Status of Fast Reactor Technology Development in Korea

FBR Seminar
Tsuruga
March 8, 2012

Dohee Hahn
I Status of Nuclear Energy in Korea
Status of Energy Supply in Korea

96.6 % of energy was imported in 2010

Year 2010

Korea's Energy Consumption

8th World Ranking

- Energy Consumption : 261 Mtoe
  * Ref: BP (2011), Statistical Review of World Energy

Korea's Energy & Oil Import

- Energy Import : 252 Mtoe
  (118 Billion USD, 27 % in total import)
- Oil Import : 147 Mtoe
  (69 Billion USD)

* Ref: Korea Energy Economics Institute (2011)
Electricity demand increases with the growth of economy
Nuclear power plays a significant role for electricity generation
Nuclear Power Plants in Korea

- Wolsong (#1,2,3,4)
- Shin-Wolsong (#1,2)
- Ulchin (#1,2,3,4,5,6)
- Shin-Ulchin (#1,2)
- Kori (#1,2,3,4)
- Shin-Kori (#1)
- Shin-Kori (#2,3,4)
- Yonggwang (#1,2,3,4,5,6)

### Units [MWe]

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<tr>
<th>Site</th>
<th>In Operation</th>
<th>Under Construction</th>
<th>Total (2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Sin)Kori</td>
<td>5 (4,137)</td>
<td>3 (3,800)</td>
<td>8 (7,937)</td>
</tr>
<tr>
<td>(Sin)Wolsong</td>
<td>4 (2,779)</td>
<td>2 (2,000)</td>
<td>6 (4,779)</td>
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<tr>
<td>Yonggwang</td>
<td>6 (5,900)</td>
<td>-</td>
<td>6 (5,900)</td>
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<tr>
<td>Ulchin</td>
<td>6 (5,900)</td>
<td>2 (2,800)</td>
<td>8 (8,700)</td>
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<tr>
<td>Total</td>
<td>21 (18,716)</td>
<td>7 (8,600)</td>
<td>28 (27,316)</td>
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</table>

- Plants Under Construction
  - OPR1000: Shin-Kori (#2), Shin-Wolsung (#1,2)
  - APR1400: Shin-Kori (#3,4), Shin-Ulchin (#1,2)

- Radioactive Waste Disposal Facility (Under construction)

Electricity Generation Cost in Korea

- Nuclear: 43.9 KRW/kWh
- Coal: 61.1 KRW/kWh
- LNG: 121.9 KRW/kWh
- Wind: 107.0 KRW/kWh
- Solar: 647.0 KRW/kWh

※ Ref: www.kosis.kr (2010. 02)
Impact of Fukushima Accident
Actions after Fukushima Accident

◆ Immediate Response to Fukushima Accident
  ✓ Emergency Response Team
  ✓ Close Communication with Public and Media
  ✓ Strengthened Environmental Monitoring
  ✓ Special Safety Inspection on Nuclear Facilities

◆ Actions for Safety Enhancement
  ✓ Establishment of an Independent Regulatory Body: Nuclear Safety and Security Commission (NSSC)
  ✓ Implementation of Action Items Identified by Special Safety Inspection
  ✓ Planning for Strengthened Nuclear Safety Research
  ✓ IAEA Integrated Regulatory Review Service Mission
Results of the Special Safety Inspection

- No Imminent Risks to Operating Nuclear Facilities
- 50 Action Items to Further Strengthen Defense in Depth
  - To minimize the impact of extreme natural disaster
  - To make emergency power and ultimate heat sink available during accidents
  - To ensure containment building integrity and emergency response capability
- Examples of Action Items
  - Re-evaluation of seismic capability for safety systems
  - Installation of a mobile emergency generator and battery
  - Installation of passive hydrogen removal equipment
  - Modification of 'radiological emergency plan' considering multiple emergencies
Securing a high level of safety is a pre-requisite for further development and utilization of nuclear energy

Very high level of safety is expected by incorporating the lessons learned from Fukushima accident

Honest, sincere, continuous communication on nuclear and radiation safety is important
“I do not think that Fukushima accident should be cause to renounce nuclear energy; on the contrary, this is a moment to seek ways to promote the safe use of nuclear energy based on scientific evidence.”

“The use of nuclear energy is inevitable as there still remain technical and economic limits for alternative energy…”

“we will actively utilize nuclear energy in accordance with our ‘low carbon, green growth’ policy.”
Nuclear Promotion Policy

◆ Development of Nuclear Energy as Driver for Economic Growth
  ✓ Development of Small and Medium Reactors and Research Reactors
  ✓ Non-electricity applications including hydrogen production

◆ Development of Advanced Technologies
  ✓ Spent fuel recycle technologies
  ✓ Environmentally friendly decommissioning technologies

◆ Enhancement of Safety
  ✓ Safety against extreme natural disasters
  ✓ Center of excellence for safety R&D

◆ Higher Standard of Living
  ✓ Medical application of radiation
  ✓ Stable supply of medical isotopes

◆ Expansion of Infra-structure
  ✓ High level human resources development
  ✓ International cooperation
National Energy Basic Plan

Power Plant Capacity Share (%)

2007
- LNG (-8\%) 26%
- Coal 30%
- Nuclear (+15\%) 26%

2030
- LNG (-8\%) 18%
- Coal 31%
- Nuclear 41%

Electricity Generation Share (%)

2007
- LNG (-19\%) 20%
- Coal (-9\%) 38%
- Nuclear (+23\%) 36%

2030
- LNG (-19\%) 1%
- Coal 29%
- Nuclear 59%

Ref: National Energy Committee (2008.8.27)
Comprehensive Nuclear Energy Promotion Plan for ‘12-'16

Nuclear Systems
- Gen IV (SFR, VHTR)
- SMR (SMART)
- ALWR (APR+, PPP)

Plant Performance
- Equipment development
- System improvement
- Advanced fuel

Medical Application
- Radiation Image (PET)
- Biological radiation effects
- Radiation Therapy

Radiation Application & RI
- RI Production system
- Detector and radiation sources
- Materials and radiation physics

Radiation Protection
- Regulatory guide establishment
- Long-term epidemic study
- Environment effect analysis

Nuclear Safety
- Analysis tools and experiments
- Risk analysis and applications
- Material degradation
- Seismic geology

Plant Performance
- Equipment development
- System improvement
- Advanced fuel

Radwaste Management
- Radwaste disposal
- Pyroprocess
- Decommissioning & decontamination

Nuclear R&D
III

SFR R&D Program
Why Fast Reactor?

Reduction of Spent Fuel Disposal
Reduction of Radiotoxicity

Efficient Utilization of Uranium Resources

Sustainability of Nuclear Energy

Fast Reactors

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Fast Reactors

Why Fast Reactor?
Reactors Transition Scenario - KAERI Study

- Growth rate of electricity generation
  - 2006~2030: Planned
  - 2031~2050: 1.0%/year
  - 2051~2100: Reduced to 0%/year in 2100
- Nuclear share of 59.0% after 2030
Long-term Plan for SFR Technology Development

- 2012: Conceptual design for prototype reactor
- 2017: Safety Analysis Report for Specific design
- 2020: Specific design approval
- 2028: Prototype reactor construction
R&D Activities

**STELLA-1**
- Design and manufacture completed
  - Heat exchangers and mechanical pump
  - Main component: tank, heater, cold trap, electro-magnetic pump, etc
- Installation completed

**Metallic Fuel**
- Fuel Rod Fabrication (7.0mm OD, 1000mm L)
- HT9 Cladding Fabrication

**V&V of core neutronics code system**
- Sensitivity analysis code development (APSTRACT)
- Generation of adjusted cross section
- Reactor physics experiment in collaboration with IPPE

**Under-Sodium Viewing Technology**
- Waveguide Sensor Module
- Performance Tests in Sodium

**Validation of Safety Analysis Code Models**
- Analysis of Phenix End of Life Test
- Reactivity model evaluation with EBR-II test

**New Compact Heat Exchanger for S-CO₂ Brayton Cycle**
- Development of a new compact Na/CO₂ heat exchanger
- Construction of test facility

**V/V of commix code model by water mockup facility**
- Measurement of velocity field by PIV
- Measurement of pressure loss of components in flow path

FBR Seminar, Tsuruga, 8 March 2012
STELLA-1: Sodium Integral effect Test Loop for safety simulation and Assessment

- Performance demonstration for mechanical sodium pump
- Evaluation of HX performance & verification of HX design codes

STELLA-1 Main Characteristics
- Working fluid: Sodium
- Total electric power: 2.5MW
- Sodium mass: 11ton
- Max. sodium temp.: 600°C
- HX capacity: 1.0MW_t
- Max. HX flowrate: 10kg/sec
- Nominal pump flowrate: 123kg/sec

Schedule

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<tr>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
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<tr>
<td>Construction of STELLA-1 and Performance Experiment</td>
<td>Design Req’t</td>
<td>STELLA-1 Design</td>
<td>Manufacture and Installation of STELLA-1</td>
<td>Start-up test</td>
<td>Experiment</td>
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Metal Fuel Technology Development

**Fuel Slug Manufacturing**
- Establishment of Metal Fuel Slug Manufacturing System
- Manufacturing and Evaluation of Metal Fuel Slugs (U-10Zr) and Trial Rod
- Simulation for Remote Manufacturing of Metal Fuel Slugs

**Advanced Cladding**
- Design, Manufacturing and Evaluation of the Candidate Cladding Materials
- Preliminary Fabrication of HT9 Cladding Tube
- Barrier Technology Development for Preventing the FCCI

**Performance Evaluation**
- Irradiation of Metal Fuel in HANARO
- Development of Performance Evaluation Models for MA-bearing Metal Fuel

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**Objective**: To promote collaboration on advanced reactor technologies

- 6 candidates: SFR, VHTR, SCWR, GFR, LFR, MSR

**Status of SFR Projects**

<table>
<thead>
<tr>
<th>SFR System Arrangement (15 Feb 2006)</th>
<th>EUR</th>
<th>FRA</th>
<th>JPN</th>
<th>PRC</th>
<th>ROK</th>
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X=Signatory, D=Under Discussion
JAEKAERI Collaboration based on Monju Experience

- Monju design, construction and operation experiences can play an important role for SFR technology development
  - Safety analysis code validation with Monju experimental data
  - Development of under sodium viewing requirements

- Collaboration under the framework of GIF SFR Safety & Operation (SO) Project
  - SO Project Plan of 15 December 2011

Temp measurement in Monju upper plenum

Under sodium viewing technology
JAEA’s Sodium Handling Technology Training for KAERI

◆ Objective
- To enhance KAERI’s capability of sodium handling technology
- To share JAEA’s experiences on FBR construction & operation

◆ Course Overview
- Number of participants
  - 6 KAERI SFR experts
- Period
  - 16 Jan. – 20 Jan. 2012 (5 days)
- Venue
  - International Nuclear Information and Training Center (INITC), Tsuruga Head Office, JAEA

◆ Main program
- Fundamentals of sodium handling
- Sodium loop operation and instrumentation
- Sodium fire extinction
IV Summary
Summary

◆ Korea needs nuclear power plants to meet increasing demand for energy
  ✓ Energy security under poor energy resource situations

◆ Nuclear Promotion Policy remains the same after Fukushima accident
  ✓ Higher level of safety should be ensured for expansion of nuclear energy utilization

◆ SFR program plan
  ✓ Final goal is the construction of a prototype reactor by 2028

◆ GIF SFR Collaboration
  ✓ Plans for JAEA-KAERI joint work have been established for SFR safety enhancement utilizing Monju operation in the near future
  ✓ Monju design, construction and operational experience can play an important role