Nuclear Developments in the Korean Peninsula

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Outline

- Nuclear Energy Development in the ROK
- Nuclear Weapons Development in the DPRK
- Possible Cooperation between the ROK and the DPRK in Peaceful Use of Nuclear Energy
- Conclusions

Early History of Nuclear Development in the ROK and the DPRK

ROK	DPRK
1959: Opening Korea Atomic Energy Research Institute 1963: TRIGA Mark-II (0.1MWth) research reactor in operation (shutdown in 1995) 1969: TRIGA Mark-III (1MWth) research reactor in operation (shutdown in 1995) 1978: First commercial reactor, 580 MWe Pressurized Water Reactor in operation Since 1983: Deploying 15 PWRs and 4 CANDUs 1995: 30 MWth research reactor (HANARO) in operation	1956: Opening Nuclear Physics Laboratory at Institute of Physics & Mathematics 1965: IRT (2-8MWth) research reactor in operation Early 1980s: Starting construction of fuel fabrication facility with capacity of about 100 t uranium a year 1984: Starting construction of reprocessing facility with capacity of about 110 tHM of spent fuel a year; Starting construction of 50 MWe (200 MWth) graphite moderated reactor (halted since 1994) 1986: 5 MWe (25 MWth) graphite moderated reactor in operation Late 1980s: Starting construction of 200 MWe (800 MWth) graphite moderated reactor (halted since 1994)

Status & Prospects of Nuclear Power in the ROK

Figure 1. NPPs sites in the ROK

- Kori: 4 PWRs in operation;
  4 PWRs under construction
- Yonggwang: 6 PWRs in operation
- Ulchin: 6 PWRs in operation;
  2 PWRs to be deployed by 2016
- Wolsong: 4 CANDUs in operation;
  2 PWRs under construction

- 11 PWRs (1.4 GWe each) are planned to be deployed between 2017 and 2030, according to a "National Energy Basic Plan" (August 2008)

	2008	2016	2030
# of PWR (GWe)	16(14.9)	24(24.5)	35(39.9)
# of CANDU (GWe)	4 (2.8)	4(2.8)	4(2.8)
# of NPPs (GWe)	20 (17.7)	28(27.3)	39(42.7)

Status & Prospects of Nuclear Power in the ROK (cont)

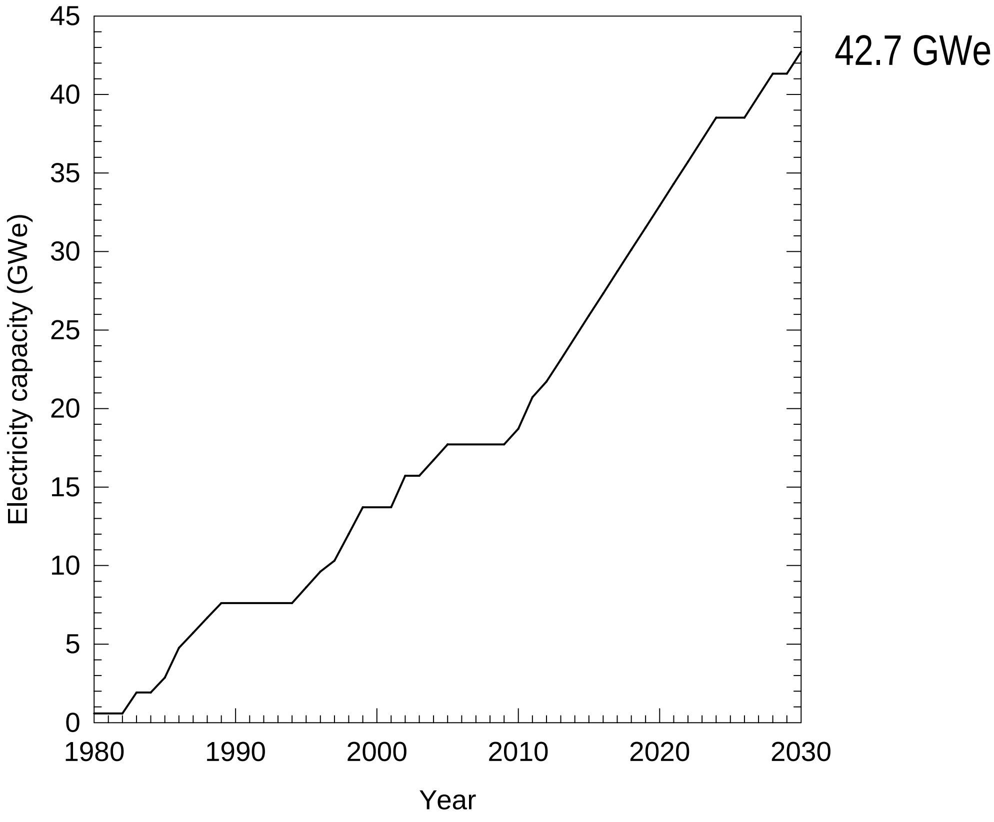

Figure 2. Installed nuclear capacity in the ROK (1980-2030)

Status of Nuclear Energy Development in the ROK

- Uranium
  - About 100,000 t U_3O_8 reserve with grade 0.035% uranium in Ogcheon, a middle part of the ROK. [Note: Uranium ore containing roughly less than 0.1% uranium has no economic value to extract at current uranium market.]
  - Importing uranium concentrates of about 4,000 t U_3O_8 per year from Australia, Canada, France, Kazakhstan and the US to supply for 16 PWRs and 4 CANDUs, as of the end of 2008 [Note: About 230 t U_3O_8, i.e. 195 t U needs to supply LEU fuel for 1 GWe PWR per year.]
- Enrichment
  - No domestic enrichment plants
  - Importing enrichment services of about 1,500 t SWU (separative work unit) per year from France, Russia, the US and UK to supply low enriched uranium (LEU) fuel for 16 PWRs, as of the end of 2008 [Note: About 100 t SWU/year of enrichment service needs to supply LEU fuel for 1 GWe PWR per year.]
  - No future plan for developing domestic capability in enrichment
    - Supply assurance by diversifying importing enrichment services

Status of Nuclear Energy Development in the ROK (cont)

- Fuel Fabrication
  - Domestic fuel fabrication plant
  - Capacity of 400 t U of PWR fuel per year for 16 PWRs and 400 t U of CANDU fuel per year for 4 CANDUs
- Spent Fuels
  - Discharging about 290 metric tons of heavy metal (tHM) of PWR spent fuels from 16 PWRs per year and about 380 tHM of CANDU spent fuels from 4 CANDUs per year
  - By end of 2007, about 10,300 tHM of spent fuels had been discharged from PWRs and CANDUs, and stored in spent fuel storage facilities at four NPP sites: about 4,300 tHM of PWR spent fuels and 6,000 tHM of CANDU spent fuels.
  - Projections of spent fuel generation in the ROK is given in Figure 3.

Projections of Spent fuel Generation in the ROK

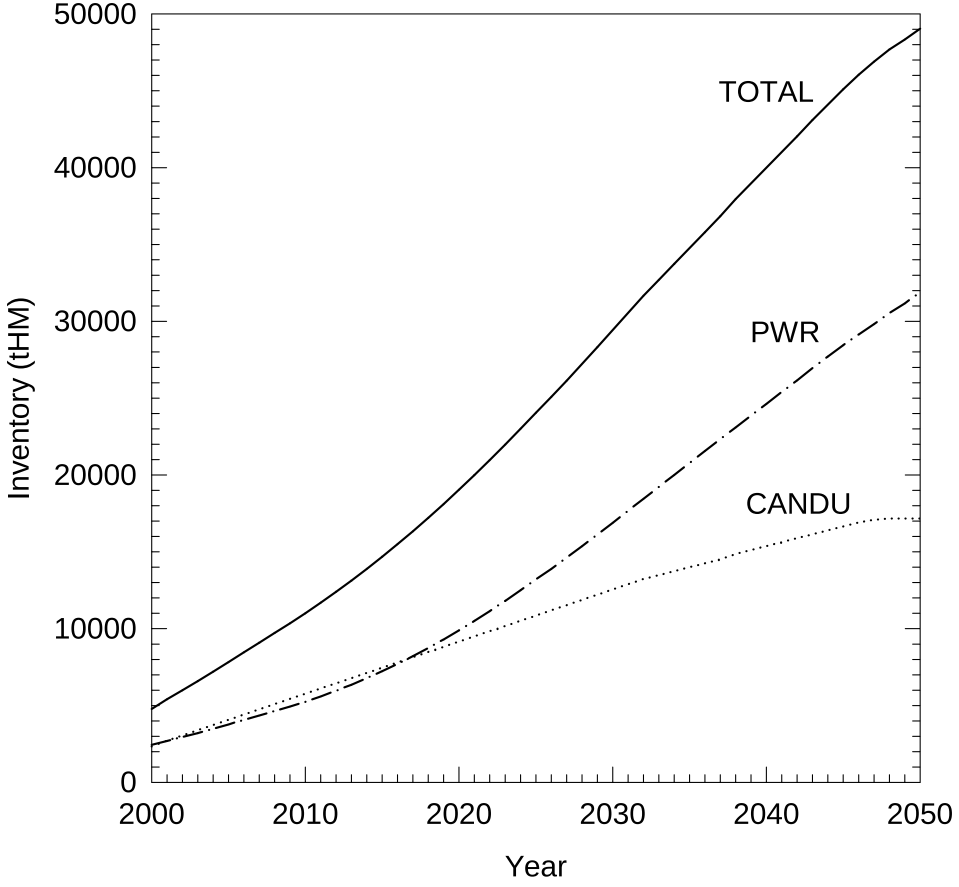

Figure 3. Cumulative inventory of spent fuel generation in the ROK (2000-2050)

Status of Nuclear Energy Development in the ROK (cont)

- Spent Fuels (cont)
  - Spent fuel management is a hot issue in the ROK as its at-reactor (AR) spent fuel storage pools become saturated.
    - KHNP, a utility company argues that Kori, Ulchin, and Yonggwang site would run out of their spent-fuel storage capacities by 2016, 2018, and 2021, respectively.
    - The ROK government is about to begin the public hearing process for formulating a national policy for long-term spent fuel management.
    - Ministry of Knowledge Economy (MKE) and Ministry of Education, Science and Technology (MEST) are decision making authorities in the spent fuel management in the ROK.
    - MKE, controlling KHNP, seems to prefer to long-term interim storage of spent fuel, while MEST, controlling KAERI, insists recycling spent fuel based on pyroprocessing, as an alternative to the spent fuel management in the ROK.
- Human Power
  - About 21,000 workers as the end of 2005.
  - Among them, about 12,000 workers for construction and operation of NPPs, about 3,000 workers for safety of NPPs, about 2,000 workers for research and development, about 1,000 workers for radioisotopes application, and about 3,000 workers for supporting nuclear energy development

Status of Nuclear Weapons Development in the DPRK

- Uranium
  - Not known officially.
  - About 4 million tons of commercial grade ore near Unggi, North Hagyong Province.[Note: Assuming the DPRK uranium reserve 4 million tonnes of 1% uranium ore, corresponding to 46,000 t U_3O_8 , it can supply LEU for 1 GWe PWR for 200 years or for five 1 GWe PWRs for 40 years of lifetime.]
  - In addition, 5 t UO_3 stock at fuel fabrication facility
- Enrichment
  - No need for the DPRK graphite-moderated reactors because they use natural uranium metal fuel
  - Implementing R&D programs, including uranium enrichment, fast breeder reactor, reprocessing and radioactive waste treatment during 1st and 2nd periods of its National 3-year R&D Program (1988-1993)
  - Any significant uranium enrichment facilities, including any centrifuge manufacturing facilities and any facilities producing uranium hexafluoride, needs to be verified.

Status of Nuclear Weapons Development in the DPRK (cont)

- Reactors
  - The 5 MWe graphite moderated reactor under disablement
    - Severing secondary cooling loop and destruction of cooling tower (Jun. 27, '08)
    - Discharging spent fuels to pond (not done yet)
    - Removing control rod drive mechanism (not done yet)
  - The 50 MWe and the 200 MWe graphite moderated reactors have been abandoned since 1994.
  - The IRT reactor is still in operation.
    - The IRT driver fuels originally contains 38 fuel rods of 10% U-235 (48.6 kg of U), 23 fuel rods of 36% U-235 (13.5 kg of U), and 30 fuel rods of 80% U-235 (6.0 kg of U)
    - Converting IRT reactor from highly-enriched uranium (HEU) to LEU fuel

Status of Nuclear Weapons Development in the DPRK (cont)

- Fuel Fabrication
  - The fuel fabrication facility under disablement
    - Removing uranium fuel rod casting furnaces and machine equipment
    - Removing uranium metal reduction furnaces
    - Removing uranium ore concentrate dissolver tanks and empty process tanks and pipes
    - Disablement of fresh fuel (not done yet)
      - The DPRK has in storage about 2,400 fuel rods for the 5 MWe reactor and about 12,400 fuel rods for the 50 MWe reactor. These fuel rods stock were fabricated during 1991 -1994. The total amount of fuel rods stock corresponds to 101.9 t uranium.
- Reprocessing
  - The reprocessing facility under disablement
    - Removing drive mechanism for fuel cask transfers
    - Removing receiving cell door mechanism and overhead crane
    - Removing mechanism for fuel shearing and declading
    - Severing process equipment steam line valves

Status of Nuclear Weapons Development in the DPRK (cont)

- Spent Fuels
  - As of mid-January 2009, the DPRK has discharged about 6,000 over 8,000 spent fuel rods, assumed to contain about 8-10 kg of plutonium, with speed of 15 fuel rods per day.
- Plutonium
  - In its nuclear declaration in June 2008, the DPRK declared that it had extracted 30.8 kilograms of plutonium from spent nuclear fuel using its reprocessing facility and that it had used 2 kilograms of that amount in its October 2006 nuclear test.
  - Need verification
    - The technique of graphite isotope ratio method (GIRM) is used to estimate the total plutonium production in a graphite-moderated reactor without detailed information on the reactor's operating history.
- Nuclear Weapons
  - The DPRK is estimated to have less than five nuclear weapons, based on its nuclear declaration.
  - Need verification

Possible Cooperation between the ROK and the DPRK in Peaceful Use of Nuclear Energy

- To achieve denuclearization of the DPRK, more than simply removing nuclear material and infrastructure, it is vital to provide the DPRK's nuclear workers with alternative civilian jobs, since they could presumably resume the country's nuclear activities in the future or hire themselves out to help other countries build nuclear weapons. Peaceful nuclear energy activities are likely to be the most acceptable alternative to the DPRK's nuclear workers, including following areas.
  - Decommissioning and decontamination (D&D) of Yongbyon's nuclear facilities
    - More than 100 of the DPRK's nuclear personnel for site and facilities characterization
    - More than 500 of the DPRK's nuclear personnel for initial dismantlement
    - More than 2,000 of the DPRK's nuclear personnel for full dismantlement
  - Utilization of the IRT research reactor after converting it to LEU fuel
    - About 200-500 of the DPRK's nuclear personnel for the reactor, its ancillary facilities, experiments and programs
  - Establishment of an International Science and Technology Center (ISTC) in Pyongyang or Yongbyon, similar to the one in Moscow

Possible Cooperation between the ROK and the DPRK in Peaceful Use of Nuclear Energy (cont)

- Light Water Reactor Project
  - A never giving up request by the DPRK in return for giving up its nuclear weapons
  - The September 2005 Joint Statement of the Six Party Talks expressed an interest in discussing at a later time supplying LWRs to the DPRK, though currently such a project seems impractical given the inability of the DPRK's electric grid to accommodate them.
    - The electric grid of the DPRK is currently localized and has no unified national grid system.
    - Furthermore, the practical total electricity generation capacity of the DPRK is estimated at most less than 3 GWe.
    - To accommodate a 1 GWe NPPs, the total electricity capacity of the DPRK should exceed roughly at least 10 Gwe to prevent unstability of its national grid system.
    - Assuming 3 GWe for the total electricity capacity of the DPRK and even 10% increase of electricity demand annually, it will take 13 years for the DPRK to have 10 GWe electricity capacity.
  - If the DPRK were to return to the NPT and overcome other technical challenges, including grid problems, the LWRs that were started following the 1994 Agreed Framework might be resumed in the future.
    - More than 500 DPRK's nuclear personnel for the LWRs project
    - In addition, about 100-150 DPRK's nuclear personnel for developing and implementing its regulatory system for the safety of the LWRs

Costs of Redirection of the DPRK's Nuclear Workers

- To redirect the DPRK's nuclear workers, it is necessary to know the current status of involved personnel.
  - There are estimates that number of the DPRK's nuclear engineers between 3,000 and 6,000, including 200 personnel related to its nuclear weapons program.
- Redirection of the DPRK's nuclear workers will be achieved by inducing retirement and job conversion.
  - Salary of a DPRK's worker of Gaesung industrial complex is less than 70 USD per month, i.e., less than 1,000 USD per year.
  - Assuming roughly 5,000 for the number of the DPRK's nuclear workers, 5 million USD per year would be sufficient to pay for DPRK's nuclear workers for their redirection till settlement.
  - Besides, additional costs, including salary of trainers and administration fee, for assistance for the job conversion of DPRK's nuclear workers would be considered.

Conclusion

- To achieve denuclearization of the DPRK, not only removing nuclear material and infrastructure, but also redirection of the DPRK's nuclear workers are vital.
- Peaceful nuclear energy activities are likely to be the most acceptable alternative for the redirection of the DPRK's nuclear workers, including areas of decommissioning and decontamination of Yongbyon's nuclear facilities, utilization of the IRT research reactor after converting it to LEU fuel, establishment of an International Science and Technology Center in Pyongyang or Yongbyon, and probably Light Water Reactor Project.
- The ROK can contribute for the redirection of the DPRK's nuclear workers by providing technical know-how of the peaceful nuclear energy development and some portion of financial support in which the cost of redirection of Yongbyon nuclear workers would be modest.