1. Nuclear surprises in 2009

2. Bit of geography/history

3. Korean nuclear overview

4. Koreanization of nuclear power technology

5. Lessons learned
1. Nuclear surprises in 2009

- May 25: NK detonated its second NW
  - Test site Punggye, yield 2-6 kiloton Pu type
  - UNSC Resolution 1874, stiff sanctions

- Dec. 27: SK consortium won UAE NPP project
  - “Surprise Choice”
  - 4X1400 MWe APR, first in GCC

- Dec. 4: KAERI won Jordan RR supply contract

- June, 2010: KEPCO sole bidder for Turkey Sinop NPP
Questions

- How could they do it?
- How credible is it?
- What are the lessons?
UAE Nuclear Power contract

- NPP turnkey package contract
  - APR 1400 4 Reactors
  - Supply of Nuclear Fuel (for next 3 yrs)
  - Support of Operating and Maintenance
  - Education & Training

- Contract worth
  - $20 billion +

- Completion schedule
  - 2017 - 2020
UAE NPP Braka Site
Summary of UAE Project

- International tender: Areva/H-GE/KEPCO
  - Single largest NPP project ~ $3,300/kW

- UAE selection comment
  - "Proven safety and economy"

- UAE/ROK common nonproliferation doctrine
  - No reprocessing, no enrichment

- Emergence of a new NPP supply chain from Asia
Project Summary

- Start Date: March 30, 2010
- Completion: Feb. 2014
- Capacity: 5MW
- Ref. Plant: HANARO, 30MW
2. Bit of geography/history
Nuclear map of KOREA

Nuclear R&D center

Uranium mine

Daedeok Innopolis
Nuclear R&D, safety, fuel

Yonggwang NPP (Y)

Nuclear heavy industry

KEDO LWR site

Nuclear test site

Kori NPP (K)

Ulchin NPP (U)

Ulsong NPP (W)
Radwaste repository

Changwon

Daegu

Innopolis

Nuclear R&D, safety, fuel

Yonggwang NPP (Y)

Nuclear heavy industry
2. Bit of history

- Unified peninsula until 1945
- Same race, language, history
  - Korean alphabet “Hangul” 1446
- Communist DPRK/democracy ROK
- Bitter Korean War (1950-1953…)
- Nuclear dichotomy since 1970’s
  - North: NW for blackmail, isolation
  - South: NPPs for economic miracle
Land of extreme contrasts

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>S</th>
<th>N/S %</th>
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<tbody>
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<td>Pop (mil)</td>
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<tr>
<td>PCI ($)</td>
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<tr>
<td>Elec(bkWh)</td>
<td>255</td>
<td>4,200</td>
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</table>

“and the gap is widening”
3. Korean nuclear overview

- 1959: Atomic Energy law, KAERI founded
- 1968: Official first NPP construction plan approved
- 1978: Kori-1 commercial operation
- 1987: Yonggwang-3/4 construction with Technology Transfer
- 1995: Y3/4, NPP technical self-reliance 95% achieved
- 1998: First KSNP U3 commercial operation
- 2009: First NPP turnkey export to UAE
Nuclear Power Plants chronology in Korea

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<thead>
<tr>
<th>No. of Units</th>
<th>Operation</th>
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<td>YGN 3&amp;4</td>
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-15-
## Nuclear power generation 2009-10

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<th>Country</th>
<th>GWe</th>
<th>TWh</th>
<th>Units</th>
<th>%Elec</th>
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<td>USA</td>
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<td>797</td>
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<td>France</td>
<td>63</td>
<td>392</td>
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<td>75</td>
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<tr>
<td>Japan</td>
<td>47</td>
<td>263</td>
<td>54</td>
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<td>Russia</td>
<td>23</td>
<td>153</td>
<td>32</td>
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<td>S Korea</td>
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<td>78</td>
<td>15</td>
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<td>China</td>
<td>9</td>
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<td>11</td>
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<td>8</td>
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<td>WORLD</td>
<td>374</td>
<td>2558</td>
<td>438</td>
<td>14</td>
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</table>
4. Koreanization of nuclear power technology

4.1 Nuclear policies from heads of State

4.2 National lab’s participation

4.3 Utility’s project management, operations

4.4 Nuclear industries’ commercial competitiveness

*plus good luck, and timing*
4.1 Nuclear policies from heads of State

- 50’s: Rhee Syngman
  - “Atomic machine”, education/manpower

- 70’s: Park Chung-hee
  - Choice between peaceful nuclear power over military use

- 80’s: Chun Doo-hwan
  - Localization of NPP technology, KAERI’s role

- 2009: Lee Myung-Bak
  - Summit diplomacy, super salesman
Leadership of Han Pil-soon
(KAERI president for 1982 – 1991)

- “CAN DO” spirit, technical self-reliance
- Transparency from commercial projects

- Step-by-step demo of confidence
  - CANDU fuel, PWR fuel, NSSS system design

- Hitch-hike strategy on proven technology
  - Know-how’s from technology transfer

- Joint Design approach for developing country
  - Shortage of time/money/exp. manpower
NPP standardization policy (1981-85)

- Reactor type: 1,000 MWe PWR + ADFs
- Technology self-reliance entity/area
  - KEPCO: overall project management (KHNP)
  - KOPEC: architect engineering
  - KHIC: NSSS, T/G supply (Doosan)
  - KAERI: NSSS system, initial core design
  - KNFC: nuclear fuel fabrication (KNF)

Electric Power Group Cooperation Council
4.2 National lab’s (KAERI) participation

- Breakdown of reprocessing venture (1975)
- Name change: “Atomic” to “Advanced” (1980)
- CANDU/PWR fuel localization (1983)
- KAERI in the commercial NPP projects (1985)
  - NSSS system, initial core design
  - Int’l tender among W, C-E, Fram, AECL
  - Technology buyer’s market after Chernobyl
- Y3 /4 construction with Technology Transfer
NSSS system designer’s role

- Determines NPP type, power level, safety
  - Designs RCS + aux sys + safety sys + MCR
  - Top-tier know-how, know-why
- Commissioning test, performance warranty
- Reactor control and protection architecture
- Central to regulatory licensing
- NSSS vendors’ reactor models
  - W: AP1000, Areva: EPR, KEPCO: APR1400
  - GE: ABWR, AECL: EC6, AEP: VVER1000, H/T/M
NSSS system design comparison (1985)

- **Westinghouse (Framatom)**
  - RCS 2/3/4 loops, submarine technology
  - Largest no. built, tech transfer licensees
  - AP-1000, EPR development

- **Combustion Engineering (C-E, now part of W)**
  - RCS all 2-loop, boiler maker technology
  - Simpler, robust design
  - Only 1300 MWe System-80s built in US
  - No technology transfer licensing experience
Technology Transfer thru Joint Design (1987)

- Unique concept to overcome shortages
  - Experienced manpower
  - Save time and budget costs
  - Performance guarantee/warranties

- US/Korean counterparts
  - Reactor systems/core design: CE/KAERI
  - Plant engineering: S&L/KOPEC
  - Component design/manufacturing: CE/GE/KHIC
  - Fuel fabrication: CE/KNFC
Technology Transfer thru Joint Design

- Transfer of design tools (1987)
  - Computer codes, documents, patent rights

- Design center moved, US to Korea (1989)
  - Joint design team from Windsor to Daedeok

- Transition of performance warranty

- Additional training, R&D participation
- Technical self-reliance 95% by 1995
  - Birth of Korean reactor model OPR1000, APR1400
First KAERI Joint Design team sent to Windsor (1986)
### OPR 1000 & APR 1400

#### OPR1000

#### APR1400

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<thead>
<tr>
<th>Parameters</th>
<th>OPR1000</th>
<th>APR1400</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power capacity (MWe)</td>
<td>1000</td>
<td>1400</td>
</tr>
<tr>
<td>Design life time (yr)</td>
<td>40</td>
<td>60</td>
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<tr>
<td>Seismic design criteria</td>
<td>0.2g</td>
<td>0.3g</td>
</tr>
<tr>
<td>Core damage frequency</td>
<td>$6.8 \times 10^{-6}$/RY</td>
<td>$2.4 \times 10^{-6}$/RY</td>
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<tr>
<td>Emergency core cooling</td>
<td>2 Train</td>
<td>4 Train</td>
</tr>
<tr>
<td>Main control type</td>
<td>Analog + Digital</td>
<td>Digital</td>
</tr>
</tbody>
</table>

- OPR1000: Optimized Power Reactor 1000MW
- APR1400: Advanced Power Reactor 1400MW
Technical Bases – Evolutionary Design

EPRI URD/EURD
System 80+
(CE, 1300MWe)

APR 1400
1,400 MWe
Under Construction
- SKN # 3,4, SUN # 1,2

System 80+
(CE, 1300MWe)

ADF/PDF
Latest Codes
& Standards

* OPR1000: Optimized Power Reactor 1000

Improved OPR 1000
1,000 MWe

- In Operation
- YGN #5,6 (’02/’02)
- UCN #5,6 (’04/’05)

- Under Construction
- SKN #1,2
- SWN #1,2

OPR 1000
1,000 MWe

- In Operation
- YGN #3,4 (’95/’96)
- UCN #3,4 (’98/’99)

NSSS Design
Palo Verde #2 (CE,1300MWe)

Core Design
ANO #2 (CE,1000MWe)

*APR1400: Advanced Power Reactor 1400
Safety System – Safety Injection System

- 4 independent trains
  - 1 SIP/train
  - 1 SIT/train

- Direct Vessel Injection (DVI)
  - No injected water spillage in LOCA

- In-containment Refueling Water Tank (IRWST)
  - No switchover for long-term cooling during LOCA

- Fluidic Device in Safety Injection Tank
  - Play the role of Low Pressure SIP
Unfinished self-reliance (5%)

- Third party owned restricted codes
  - Replacement codes developed at KAERI
    ATLAS verification test
  - Korean NPP original know-why’s
- Reactor coolant pump design/manufacturing
- Main Control Room MMIS

“Westinghouse scope in UAE contract”
4.3 Utility’s project management/operation

- **In Operation**: 20 units (17,716MW)
- **Under Construction**: 8 units (6,800MW)

**Radioactive Waste Disposal Facility** (Under construction)

**Ulchin**: 1, 2, 3, 4, 5 & 6
- Shin–Ulchin 1 & 2 (Under construction)

**Wolsong**: 1, 2, 3 & 4
- Shin–Wolsong 1 & 2 (Under Construction)

**Kori**: 1, 2, 3 & 4
- Shin–Kori 1–4 (Under Construction)

**Younggwang**: 1, 2, 3, 4, 5 & 6
Status of nuclear power construction

Shin Kori 1&2

Shin Wolsong 1&2

Shin Kori 3&4

Shin Ulchin 1&2
NPP construction management

- Integrated management from K1
- Project Management 3 principles
  - On time: construction period
  - In budget: initial capital cost
  - In quality: meeting ASME/IEEE codes
- KEPCO lead, EPGCC teamwork
- Lessons learned from repeat projects
Enhancement of Construction Method

Open-Top Method

Modularization
Operational performance

Capacity Factor

- Korea: 93.4%
- Canada: 66.7%
- Russia: 73.1%
- France: 76.1%
- USA: 89.9%

World Average: 79.4%

Unplanned Capability Loss

- Korea: 0.36%
- Russia: 1.40%
- France: 3.01%
- USA: 9.16%

World Average: 5.65%

※ Source: Nucleonics Week (2009, 3)

※ Source: IAEA
Accomplishments of nuclear power

Economical efficiency

- Sales price (KRW/kWh): Nuclear is the cheapest (year 2008)

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Solar</th>
<th>Wind</th>
<th>Oil</th>
<th>Gas</th>
<th>Hydro</th>
<th>Coal</th>
</tr>
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<tbody>
<tr>
<td>Price (KRW/kWh)</td>
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<td>126.7</td>
<td>191.5</td>
<td>143.6</td>
<td>135.6</td>
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<tr>
<td>Nuclear Price (KRW/kWh)</td>
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</tr>
</tbody>
</table>

Contribution to national economy

- Consumer price 221.4% rise
- Electricity price 10.2% rise

1982 → 2008
4.4 Nuclear Industry commercial competitiveness

Electric Power Group Cooperation Council
5. Lessons learned

- Anti-nuclear movements since 1988

- 20 years for LM radwaste repository site

- Nuclear armed North Korea
  - KEDO LWR mothballed after ~$1 bil

- Spent fuels keep piling up
Key Factors for Success

- Consistent pro-nuclear government policy
  - 4 Presidents’ personal support
- Standardization with repeat plants
  - 12 KSNP 1000 MWe PWRs built by EPGCC
  - Licensing process, supply chains streamlined
- National lab for early technical self-reliance
  - KAERI on NSSS system design with C-E
- Powerful utility with proven management
  - KEPCO and EPGCC ready for export market
- “Two-out-of-three” mentality
  - Hard work + inter-personal skills
What are the lessons?

- For the nuclear majors:
  - Chernobyl fallout
  - Less secrecy, competition
    More cooperation, networking

- For developing countries:
  - "Can Do" spirit, "2 out of 3" + 1

- For NPP market:
  - Market economics over politics

"Nuclear Silk Road builders"
Koreanization of Nuclear Power Technology

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bkkim9@gmail.com