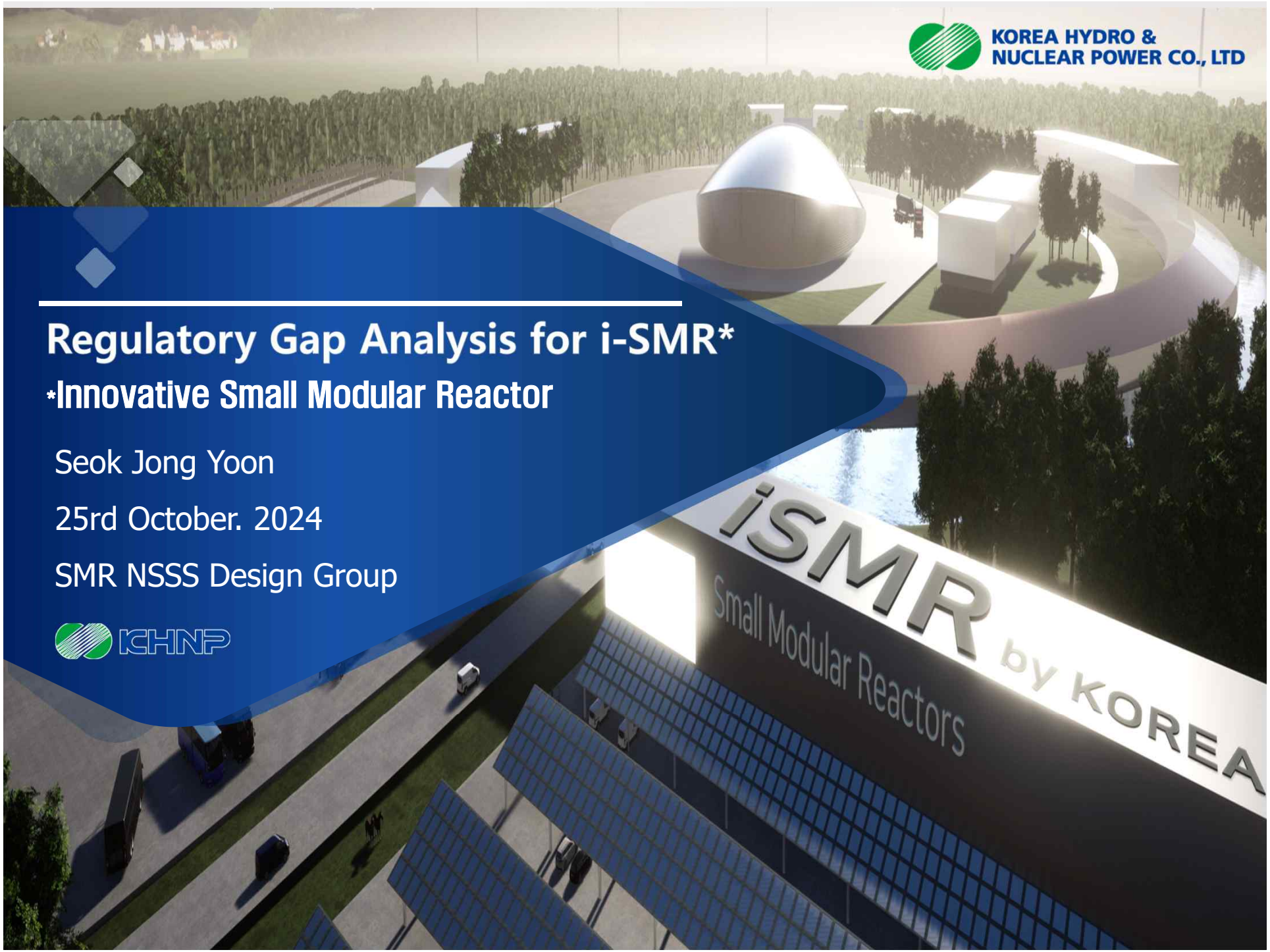

Regulatory Gap Analysis for i-SMR*

*Innovative Small Modular Reactor

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25rd October. 2024

SMR NSSS Design Group

KHNP

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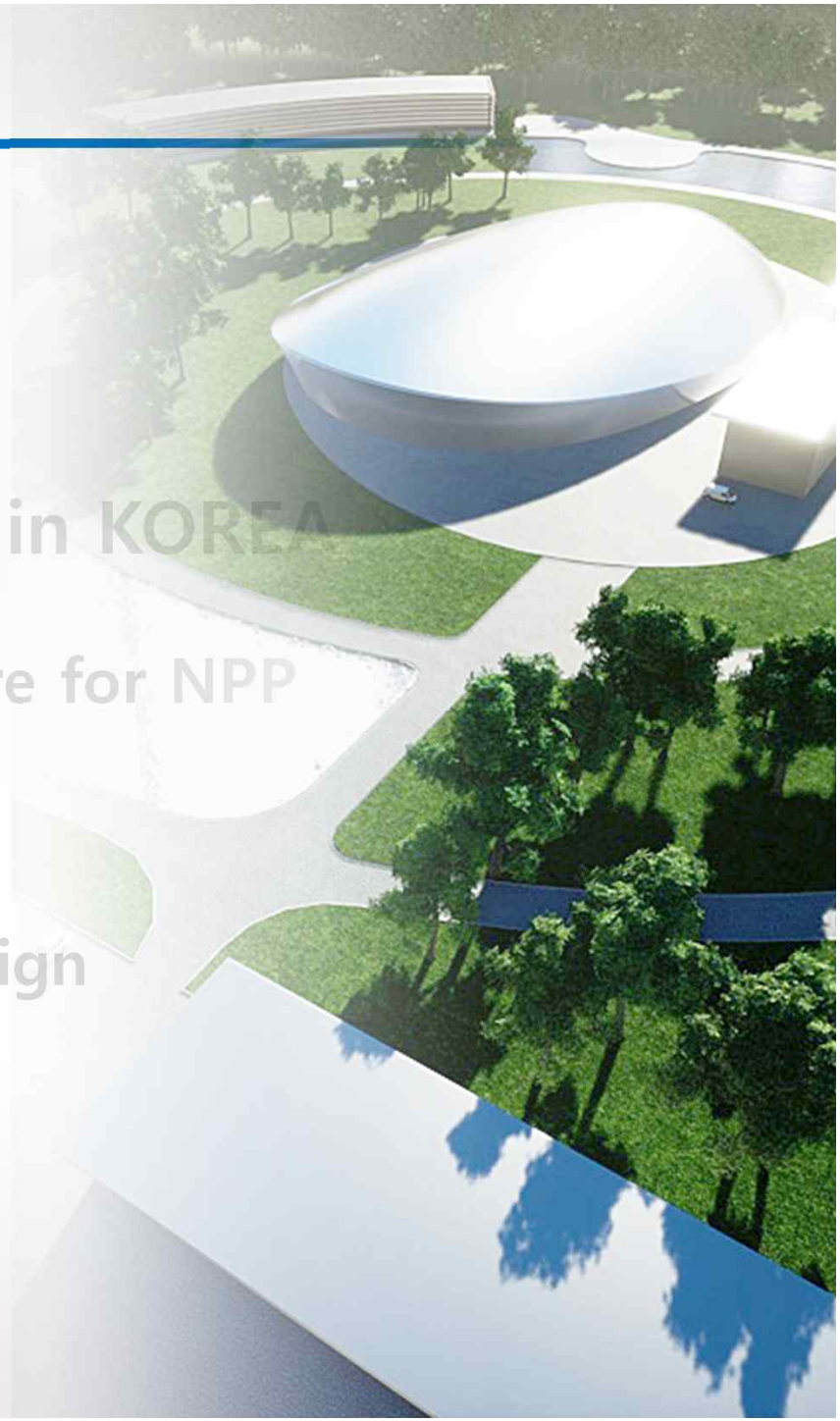

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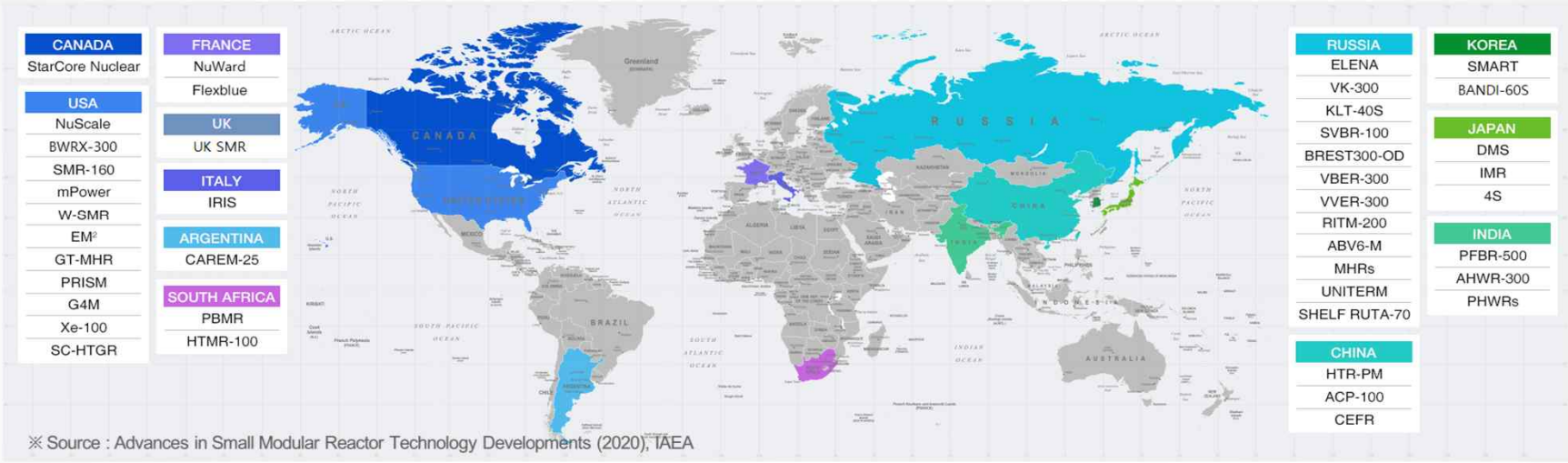
1. Introduction

SMR Models

More than 70 SMRs are being developed worldwide

CANADA	FRANCE		RUSSIA	KOREA	
StarCore Nuclear	NuWard		ELENA	SMART	
USA	Flexblue		VK-300	BANDI-60S	
NuScale	UK		KLT-40S	JAPAN	
BWRX-300	UK SMR		SVBR-100	DMS	
SMR-160	ITALY		BREST300-OD	IMR	
mPower	IRIS		VBER-300	4S	
W-SMR	ARGENTINA		VVER-300	INDIA	
EM²	CAREM-25		RITM-200	PFBR-500	
GT-MHR	SOUTH AFRICA		ABV6-M	AHWR-300	
PRISM	PBMR		MHRs	PHWRs	
G4M	HTMR-100		UNITERM		
Xe-100			SHELF RUTA-70		
SC-HTGR			CHINA		
			HTR-PM		
			ACP-100		
			CEFR		



※ Source : Advances in Small Modular Reactor Technology Developments (2020), IAEA

KOREA | Other Countries

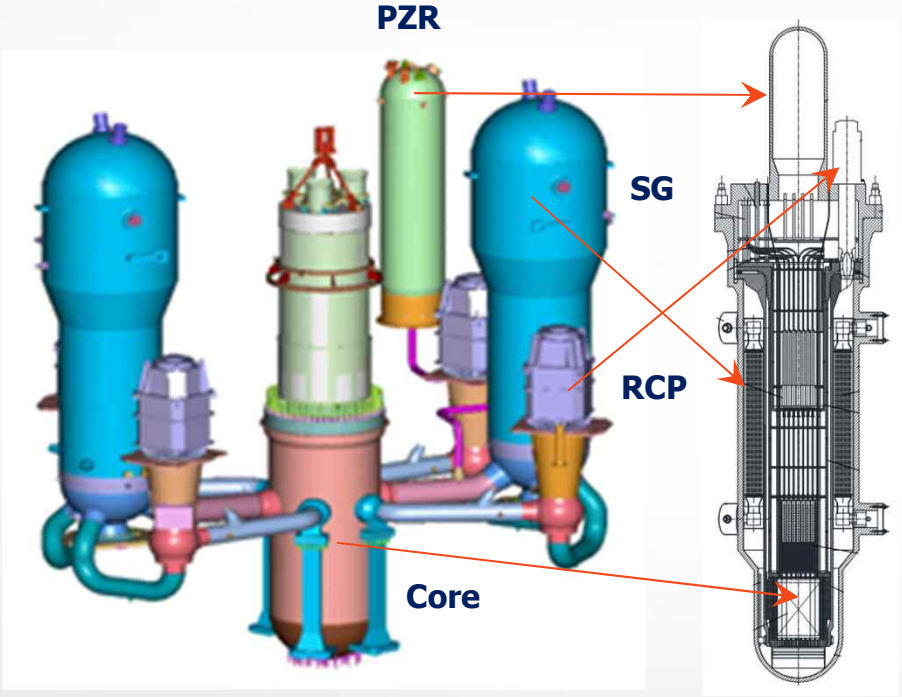
i-SMR*	SMART	NuScale	BWRX-300	SMR-160	KLT-40S	ACP-100	NuWard	UK SMR
KHNP	KAERI	NuScale (US)	GE-Hitachi (US)	Holtec (US)	OKBM (RUS)	CNNC (CNA)	EDF (FRA)	Rolls-Royce (ENG)
Under Development (Since, 2020)	Design Certification (July. 2012)	Natural Circulation NRC DC (2020)	BWR Cons. Planning (CAN)	Block Type NRC Pre-review (ing)	Offshore Floating Operating (2019)	Site-Permit Constructing (2021)	Conceptual Design Con. Plan (2030)	440MWe, Loop Type Con. Plan (2030)

*Innovative - SMR

1. Introduction

i-SMR has Strength that conventional (large) NPPs doesn't have

- Arranged all Reactor Coolant Structures in an Integrated Reactor Vessel(IRV)
- Eliminated Large Pipe (Large Commercial Reactor) → Eliminated inherently LBLOCA(i-SMR)



Conventional NPP

i-SMR

i-SMR design features meet to Safety, Economy, and Flexibility	
Key design features	• Soluble boron free operation • In-Vessel Control Element Drive Mechanism • Top-mounted ICI • Fully passive safety systems • Canned-motor RCPs • In-Vessel Pressurizer • In-Vessel Steam Generator • Compact steel containment vessel • Automatic load following

1. Introduction

The directions of i-SMR technology development

- Representative items of expected regulatory issues

Safety system without safety- 1E electricity

Robust seismic design

Passive Safety System

No Severe Accident

No need for Evacuation (EPZ)

Improved Safety

Reduced construction cost

Modularization, factory manufacturing, inland transportation

Digital Twin Program & Diagonosis

Competitive Cost

Reduction in operators for multiple modules

Enhanced Economics

Hydrogen production for industrial use

Desalination /Process heat supply

Flexible operation

Complement ing renewable energy

Coping with climate change

Increased Flexibility

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2. Current Safety Standards in KOREA

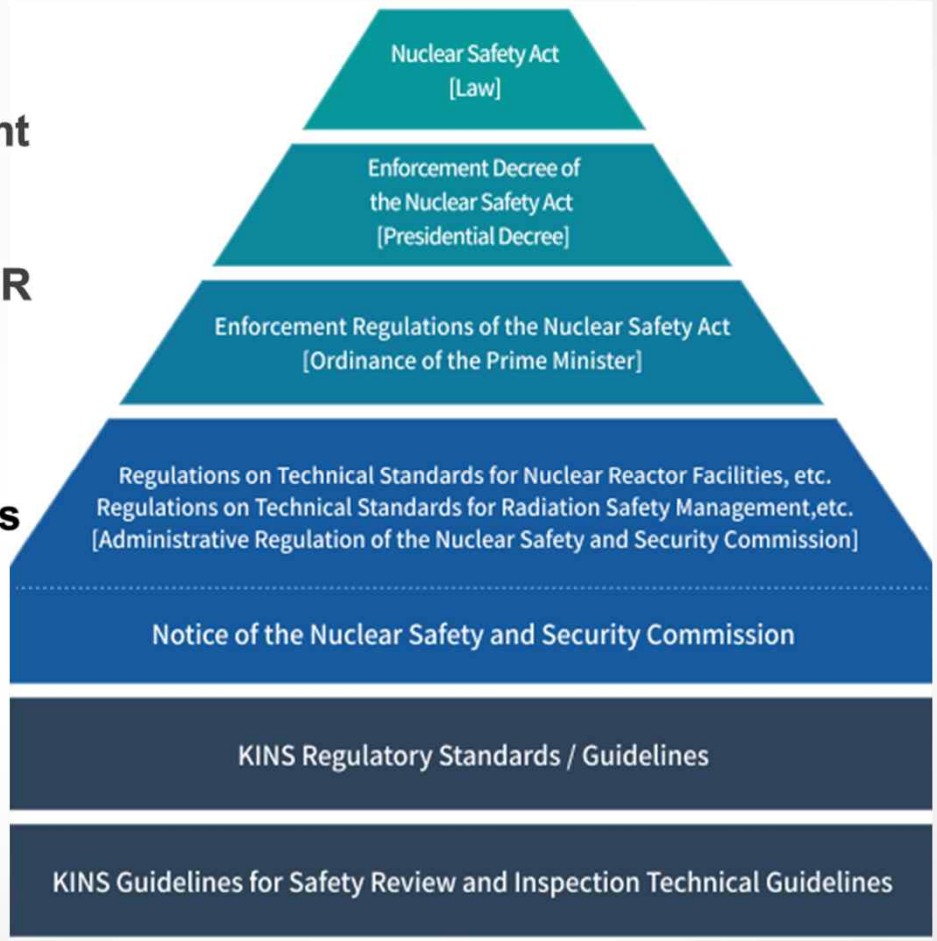
- **Safety regulation infrastructure systems in Korea**

✓ **Most of the current regulatory standards are focused on Large Nuclear Power Plant**

✓ **Difficult to meet the safety standards for Innovative design characteristics of i-SMR**

➢ **Necessary to analyze the gap between i-SMR design and regulatory requirements**

➢ **Analysis and comparison with safety standards are conducted based on TTR(Top-Tier Requirement), PDD(Plant Design Description) of i-SMR in this presentation**



New technology-inclusive regulatory framework will be needed

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3. Gap Analysis Results

Classification of Topics by Gap Analysis

- ✓ KHNP derives “16 Gaps” inappropriate with the existing regulation and technical guideline
- ✓ Details of the gap is classified into **system improvement(2), safety standard design(14)**

Group		Classification by gap
System improvement (2)		1.Multiple utilization
		2.Exemption or specification of application an a lternative regulations
Safety standard gap by design (14)	Common designs (5)	1.Safety class
		2.Multiple failure accidents
		3. Construction of Multiple Units
		4.Emergency Planning Zone
		5.Alternative radioactive source
	System designs (9)	6.Independent reactivity control system
		7.Leakage reactor coolant pressure boundary
		8.Measurement control
		9.Power supply system
		10.Multi-module integrated MCR and operators
		11.Diverse protection system
		12.Steel containment vessel
		13.Surveillance specimen
		14.Passive safety system

3. Gap Analysis Results

- **Deviation with Nuclear Safety Act [Law]**

1. Number of operators in MCR

✓ **(Law)** Each nuclear reactor module requires at least one SRO and RO licensed person

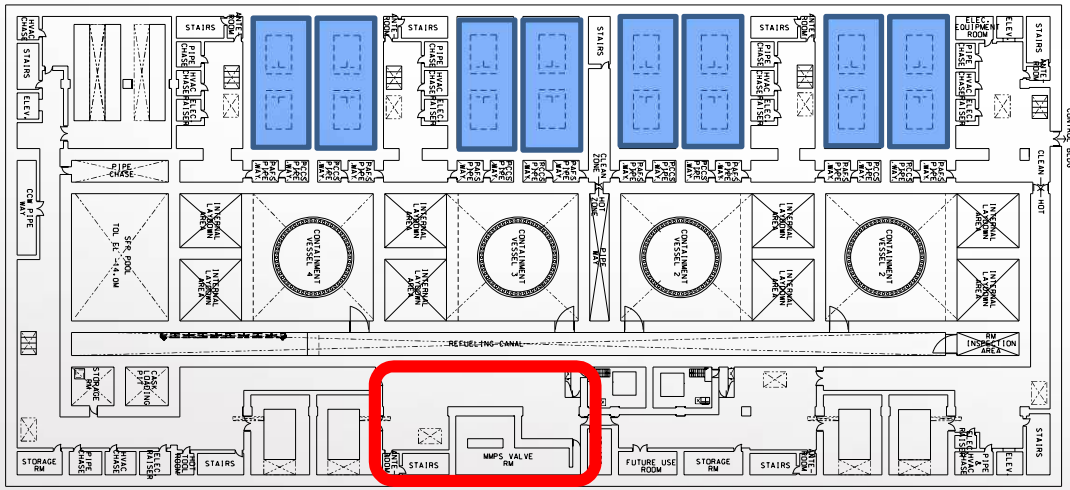
✓ **(i-SMR)** Four nuclear reactor module can be operated by three operators in an integrated MCR

2. Defining the EPZ* in the site boundary

✓ **(Law)** Precautionary action zone and urgent protective action planning zone are within a maximum radius of 30 km

✓ **(i-SMR)** EPZ would be set within the site boundary

*Emergency Planning Zone



Integrated MCR

Reduction of operators

EPZ < site boundary

3. Gap Analysis Results

- **Deviation with Regulation on Technical standards for nuclear reactor facilities [Regulation]**

  1. Limitation on Location

  ✓ **(Regulation)** Nuclear reactor facilities could be <u>located away from the populated areas</u>

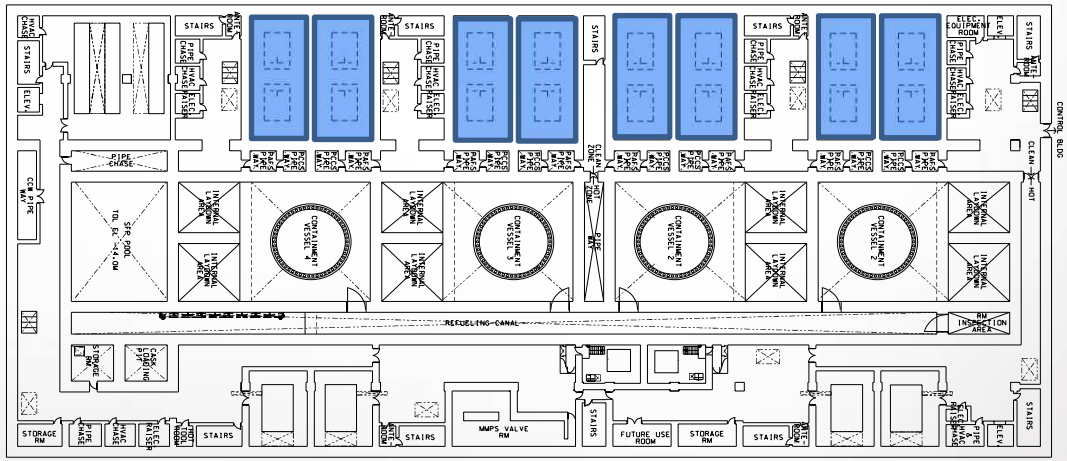
  ✓ **(i-SMR)** For multipurpose utilization, <u>located near demand areas</u>

  2. Construction of Multiple Units

  ✓ **(Regulation)** If two or more nuclear facilities are installed on the same site, <u>each nuclear reactor does not affect the safety each other</u>

  ✓ **(i-SMR)** <u>Four reactor modules</u> are adjacent each other

Located near demand areas



4 modules are adjacent

3. Gap Analysis Results

- **Deviation with Regulation on Technical standards for nuclear reactor facilities [Regulation]**

  3. Instrument and Control system

  ✓ **(Regulation)** Twelve physical monitor variables are need to be measured (For reliable, safe operation of NPP)

  ✓ **(i-SMR)** Some measurement variables cannot be measured or unnecessary

  ※ Boric acid concentration(Boron free), hydrogen concentration(Vacuum state)

  4. Electric Power System

  ✓ **(Regulation)** Onsite and offsite electric power systems which are important to safety shall be provided

  ✓ **(i-SMR)** Adopts fully passive safety system without power supply system.

  All power systems are designed to a non-safety class, no need to install an AC power

Inherent Safety for no severe accident

Safety system without safety- 1E electricity

3. Gap Analysis Results

- **Deviation with Regulation on Technical standards for nuclear reactor facilities [Regulation]**

5. Diverse Protection System

- ✓ **(Regulation)** Have a diversity protection system in preparation for the possibility of ATWS
- ✓ **(i-SMR)** Design to reduce software common cause failure, and applies heterogeneous platforms to design diversity

6. Reactivity Control System

- ✓ **(Regulation)** Requires two independent reactivity control system with different design principles
- ✓ **(i-SMR)** Adopts boric acid-free, designing only utilize burnable poison material

7. Residual Heat Removal system

- ✓ **(Regulation)** Maintain safety even under the assumption of single power and single failure
- ✓ **(i-SMR)** Adopts fully passive safety system without electricity.

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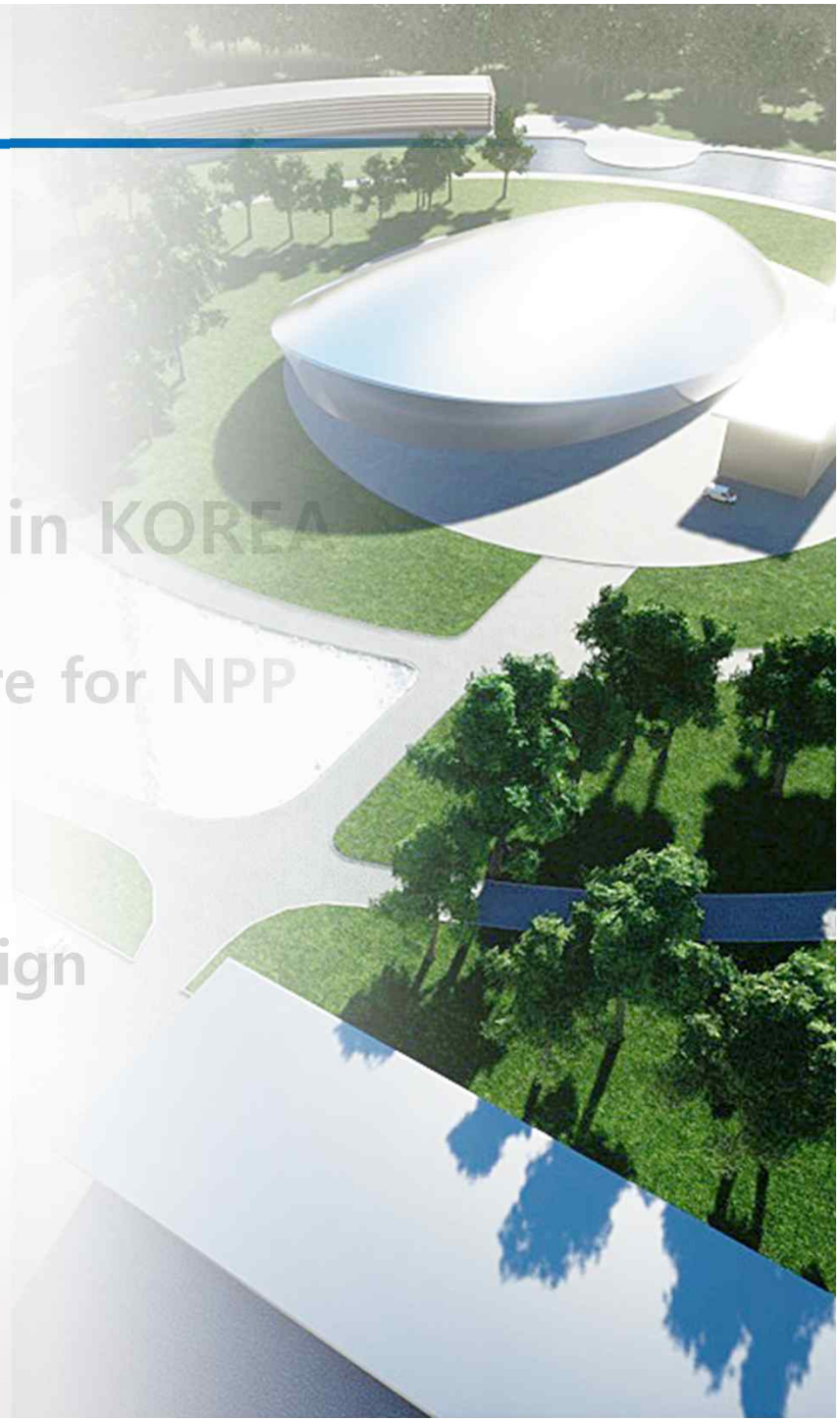

4. Conclusion

- For achieving successful i-SMR standard design approval, gap analysis assessment is required due to the difference characteristics of i-SMR and Large NPP

- In this presentation, the results of the gap analysis assessment are summarized
  1. Detail review of Korea nuclear safety laws are performed
  2. KHNP derives “16 gaps” inappropriate with the existing regulations and i-SMR design

- The KHNP had published the gap analysis report

4. Conclusion – Future plan

- KHNP requested PDR (Pre-Design Review) and approval from Korea regulatory body
- Objective of PDR is to identify;

  (1) Major technical issues, (2) Resolution plan for technical issues
- Related documents had been submitted ;
  - ✓ Gap Analysis Report
  - ✓ Plant Design Description
  - ✓ 14 Technical Reports (Ex, LOCA/Non-LOCA methodology, Passive Safety System)

- Also, KHNP are planning to receive vendor design review from Canada nuclear regulatory body for expected technical issues during the standard design approval

KHNP
KOREA HYDRO & NUCLEAR POWER CO., LTD

THINK SAFETY

Thank you