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UE-BX-0167

The Workshop on Innovative Nuclear Energy Systems

Development of Hitachi-GE's Advanced Reactors

January 26, 2024

Kazuaki Kito

Hitachi-GE Nuclear Energy, Ltd.

1 Hitachi and GE global alliance

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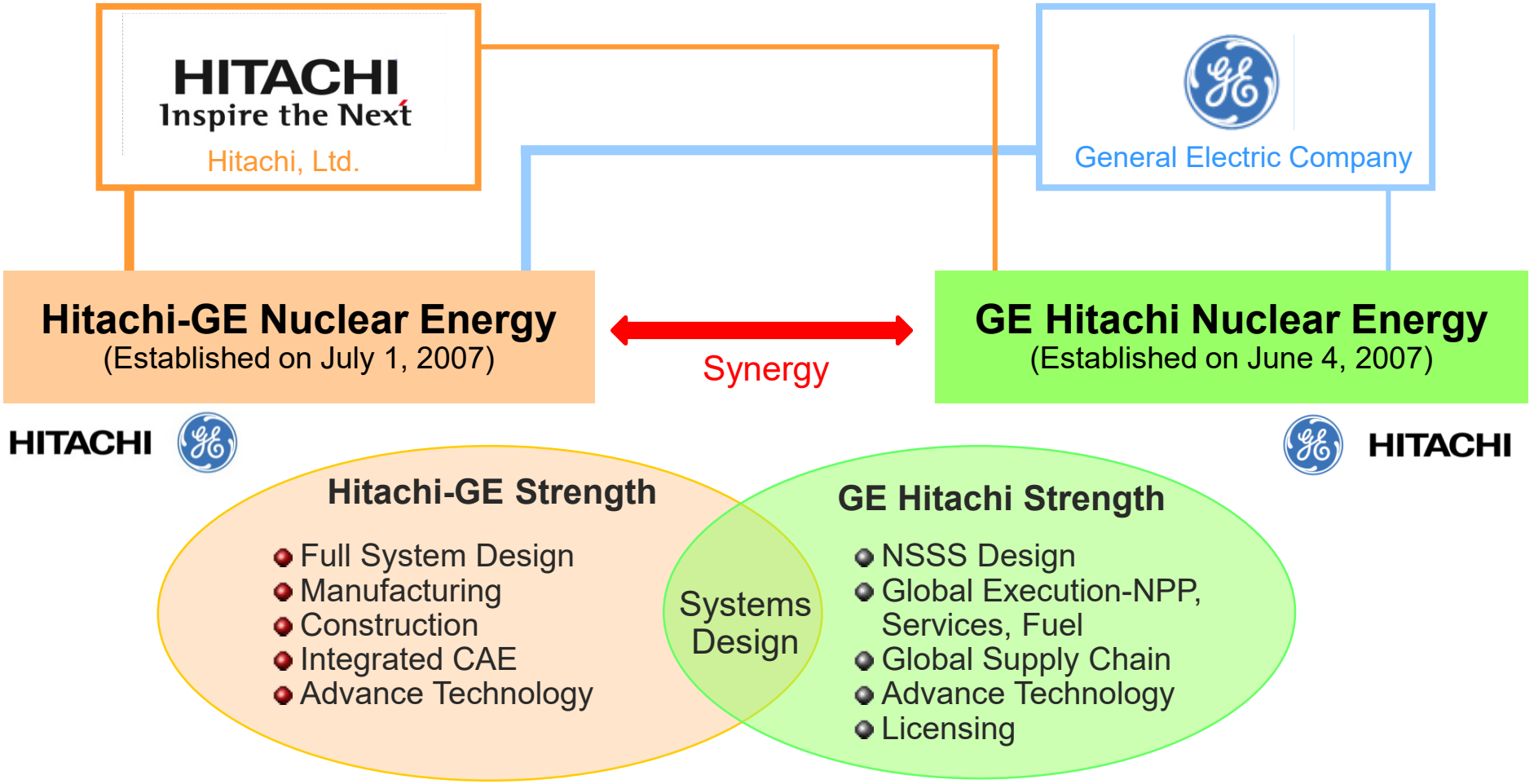


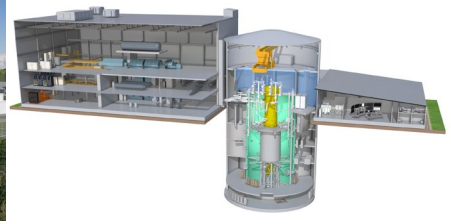
- Hitachi and GE alliance based on nuclear business collaboration for 50 years
- Committed to develop and promote latest BWR technologies and services

2 Hitachi-GE nuclear business scope

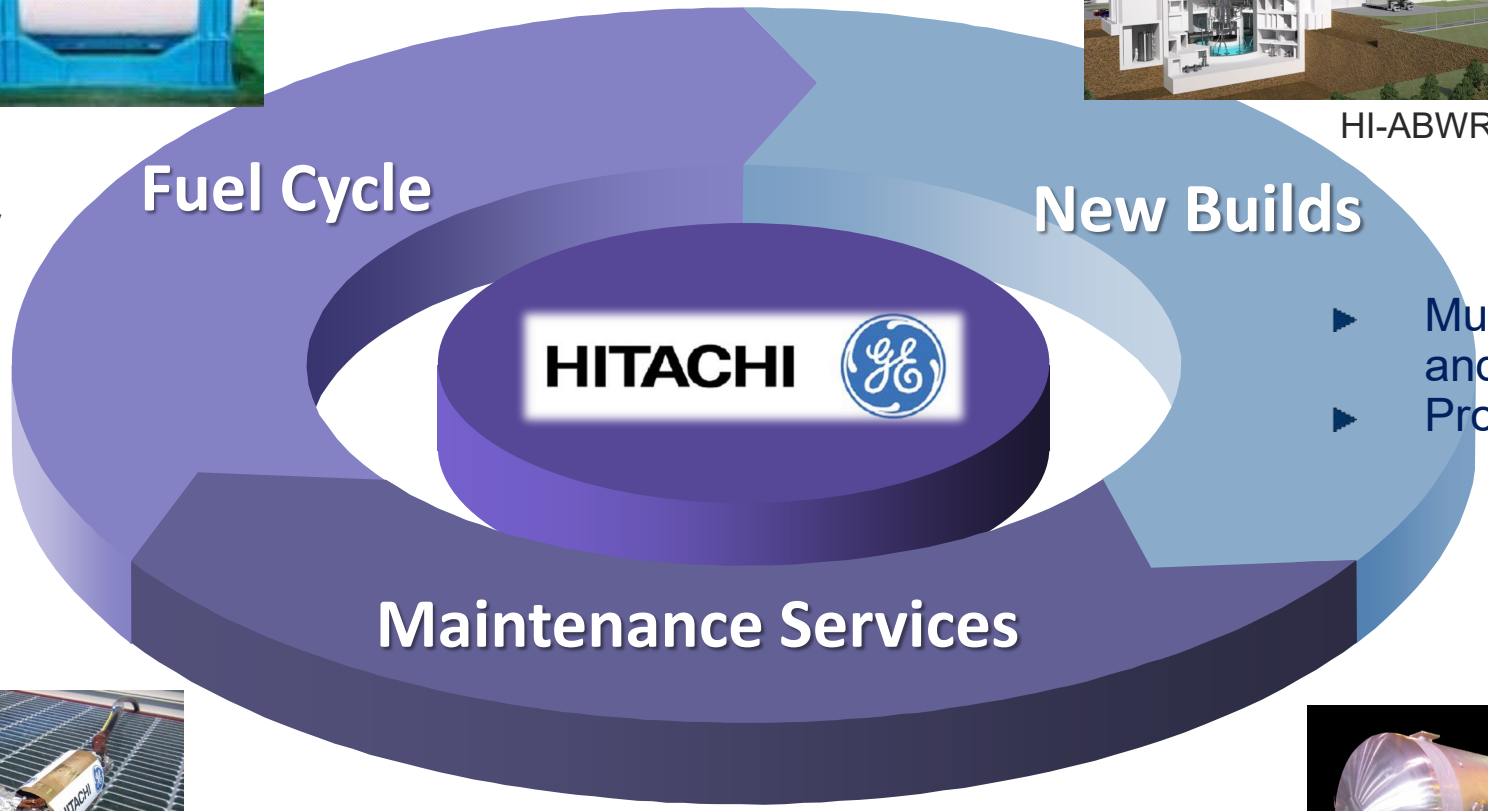
Rokkasho Reprocessing Plant

Spent fuel cask

HI-ABWR

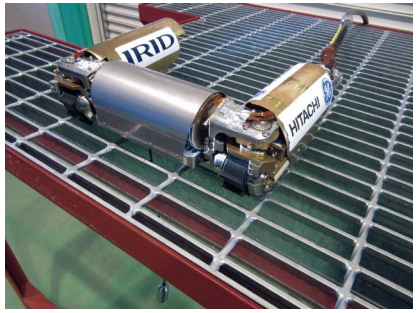


BWRX-300 (SMR)



- Components supply for Monju (SFR) or Rokkasho
- Spent fuel Interim Storage Casks

- Multiple ABWRs in operation and under construction
- Promotion to global market



Robotics for Fukushima

- Safety enhancement of Japanese NPPs to allow restart
- Fukushima Decommissioning etc.
- Operating plant maintenance service

Filtered Containment Vent

3 World Trend on Nuclear Power

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Recent New Builds

- ~60% of new builds constructed by China or Russia
- Russia holds large portion of replace market

Future New Builds

- Majority of planned units to be constructed by China or Russia
- Small number of plants planned in US, UK and Canada

Decom Units Increasing

- Government policy or economic reason to shutdown old units

Utilizing existing units

- Utilizing existing units are on-going in many countries
- Improvement on availability and 60/80 years operation being promoted in US

+

Carbon Neutral

- Based on the Paris agreement, more than 150 countries/regions had declared CN in 2050
- Plan for large scale deployment of renewable energy

Adv. Reactor Development

- US launched and promoting advanced reactors by ARDP (Advanced Reactor Demonstration Program)
- Canada declared nation's Action Plan to promote SMRs in Canada

Prepare for changes of environment in nuclear power

4 Trend on Advanced Reactors Deployment

US Canada: SMR demo/construction, UK/France: Both large and SMR

Country	Recent	Current Status
USA	Promote SMRs	• TVA announced to proceed with BWRX-300 • DOE chose small fast reactor and high temperature gas reactor in ARDP (Adv. Reactor Development Program)
Canada		• OPG and SaskPower picked BWRX-300 for deployment • Declared to be a leader in SMR technologies
UK	Support for large scale reactor project, while SMR development is under consideration	• UK Gov supports Sizewell C project (2 EPRs), with aiming to build max. 8 reactors and to realize 25% by nuclear (2050) • Great British Nuclear has been launched by government with a mission to identify the best small modular reactor (SMR) technology for the UK (potentially 2 units) • FNEF(Future Nuclear Enabling Fund) for SMR developments
France		• President supports 6 units of EPR2 (potentially 8 units) • Promoting to develop/deploy SMRs
EU	Preparing SMR development	• SMRs deployment planned in Poland, Estonia and Czech to follow • Cooperating in regulatory issues for deploying SMR

TVA： Tennessee Valley Authority　　OPG： Ontario Power Generation

5 Hitachi-GE's Nuclear Future Vision in Japan

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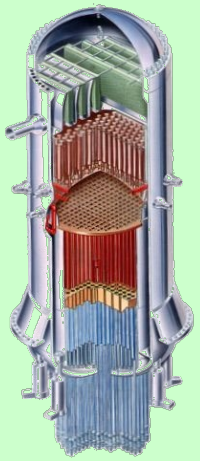
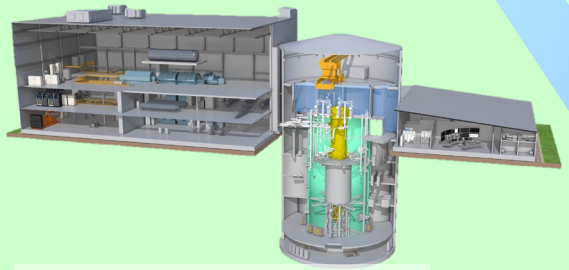
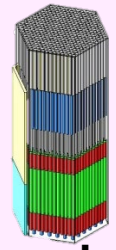
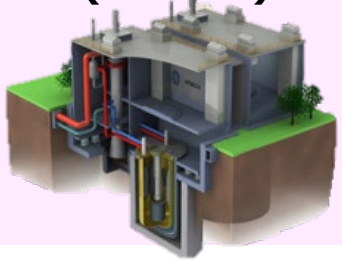
Creation of new value and contribution to safe and sustainable power generation

Value	2020	2030	2040	2050	2060
Stable energy source contributing to carbon neutrality	 **ABWR**	Large reactor with improved safety to secure stable power supply  BWRX300 ***(SMR)**		HI-ABWR Highly Innovative ABWR • Global standard design based on Fukushima L&L and UK GDA • Installing new safety mechanisms	- Needs of small to medium power supply - Replacement of old plant
Improved energy self-sufficiency - Utilize Pu as resource - Reduction of spent fuel toxicity	Burnup of Pu by light water reactor MOX fuel Gradual utilization of fast neutron: - Efficient burnup of Pu, Pu multi-recycling, Reduction of rad waste toxicity and volume	 **Light water-cooled fast reactor (RBWR)**			**Sodium-cooled fast reactor (PRISM)** 

RBWR: Resource reusable BWR, PRISM: Power Reactor Innovative Module

* BWRX-300 has been being developed with our sister company GE Hitachi Nuclear Energy.

6 Concept of Highly Innovative ABWR (HI-ABWR)

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Based on international standard ABWR※ which considers Fukushima lessen learned and meet UK/European requirements, further new safety mechanisms are implemented

HI-ABWR Highly Innovative ABWR **Highly Innovative ABWR (HI-ABWR)**

Reactor to be accepted by society that experienced Fukushima

1. Innovative safety

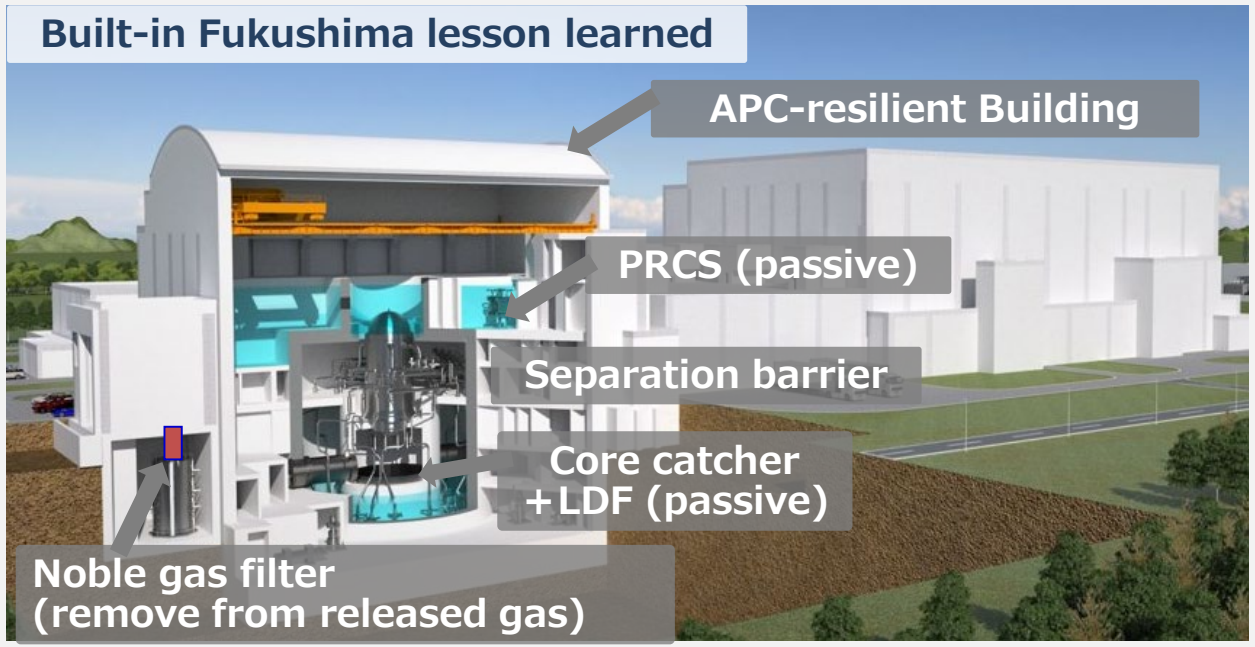
■ Stronger measures for natural disaster, terrorism, internal hazards
- ➢ Strengthen building for airplane crash
- ➢ Enhanced seismic design
- ➢ Safety-divisional separation barrier for internal hazards

■ Passive safety system
- ➢ PRCS*1
- ➢ Core cacher + LDF*2
- ➢ COPS*3

■ Cut externalities during severe accident
- ➢ Compact radioactive (noble gas) filter

2. Contribution to carbon neutral

■ BWR's inherent flexible operation for social needs
- ➢ 10x10 fuel for high burn-up, uprate, extended cycle, full core MOX
- ➢ Load following



■ Competitiveness among diverse power sources
- ➢ Innovative but matured systems, proven ABWR construction method

■ Operation/maintenance efficiency
- ➢ Next generation control room
- ➢ Designed for maintenance

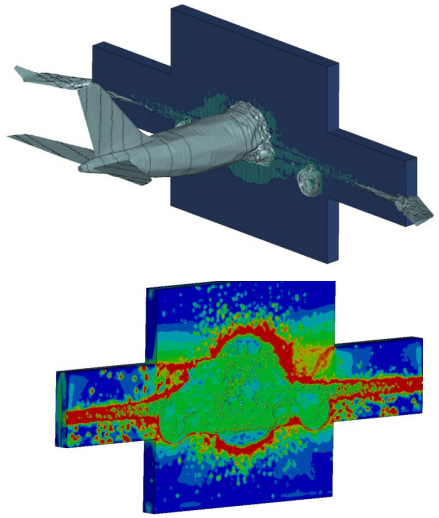
*1 : Passive Reactor Cooling System
*2 : Lower Drywell Flooder
*3 : Containment Over pressure Protection System

7 Safety systems of HI-ABWR (1/2)

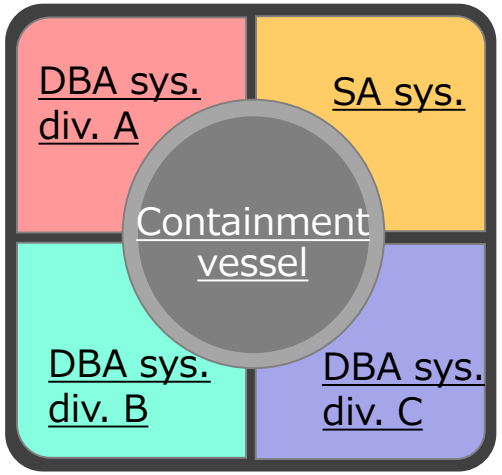
Airplane crash countermeasures

Protection planned according to NEI guideline (NEI 07-03), reviewed in UK ABWR licensing.

- Physical damage: protection by exterior walls
- Fire: safety-divisional separation barriers protect so that at least one safety division always survives
- Shock vibration: the effect is reduced by exterior walls



Example of physical damage analysis

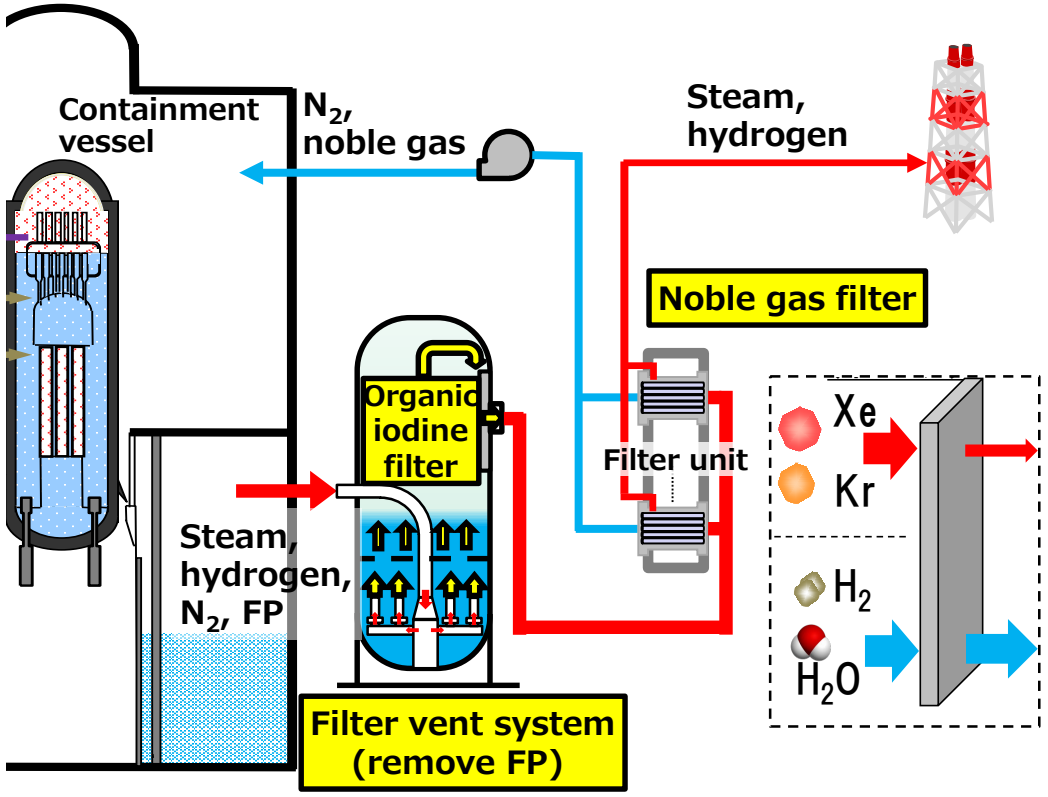


Safety-divisional separation barrier

Containment system for radioactive materials

Noble gas filter avoids to release radioactive noble gases while releasing steam and hydrogen during severe accidents.

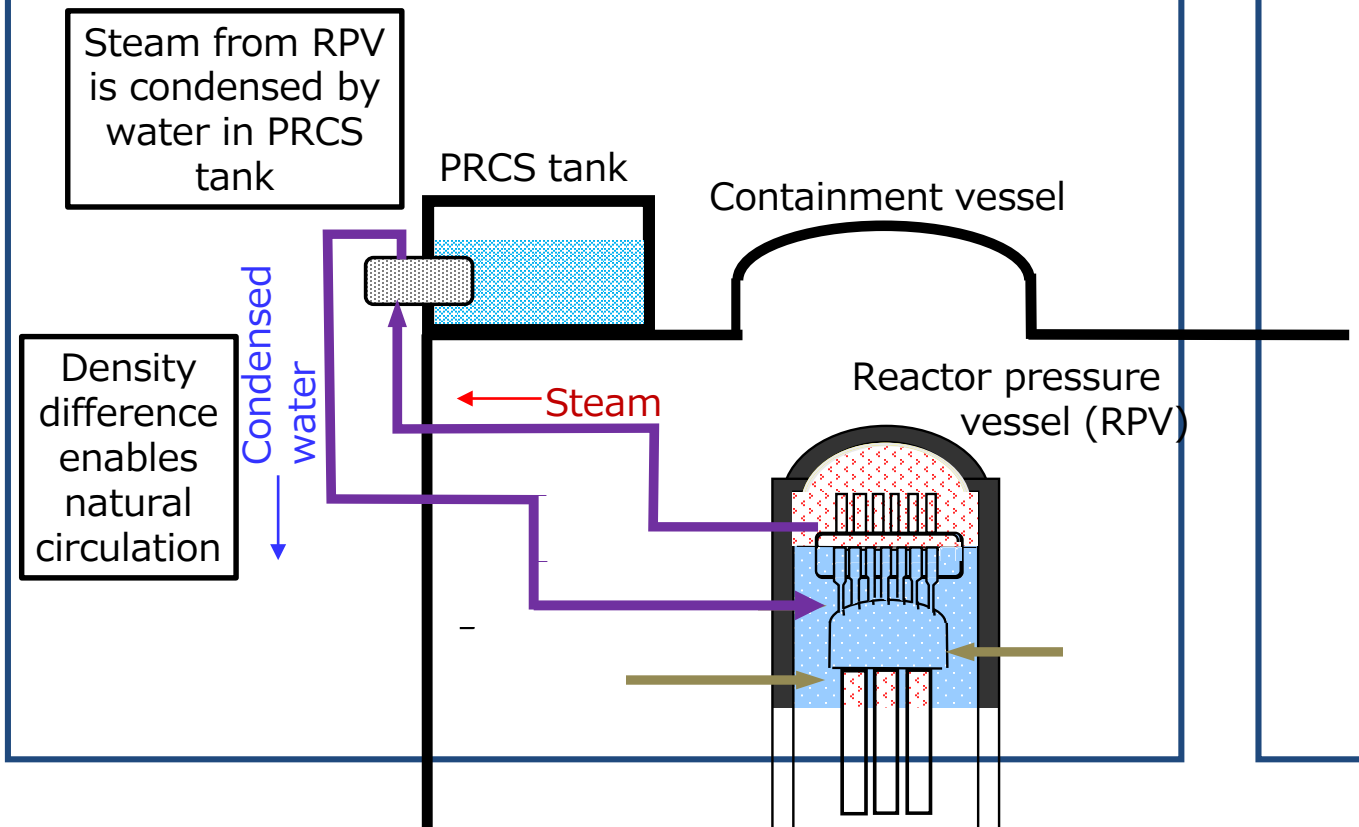
- Reduce the risk of hydrogen combustion
- Reduce the risk of local resident's evacuation



8 Safety systems of HI-ABWR (2/2)

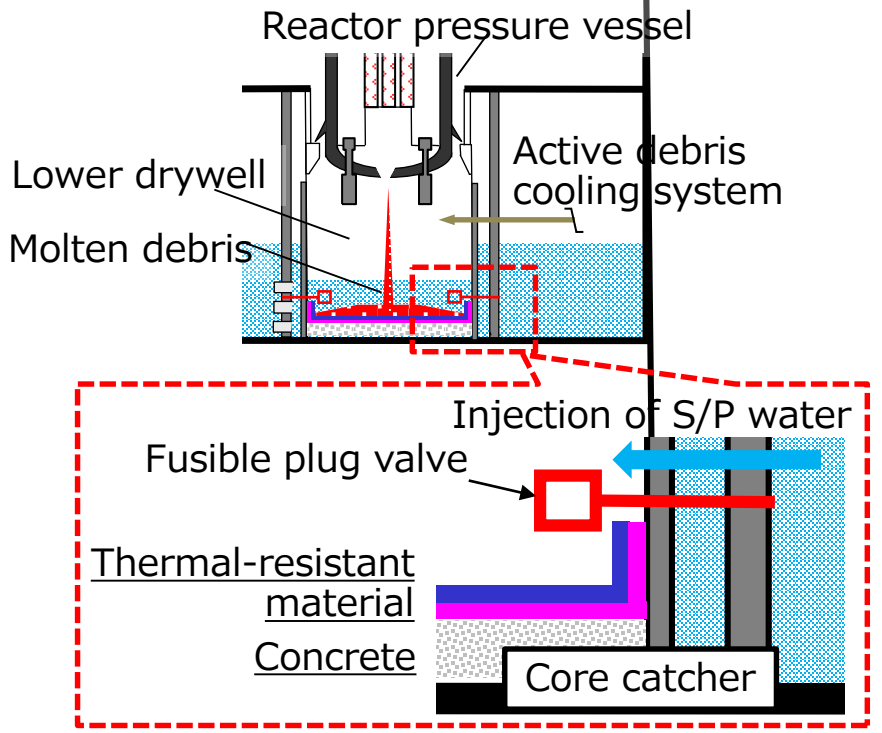
PRCS: Passive Reactor Cooling System

- Decay heat can be removed by natural circulation during severe accidents.
- No operator actions are required for 24 hours with automatic start.



LDF: Lower Drywell Flooder

- Core catcher prevents the concrete erosion by molten debris.
- Cooling water is supplied from suppression pool (S/P, enough for 3 days cooling) without operator actions using fusible plug valve which is open automatically when the atmosphere heatups.



Major Features of BWRX-300

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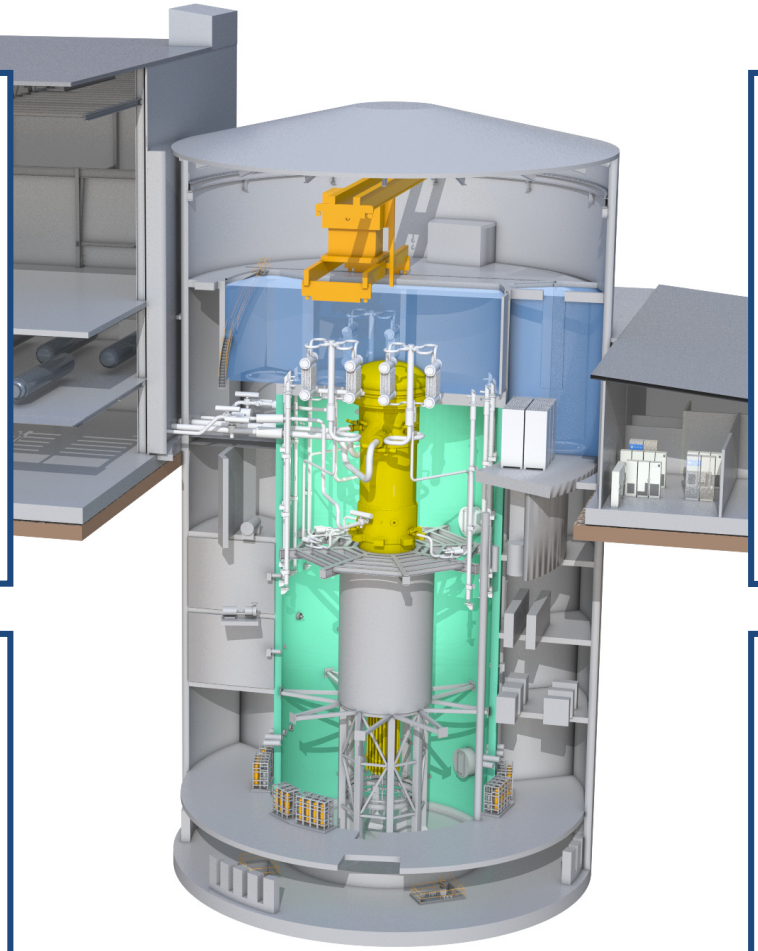
Small LWR with enhanced safety, economy, construction and flexibility Developing with our sister company, GE Hitachi Nuclear Energy

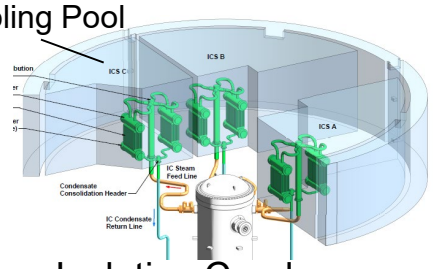


Innovative safety system

Mitigating LOCA

Integral RPV Isolation Valve

7 days cooling without power/actions



Isolation Condenser System (ICS)

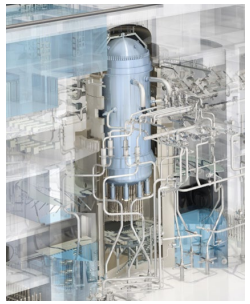
Shortened construction

Module construction technology

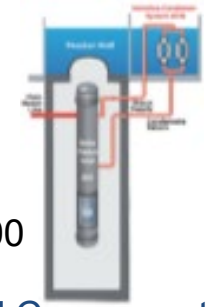
Module of HP Drain Pump/ Piping/Valves for ABWR

Cost Reduction

Introduction of innovative system leads to reduction of SSCs*



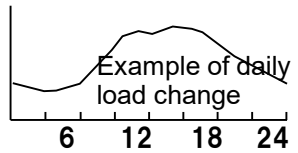
ABWR → BWRX-300



* SSCs: Structures, Systems and Components

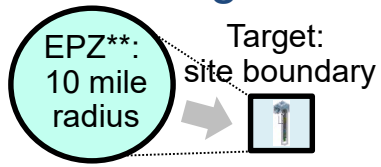
Flexibility

Operation



Responding to daily load change

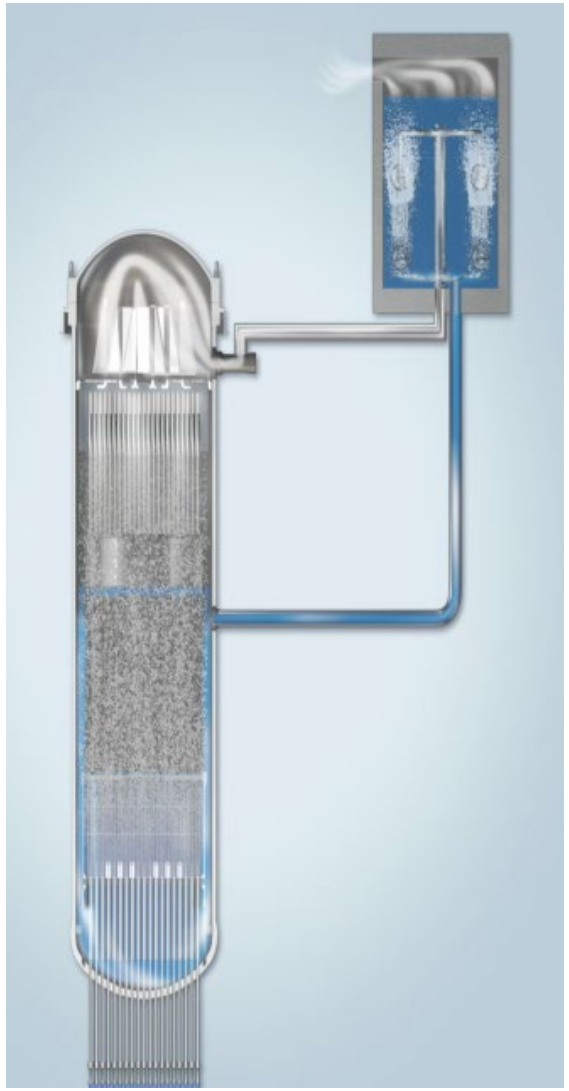
Siting



Mitigated effects of severe accident leads to small EPZ**

** EPZ: Emergency Planning Zone

10 Innovative Safety System

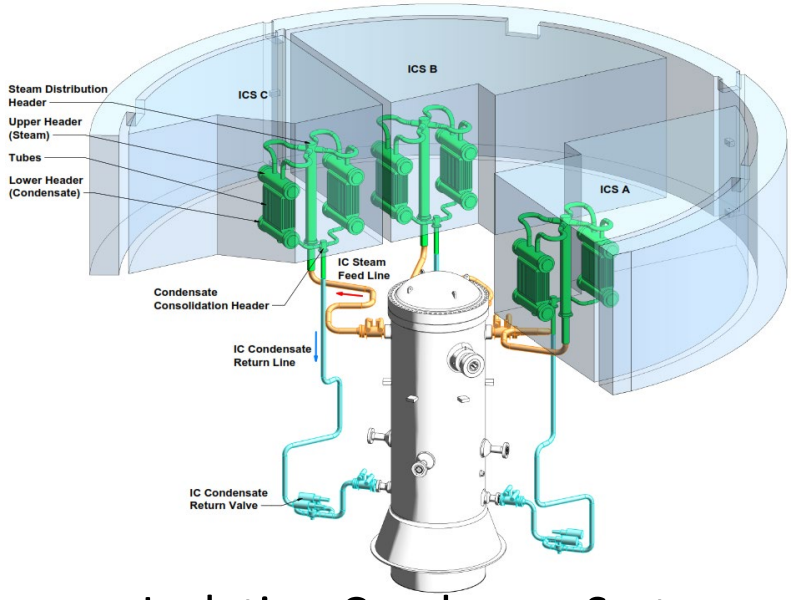


Natural circulation design +
Isolation Condenser System (ICS) +
Integral Isolation Strategy

Outcomes:

- LOCA (Loss of Coolant Accident) mitigation
- Eliminates need for multiple systems
- Removes decay heat while maintaining water inventory
- Inherently safe with no operator action or AC power
- 7 days cooling without power/actions

Integral RPV Isolation Valve



Isolation Condenser System

11 Integral RPV Isolation Valve

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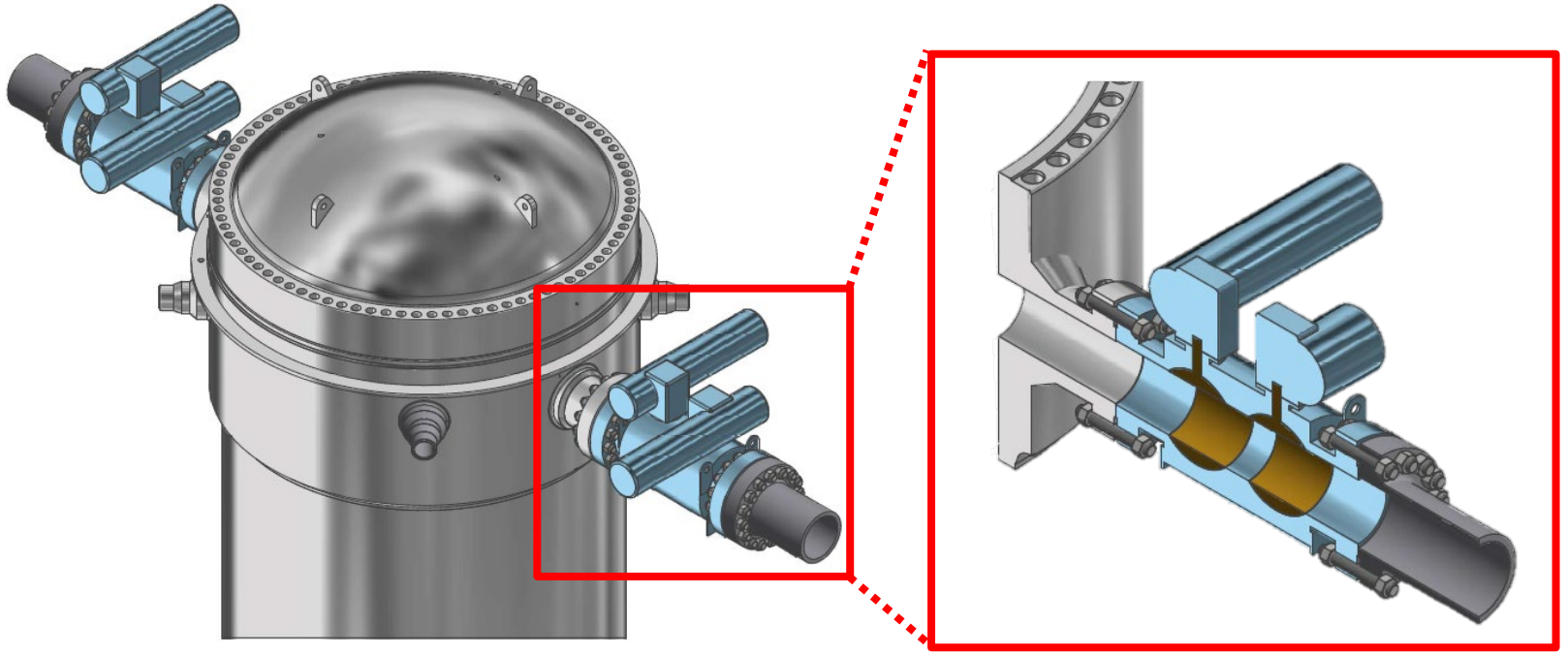
Breakthrough innovation concept to mitigate large and medium LOCA

- Large non-isolable pipes between RPV and isolation valves eliminated
- Large break Loss of Coolant Accident (LOCA) potential greatly reduced
- Nuclear Regulatory Commission (NRC) approved in the U.S.
- Enables dramatic design simplification and elimination of unnecessary systems



12 Countermeasures for Natural Disasters and Terrorisms

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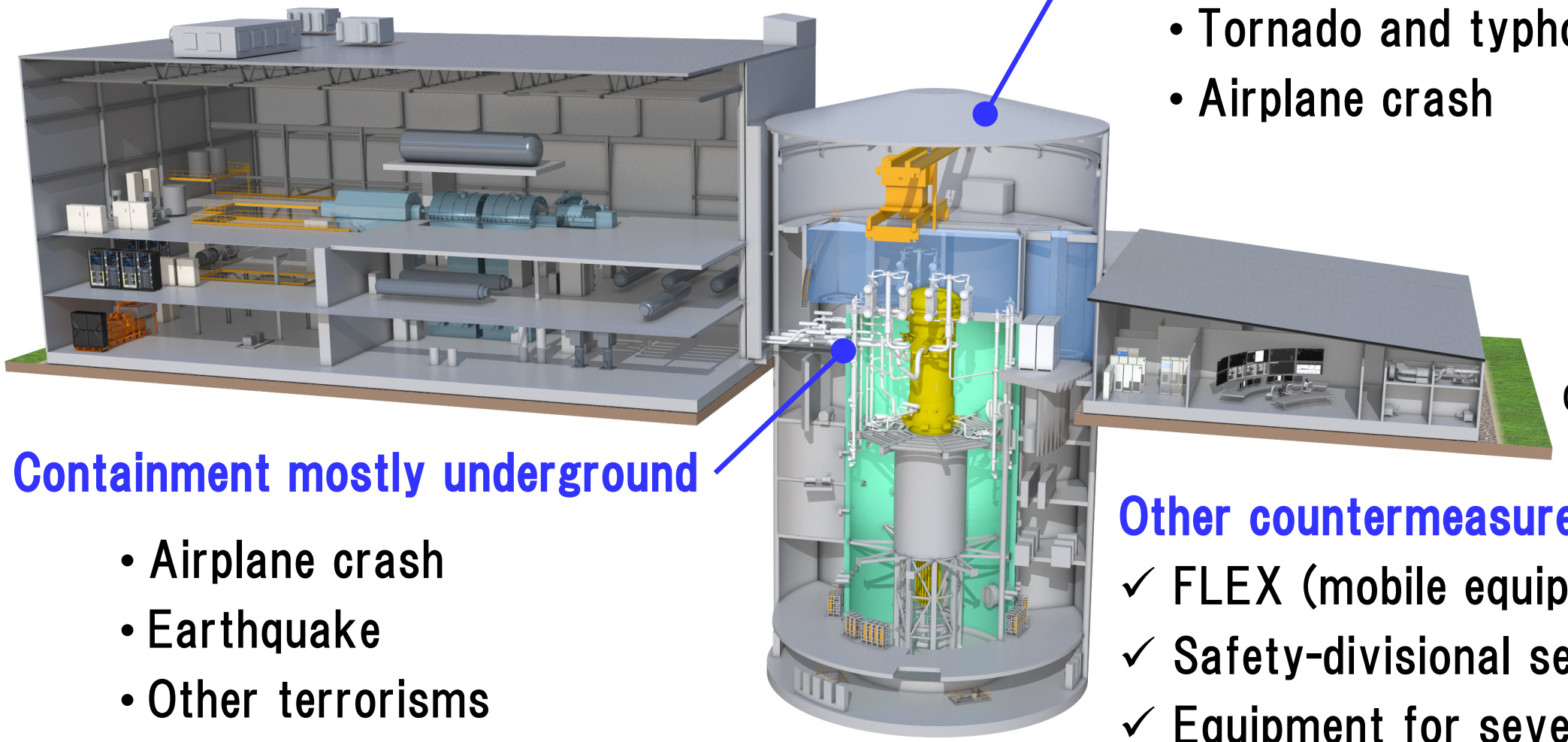
Cylindrical building with sloped roof

- Tornado and typhoon
- Airplane crash



Ground level

Containment mostly underground

- Airplane crash
- Earthquake
- Other terrorisms

Other countermeasures

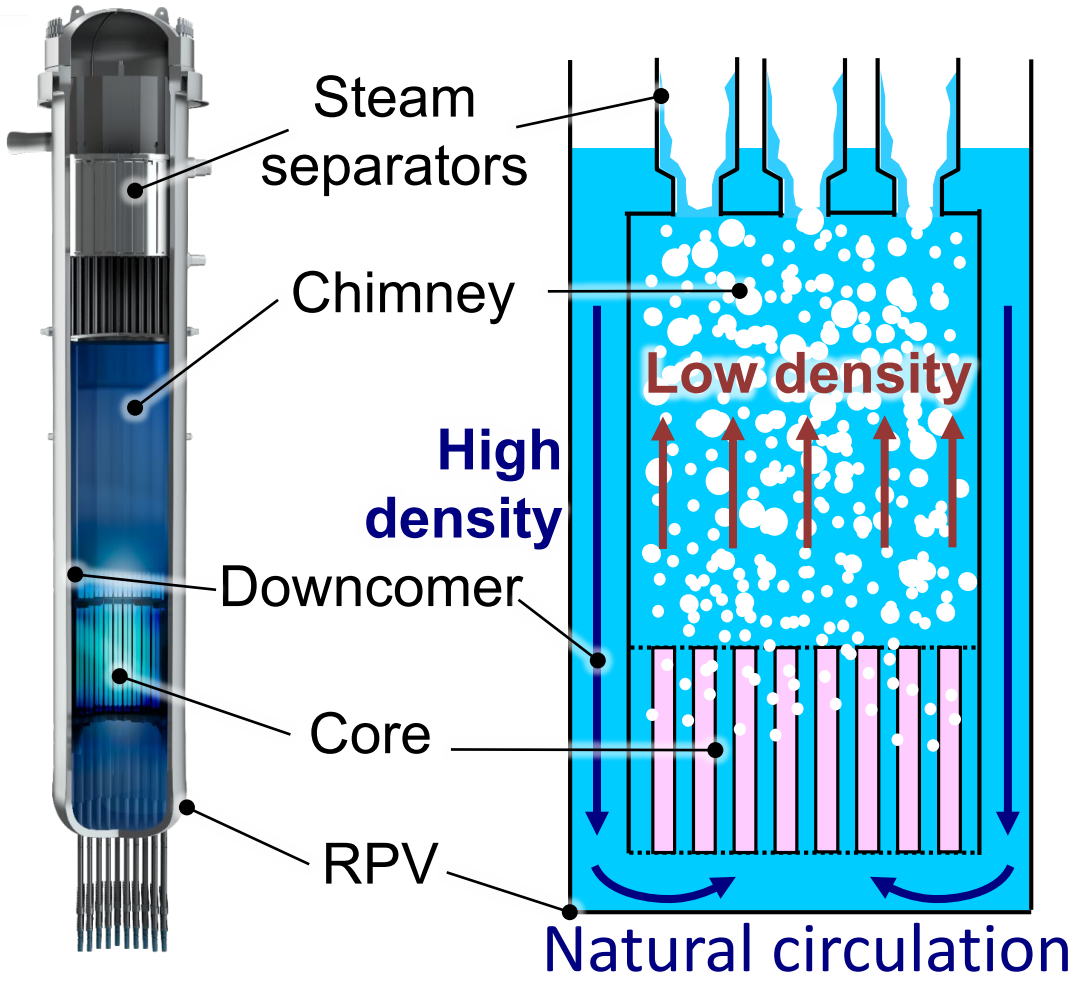
✓ FLEX (mobile equipment)

✓ Safety-divisional separation barrier

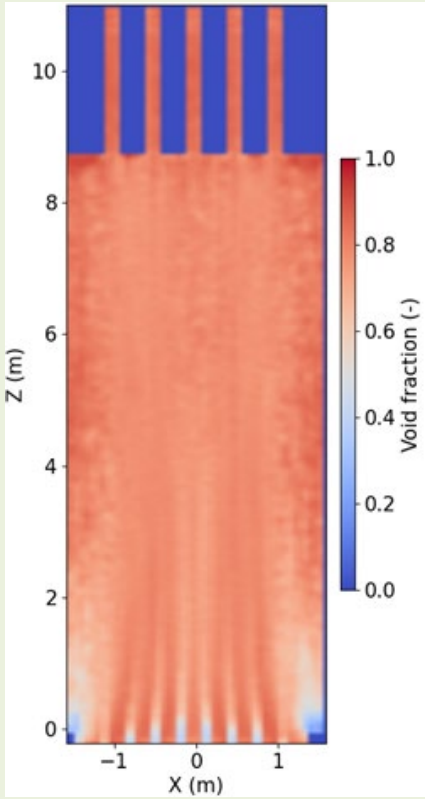
✓ Equipment for severe accidents

13 Example of Hitachi-GE activity: BWRX-300 chimney

To support global licensing, CFD and test to validate chimney flow characteristics (water and steam fluxes ⇒ Void fraction ⇒ Density)



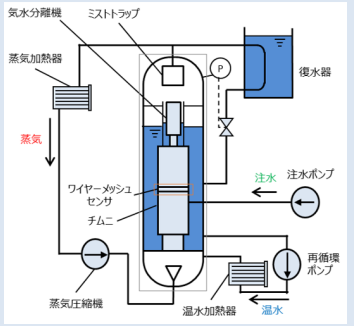
CFD simulation

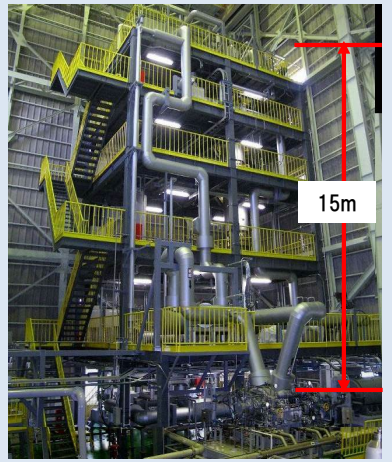


Benchmarking system code TRACG

Test at nominal pressure

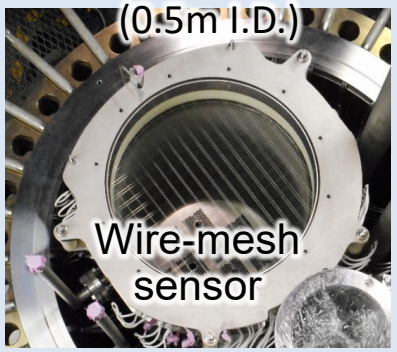
Steam + water loops

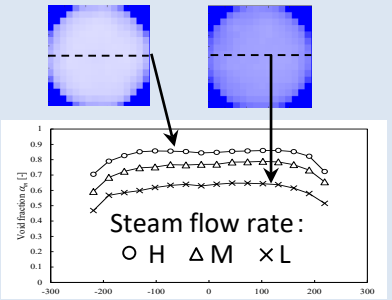




HUSTLE facility

Test body (0.5m I.D.)





Obtained validation data

14 Deployments of BWRX-300

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In Canada, OPG(Ontario Power Generation) progressing to deploy BWRX-300
Important licensing documents approved in USA

Europe

- Poland: ORLEN Synthos Green Energy(SGE) partnered to deploy multiple BWRX-300s
- Polish regulator: General Opinion and Decision in Principle for 6 sites with multiple BWRX-300s each
- Estonia: Fermi Energia choses BWRX-300
- UK: GE Hitachi applied for GDA

Hitachi-GE

- Developing BWRX-300 from the beginning
- Try to establish Supply Chain for domestic and supporting global projects

Canada

- **OPG DNNP – first unit deployment status**
  - License to Construct application submitted
  - Site preparation started
  - Initial contract for EPC signed
- **Licensing activities on-going**
  - VDR completed
  - License to Construct under review
- **Next BWRX-300s** (3 in Darlington, SaskPower)

USA

Utilities actions

- Tennessee Valley Authority (TVA) progressing with deploying the BWRX-300 at its Clinch River site

Licensing activities on-going

- 5 Licensing Topical Reports (LTRs) issued and approved

DNNP: Darlington New Nuclear Project
GDA: Generic Design Assessment
GEH: GE Hitachi Nuclear Energy
GNF-A: Global Nuclear Fuel - Americas
OPG Ontario Power Generation
TVA: Tennessee Valley Authority
VDR: Vendor Design Review

15 Summary

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- Nuclear power is an important source of low-carbon electricity.
- Hitachi-GE is developing four advanced reactors to contribute carbon neutrality with stable and self-sufficient energy source.
- In this presentation, I introduced innovative large LWR HI-ABWR and highly economic small LWR BWRX-300. Both reactors have innovative safety features and countermeasures for natural disasters.
- Hitachi-GE will propose innovative technologies by open innovation with global collaboration schemes. It contains the cooperation with the governments, academia and industries.

END

Development of Hitachi-GE's Advanced Reactors

January 26, 2024

Kazuaki Kito
Hitachi-GE Nuclear Energy, Ltd.


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