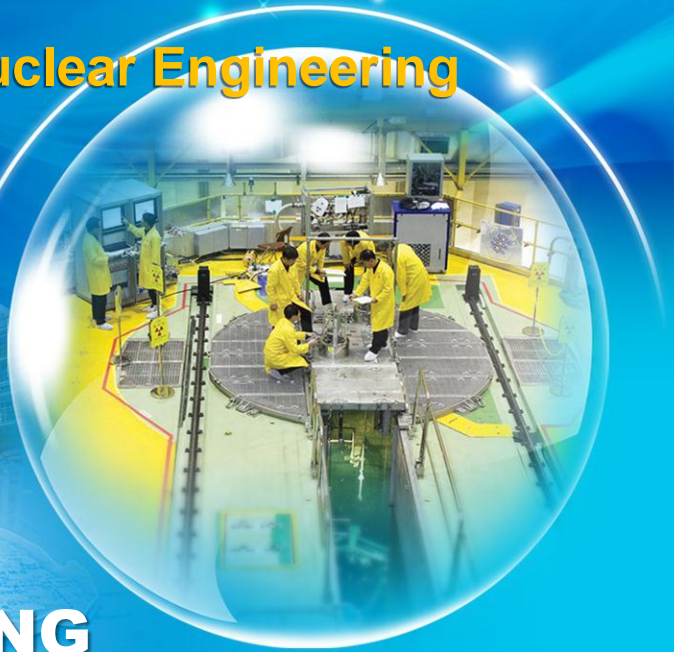


Nuclear Energy in Korea – Now and Future

23rd International Conference on Nuclear Engineering
May 18, 2015



Chiba, Japan



Moon Hee CHANG
President of KNS

Atoms for Peace, Nuclear for People

Contents

- 1 Nuclear Energy - Now
- 2 Post-Fukushima Days
- 3 Nuclear Energy Policy
- 4 Nuclear Energy - Future
- 5 Conclusion



Nuclear Energy - Now





**Isolated Electricity
Network**

Energy Environments of Korea

Import of Energy

◆ Cost for Total Import : 526 B\$ in 201>

- Cost for Energy Import: 119 B\$(33% of Total Import)



Dependency on Energy Import

95.7%

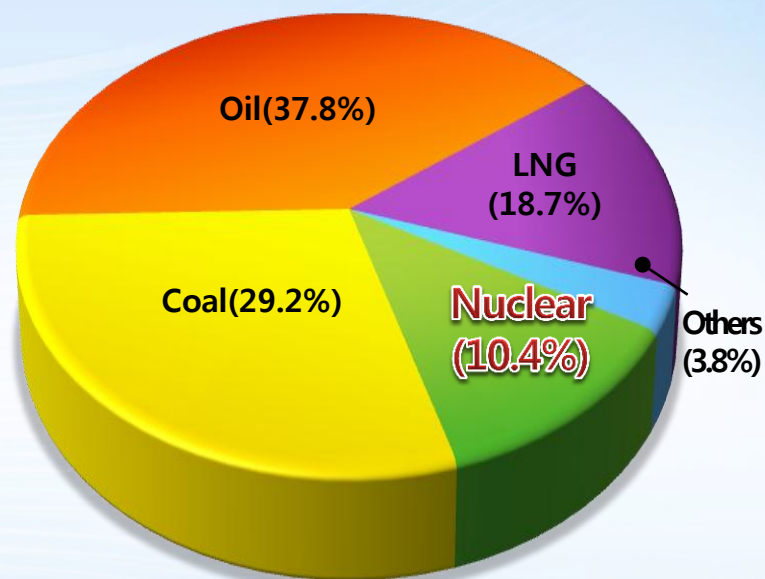
	Oil	Coal	LNG
rank	5th	3rd	9th

- ▶ Oil : USA>China>Japan>India>Korea ...
- ▶ Coal : Japan>China>Korea>India>Taiwan ...
- ▶ LNG : USA>Japan>Germany> ... >Korea

(source : KEEI)

Consumption of primary Energy

<TOE based, 2013>



Share of Fossil Fuel : 85.8%

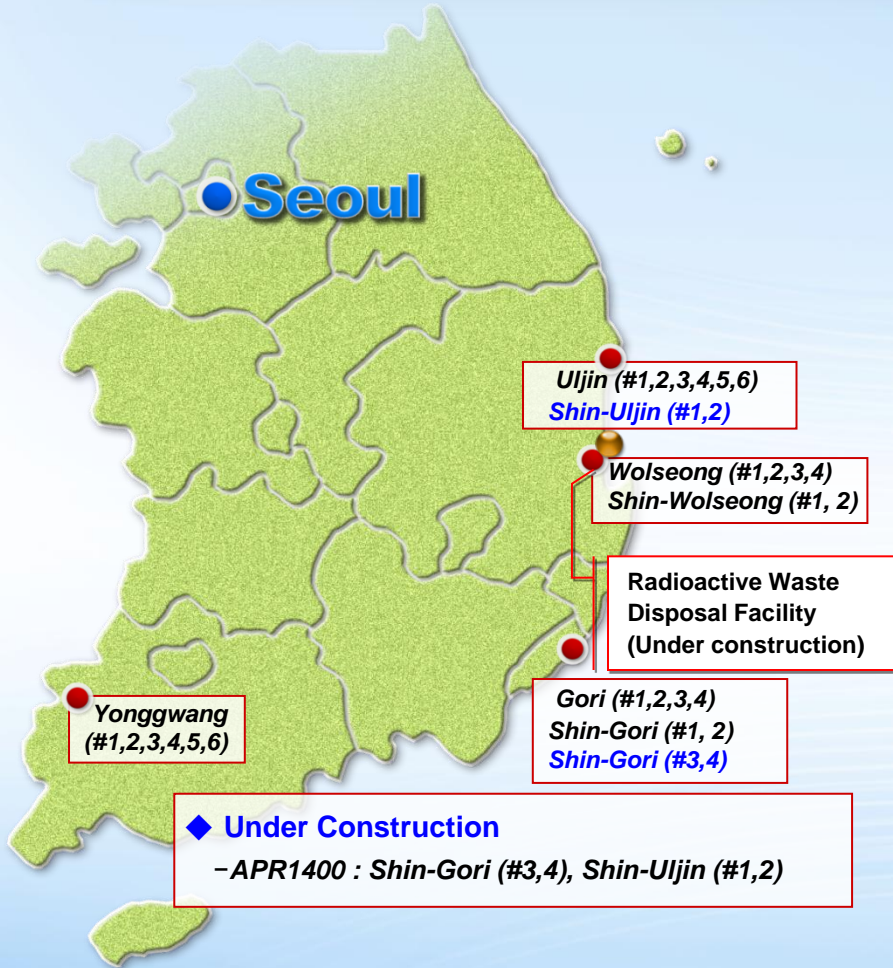
(source : KEEI)

Nuclear Power Plants in Korea

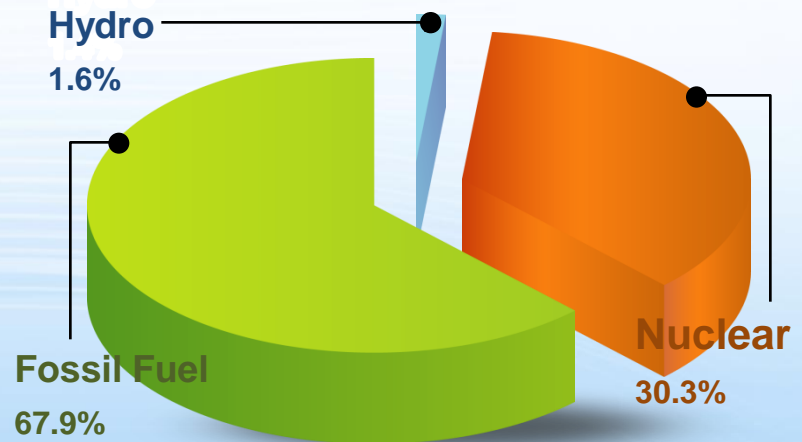
As of Dec., 2014

Site	In Operation	Under Construction	Total (2016)
Gori	6 (5,137)	2 (2,800)	8 (7,937)
Wolseong	6 (4,779)	-	6 (4,779)
Yonggwang	6 (5,900)	-	6 (5,900)
Uljin	6 (5,900)	2 (2,800)	8 (8,700)
Total	23 (20,716)	4 (5,600)	28 (27,316)

Source : www.khnp.co.kr



Ratio of Electricity Generation



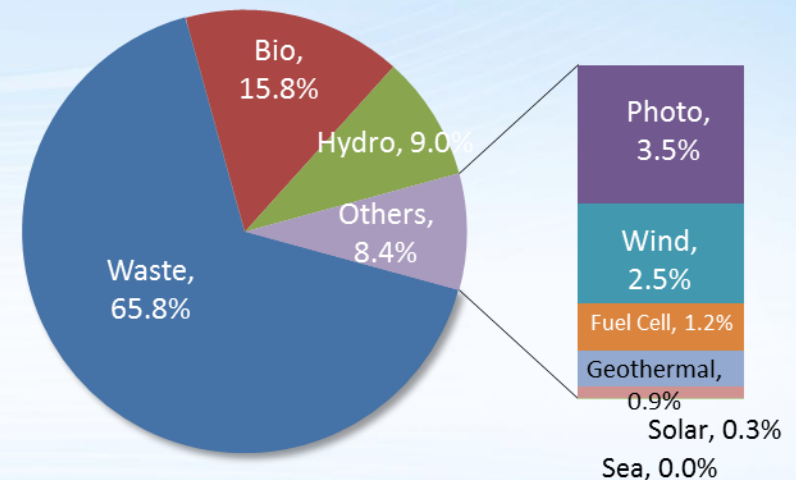
Source : www.Kepeco.co.kr

Supply of Renewable Energy in Korea

Trend in Supply of Renewable Energy



Share in Supply of Renewable Energy



Target of Renewable Energy Supply

- 2nd NEBP (2014)
- 6th Electricity Supply Basic Plan (2013)

- **11% Share in Primary Energy by 2035**
- **12.6% Share in Total Electricity Generation by 2027**

2nd National Energy Basic Plan (Jan. 2014)

- ◆ **Nuclear Share in Capacity : 29% by 2035** (1st NEBP in 2008, 41% by 2030)
 - ✓ Energy Security – Less Dependency on Fossil Fuels, Balanced Energy-Mix
 - ✓ Economics – Industry Competitiveness, Nuclear favorable(80%Capacity Factor)
 - ✓ Reduction of GG & Response to CC – Expansion of Low-carbon Nuclear & Renewable Energy
- ➡ **Total 43GW Needed by 2035 – 6th Power Supply/Demand Plan(36GW by 2024), 7GW Additionally Needed**
- ◆ **Major Subjects to Do for Policy Implementation**
 - ✓ Top Priority on Safety – Investment for Safety, NPP Management with Safety
 - ✓ Innovation in Nuclear Industry– De-root Absurdity, Transparent Management
 - ✓ Nuclear Export– Buildup of Experts, Export of Nuclear Parts and Components
 - ✓ Communication & Regional Cooperation – Transparent Communication, Involvement by Regional Residents, Support Regional Development
- ◆ **Strengthen Infrastructures for Back-End Cycle Management**
 - ✓ SF Public Engagement Committee, Timely Security of LMLRW Disposal Site, Technology Development for Decommissioning, etc.

What is Going on Now in Nuclear Power Sector?

- 23 NPP in Operation, 1 Unit (Shin-Wolseong #2) In Test Operation
- 4 Units under Construction, 4 Units Construction Confirmed

- ◆ **Wolseong #1** : 1st 10-year extended operation approved (**Feb. 2015**)
- ◆ **Kori #1** : 1st 10-year extended operation by **June 2017**
 - ✓ Should apply for 2nd extended operation by June 2015
- ◆ **Siting** for New Units : Need solution to struggles with local residents
 - ✓ Sam-Chuck (4 units), Young-Duk (4 units)
 - ✓ Political opposition party, NGOs – **stop new NPP**
- ◆ **Electricity Transmission** to Consumers – Conflict with local areas
- ◆ **Used Fuel Management** for PWRs, CANDUs
 - ✓ In-plant(site) storage approaches full capacity (~ 75%)
 - ✓ **UF Public Engagement Committee** under operation by **June 2015**
 - ✓ Issues : storage at sites, interim storage, reuse, disposal, etc.
- ◆ **Extended Operation or Decommissioning**
 - ✓ **8 units** complete licensed operation **before 2030**

Status of Licensed NPP Operation

Unit	Licensed Date	End of Operation	Unit	Licensed date	End of Operation
Kori #1	June 1977	June 2017	Hanul #3	Nov. 1997	Nov. 2037
Wolseong #1	Nov. 1982	Nov. 2022	Hanul #4	Oct. 1998	Oct. 2038
Kori #2	April 1983	April 2023	Wolseong #3	Dec. 1997	Dec. 2027
Kori #3	Sep. 1984	Sep. 2024	Wolseong #4	Feb. 1999	Feb. 2029
Kori #4	Aug. 1985	Aug. 2025	Hanbit #5	Oct. 2001	Oct. 2041
Hanbit #1	Dec. 1985	Dec. 2025	Hanbit #6	July 2002	July 2042
Hanbit #2	Sep. 1986	Sep. 2026	Hanul #5	Oct. 2003	Oct. 2043
Hanul #1	Dec. 1987	Dec. 2027	Hanul #6	Nov. 2004	Nov. 2044
Hanul #2	Dec. 1988	Dec. 2028	Shin-Kori #1	May 2010	May 2050
Hanbit #3	Sep. 1994	Sep. 2034	Shin-Kori #2	Dec. 2011	Dec. 2051
Hanbit #4	June 1985	June 2035	Shin-Wolseong#1	Dec. 2011	Dec. 2051
Wolseong #2	Nov. 1996	Nov. 2026	Shin-Wolseong#2	Feb. 2015	Fe. 2055

Status of UF Storage at Site (As of June 2014)

NPP Site	Capacity (Bundle)	Current Storage (Bundle)	Expected Full Capacity	Possible Extension	Remarks
Kori	6,494	5,257	2016	2028	<ul style="list-style-type: none"> ✓ Addition of Compact Racks to Shin-Kori #1, 2 UF Pits ✓ Relocation of UF from Kori #1-4 to Shin-Kori #1-6 Pits
Young-gwang	7,912	5,348	2021	2024	<ul style="list-style-type: none"> ✓ Compact Racks for Hanbit#2 ✓ Relocation of UF between Hanbit #1-6 Pits
Uljin	7,066	4,518	2018	2028	<ul style="list-style-type: none"> ✓ Relocation of UF from Hanul #1-6 to Shin-Hanul#1-4 Pit
Wolseong	499,632	385,172	2017	2025	<ul style="list-style-type: none"> ✓ Addition of Compact Dry Storage Facility(MACSTOR)

Source : KHNP



- ◆ Relocation of Site Storage of UF : Kori & Shin-Kori, Hanul & Shin-Hanul
- ◆ Additional Installation of Compact Dry Storage Facility(MACSTOR) at Wolseong

Post-Fukushima Days



Post-Fukushima Reactions: World

Many countries keep positive prospects for nuclear power
(Only a few countries have taken drastic action to shut down or abandon)



❖ IAEA perspective : 545~803GW by 2030(55th General Conference; '11.9)

Change in Environments of Nuclear Energy Use

- ◆ Fukushima – **Sank Down the Nuclear Renaissance**
 - Germany, Swiss, Italy Declared Escape from Nuclear Energy Use
 - Strengthen Safety Inspection & Safety Measurements by Major Nuclear-Use Countries
- ◆ Oil Countries & Developing Countries – **Interest in Nuclear**
 - Preservation of Oil-Resource, Uncertainty in Future Energy-Resources , Favorable in Economical Nuclear Energy
- ◆ Movements by **Well-Developed Nuclear Countries**
 - New NPP Construction(UK), Extended Operation of NPP(France), Expansion of Nuclear Plant (China, India)
 - Flexibility in Nuclear Policy of Japan – Reoperation from Zero Nuclear
- ◆ WNA – **Prospects** of about 430 New NPPs by 2030
- ◆ Economics of Nuclear Energy – Depend on **Energy-Resource Environments** of the Countries, **Different Country by Country**

Post-Fukushima Reactions: Korea

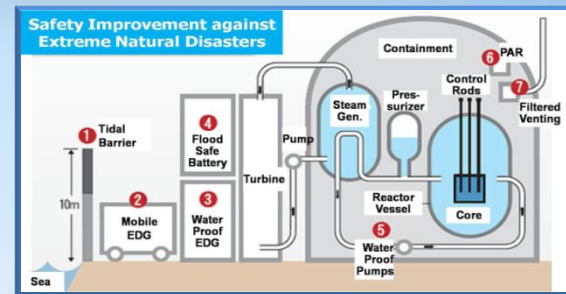
- Reinforced Safety Countermeasures

Actions for Safety Enhancement

Immediate on-site special safety inspection of all nuclear facilities

Identification of 50 items for enhanced safety of nuclear facilities

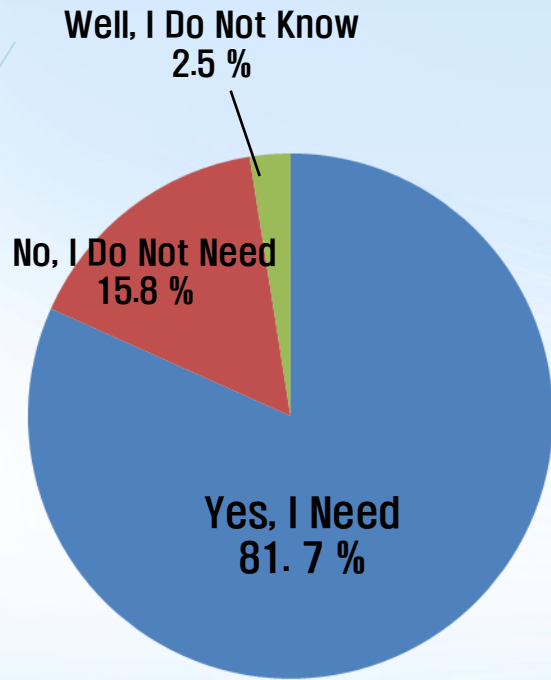
1 billion USD investment for implementation by 2015



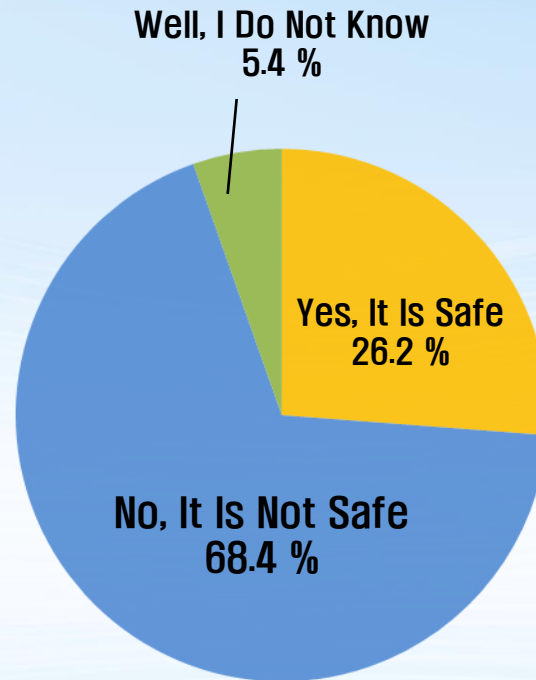
- New Nuclear Safety Act
- Nuclear Safety and Security Commission as an Independent Regulatory Body

New legal and organizational framework ('11.10)

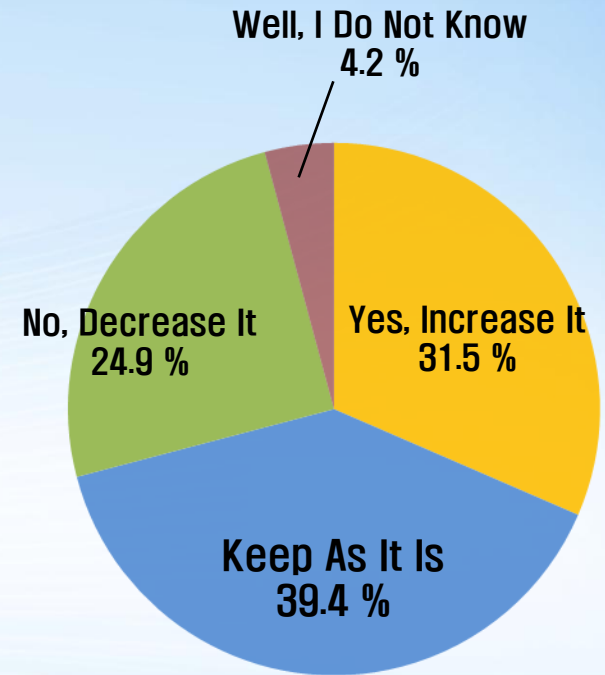
Public Perception on Nuclear Energy (as of Nov. 2014)



**Nuclear
Power
Necessity**



**Nuclear
Power
Safety**



**Nuclear
Power
Increase**

What Did We Learn From Fukushima Accident

Technical Aspect

- ◆ **Absolutely Secure Power Source at Any Cases**
 - ✓ EDG for Active, or Passive Safety Capability
- ◆ **Strengthen Response to and Protect Systems from Extreme Natural Events**
 - ✓ Heat Removal for Fuel Protection
- ◆ **Security of In-House Spent Fuel Pits**
 - ✓ Keep Cooling Capability
- ◆ **Prohibition of Hydrogen Explosion**
 - ✓ Control Hydrogen Contents in Containment
- ◆ **Inhabitability of Main Control Room even at Fukushima-like Accidents**
 - ✓ Monitor and Control at Site
- ◆ **Inspect All Existing Plant , Check Safety and Strengthen the Measures**
 - ✓ Stress tests, Counter-Measures If Needed
- ◆ **Reinforce Safety-related R&D**

Policy Aspect

- ◆ **Safety-focused Operation First, and then Management-focused Operation**
 - ✓ Safety is Top Priority than Others
- ◆ **Is It Acceptable to Have Multi-units of Reactors with Same Design at a Site ?**
 - ✓ A single failure cause influences all units
- ◆ **Responsible Functions of Control Tower**
 - ✓ Legal & Institutional System for Emergency
- ◆ **Safety Cultures and Responsibility**
 - ✓ Safety First at Any Cases by Myself
- ◆ **Evacuation Strategy – Well Established and Implementable ?**
 - ✓ Practicability of Implementation
- ◆ **Timely Communication and Information Share with Regional Public**
 - ✓ Rapidness, Transparency, Correctness

Nuclear Energy Policy



Environments of Energy Supply

Expectations on Energy Industry

Supplier

- High Profit, Profit Sustainability

User

- Low Cost, Safety, Convenience, High Quality, Supply Stability

Government

- Supply Stability, Sustainability, Environment-Friendly, Safety

Fossil Fuel

- ❖ High Profit for Supplier
- ❖ Convenience for User
- ❖ Uncertainty in Sustainability, Supply Stability and Cost, etc.
- ❖ Climate Change

Renewable

- ❖ Still Premature Technology in All Aspects
- ❖ Resources Limited
- ❖ Investment for Future Value

Nuclear

- ❖ Mostly Satisfactory for Supplier, User, and Government for the time being
- ❖ Safety and UF Issues Concerned

➤ **Nuclear Closely Satisfies Most of Industrial Energy Requirements**

What Happened in Nuclear Industry

- ◆ Country-shaking **Scandals and Absurdity**
 - ✓ Concealment of mistaken SBO at Kori unit !
 - ✓ False certificates scandal for parts supply to new units
 - ✓ Forged quality and safety warranties
 - ✓ Bribery scandal, etc
- ◆ Controversial Issues of **Extended Continual Operation**
 - ✓ Wolsong #1 approved for extended 10yrs operation
 - ✓ Decisive impact on public confidence due to Fukushima accident
- ◆ Public Engagement in Policy-making for **UF Management**
 - ✓ Disputes between stake holders – difficult to reach consensus

**Accelerate the Loss of Public Confidence and Reliability
on NPP & Use of Nuclear Energy**

What Will Happen If All NPPs Stop

- ◆ About **25% Deficit** in Total National Electricity Supply
 - ✓ Limited transmission, Impact on industry, Worsen in life environments
 - ✓ 4 time increase in electricity cost (assuming alternatives available)
- ◆ Full Operation of Other Sources **does not** Cover the Nuclear Share
 - ✓ Reserved capacity is far below the safety limit at demand peak
- ◆ Crucially **Negative** Impact on Industries and Its Competitiveness
 - ✓ About 50% of electricity supply is used by industries
 - ✓ Impact on electricity-intensive industries, quality, export etc.
- ◆ Construction/Operation **Cost** of Fossil-fueled Plants Raises High
 - ✓ Fuel cost vulnerable to international energy-source environment
 - ✓ High uncertainties in operation of plants

- 
- 3 NPP stop due to absurdity brought the country to near **Brown-out** crisis
 - Assertion without countermeasures – **Pain** to people, society, country

Messages from President Park !



Urgent Issues : Stability of Energy Supply, UF Management (2013. 1)



Korea-US Nuclear Cooperation Agreement Renewal for Expansion of Peaceful Use of Nuclear Energy (2013. 3)



Technology Development to Overcome the Rad-Waste Management Issue (2013. 4) – Bill Gates



- ✓ Identification of Reasons for Accidents & Responsibility(2013. 5)
- ✓ Reform of Nuclear Sector from Past Scandals, Use of Nuclear for Responding to Climate Changes (2013. 7)
- ✓ New Opportunity for Nuclear with respect to Energy Environment & Response to Climate Changes (2014.1, 2015. 1)
- ✓ Initiative for East-North Asia Governmental Nuclear Safety Form (2014. 8)
- ✓ Public Concern Increase on Nuclear Safety, All-out Watch for Public Safety against Radiation Hazards (2015. 1)



Nuclear Policy – Agenda of Park's Government

- ◆ **National Energy Security** for Sustainable Development
 - ✓ Recognize the role of nuclear energy and Recognizing the limited role of renewable energies
 - ✓ Reasonable energy mix for coming 20 years
- ◆ **Security of Safe and Reliable Society**
 - ✓ Safety-first principle, and Build-up public trust & confidence
 - ✓ Root-out absurdity, Reform safety culture
- ◆ **Support the Creative Economy**
 - ✓ Strengthen efforts for nuclear technology export
 - ✓ All-out effort for revision of Korea-US nuclear cooperation Agt.
- ◆ **Reliable Management of Used Fuels**
 - ✓ Relieve the burden of UF management : storage, recycling, transport, disposal, etc.
- ◆ **Transparent Decision & Communication** for NPP Construction
 - ✓ Recover and enhance the public trust & confidence

Nuclear Energy - Future



Nuclear Technology Development

1959~1969 Basic Studies

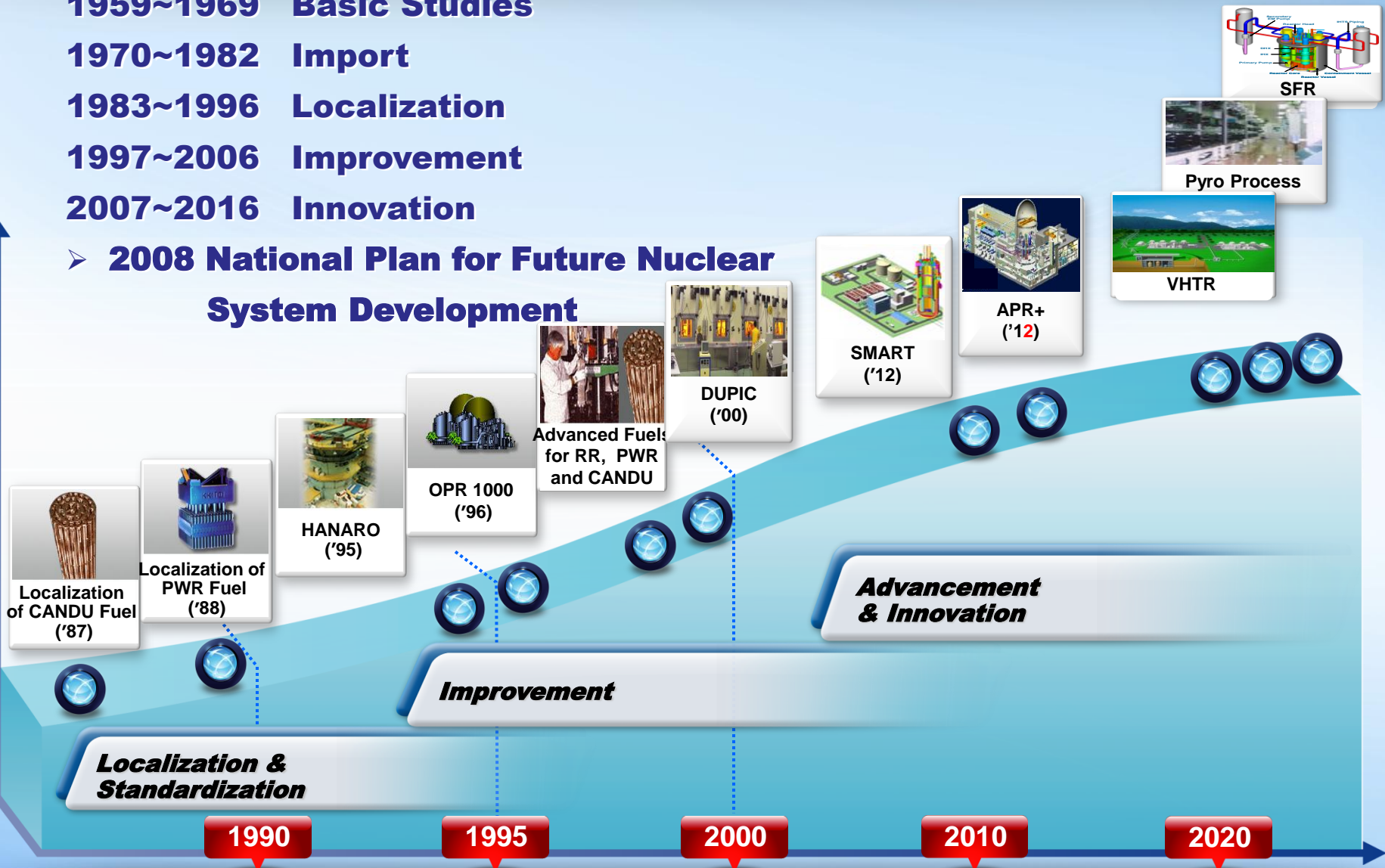
1970~1982 Import

1983~1996 Localization

1997~2006 Improvement

2007~2016 Innovation

➤ 2008 National Plan for Future Nuclear System Development



Development of Advanced Nuclear System



Advanced Research Reactor



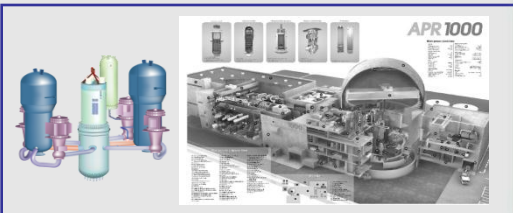
Innovative Nuclear System

Now



APR 1400
(Advanced Power Reactor)

Near-Term

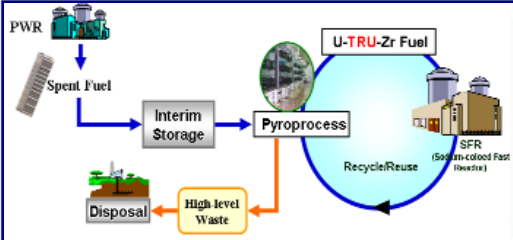


**APR 1000+
APR+(1500)**
(Advanced Power Reactor, Gen III+)

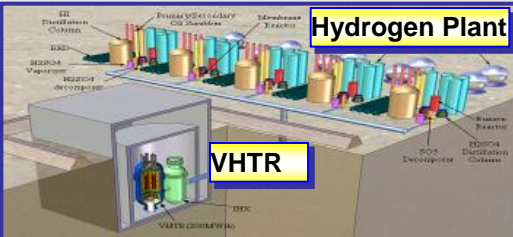


SMART
(System-integrated Modular Advanced Reactor)

Long-Term



SFR fuel cycle
(Sodium-cooled Fast Reactor + Pyroprocess)

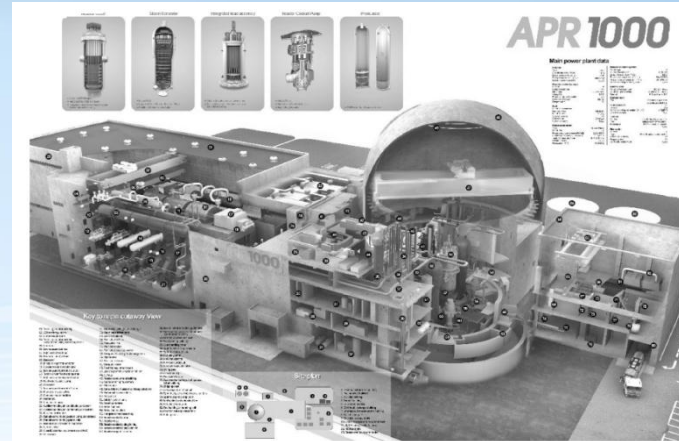


NHDD
(Nuclear Hydrogen development and demonstration)

APR1000+ Development

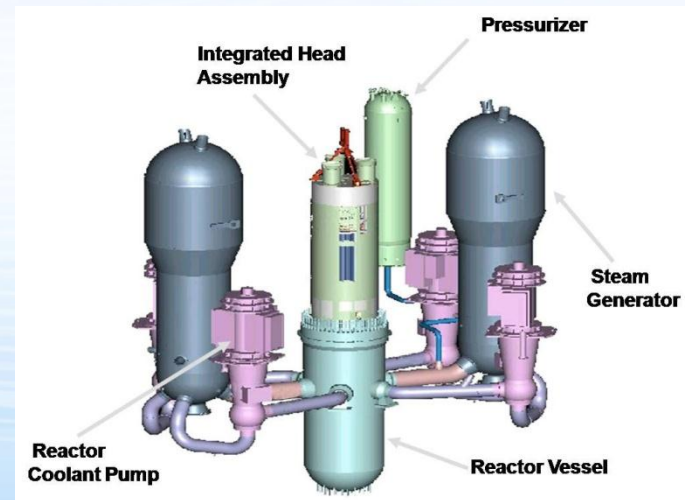
Outline of APR1000+

- **Target for Medium-Size Reactor Market**
- Application of ADF (Advanced Design Features) based on OPR1000
- Implementation of Advanced APR+ Design Features
- Application of IAEA Safety Criteria, NRC Reg. Requirements, & Domestic Safety requirements
- Application of Gen III+-Class Design Req't



Design Feature of APR1000+

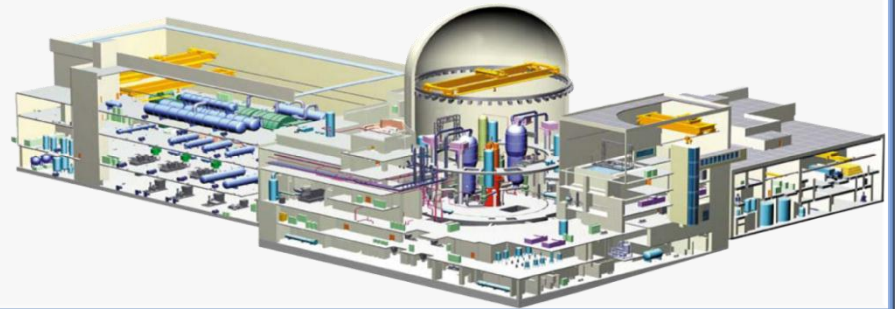
- Plant Capacity(Gross) : 1,000 MWe
- Plant lifetime : 60 years (OPR1000 : 40 years)
- Reinforced Seismic Design Basis (0.2g→0.3g)
- Safe-Shutdown System Strengthened (2→4 trains)
- Improvement in SBO Response(8hrs→72hrs)
- Strengthened Severe Accident Response Function (PECS, De-Pressurization)
- Design against Aircraft Collision



APR+ (APR1500) Development

Outline of APR+

- Advancement of the APR1400 concept
- Strengthened Competitiveness
- Improvement in Safety, Economics
- **Standard design approval (Aug. 14, 2014)**
- **Target in large sized Reactor' Market**

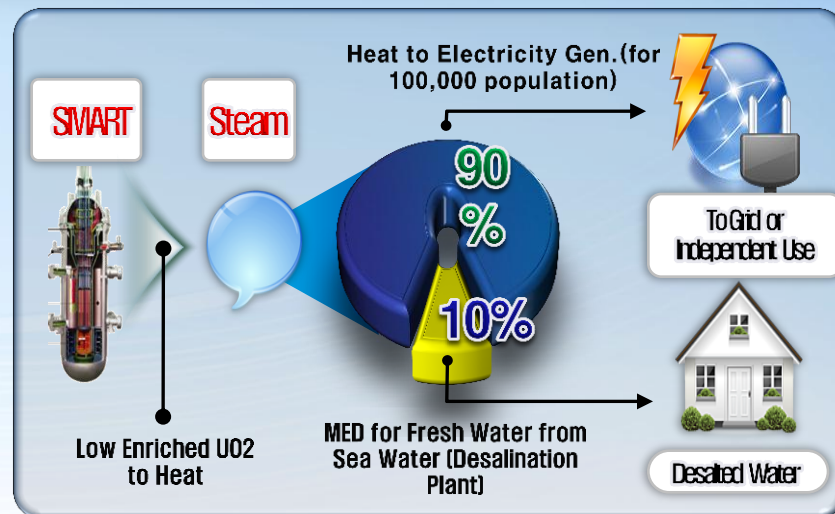
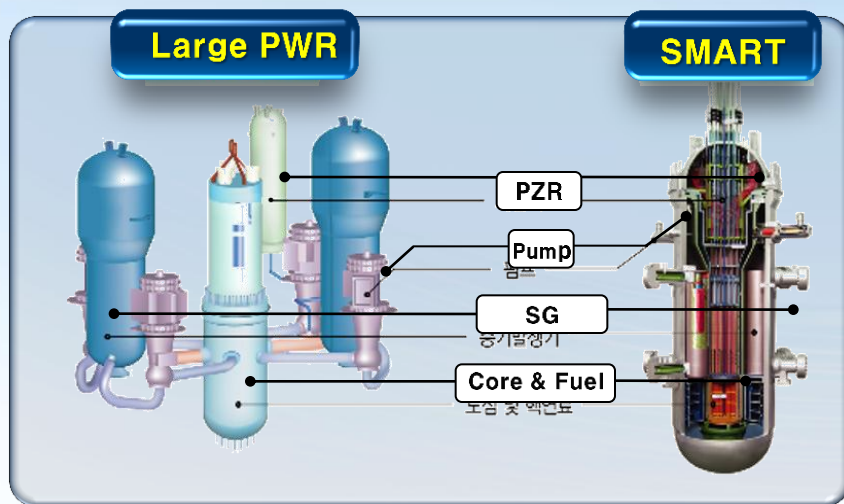


Design Improvements of APR+

- N+2 Design Philosophy : 4-train SIS (Safety Injection System), Common SCS (Shutdown Cooling System)/CSS (Containment Spray System), 4 EDG (Emergency Diesel Generator)
- Design against Aircraft Collision (Thick RB, Aux. B)
- Automatic Earthquake Stop, Anti-Inundation Design of Ultimate Heat Sink, Cyber Security
- LBB (Leak Before Break) application for Main Steam Line
- Installation of Dedicated ACC



SMART- Pioneer in SMR Market



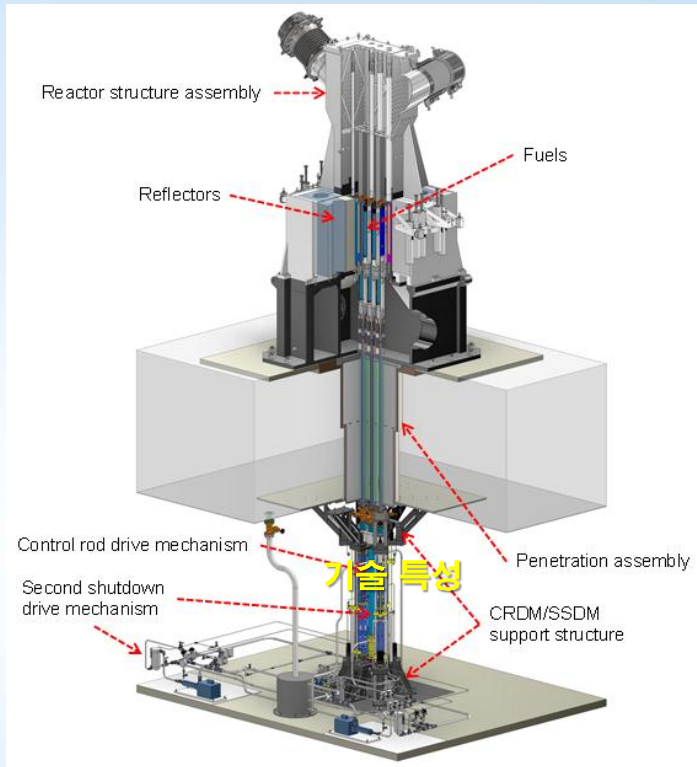
Characteristics

- ✓ Indigeneous Integral Reactor (All Primary Components in One Vessel)
- ✓ 330MWt (Electrical Power: 100MWe)
- ✓ Multi-Purposes : Power, Seawater Desalination. Decentralized Power Source, Process Heat, etc.
- ✓ Prospects for SMR Market
 - 400~1000 by 2050 (IAEA, USA, Japan)

Status/Prospects

- ✓ Development: 1997~2012 (15 years)
- ✓ World-First Design Approval for Standard Design- KEPCO Consortium (July 4, 2012)
- ✓ SMART Power Company (Jan. 29, 2015)
- ✓ Safety Strengthened for Extreme Accident Causes (Nat. Disasters, etc.)
- ✓ Int. Cooperation : Saudi. and others

Advanced Research Reactor – Export Technology



Characteristics

- ✓ 15MWth, $3.4 \times 10^{14} \text{n/sec.cm}^2$
- ✓ Proliferation Resistant : LEU Fuel
- ✓ Production of Fission Moly Isotope, Semiconductor, Radiation Analysis
- ✓ Verification of New Technology
 - HD Slab-Type Fuel (U-7Mo/Al-5Si)
 - Bottom-Inserted Control Rod DM

Status/Prospect

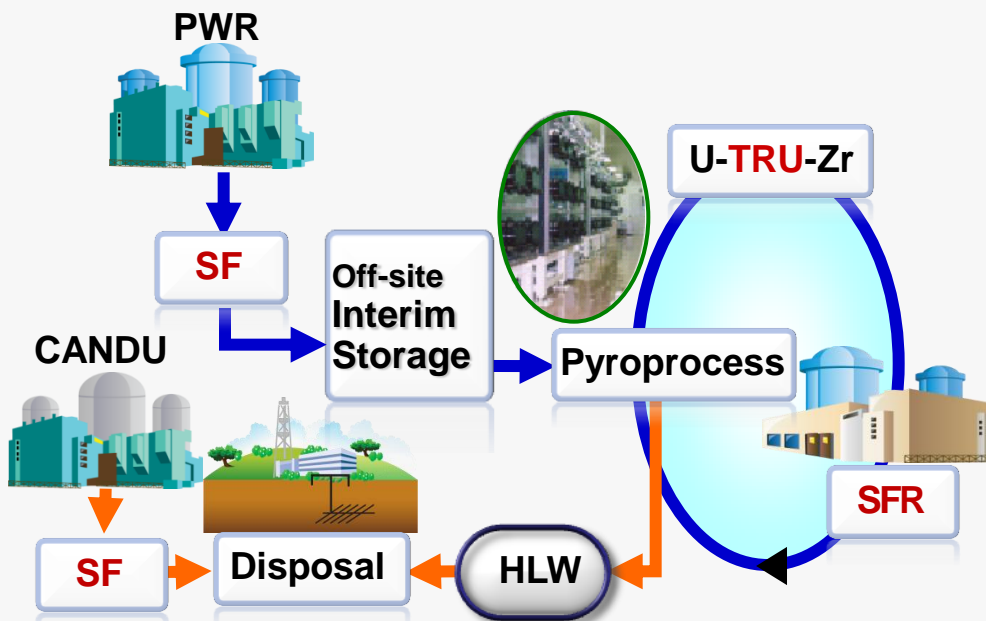
- ✓ RR – Customer Required Specifications
 - Customers decide Thermal Output, & Technologies to be Implemented
 - JRTR 75% Process (Comp. by 2016)
 - Oyster Project (Netherland, 2014)
- ✓ RI Production : NRU(Canada), OSIRIS(F.) Decommissioned
- ✓ Prospect for RR Market
 - Expect 27 New RR Order by 2050
 - Expect Restart of Dutch' s Pallas

Why SFR and Pyro-Processing for Future ?

- ◆ **Future Generation Reactor for National Energy Security**
 - ✓ A Generation After PWR, and Before the Fusion Age
- ◆ **Recycling of Reusable Energy Sources in Used Fuels of PWR**
 - ✓ SFR – Well Experienced and Potential Technology
 - ✓ Pyro – Proliferation-Resistant Technology
 - ✓ Used Fuel – Energy Resource & Burden to Sustainable Nuclear Energy
- ◆ **Relieve the Burden for Finding Final UF Disposal Site**
 - ✓ Reduction of Disposal Site Size by Separating Heat/Radiation Source from UF
- ◆ **Korea-USA Nuclear Cooperation Agreement Renewal Needed**
 - ✓ Pre-consented Approach for Recycling of UF
- ◆ **Domestic Barriers to Overcome to Go Forward**
 - ✓ NGO/Public Consensus, Political Agreement, Industry Consent, etc.

SFR Fuel Cycle System

Environment-Friendly System with Non-proliferation



- ▶ SF Volume Reduction < 1/20
- ▶ Radiotoxicity < 1/1,000
- ▶ HLW Disposal Efficiency: 100 times
- ▶ Uranium Efficiency : 100 times

R&D of Pyroprocessing

- PRIDE : 2013
- Korea-USA Joint R&D : 2011~2020

Sodium-cooled Fast Reactor

Construction

2028

Design Approval

2017

Conceptual design

2012



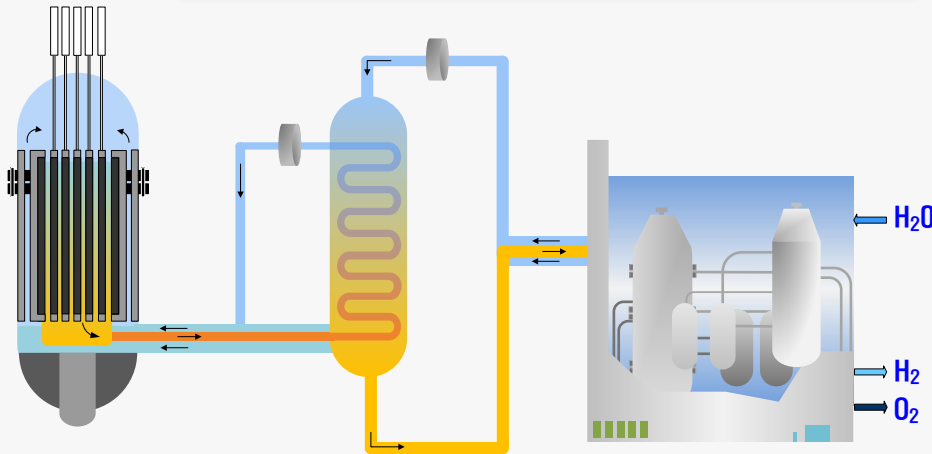
Nuclear Hydrogen Development (VHTR)

Clean, Safe Energy with a Wide Range of Application

VHTR

Very High Temperature Reactor

- Highest Level of Nuclear Safety
- Wide Temperature Range of Heat Energy
- High Efficiency
- Substitution of Fossil Fuels



➤ Major Hydrogen Market

- Fuel Cell, Synthetic Fuel
- Hydrogen Iron Ore Reduction

➤ Nuclear Hydrogen Alliance

- Collaboration with End Users
- Develop Private Partnership

Plan



Key Technology Development

System Concept

System Design

System Construction

Demonstration & Operation

R & D

- Design and Analysis Code
- Helium Test Loop
- Material & Components
- TRISO Fuel
- Hydrogen Production Process

Conclusion



Nuclear Future in Korea ?

◆ For the Time being

- Hot Debates & Argues : Nuclear Safety, Root-out Absurdity, Continual Extended Operation, Conflict for Siting , UF management, Decommissioning, Economics
- 2nd NEBP/Energy Mix : Decrease in Nuclear Capacity Share
- Site-Experts Dis-encouraged, Decrease in Experts, Decrease in R&D Investment

◆ Near Future

- Fossil Energy : Resources/ Climate Change, Renewables: Limit in Responsibility
- Revival of Overseas market: **Nuclear Renaissance was not Started Yet !**
- Bridge Role : Responsible Role connecting Today and Tomorrow
- Localized & Sustainable Energy : Essence for National Energy Security

◆ What Do We Have to Prepare Future?

- Human-resource Buildup, Reinforce Safety Culture, Responsibility & Morality, Enhance Expert Self-Confidence
- Recover Public Trust : Communication, Transparency, etc.
- **Technology Advancement through R&D Efforts !!!**



Nuclear for Sustainable Growth in Korea



○ In Korea, nuclear is not a choice, but ' **a Must** ' in Energy-Resource Environments

○ Securing a high level of safety is a pre-requisite for **future energy security**

○ Need to strengthen 'Safety Culture'

○ UF management & decommissioning : **strategic exit** for promotion

○ Strengthen nuclear R&D Program

Thank you for your attention.

Abundant energy,
Clean environment and Healthy life



Atoms for Peace, Nuclear for People