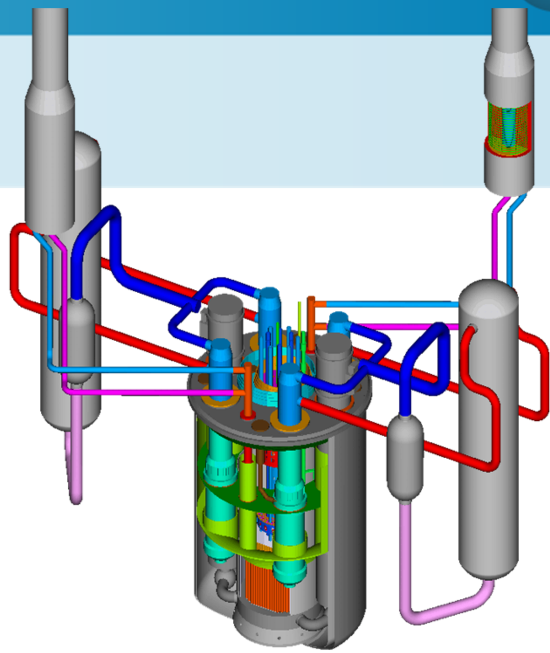
Status of Fast Reactor Technology Development in Korea

FBR Seminar
Tsuruga

March 8, 2012

Dohee Hahn



KAERI Korea Atomic Energy Research Institute

Outline

I Status of Nuclear Energy in Korea

II Impact of Fukushima Accident

III SFR R&D Program

IV Summary

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

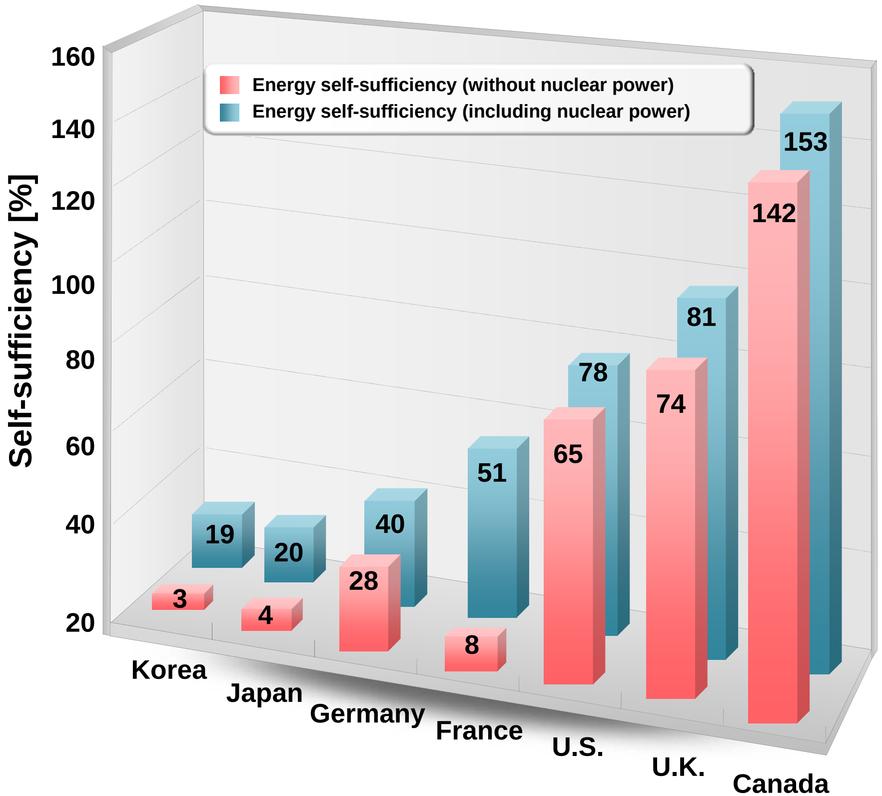
- **Energy Consumption : 261 Mtoe**

* *Ref*: BP (2011), Statistical Review of World Energy

Korea's Energy & Oil Import

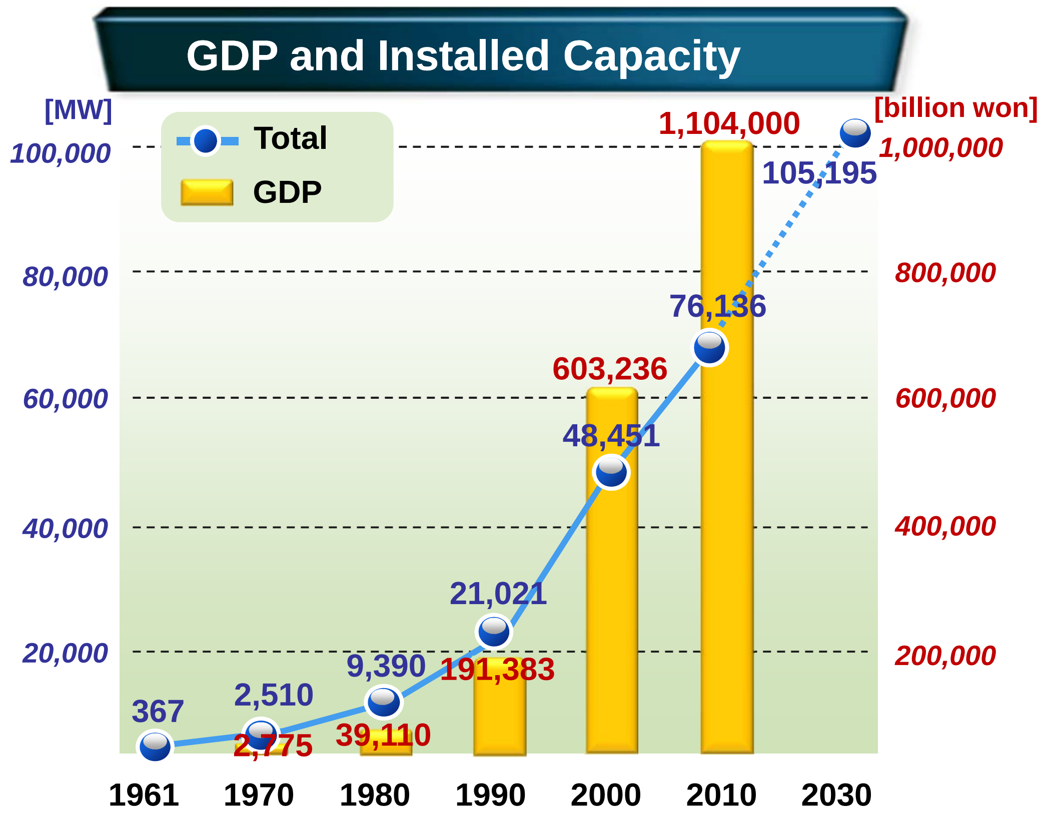
- **Energy Import : 252 Mtoe**
  (118 Billion USD, 27 % in total import)
- **Oil Import : 147 Mtoe**
  (69 Billion USD)

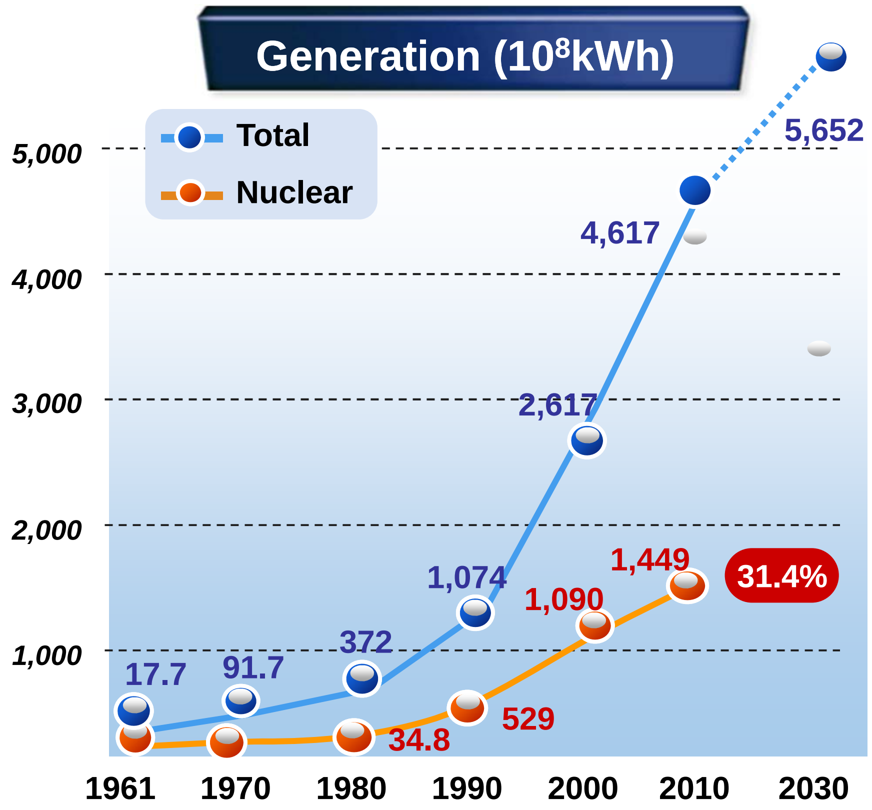
* *Ref*: Korea Energy Economics Institute (2011)



* IEA, Energy balance of OECD countries 2011

Energy Demand and Electricity Generation



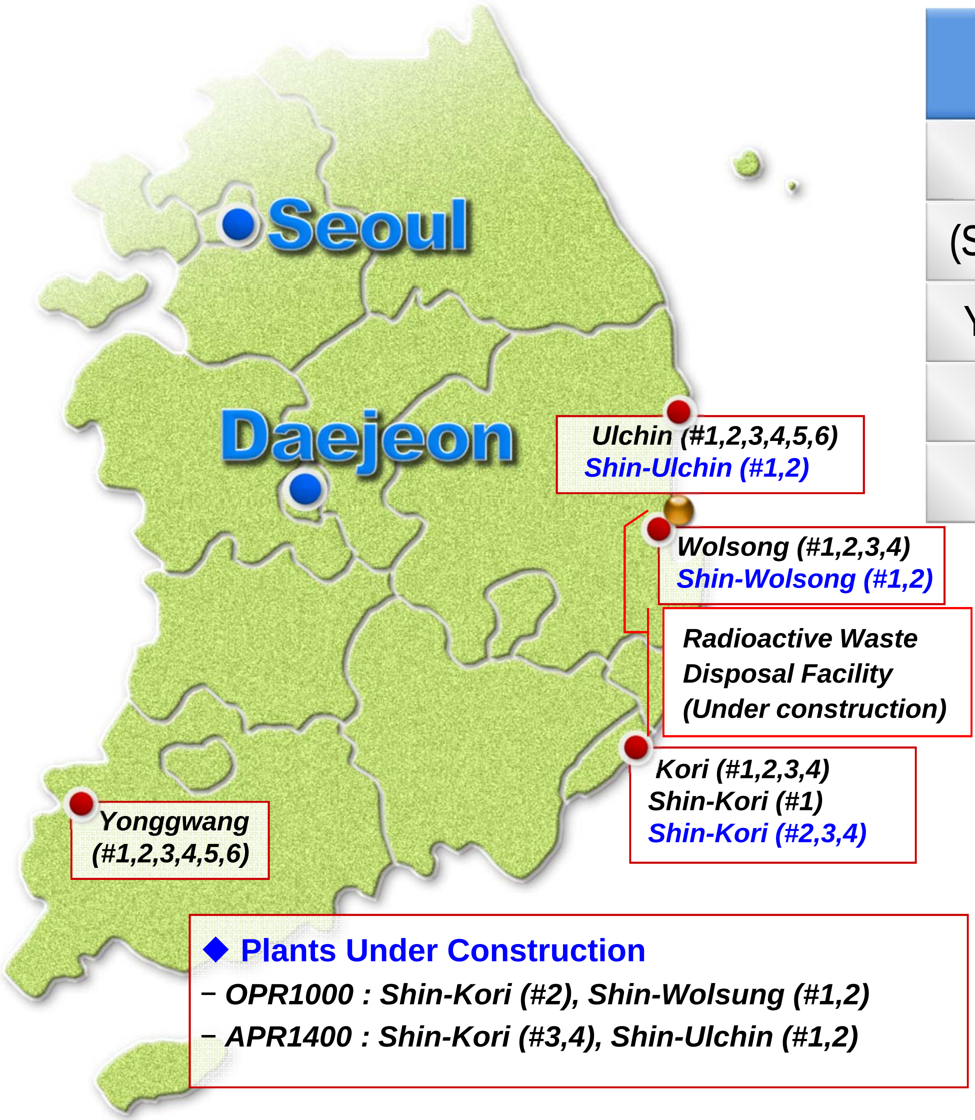


※ *Ref*: National Energy Committee (2008.8.27)

◆ Electricity demand increases with the growth of economy

◆ Nuclear power plays a significant role for electricity generation

Nuclear Power Plants in Korea

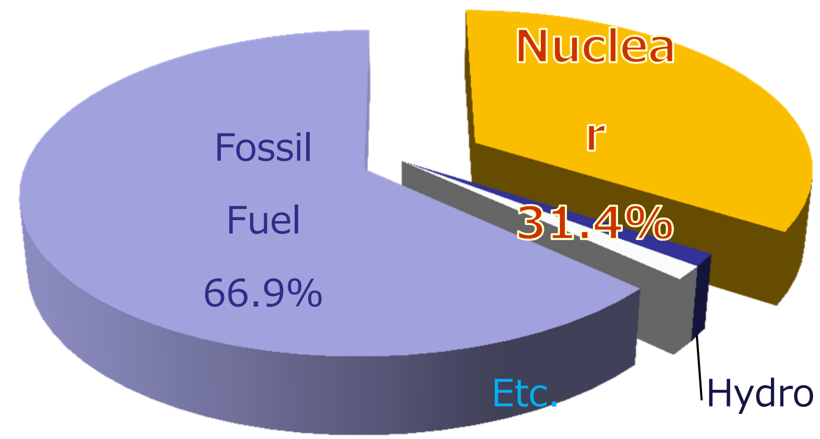


◆ Plants Under Construction

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

Units [MWe]

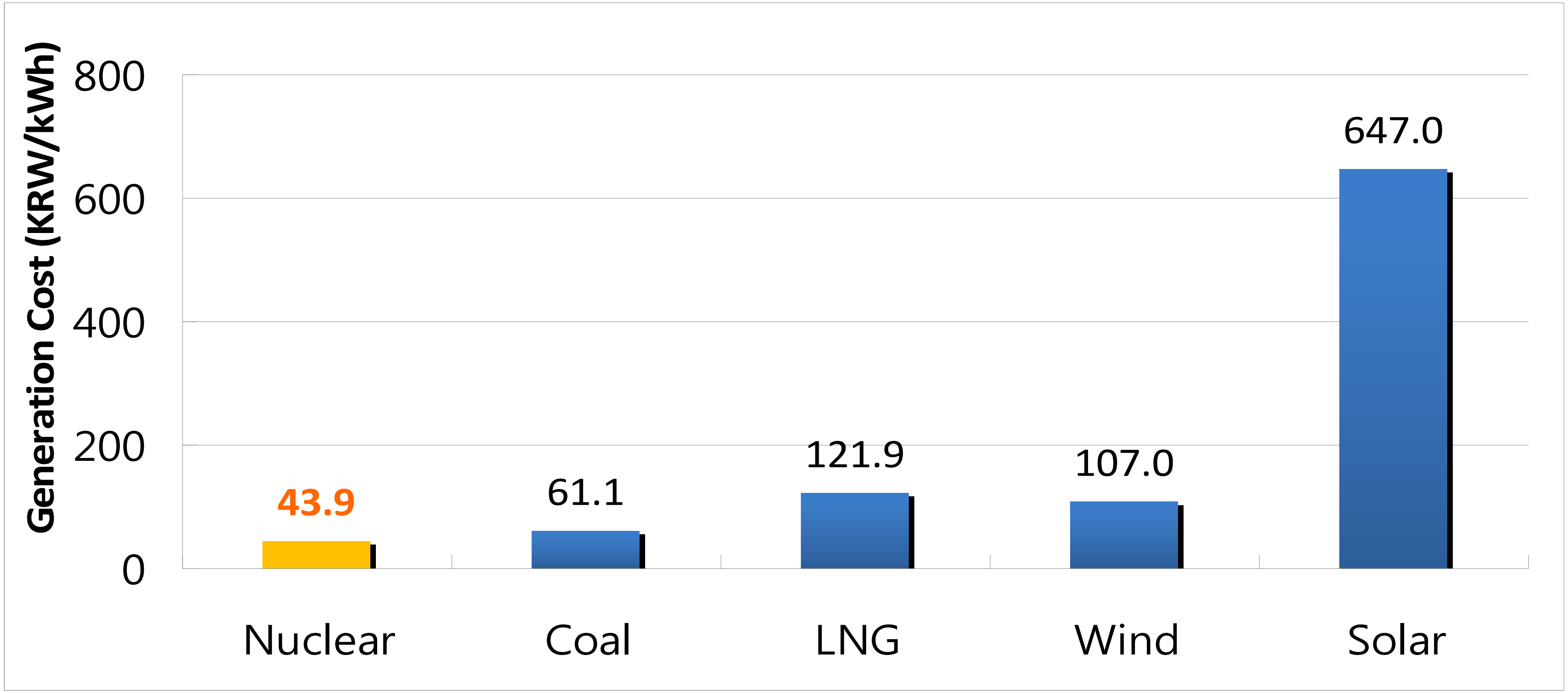
Site	In Operation	Under Construction	Total (2016)
(Sin)Kori	5 (4,137)	3 (3,800)	8 (7,937)
(Sin)Wolsong	4 (2,779)	2 (2,000)	6 (4,779)
Yonggwang	6 (5,900)	-	6 (5,900)
Ulchin	6 (5,900)	2 (2,800)	8 (8,700)
Total	21 (18,716)	7 (8,600)	28 (27,316)



※ *Ref:* www.kosis.kr(2010)

Electricity Generation Cost in Korea

※ *Ref*: www.kosis.kr(2010. 02)



II 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

Fukushima Lessons for Promotion of Nuclear Energy

- **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**

Speech from President Lee

UN High-Level Meeting on Nuclear Safety
September 22, 2011

"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."

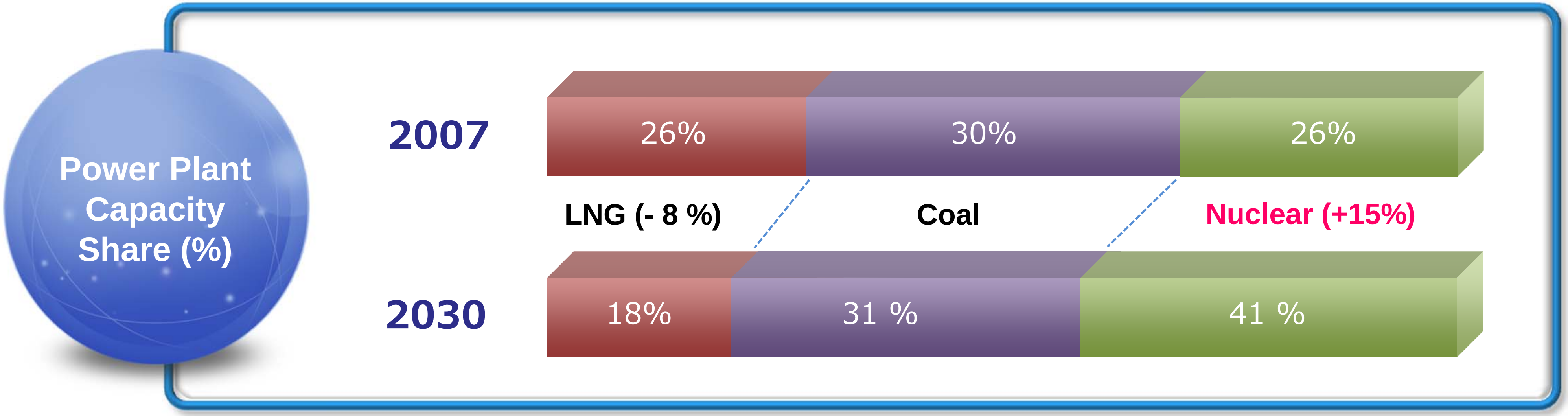
" The use of nuclear energy is inevitable as there still remain technical and economic limits for alternative energy…"

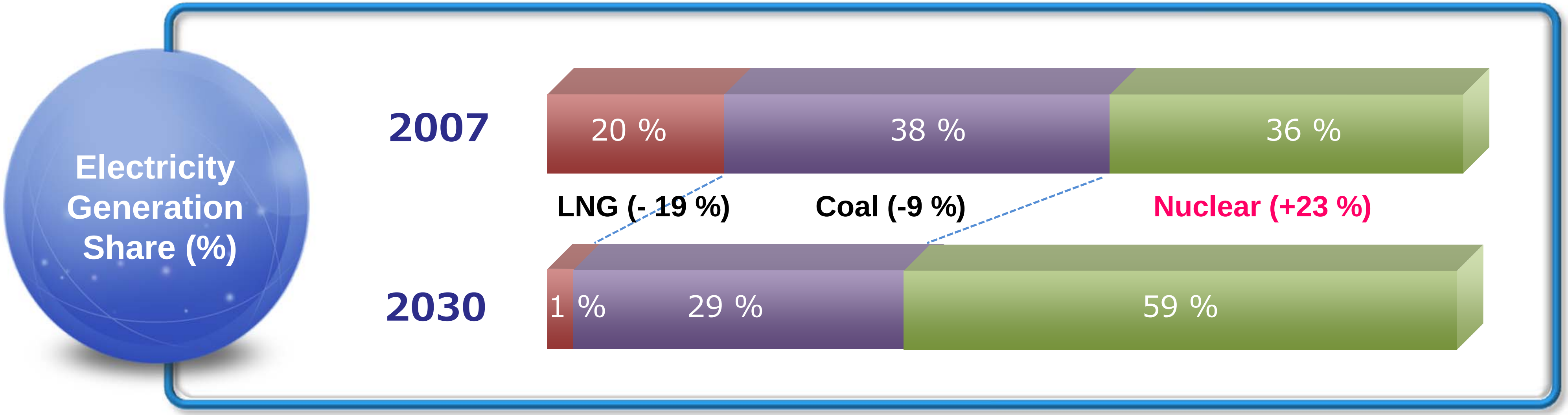
" we will actively utilize nuclear energy in accordance with our 'low carbon, green growth' policy."

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





※ *Ref*: National Energy Committee (2008.8.27)

Comprehensive Nuclear Energy Promotion Plan for '12-'16

Nuclear R&D

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

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

Plant Performance
- Equipment development
- System improvement
- Advanced fuel

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

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

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

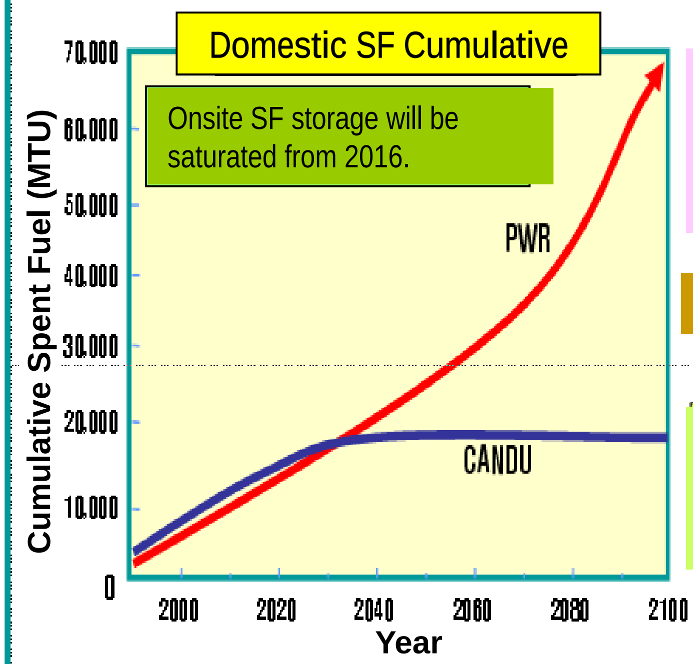
Radwaste Management
- Radwaste disposal
- Pyroprocess
- Decommissioning & decontamination

III

SFR R&D Program

Why Fast Reactor?

Reduction of Spent Fuel Disposal Reduction of Radiotoxicity

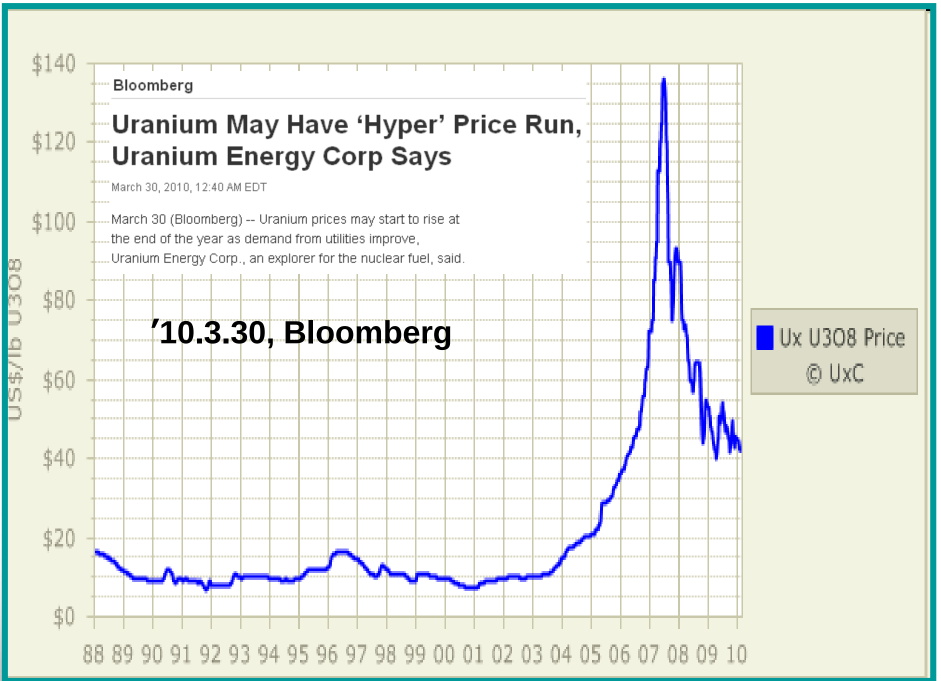


- Direct disposal
  - A formidable construction cost and huge site for final disposal repository
  - Radiotoxicity lasting over 300 thousand years

Reuse of Spent Fuel

- Safe management of SF through reduction of radwaste volume,heat load and radiotoxicity environment friendly

Efficient Utilization of Uranium Resources

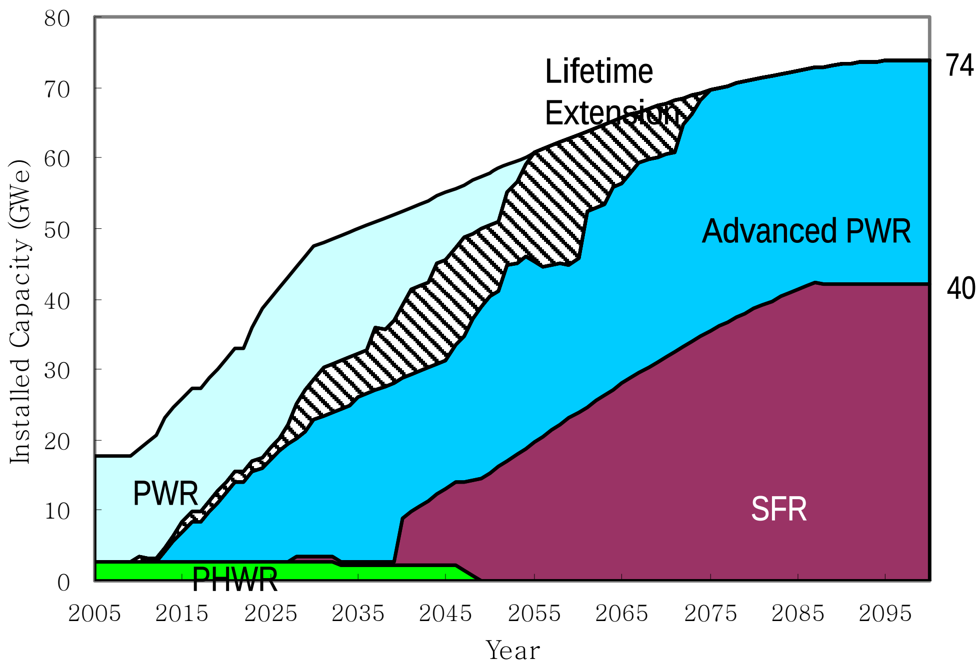


Sustainability of Nuclear Energy

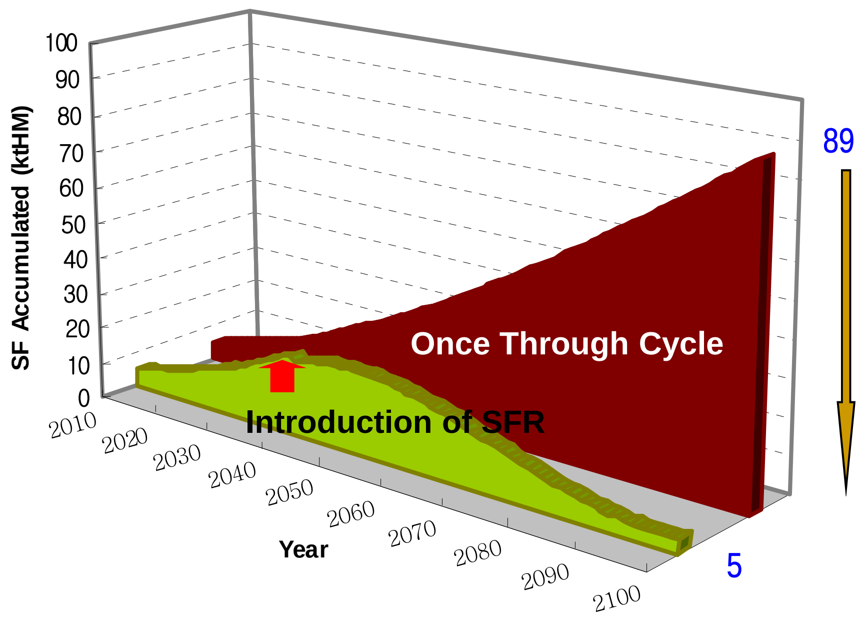
Fast Reactors

Reactor 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**



Reactor Deployment Scenario

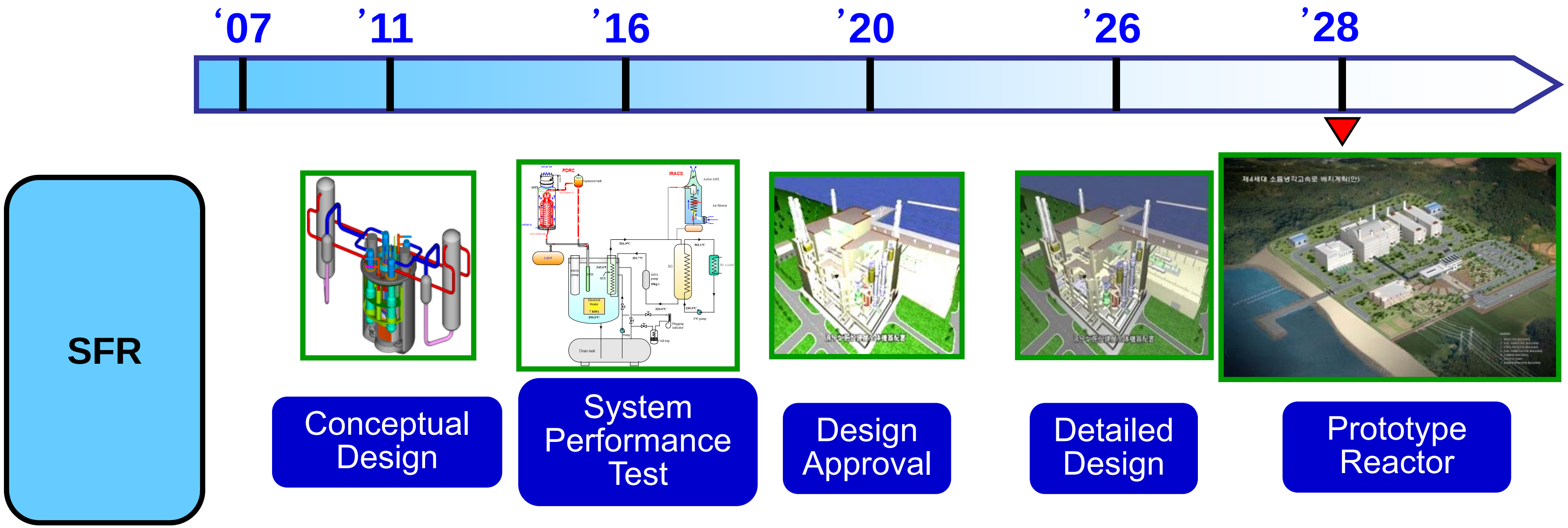


(Capacity Factor 85%)

Cumulative PWR Spent Fuel

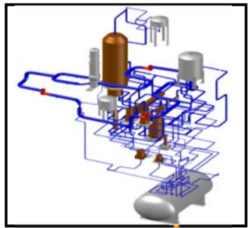
Long-term Plan for SFR Technology Development

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

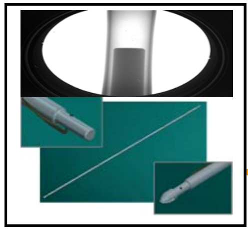


R&D Activities

STELLA-1

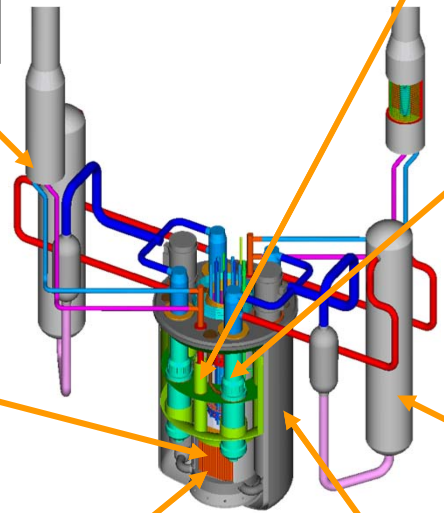


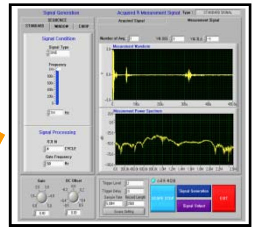
- Design and manufacture completed
  - ✓ Heat exchangers and mechanical pump
  - ✓ Main component: tank, heater, cold trap, electro-magnetic pump, etc
- Installation completed



Metallic Fuel

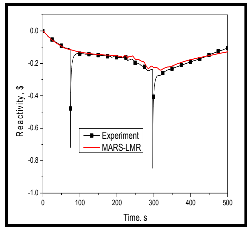
- Fuel Rod Fabrication((7.0mm OD, 1000mm L)
- HT9 Cladding Fabrication





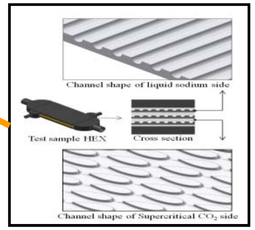
Under-Sodium Viewing Technology

- Waveguide Sensor Module
- Performance Tests in Sodium



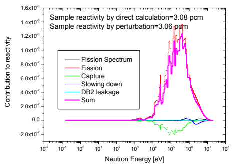
Validation of Safety Analysis Code Models

- Analysis of Phenix End of Life Test
- Reactivity model evaluation with EBR-II test



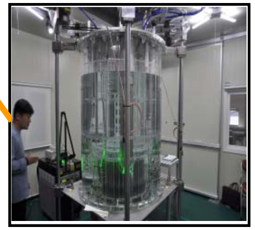
New Compact Heat Exchanger for S-CO_2 Brayton Cycle

- Development of a nes compact Na/CO_2 heat exchanger
- Construction of test facility



V&V of core neutronics code system

- Sensitivity analysis code development (APSTRACT)
- Generation of adjusted cross section
- Reactor physics experiment in collaboration with IPPE

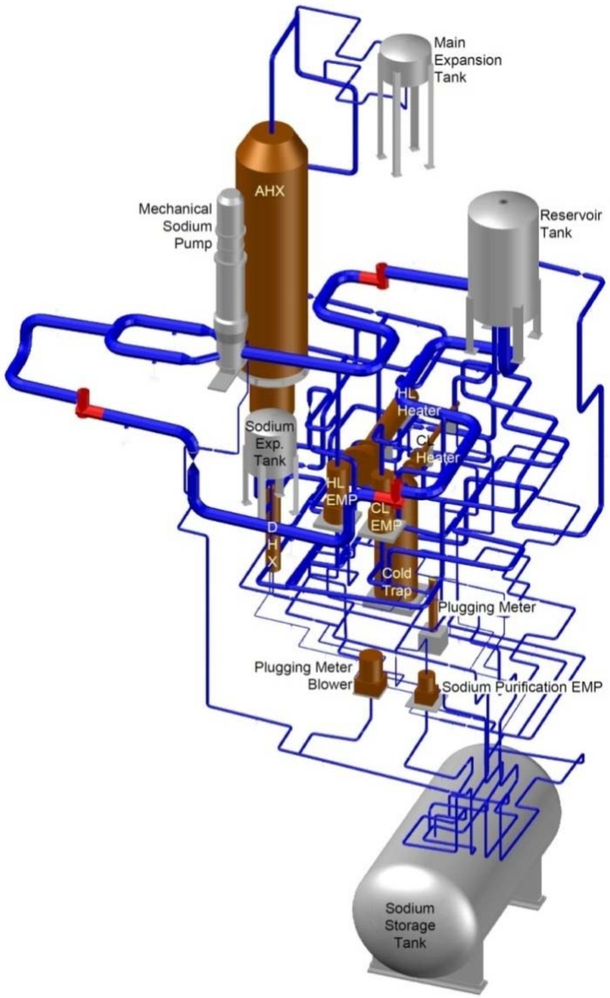


V/V of commix code model by water mockup facility

- Measurement of velocity field by PIV
- Measurement of pressure loss of components in flow path

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^{o}C
  - HX capacity: 1.0MW$_t$
  - Max. HX flowrate: 10kg/sec
  - Nominal pump flowrate: 123kg/sec

Schedule	2009	2010	2011	2012	2013	2014
Construction of STELLA-1 and Performance Experiment	Design Req't → STELLA-1 Design; Construction of Power Supply & Sodium Storage Facility	Manufacture and Installation of STELLA-1	Manufacture and Installation of STELLA-1	Start-up test	Experiment	Experiment

STELLA-1

Ceremony for Completion of STELLA-1 Construction
Feb 24, 2012

Metal Fuel Technology Development

Fuel Slug Manufacturing

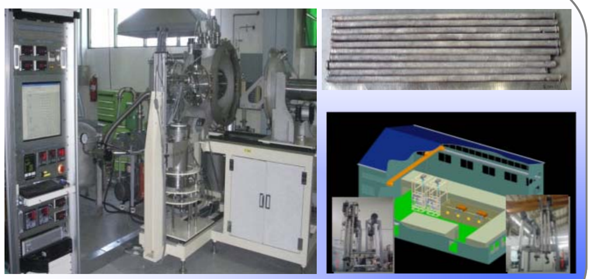
- Establishment of Metal Fuel Slug Manufacturing System
- Manufacturing and Evaluation of Metal Fuel Slugs (U-10Zr) and Trial Rod
- Simulation for Remote Manufacturing of Metal Fuel Slugs

Advanced Cladding

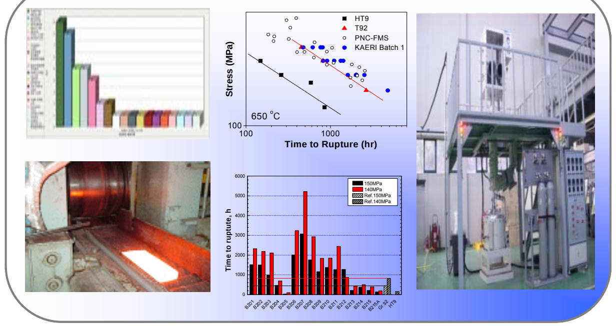
- Design, Manufacturing and Evaluation of the Candidate Cladding Materials
- Preliminary Fabrication of HT9 Cladding Tube
- Barrier Technology Development for Preventing the FCCI

Performance Evaluation

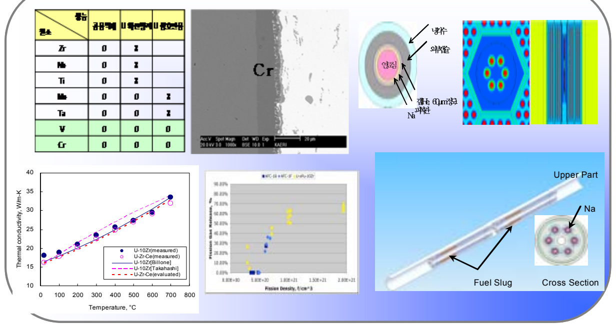
- Irradiation of Metal Fuel in HANARO
- Development of Performance Evaluation Models for MA-bearing Metal Fuel



Fuel Slug Manufacturing System & Fuel Slugs



Advanced Cladding Materials & Barriers



Irradiation & TRU fuel Performance Evaluation Models

Generation IV International Forum (GIF)

- **Objective : To promote collaboration on advanced reactor technologies**
  - ✓ 6 candidates : SFR, VHTR, SCWR, GFR, LFR, MSR

- **Status of SFR Projects**

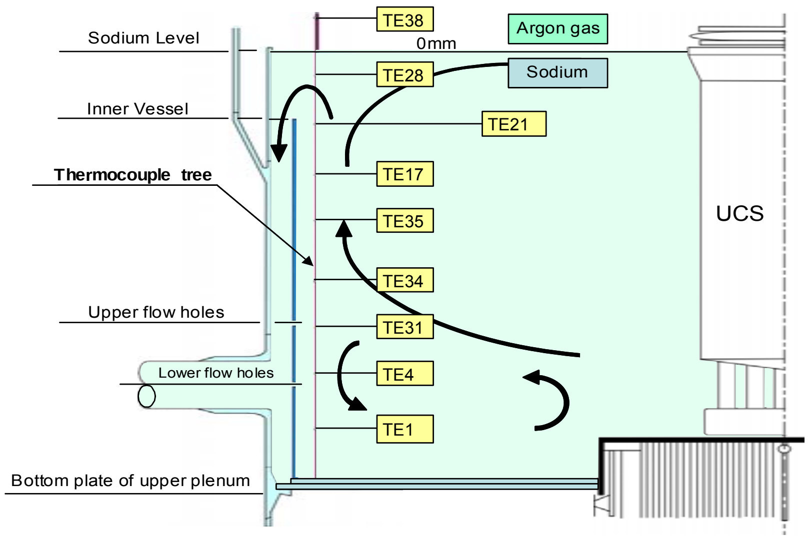
X=Signatory, D=Under Discussion

	EUR	FRA	JPN	PRC	ROK	RUF	USA
SFR System Arrangement (15 Feb 2006)	X	X	X	X	X	X	X
SFR AF PA (21 Mar 2007)	X	X	X	D	X	D	X
SFR GACID PA (Sept 2007)		X	X				X
SFR CDBOP PA (11 Oct 2007)	D	X	X		X	D	X
SFR SO PA (11 June 2009)	D	X	X	D	X	D	X
SFR SIA PA	D	D	D	D	D	D	D

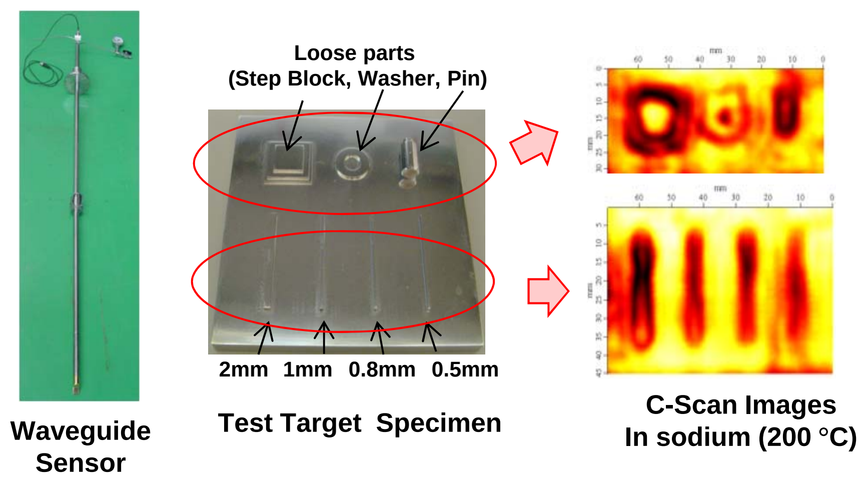
JAEA-KAERI Collaboration based on Monju Experience

- **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