear System Development, led by Vice President Seong-won Park, has been changed to the "Department of Nuclear Fuel Cycle Technology Development."

[Appointment of Personnel]

Department of Reactor System Technology Development, Moon-hee Jang

- Division of Fast Reactor Technology Development, *Do-hee Hahn*

Department of Nuclear Fuel Cycle Technology Development, Seong-won Park

- Division of Nuclear Fuel Cycle Process Development, *Han-soo Lee*
- Division of Fuel Cycle System Engineering Technology Development, *Ho-dong Kim*
- Division of Recycled Fuel Development, *Kee-chan Song*
- Division of Nuclear Fuel Cycle Development Strategy Research, *Jung-won Lee*
- Division of High Level Waste Disposal Research, *Jong-won Choi*
- Division of Decommissioning Technology Development, *Un-soo Chung*

KAERI Signs a TCA with the University of Manchester

The Korea Atomic Energy Research Institute (KAERI) and the University of Manchester signed an Arrangement for Technical Cooperation (TCA) on April 8, 2008, wherein they agreed to work together for the development of nuclear technologies. According to the TCA, the two institutes will collaborate in various areas of nuclear waste management, e.g., graphite, nuclear decommissioning, radiation sciences, building of new reactors, plant-life extension and waste minimization, radiochemistry, and radiation protection during geological (final) disposal. Mutual visits to facilities and exchange of information will accelerate the process of cooperation between the two institutes in the said fields.

The University of Manchester, founded in 1824, is home to the Dalton Nuclear Institute (DNI) that provides the focal point for the university's nuclear research and education. Aiming to support the development of expertise in the nuclear field, the DNI has a broad portfolio of capabilities in the field of nuclear research, ranging from engineering and physical sciences to the humanities.

By establishing a collaborative relationship with the DNI, KAERI expects to gain knowledge of advanced British technologies in the field of decommissioning, while facilitating additional collaborative activities in related fields.

KAERI Chronology

- John McClelland-Kerr (Director, US Department of Energy/Office of Global Security Engagement and Cooperation) and David H. Beddingfield (LANL) visited KAERI on January 17, 2008, to discuss the prospects of joint research with KAERI in order to develop safeguard technologies for pyroprocessing.
- Nine KAERI researchers participated in the 5th Korea-Japan Workshop on Nuclear Pyroprocessing (NUPYRO 2008), which was held on January 17-18, 2008, at Kyoto University in Kyoto, Japan.
- Researchers at the Japan Atomic Energy Agency (JAEA), led by Masahide Osawa (Director, Mizunami URL), visited KAERI on January 28-30, 2008, to explore the scope for the future collaborative research activities with KAERI through the use of the KAERI Underground Research Tunnel (KURT).
- Ho-dong Kim (Director, Division of Fuel Cycle System Engineering Technology Development) and Byung-wook Lee (Team Leader, International Strategy Team) attended the 4th annual meeting between Korea and the IAEA held on April 7-8, 2008, at IAEA, to discuss the activities of Korea's Member State Support Program (MSSP) for agency safeguards.
- Three JAEA researchers visited KAERI on April 7-9, 2008, to discuss their research activities with KAERI regarding the deep drilling and geophysical survey near the KURT, and to discuss the preparation of a master plan for the geological survey for the KURT.
- On May 5-9, 2008, Won-il Ko (Managing Editor, *The Nuclearancy*) advised IAEA, within the framework of the International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO), on the assessments of proliferation resistance.
- Kee-chan Song (Director, Division of Recycled Fuel Development) and Chan-bock Lee visited the Idaho National Laboratory (INL) on June 3-6, 2008 for attending the 3rd meeting of the GIF SFR Advanced Fuel Project Management Board (PMB) wherein the participants discussed their ongoing activities on the development of SFR advanced fuel and coordinated future collaborations among them.
- KAERI and IAEA held a meeting of the Working Group on June 9-11, 2008, in Daejeon, South Korea, in order to discuss the activities of the MSSP for agency safeguards.
- KAERI representative, led by Myung-seung Yang (President), visited US Departments of State and Energy on June 16-17, 2008, Washington D.C., to discuss future R&D collaboration between the two countries in the area of spent fuel management.

Ten STCs Signed between KAERI and CEA

The Korea Atomic Energy Research Institute (KAERI) signed an agreement with the French Atomic Energy Commission (CEA) where both parties concurred on ten Specific Topics of Cooperation (STCs) during the 18th meeting of the Korea–France Joint Coordinating Committee on Nuclear Energy (JCCNE) held on April 15–16, 2008, in Seoul, South Korea. It was a follow up to the 1st Joint Workshop between the two institutes held last year with a view to strengthening bilateral and cooperative ties for nuclear R&D activities.

The ten STCs cover such topics as sodium-cooled fast reactors (SFRs), very high-temperature reactors (VHTRs), and radioactive waste management. KAERI is currently developing SFRs and VHTRs as its next generation reactors, while CEA is a world leader in nuclear waste management.

By reaching this cooperative agreement, greater synergy between the two institutes is expected in the future in terms of the development of advanced nuclear fuel cycle technologies.

Recently Published

- Jong-hyuk Baek, “Breakaway Phenomenon of Zr-based Alloys During a High-temperature Oxidation,” *Journal of Nuclear Materials*, **372**, 2008.
- Jin-sik Cheon, “An Extension of the Two-zone Method for Evaluating a Fission Gas Release under an Irradiation-induced Resolution Flux,” *Journal of Nuclear Materials*, **373**, 1-3, 2008.
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IAEA

IAEA Confirms South Korea's Peaceful Nuclear Activities

The International Atomic Energy Agency (IAEA) has concluded that South Korea uses nuclear energy only for peaceful purposes and not for military ones, thereby clearing the way for the country to participate in international efforts to promote the peaceful uses of nuclear technology. On the basis of years of inspections of South Korean nuclear facilities and interviews with researchers and officials involved in this field, the IAEA confirmed that the country has not engaged in any questionable nuclear activities.

This pronouncement was included in the IAEA's Safeguard Implementation Report (SIR) for 2007—a document reporting the nuclear activities of its member nations. The agency's Board of Governors adopted the report at its annual meeting held on June 4-7, 2008, in Vienna, Austria.

"The conclusion implies the IAEA's official acknowledgement that South Korea uses nuclear technology peacefully and transparently," an official of the Korean Ministry of Foreign Affairs and Trade remarked. Further, the official added "The decision will also pave the way for the country to engage in more activities to develop nuclear technologies for peaceful uses and to strengthen collaboration with other countries."

The IAEA has been inspecting the South Korean nuclear program since 2004, after a report claimed that a group of the country's scientists had conducted secret experiments and produced a small amount of weapons-grade uranium in 2000. South Korea denied that it had conducted experiments for military purposes and pledged to abide by all IAEA rules on nuclear technology development. However, the revelation, in conjunction with reports on North Korea's attempts to develop nuclear weapons, sparked concerns about nuclear proliferation in the international community.

"All suspicions about the purpose of the research have now been cleared. South Korea is committed to the peaceful use of nuclear energy," the ministry spokesman said in this regard.

South Korea became an IAEA member in 1957 and joined the Nuclear Non-proliferation Treaty (NPT) in 1975.

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