Nuclear Power in South Korea

(*updated 18 March 2010*)

- **South Korea is set to become a major world nuclear energy country, exporting technology.**
- **Nuclear energy is a strategic priority for South Korea and capacity is planned to increase by 56% to 27.3 GWe by 2020, and then to 35 GWe by 2030.**
- **Today 20 reactors provide almost 40% of South Korea's electricity from 17.7 GWe of plant.**

Power demand in the Republic of Korea (South Korea) has increased by more than 9% per year since 1990 but slowed to 2.8% pa projected 2006-10 and 2.5% pa to 2020. Per capita consumption in 2006 was 7700 kWh, up from 850 kWh/yr in 1980. Over the last three decades, South Korea has enjoyed 8.6% average annual growth in GDP, which has caused corresponding growth in electricity consumption - from 33 billion kWh in 1980 to 371 billion kWh in 2006. Gross power production in 2007 was 439 billion kWh.

Generation capacity of 72.5 GWe in 2008 is expected to grow to 88 GWe total in 2017, 26.6 GWe (30%) of this nuclear, supplying 47% of demand (214 TWh). In 2008 nuclear capacity was 17.7 GWe net (24% of total), supplying 36% of demand (151 billion kWh gross, 144 billion kWh net in 2008). In 2020 nuclear capacity of 27.3 GWe is expected to supply 226 billion kWh - 43.4% of electricity, rising to 48% in 2022, and by 2030 the government expects nuclear to supply 59% of the power, from 41% of the installed capactiy. This will require expanding nuclear capacity from 26% to 40.6% of total, adding about 15 GWe nuclear. In 2022 nuclear capacity of 32.9 GWe is expected to be 32.6% of the national total of 100.9 GWe.

Nuclear power costs are low in Korea: for 2008 KHNP reports 39 won (KRW) per kWh (about 3c/kWh), compared with coal 53.7 won, LNG 143.6 won and hydro 162 won. KHNP average price to KEPCO is 68.3 won (about 5c) per kWh.

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From 1961 until April 2001 South Korea's sole electric power utility was Korea Electric Power Company Ð KEPCO. Set up as a government corporation, 21% of its shares were sold to the public in 1989. The power generation part of KEPCO was then split into six entities and all the nuclear generation capacity, with a small amount of hydro, became part of the largest of these, Korea Hydro & Nuclear Power Co Ltd Ð KHNP. KEPCO remains a transmission and distribution monopoly. Korea Power Engineering Company is another KEPCO subsidiary.

KHNP expects to spend 4.7 trillion won ($3.68 billion) on nuclear plants in 2009. It plans to complete 18 nuclear power plants by 2030 at a cost of 40 - 50 trillion won ($32 to 40 billion), to provide 59% of the country's electricity. This target was endorsed by the Prime Minister in March 2010.

Development of nuclear program & policy

Shortly following its sale of four modern nuclear power reactors to the United Arab Emirates (UAE), the South Korean Ministry of Knowledge Economy declared in January 2010 that it aimed to achieve exports of 80 nuclear power reactors worth $400 billion by 2030, in the course of becoming the world's third largest supplier of such technology, with a 20% share of the world market, behind the USA and France or Russia. "Nuclear power-related business will be the most profitable market after automobiles, semiconductors and shipbuilding," It said, adding that: "We will promote the industry as a major export business." The Korean industry aims to be 100% self-sufficient by 2012, with no residual intellectual property constraints. Following the UAE sale, it is marketing to Turkey, Jordan, Romania and Ukraine, as well as South East Asian countries. In addition to exporting reactors, it also plans to enter the $78 billion market for the operation, maintenance and repair of reactors.

Nuclear activities were initiated when South Korea became a member of the International Atomic Energy Agency in 1957. In 1958 the Atomic Energy Law was passed and in 1959 the Office of Atomic Energy was established by the government. The first nuclear reactor to achieve criticality in South Korea was a small research unit in 1962.

Ten years later construction began of the first nuclear power plant Ð Kori-1. It started up in 1977 and achieved commercial operation in 1978. After this there was a burst of activity, with eight reactors under construction in the early 1980s.

South Korean energy policy has been driven by considerations of energy security and the need to minimise dependence on current imports. Policy is to continue to have nuclear power as a major element of electricity production.

After drawing on Westinghouse and Framatome (now Areva) technology for its first eight PWR units, and Combustion Engineering (which became part of Westinghouse) for two more, the Korean Standard Nuclear Power Plant (KSNP) became a recognised design, and evolved a little to KSNP+. In 2005 the KSNP/KSNP+ was rebranded as **OPR-1000** (Optimised Power Reactor) apparently for Asian markets, particularly Indonesia and Vietnam. Six operating units and four under construction are now designated OPR-1000.

Under the country's 5th long-term power development plan, finalised in January 2000, eight more nuclear units (9200 MWe) were to be constructed by 2015 (in addition to the four then under construction), while two units would be decommissioned about 2008 if licences were not extended. This would bring nuclear to one third of the country's total generating capacity and it would supply 45% of the electricity.

The Ministry of Education, Science & Technology's third comprehensive nuclear energy development plan, for 2007-11, projected that South Korea should develop its nuclear industry into one of the top five in the world, with about 60% of electricity from nuclear by 2035. As well as emphasis on production of nuclear fuel, the report envisaged construction of the Korean APR-1400 reactor. In the country's 2008 Energy Plan to 2030, totalling some $100 billion, the increase was quantified as ten or eleven new nuclear power units.

KHNP and MEST are negotiating licence renewals to extend 30-year operating lifetimes by ten years, starting with Kori-1 and Wolsong-1. A six-month upgrading and inspection outage at Kori-1 in the second half of 2007 concluded a major refurbishment program and enabled its relicensing for a further ten years. At Wolsong-1, considerable refurbishment will be undertaken in a longer outage from April 2009 to late 2010, including pressure tube replacement. It has been operating at slightly derated capacity (622 MWe net) since 2004.

Power uprates of most units occurred at the end of 2005, totalling 693 MWe and reflecting the fact that may had been declaring load factors of over 100% for some time.

Power reactors operating in South Korea

Reactor	Type	Net capacity	Commercial Operation	Planned Close
Kori 1	PWR - Westinghouse	587 MWe	4/78	2017
Kori 2	PWR - Westinghouse	650 MWe	7/83	
Wolsong 1	PHWR - Candu	679 MWe	4/83	
Kori 3	PWR - Westinghouse	950 MWe	9/85	
Kori 4	PWR - Westinghouse	950 MWe	4/86	
Yonggwang 1	PWR - Westinghouse	950 MWe	8/86	
Yonggwang 2	PWR - Westinghouse	950 MWe	6/87	
Ulchin 1	PWR - Framatome	950 MWe	9/88	
Ulchin 2	PWR - Framatome	950 MWe	9/89	
Yonggwang 3	PWR (Syst 80)	1000 MWe	12/95	
Yonggwang 4	PWR (Syst 80)	1000 MWe	3/96	
Wolsong 2	PHWR - Candu	700 MWe	7/97	
Wolsong 3	PHWR - Candu	700 MWe	7/98	
Wolsong 4	PHWR - Candu	700 MWe	10/99	
Ulchin 3	OPR-1000	1000 MWe	8/98	
Ulchin 4	OPR-1000	1000 MWe	12/99	
Yonggwang 5	OPR-1000	1000 MWe	5/02	
Yonggwang 6	OPR-1000	1000 MWe	12/02	
Ulchin 5	OPR-1000	1000 MWe	7/04	
Ulchin 6	OPR-1000	1000 MWe	8/05	
Total: 20		17,716 MWe		

Net capacities updated from KAIF 2008.

In 2005 the capacity factor for South Korean power reactors averaged 96.5% - one of the highest in the world.

In 2005 permits for construction of Shin Kori 1 & 2 and Shin Wolsong 1 & 2 were authorised. First concrete for Shin Kori-1 & 2 was in June 2006 and August 2007 respectively. For Shin Wolsong first concrete for unit 1 was December 2007 and for unit 2 September 2008.

South Korean reactors under construction, on order or planned

Reactor	Type	Net capacity	Start construction	Commercial operation
Shin Kori 1	OPR-1000	1000 MWe	**June 2006**	12/2010
Shin Kori 2	OPR-1000	1000 MWe	**June 2007**	12/2011
Shin Wolsong 1	OPR-1000	1000 MWe	**November 2007**	3/2012
Shin Wolsong 2	OPR-1000	1000 MWe	**September 2008**	1/2013
Shin Kori 3	APR-1400	1350 MWe	**October 2008**	9/2013
Shin Kori 4	APR-1400	1350 MWe	**September 2009**	9/2014
Shin Ulchin 1	APR-1400	1350 MWe	March 2011	12/2015

Shin Ulchin 2	APR-1400	1350 MWe	March 2012	12/2016
Shin Kori 5	APR-1400	1350 MWe	8/2014	12/2018
Shin Kori 6	APR-1400	1350 MWe	8/2015	12/2019
Shin Wolsong 3	APR-1400	1350 MWe		6/2020
Shin Wolsong 4	APR-1400	1350 MWe		6/2021
Total 12		**14,800 MWe**		

Those not under construction are listed as planned in the WNA reactor table. Bold dates = under construction.

Construction of the first pair of third-generation **APR-1400** reactors - Shin Kori 3 & 4 - was authorised in 2006 though the actual construction licence was not issued until April 2008. In anticipation of it KHNP placed a US$ 1.2 billion order with Doosan Heavy Industries for major components of these in August 2006. Westinghouse has a $300 million contract with Doosan for part of this order. In February 2007 a contract was let to a consortium led by Hyundai to build the two plants, subsuming the Doosan order. KHNP expects the APR-1400 reactors to cost a total of around $6.3 billion ($2333/kW). Site works started in November 2007 and first concrete for unit 3 was poured at the end of October 2008 and that for unit 4 in mid September 2009. Construction time of 51 months is envisaged for these first units.

In April 2009 the government authorised construction of Shin Ulchin 1 & 2 and contracts for major components were expected to be signed soon after. The two units will be the first to be virtually free of Westinghouse IP content and are expected to cost US$ 4.7 billion and be completed in 2016.

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KEPCO is actively marketing OPR-1000 and APR-1400 units in Middle East and North African countries. In December 2009 the APR-1400 was selected as the basis of the United Arab Emirates nuclear power program, with the first four reactors to be operating by 2020 under a $20.4 billion contact, and another ten to follow. The choice was on the basis of cost and reliability of building schedule. An application for US Design Certification is likely about 2012.

Korean government data is reported to put the overnight cost of APR-1400 at the end of 2009 as $2300/kW, compared with $2900/kW for EPR and $3580/kW for the GE Hitachi ABWR. The same data puts the generation cost for Areva's APR at US$ 3.03 cents per kilowatt-hour, compared with an estimated 3.93 cents/kWh for EPR, and 6.86 cents/kWh for ABWR.

South Korea is very constrained in its fuel cycle policy by the 1970s Korea-US Atomic Energy Agreement. This constrains raw material supply and disallows uranium enrichment and reprocessing used fuel. Following the UAE agreement, the government has described these US constraints as "excessive", and will continue to push for them to be eased, preferably before the Agreement is due for renewal in 2014.

Reactor development, intellectual property

The first three commercial units - Kori 1 & 2 and Wolsong-1, were bought as turnkey projects. The next six, Kori 3 & 4, Yonggwang 1 & 2, Ulchin 1 & 2, comprised the country's second generation of plants and involved local contractors and manufacturers. At that stage the country had six PWR units derived from Combustion Engineering in USA, two from Framatome in Europe and one from AECL in Canada Ð of radically different design.

Then in the mid 1980s the Korean nuclear industry embarked upon a plan to standardise the design of nuclear plants and to achieve much greater self-sufficiency in building them. In 1987 the industry entered a ten-year technology transfer program with Combustion Engineering (now Westinghouse) to achieve technical self-reliance, and this was extended in 1997.

A sidetrack from this was the ordering of three more Candu-6 Pressurised Heavy Water Reactor (PHWR) units from AECL in Canada, to complete the Wolsong power plant. These units were built with substantial local input and were commissioned 1997-99. (see also DUPIC in R&D section below)

In 1987 the industry selected the CE System 80 steam supply system as the basis of standardisation. Yonggwang 3 & 4 were the first to use this, with great success. A further step in standardisation was the Korean Standard Nuclear Plant (KSNP), which from 1984 brought in some further CE System 80 features and incorporated many of the US Advanced Light Water Reactor design requirements. It is the type used for all further 1000 MWe units as well as the two under construction in North Korea.

In the late 1990s, to meet evolving requirements, a program to produce an Improved KSNP, or KSNP+, was started. This involved design improvement of many components, improved safety and economic competitiveness, and optimising plant layout with streamlining of construction programs to reduce capital cost. Shin-Kori 1&2 will represent the first units of the KSNP+ Program, and are expected to be among the safest, most economical and advanced nuclear power plants in the world. This design is being offered for export as the Optimised Power Reactor - OPR-1000.

Beyond this, the **Advanced Pressurised Reactor-1400** draws on CE System 80+ innovations, which are evolutionary rather than radical. The System 80+ has US Nuclear Regulatory Commission design certification as a third-generation reactor. The APR-1400 was originally known as the Korean Next-Generation Reactor when work started on the project in 1992. The basic design was completed in 1999. It offers enhanced safety with seismic design to withstand 300 Gal ground acceleration, and has a 60-year design life. Cost is expected to be 10-20% less than KSNP/OPR-1000. The first APR-1400 units - Shin Kori 3 & 4, are under construction, and operation is expected in 2013 and 2014. A 48-month construction period is envisaged. Korea Power Engineering Company (KOPEC) is the main designer, and Doosan the main manufacturer.

KHNP decided not to renew its reactor technology licence agreement with Westinghouse in 2007 but to embark upon a business cooperation agreement instead, whereby KHNP would join with Westinghouse in marketing jointly-developed technology while KHNP completes the development of its own components to replace those, eg in the APR-1400, dependent on the licensing. This will lead into a KHNP $200 million program to develop an exportable AP+ large reactor design by 2015, though Westinghouse is not likely to let it compete in main markets such as USA and China without KEPCO buying the rights to the design. However, securing the $20.4 billion contract to build four APR-1400 reactors in UAE is a major boost for KEPCO.

KEPCO has signed an agreement with Indonesia's PLN power utility to conduct a feasibility study - with KHNP - for Indonesia's first nuclear power plant. This will probably be one or more OPR-1000 units. The Indonesian government earlier confirmed in principle approval of four 1000 MWe units on the Muria peninsula, 450 km east of Jakarta in central Java, with a view to commissioning in 2016.

KEPCO and Doosan were reported to be offering Jordan their OPR-1000 nuclear reactor. However, the OPR is designed for 200 Gal seismic acceleration and would need to be upgraded to at least 300 Gal for Jordan and Turkey. Jordan is now considering the APR-1400.

The Korean Atomic Research Institute (KAERI) has designed an integrated desalination plant based on the 330 MWt SMART reactor (see R&D section) to produce 40,000 m^3/day of water and 90 MWe at less than the cost of gas turbine. The first of these was envisaged for Madura island, Indonesia.

Fuel cycle

South Korea has had an open fuel cycle, without reprocessing, due to the terms of its nuclear cooperation agreement with the USA, which needs to be renewed in 2014. In recent years diplomatic efforts have sought to remove this constraint so as to get some 30% more energy from imported uranium and reduce the amount of high-level wastes.

Uranium for fuel comes from Canada, Australia, and elsewhere - 3100 tU being required in 2008. KEPCO, KNFC, Hanwha and KHNP are together becoming involved with uranium exploration in Canada. The state-owned Korea Resources Corporation (KORES) has declared an intention to invest heavily in uranium and copper mines in Africa and South America. In December 2009 KEPCO agreed to take a 20% interest in the Imouraren operating company in Niger, along with 10% of the product - expected to be 500 tU/yr over 35 years. The figure of US$ 360 million in uranium projects to 2026 has been mentioned.

Korea has no known and quantified uranium resources, though Perth-based Stonehenge Metals has acquired Chong Ma Mines Inc which holds the rights to the Daejon uranium deposit, identified by the Korean Institute of Energy and Resources (KIER) in a 1986 report. A JORC-compliant estimate is expected in 2010. The Korean Resources Corporation (KORES) holds the adjoining Gumsan deposit along strike to the south from Daejon.

In 2006 enrichment demand was 1.8 million SWU, supplied from overseas. Tenex, Urenco and USEC have previously supplied this, but in mid 2007 KHNP signed a long-term (10+ years) EUR 1 billion contract with Areva NC for enrichment services at the new Georges Besse II plant in France. Then in mid 2009 it took a 2.5% equity stake in the plant.

KAERI has developed both PWR and Candu fuel technology. It and Korea Nuclear Fuel Company (KNFC) have supplied PWR fuel since 1990 and Candu PHWR fuel (unenriched) since 1987. KNFC has capacity of 550 t/yr for PWR fuel and 700 t/yr for Candu PHWR fuel, and supplies all KHNP's needs.

In February 2009 Westinghouse announced that it and KNFC will manufacture control element assemblies for Combustion Engineering-design power reactors in the USA and South Korea. A new joint venture (Westinghouse 55%, KNFC 45%), KW Nuclear Components, will make the elements at KNFC's fuel fabrication facility in Daejeon. The Shin Kori-4 APR-1400 under construction is likely to include the first control elements manufactured by the venture.

Radioactive Waste Management

The Korea Radioactive Waste Management Co. Ltd (KRWM) was set up early in 2009 as an umbrella organisation to resolve South Korea's waste management issues and waste disposition, and particularly to forge a national consensus on high-level wastes. Until then, KHNP had been responsible for managing all its radioactive wastes. KHNP now contributes a fee of 900,000 won (US$ 705) per kilogram of used fuel to KRWM.

The Atomic Energy Act of 1988 established a 'polluter pays' principle under which KHNP was levied a fee based on power generated. A fee was also levied on KNFC. The fees were collected by MEST and paid into a national Nuclear Waste Management Fund. A revised waste program was drawn up by the Nuclear Environment Technology Institute (NETEC) and approved by the Atomic Energy Commission in 1998.

Used fuel is stored on the reactor site pending construction of a centralised interim storage facility by 2016, eventually with 20,000 tonne capacity. About 10,000 t was stored at the end of 2008, onsite pool capacity being 12,000 t, about half of both figures being for Candu fuel at Wolsong. About 6000 t was stored at end of 2002. Dry storage is used for Candu fuel after 6 years cooling. Long-term, deep geological disposal is envisaged, though whether this is for used fuel as such or simply separated high-level wastes depends on national policy.

Reprocessing, either domestic or overseas, is not possible under constraints imposed by the country's cooperation agreement with the USA. However this is being appealed. KHNP has considered offshore reprocessing to be too expensive, and recent figures based on Japanese contracts with Areva in France support this view, largely due to transport costs.

Low and intermediate-level wastes (LILW) are also stored at each reactor site, the total being about 60,000 drums of 200 litres. Volume reduction (drying, compaction) is undertaken at each site. A 200 ha central disposal repository is envisaged for all this from about 2008, eventually with capacity for 800,000 drums. It will involve shallow geological disposal of conditioned wastes, with vitrification being used on ILW from about 2006 to increase public acceptability.

NETEC took over the task of finding repository sites after several abortive attempts by KAERI and MEST 1988-96. In 2000 it called for local communities to volunteer to host a disposal facility. Seven did so, including Yonggwang county with 44% citizen support, but in 2001 all local governments vetoed the proposal. The Ministry of Commerce, Industry & Energy (now the Ministry of Knowledge Economy - MKE) then in 2003 selected four sites for detailed consideration and preliminary environmental review with a view to negotiating acceptance with local governments from 2004.

The area selected for the LILW facility will get 300 billion won (US$ 290 million) in community support according to "The Act for Promoting the Radioactive Waste Management Project and Financial Support for the Local Community" 2000. The aim of this is to compensate for the psychological burden on residents, to reward a community participating in an important national project, and to facilitate amicable implementation of radioactive waste management.

In November 2005, after votes in four provincial cities, Kyongju /Gyeonju on the east coast 370 km SE from Seoul was designated as the site. Almost 90% of its voters approved, compared with 67 to 84% in the other contender locations. It is close to Wolsong.

In June 2006 the government announced that the Gyeongju repository would have a number of silos and caverns some 80m below the surface, initially with capacity for 100,000 drums and costing US$ 730 million. Further 700,000 drum capacity would be built later, total cost amounting to US$ 1.15 billion. As well as the $300 million, annual fees would be paid to the local community.

Regulation and safety

The Atomic Energy Commission is the highest decision-making body for nuclear energy policy and is chaired by the Prime Minister. It was set up under the Atomic Energy Act.

The high-level Nuclear Safety Commission (NSC) chaired by the Minister of Education, Science &

Technology is responsible for nuclear safety regulation. It is independent of the AEC and was set up by amendment of the Atomic Energy Act in 1996. The regulatory framework is largely modelled on the US NRC.

The Ministry of Education, Science & Technology (MEST) has overall responsibility for nuclear R&D, nuclear safety and nuclear safeguards.

The Korean Institute of Nuclear Safety (KINS), an expert safety regulator, comes under MEST, though the Korea Atomic Energy Research Institute (KAERI), responsible for R&D, comes under the Korea Research Council of Public Science & Technology (KORP).

The Technology Centre for Nuclear Control, responsible for nuclear material accounting and the international safeguards regime, was transferred from KAERI to KINS at the end of 2004 and has since been replaced by the National Nuclear Management and Control Agency (NNCA). Action is planned in 2006 to strengthen its independence.

The Ministry of Knowledge Economy (MKE) is responsible for energy policy, for the construction and operation of nuclear power plants, nuclear fuel supply and radioactive waste management. KEPCO, KHNP, KNFC, NETEC and heavy engineering operations come under MKE, and KEPCO seems to have a controlling role re the others. The Korea Nuclear Energy Foundation (KNEF) is a public information body also under MKE.

R&D

The main roles of nuclear R&D are to ensure that the national energy supply is secure, and to build the country's nuclear technology base so that it becomes a nuclear exporting country by early in the 21st century. KAERI is the main body responsible for R&D.

Particular goals established in 1997 include reactor design and nuclear fuel, nuclear safety, radioactive waste management, radiation and radioisotopes application, and basic technology research. The last, taking 27% of the funds, includes: development of liquid metal reactors, Direct Use of spent PWR fuel In Candu reactors (DUPIC), application of lasers, and research reactor utilisation.

The **DUPIC** program is the subject of South Korea's national case study for the IAEA's INPRO project, evaluating new fuel cycle technologies. It involves taking used fuel from light water reactors such as PWRs, crushing it, heating it in oxygen to drive off some 40% of the fission products, and re-forming it into PHWR fuel. It still contains all the actinides including about 1% plutonium, and about 96% uranium including approx 1% U-235. So the fissile content is about 1.5%, more than double that of natural uranium usually used for today's PHWRs. DUPIC research has been supported by Canada and is described more fully in the Processing Used Nuclear Fuel paper.

The other major research initiative by KAERI related to used fuel is an **advanced spent fuel conditioning process - ACP.** Development of this process involves substantial US-South Korean nuclear cooperation, since the USA effectively controls what is done with the country's used fuel, and will be central to the renewal of the US-ROK agreement in 2014. Much of the R&D has been done in the USA, based on earlier US work in 1970s, but paid for by KAERI. However, the US government then suspended this. South Korea has declined an approach from China to cooperate on electrolytic reprocessing, and it has been rebuffed by Japan's CRIEPI due to government policy.

The US Department of Energy included in its 2008 budget funding for pyroprocessing R&D. This is significant in that the USA had strongly discouraged reprocessing in Korea previously. But after the USA announced its Global Nuclear Energy Partnership (GNEP) early in 2006, the S. Korean government pressed it to include KAERI's R&D in GNEP, including particularly ACP. The DOE funding request for KAERI links pyroprocessing research to GNEP, while US DOE laboratories work with KAERI staff on ACP.

Using electrometallurgical pyroprocessing to close the fuel cycle with oxide fuels however requires them to be reduced to the metal on a commercial basis. It involves heating the pulverised used fuel to drive off volatile fission products and then reducing it to metal. This is put into a bath of molten lithium and potassium chloride, and uranium is recovered electrolytically. The remaining tranuranics (Pu, Np, Am, Cm) are concentrated and removed with the remaining fission products (notably cerium, neodymium & lanthanum) to be fabricated into fast reactor fuel without any further treatment. This is intrinsically proliferation-resistant because it is so hot radiologically, and the curium provides a high level of spontaneous neutrons. Also it recycles about 95% of the used fuel.

In 2008 IAEA approved an electrorefining laboratory - the Advanced Spent Fuel Conditioning Process Facility (ACPF) at KAERI, which is to be built by 2011 and expanded to engineering scale by 2012. This is envisaged as the first stage of a Korea Advanced Pyroprocessing Facility (KAPF) to start experimentally in 2016 and become a commercial-scale demonstration plant in 2025. In connection with renewal of the US-ROK agreement in or by 2014, discussions are proceeding on pyroprocessing.

Closely related to this, and designed to be fueled by the product of it, KAERI has proposed development of a **sodium-cooled fast reactor,** the **SFR**, which will operate in burner (not breeder) mode. This was supported by the USA in connection with GNEP and a demonstration Korean fast reactor is planned for 2028.

As well as the fast reactor means of burning actinides, KAERI is researching HYPER (HYbrid Power Extraction Reactor), a kind of subcritical reactor which will be activated by a proton accelerator.

KAERI has been developing the **SMART** (System-integrated Modular Advanced Reactor) - a 330 MWt pressurised water reactor with integral steam generators and advanced passive safety features. It is designed for generating electricity (up to 100 MWe) and/or thermal applications such as seawater desalination. Design life is 60 years, with a 3-year refuelling cycle. A one-fifth scale plant (65 MWt) was being constructed. While the basic design is complete, the absence of any orders for an initial reference unit has stalled development. KAERI is now intending to proceed to licensing the design by 2012.

KAERI has also constructed 30 MW thermal research reactor based on the Canadian Maple design called HANARO, which started up in 1995. In contrast to Canada's experience with Maple, this apparently works very well.

KALIMER (Korea Advanced LIquid MEtal Reactor) is a 600 MWe pool type sodium-cooled fast reactor designed since 1992 to operate at 510ºC. A transmuter core consisting of uranium and transuranics in metal form from pyro-processing is being designed, and no breeding blanket is involved. Future deployment of KALIMER as a Generation IV type is envisaged.

A 150 MW fast reactor has also been designed by KAERI.

A second stream of fast reactor development is via the Nuclear Transmutation Energy Research

Centre of Korea (NuTrECK) at Seoul University (SNU), drawing on Russian experience. It is working on lead-bismuth cooled designs of 35, 300 and 550 MW which would operate on pyro-processed fuel. The 35 MW unit is designed to be leased for 20 years and operated without refuelling, and then returned to the supplier. It would be refuelled at the pyro-processing plant and have a design life of 60 years.

KAERI has also submitted a Very High Temperature Reactor (VHTR) design to the Generation IV International Forum with a view to hydrogen production from it. This is envisaged as 300 MWt modules each producing 30,000 tonnes of hydrogen per year. KAERI expects the design concept to be ready in 2008, engineering design in 2014, construction start 2016 and operation in 2020.

In 2005 KAERI embarked upon a US$ 1 billion R&D and demonstration program aiming to produce commercial hydrogen using nuclear heat around 2020. KAERI has close links on hydrogen with the Institute of Nuclear & New Energy Technology (INET) at Tsinghua University in China, based on China's HTR-10 reactor, and is forming other links with its counterpart in Japan. In 2005 it set up a South Korea-US Nuclear Hydrogen Joint Development Center involving General Atomics.

It plans to develop the sulfur-iodine (SI) process for hydrogen production while also developing high-temperature reactors and the alloys enabling them to be used with heat exchangers for chemical plants. Prototype SI hydrogen production is expected about 2011, followed by a pilot plant in 2016, which will then be connected to a high-temperature reactor. Which type of reactor will be decided in 2006.

Beyond fission, KSTAR (Korea Superconducting Tokamak Advanced Research) was launched in December 1995 and began operating in September 2007 at Daejeon. The US$ 330 million facility is the world's eight fusion device and will be a major contribution to world fusion research, contributing to the ITER project taking shape in France.

Non-proliferation

South Korea is a party to the Nuclear Non-Proliferation Treaty (NPT) as a non-nuclear weapons state. Its safeguards agreement under the NPT came into force in 1975 and it has signed the Additional Protocol in relation to this.

North Korea

In the 1990s there was a proposal to build two KSNP reactors at Sinpo in North Korea. See: North Korea section of Emerging Nuclear Energy Countries paper for details.

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