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Chunghwa Nuclear Society 2024 Annual General Meeting

Features of BWRX-300 Small Modular Reactor

16 December 2024

Hitachi-GE Nuclear Energy, Ltd.

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Contents

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1. Company profile and Hitachi-GE's nuclear future vision

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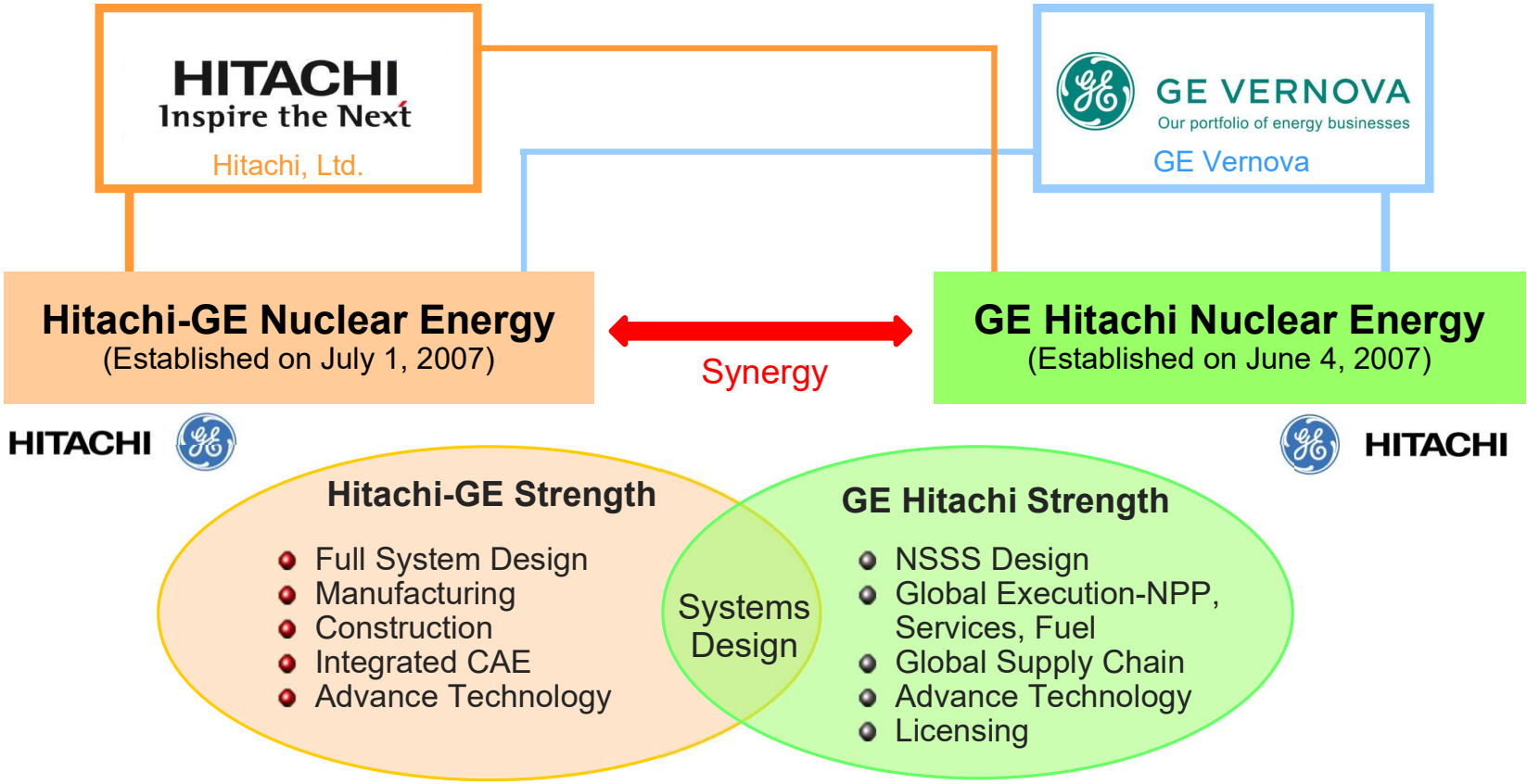
1-1 Hitachi and GE Vernova global alliance



- Hitachi and GE alliance based on 50-year collaboration in the nuclear business
- Committed to developing and promoting latest BWR technologies and services

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1-2 Business portfolio of Hitachi-GE

Rokkasho Reprocessing Plant

Spent fuel casks

Shika-2 ABWR

UK project (Withdrawal)

Fuel Cycle

- Components supply for Monju / Rokkasho
- Spent fuel Interim Storage Casks

New Builds

- Multiple ABWRs are for operation and under construction

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Maintenance Services

- Safety enhancement work for plant restarts
- Fukushima decommissioning work
- Outage and plant maintenance services

Robotics for Fukushima

Filtered Containment Vent

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1-3 Hitachi-GE's vision for nuclear future

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Creation of new value and contribution to sustainable power generation

Value	2020	2030	2040	2050	2060
Stable energy source to contribute 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		
Improved energy self-sufficiency - Utilize Pu as resource - Reduce spent fuel and its impact	Burn Pu in a light water reactor MOX fuel		Light water-cooled fast reactor (RBWR)	Sodium-cooled fast reactor (PRISM)	

- Demand for small to medium power supply
- Replacement of old plants

Gradual utilization of faster neutrons:
- Efficient burnup of Pu, Pu multi-recycling, Reduction of rad waste toxicity and volume

* BWRX-300 is being jointly developed with our sister company GE Hitachi Nuclear Energy.

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2. Concept of BWR-300

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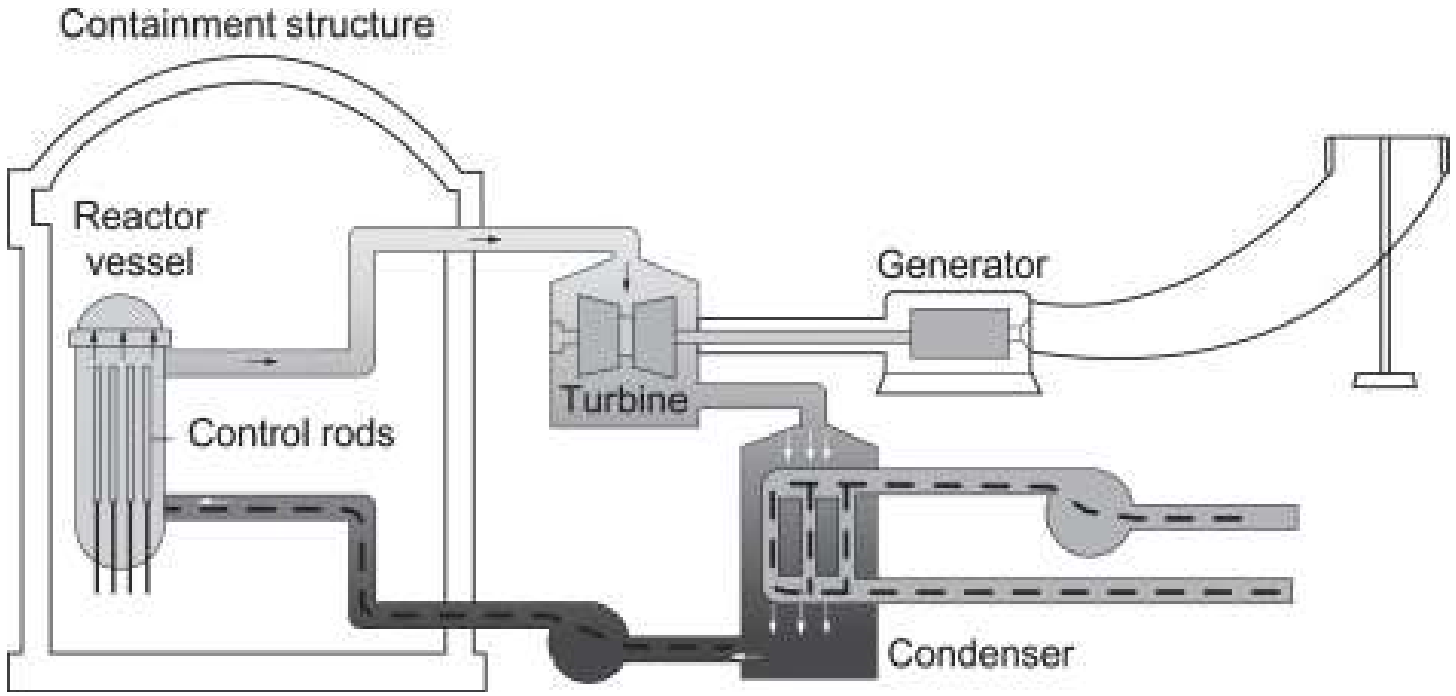
2-1 Boiling Water Reactor (BWR) concept



- Direct cycle design with no secondary loop, steam generator and pressurizer
- Water as coolant (boiling) and moderator (use of void feedback for reactivity control)
- Water circulated through core by natural circulation (enhanced by pumps in legacy plants)
- Low enriched (3-5% U-235) oxide fuel in metal cladding

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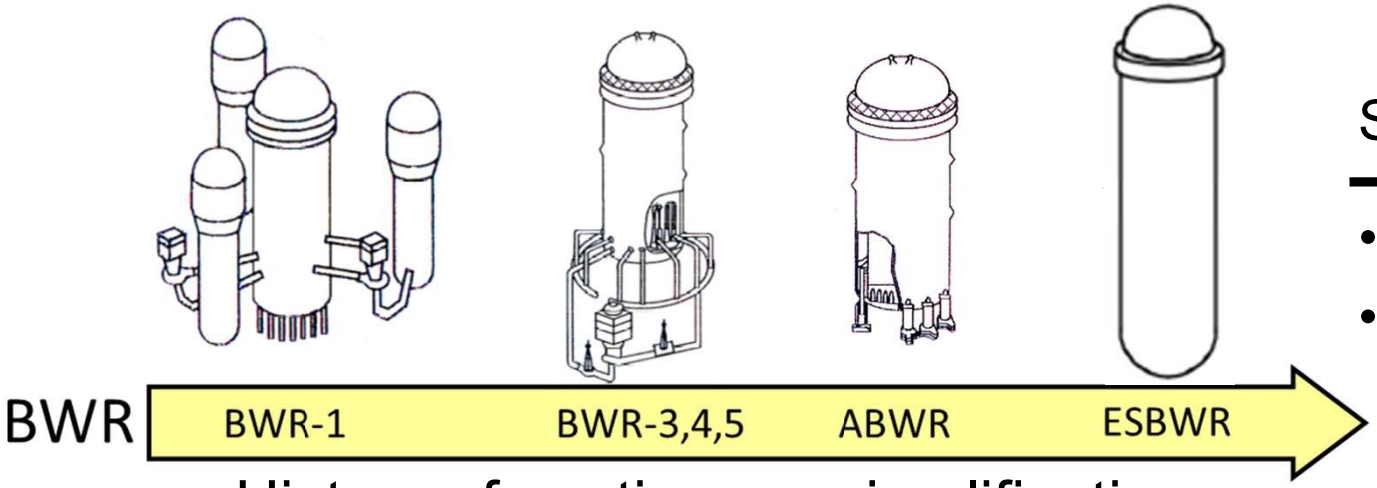
Simplicity allows SMR to overcome "Scale Demerit" without compromising safety

- Simplify by reducing:
  - Number of components
  - Volume of bulk material
  - Potential points of failure

BWR:
- inherently simple
- continuously simplified

⇒ great potential as SMR using proven technology



History of continuous simplifications

Scaled-down with
- Innovation
- Simplification

BWRX300

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2-3 BWRX-300 plant image

https://nuclear.gepower.com/build-a-plant/products/nuclear-power-plants-overview/bwrx-300

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2-4 Overview of BWRX-300

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- 10th generation Boiling Water Reactor with natural circulation
- 300 MWe, water cooled, natural circulation SMR
- Leverages U.S. NRC licensed ESBWR*
- World class safety using innovative integral RPV isolation valve and passive safety system
- Design-to-cost approach
- Constructability integrated into design
- Significant capital cost reduction per MW compared to conventional large reactors
- Licensing started in the U.S., Canada, UK and Poland
- Operational as early as 2029
- Mix of proven technology and innovation

BWRX300

*ESBWR (Economic Simplified Boiling Water Reactor)
1,550MWe reactor, which uses natural circulation has passive safety features.

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2-5 Key features of BWRX-300

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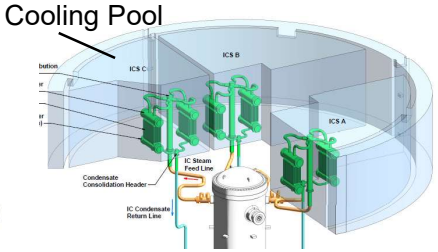
Small LWR with enhanced safety, economy, constructability and flexibility

Innovative safety system

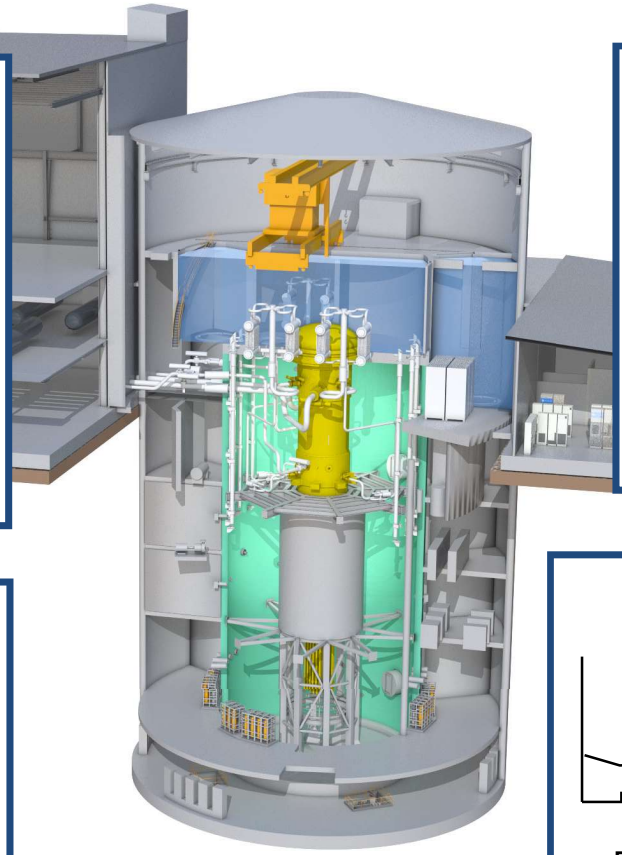
Mitigating LOCA

Integral RPV Isolation Valve

7 days cooling without AC power/actions



Isolation Condenser System (ICS)

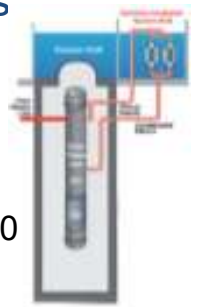


Cost Reduction

Introduction of innovative systems leads to reduction of structures, systems and components

ABWR

BWRX-300



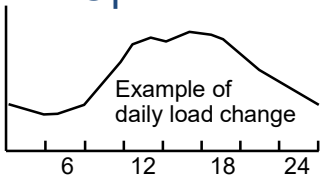
Shortened construction

Module construction technology

Module of HP Drain, Pump, Piping, Valves for ABWR

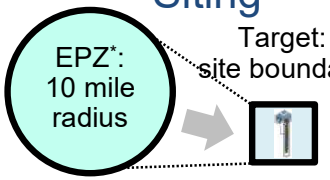
Flexibility

Operation



Responding to daily load change

Siting



Mitigated effects of severe accident leads to small EPZ (Emergency Planning Zone)

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2-6 Integral RPV Isolation Valve (RIV)

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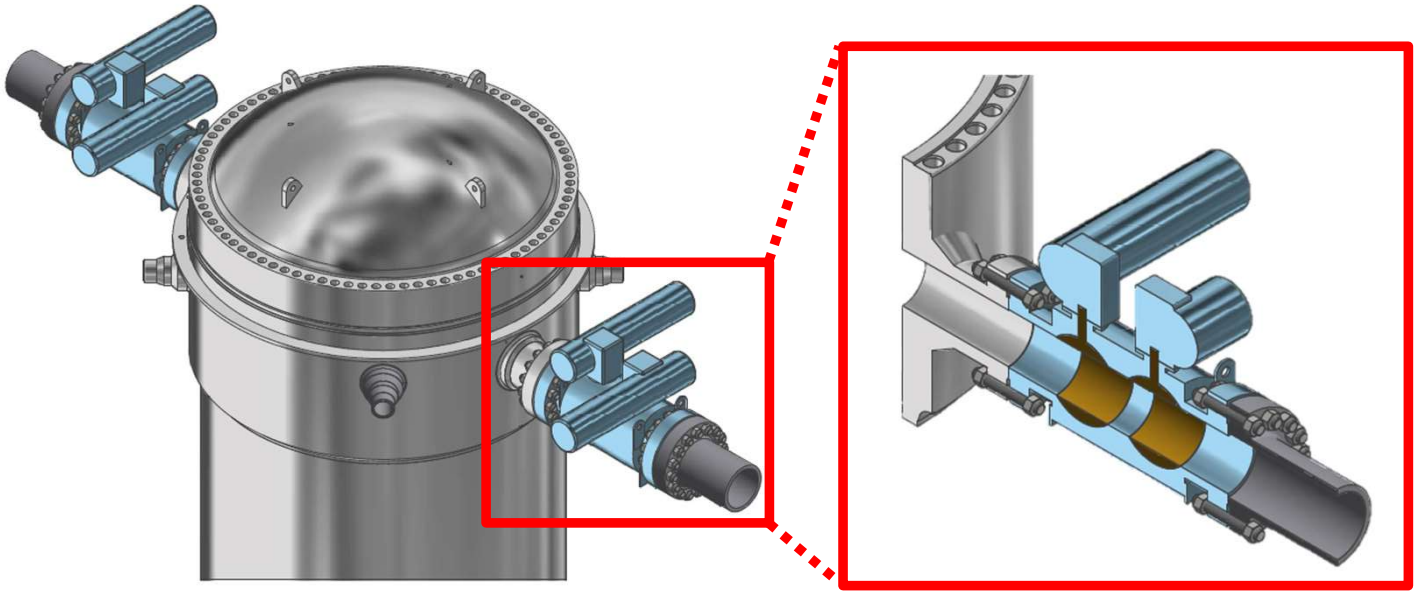
Breakthrough innovation concept to mitigate large and medium LOCA

- 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



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2-7 Isolation Condenser System (ICS)

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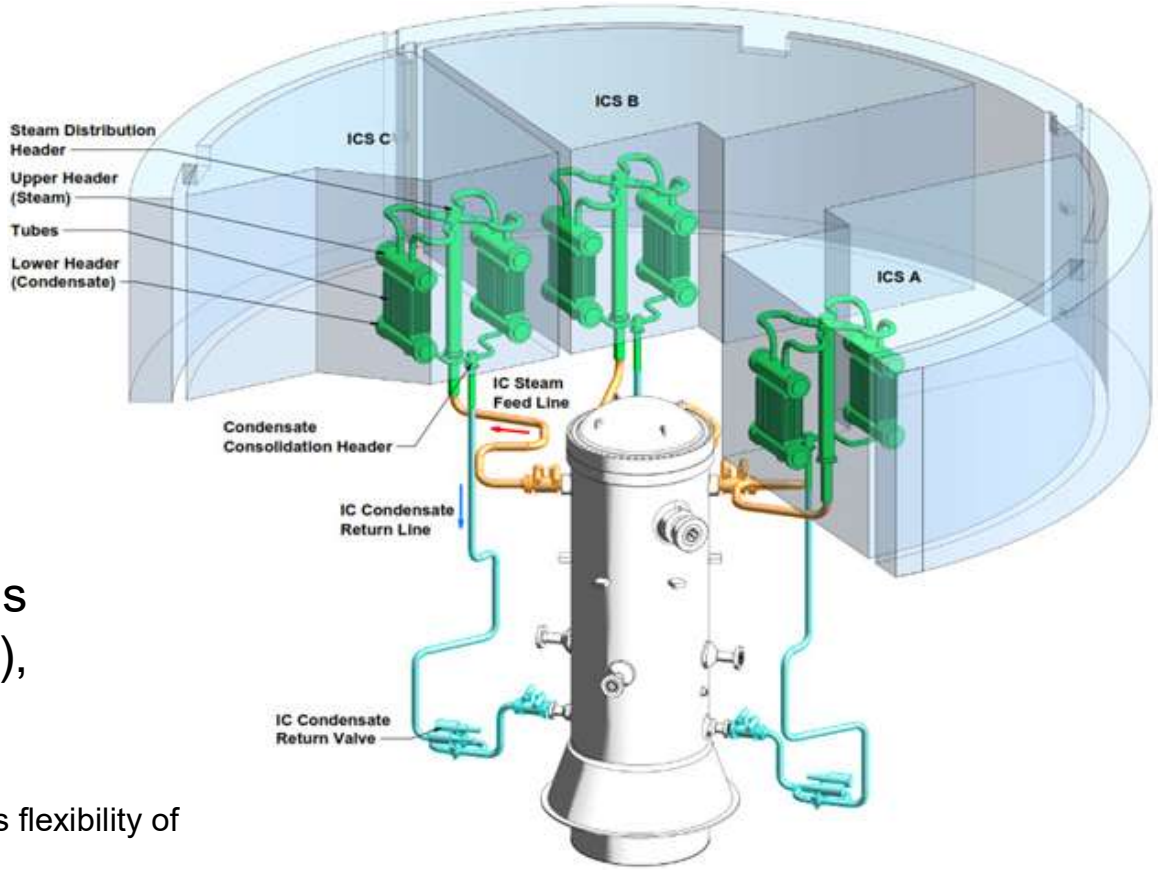
Phase-change passive decay heat removal and RPV pressure control

- Inherently safe, requiring with no operator action or AC power
- Passive Safety Class 1 system with 3 independent trains
- Only 1 Isolation Condenser train required for design basis accidents, capacity sufficient for mitigating various plant transients
- Seven-day coping time* for design basis accidents (station blackout, LOCA, etc.), can be extended with simple actions

Isolation Condenser System



* Coping time: Only limited operator actions are needed. It gains flexibility of operator actions for mitigating any transients.

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2-8 BWRX-300 cost reduction by simplification

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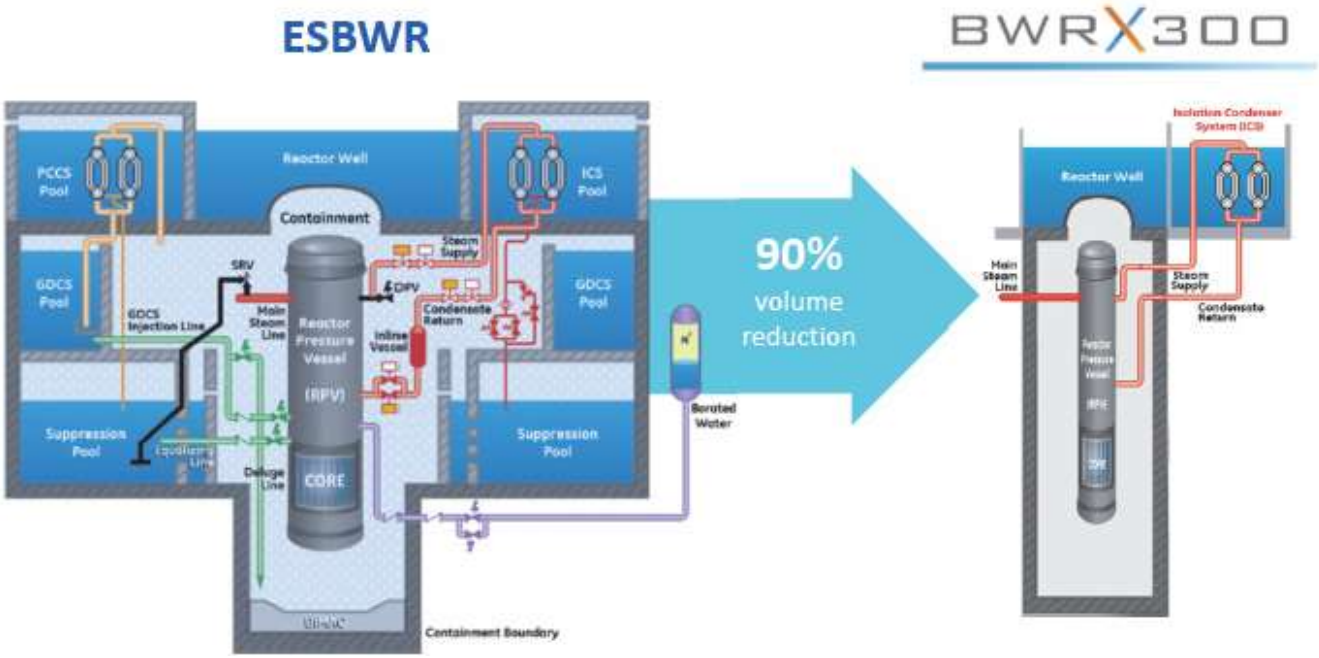
The “Natural circulation + ICS + Integral Isolation” strategy drives cost reduction

- Eliminates need for multiple systems and components found in traditional BWR designs (recirculation pumps, suppression pool, safety relief valves, depressurization valves …)
- Less than 50% building volume/MW and less than 50% concrete/MW



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2-9 Countermeasures for natural disasters and terrorisms

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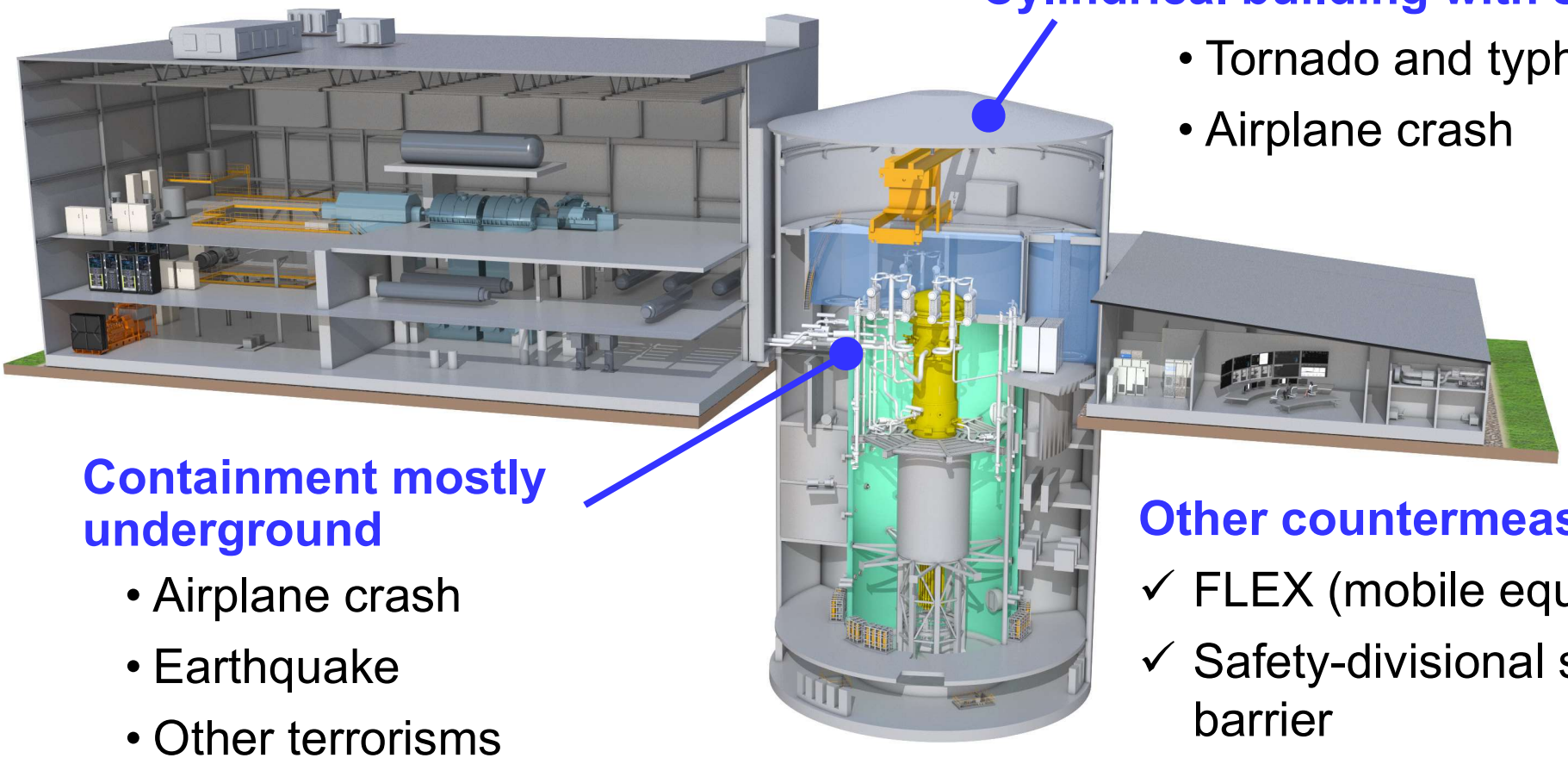

Cylindrical building with sloped roof

- 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

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2-10 Shortened construction

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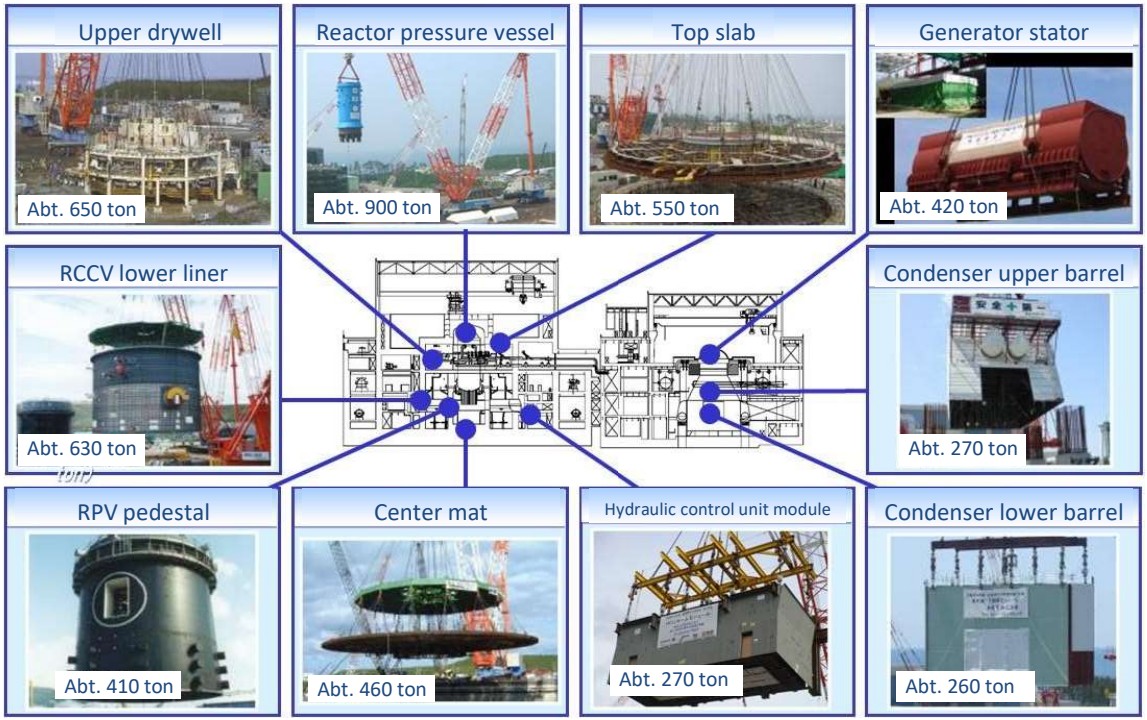
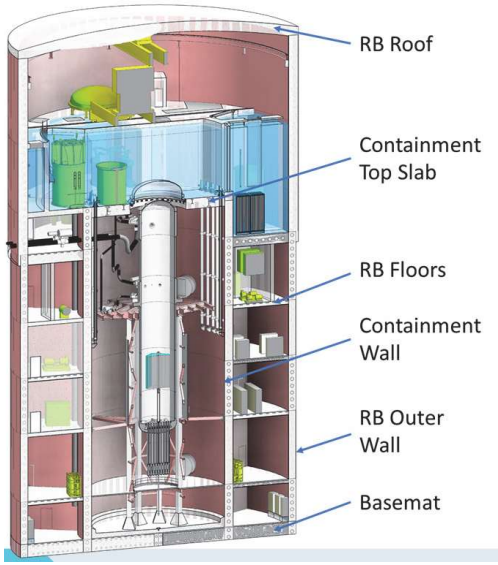
Incorporation of modularization lessons learned

ABWR Modules





- Maximizing advantages of small reactors
  - Factory-fabricated complete modules
  - Modularity to the appropriate level based on experiences

→ Shortened construction time with reduced site execution risks and cost overruns

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2-11 Utilizing proven technology

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Proven components, prior testing and operation history

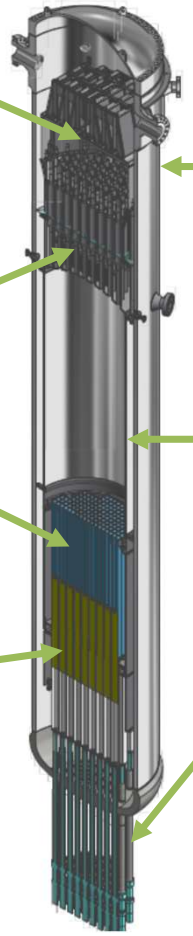
* ABWR fleet has combined 27+ years of operating experience
** Kernkraftwerk Mühleberg (KKM): 355 MWe BWR/4 in operation since 1972
*** Dodewaard: 58MWe natural circulation BWR, 1969 ~ 1997

Steam Dryer:
Same features as ABWR* & ESBWR …
Same as upgrades for existing fleet …
Size nearly identical to KKM**

Steam Separators:
Same as ABWR* & ESBWR …
Similar to others in the BWR fleet

GNF2 Fuel:
>26,000 bundles delivered …
Utilized by ~70% of BWR fleet

Control Rod Blades:
Same as ABWR* …
Longer than ESBWR …
Almost identical to latest design for BWR fleet



Reactor Pressure Vessel:
Same material and fabrication processes as ABWR*, ESBWR and many of the BWR fleet …
Diameter almost identical to KKM**

Chimney:
Uses ESBWR and Dodewaard*** technology …
Simplified

Fine Motion Control Rod Drives:
Same as ABWR* & ESBWR

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2-12 BWRX-300 siting flexibility

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Possibility of EPZ (Emergency Planning Zone) reduction

- TVA[*1], DOE[*2] and IAEA[*3] have been investigating to minimize EPZ considering SMR features:
  - Less fission product release during accidents because of smaller fuel amount in the reactor core
  - Improved safety features (e.g. seven days or longer grace period)
- Potential to minimize EPZ* to the site boundary, leveraging enhanced safety of BWRX-300

* EPZ: Emergency Planning Zone

EPZ for innovative SMRs
(Ex. Dose-based, consequence oriented methodology (US))

Site boundary

1. "Clinch River Nuclear Site Early Site Permit Application", TVA (2017), NRC accepted
2. "The Pathway to SMR Commercialization", DOE SMR Workshop Final Report (2016)
3. "Report from Working Group on Emergency Planning Zone", IAEA SMR Regulator's Forum (2018)

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2-13 Current situation in Canada

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ONTARIO POWER GENERATION

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TORONTO | DECEMBER 2, 2021

GE Hitachi Nuclear Energy selected by Ontario Power Generation as technology partner for Darlington new nuclear project

- Operational as early as 2029
- Submitted license-to-construct in 2022 to Canadian regulator
- GEH, OPG, AtkinsRéalis, and Aecon signed contract for deployment of a BWRX-300
- First commercial contract for grid-scale SMR in North America.
- Substantial economic opportunity for Ontario and Canada
- Ontario government announced pursuing 3 additional units at Darlington New Nuclear Project site

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2-14 BWRX-300 in deployment … not a demonstration project

Source: Ontario Power Generation

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2-15 BWRX-300 commercial activity

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TVA, OPG, Synthos Green Energy and GE Hitachi to share in the investment of approximately

$400 MILLION

to develop the

BWRX-300

standard design

NORTH AMERICA

Ontario Power Generation (OPG), GEH, AtkinsRéalis and Aecon signed a contract for the deployment of a BWRX-300 small modular reactor at OPG's Darlington New Nuclear Project site – 3 additional units being planned.

Tennessee Valley Authority (TVA) began planning and preliminary licensing for potential deployment of a BWRX-300 at Clinch River Site near Oak Ridge, Tennessee.

SaskPower entered an agreement with GEH to collaborate on project planning and to share expertise for the BWRX-300.

EUROPE & MIDDLE EAST

Poland

- Government of Poland has reached a decision in principle and approved 6 locations for construction of 24 BWRX-300s.
- U.S. Export-Import Bank and U.S. International Development Finance Corporation sign letters of interest to lend up to $4 billion to support projects.
- Regulator's general opinion concludes BWRX-300 design is compliant with Polish nuclear safety.

United Kingdom

- GEH awarded £33.6 million UK Future Nuclear Enabling Fund grant and enters Generic Design Assessment process for BWRX-300.
- Down-selected to final 4 for Great British Nuclear SMR competition which will ultimately select 2 technologies

Estonia - Fermi Energia selected GEH's BWRX-300 for potential deployment

Sweden – Vattenfall shortlisted BWRX-300 for further evaluation at Ringhals

EU SMR Industrial Alliance – joined as member to progress SMRs in EU

United Arab Emirates, Czech Republic, Sweden, etc. - GE Hitachi has memoranda of understanding or other agreements in place with companies to support global deployment of BWRX-300

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3. Hitachi-GE development activities

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3-1 Japanese government activity

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To achieve carbon neutrality by 2050, Japan decided to enhance nuclear power usage

Ministry of Economy, Trade, and Industry **launched NEXIP in 2019**

NEXIP: Nuclear Energy x Innovation Promotion

Integrated support from business sector, academia and public institutions

- Nuclear power can respond to various social demands such as coexistence with renewable energy, carbon-free stable energy, hydrogen production, etc.

R & D Support
Provision of Facilities
Human Resource Development
Supply Chain Reinforcement

Hitachi-GE's developments also have been supported by NEXIP

An excerpt slide of METI presentation to explain NEXIP

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3-2 Example of Hitachi-GE activity: BWRX-300 chimney

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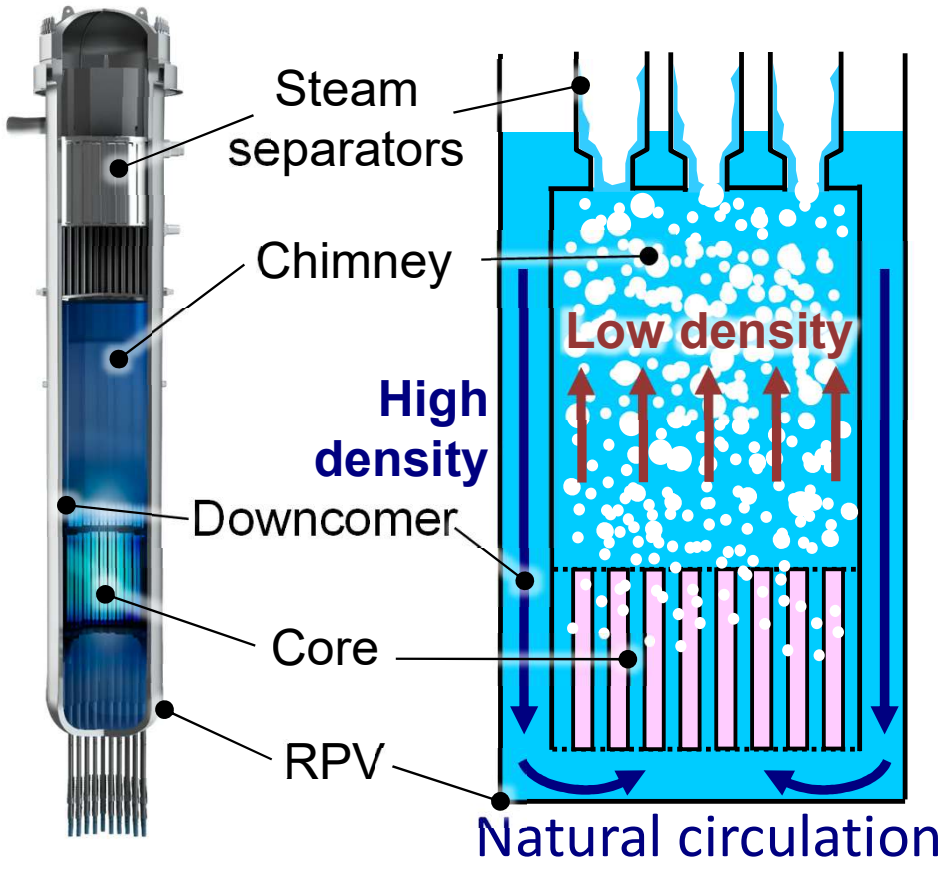
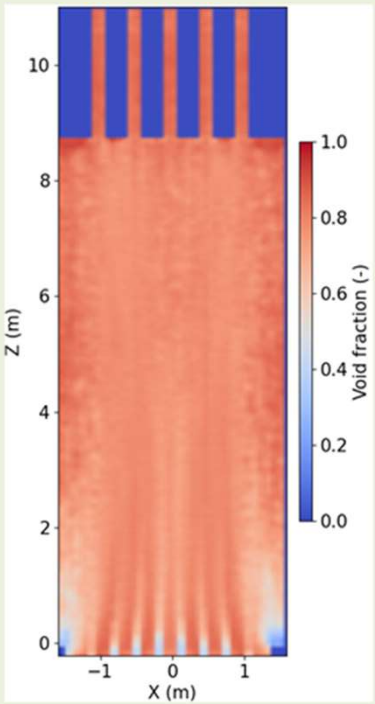
To support global licensing, CFD and tests to validate chimney flow characteristics (Water and steam fluxes ⇒ Void fraction ⇒ Density) to ensure fuel cooling capability.



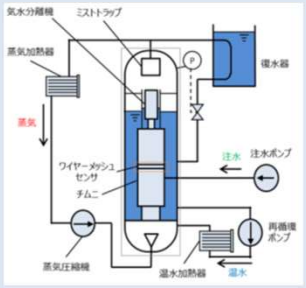
CFD simulation

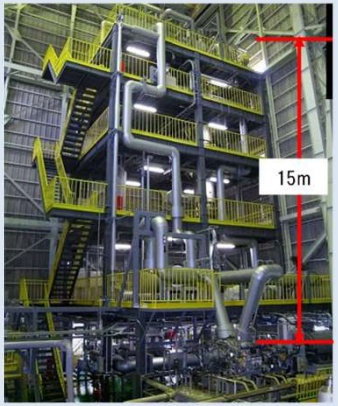


Benchmarking system code TRACG

Test at nominal pressure

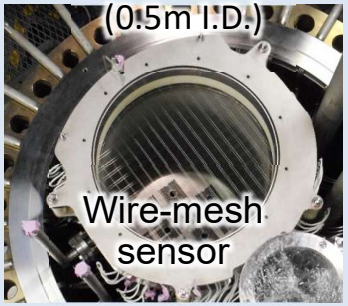
Steam + water loops

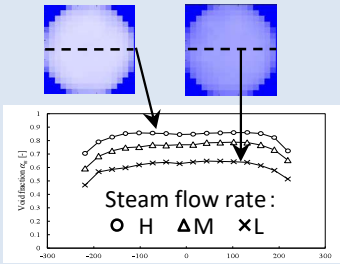




HUSTLE facility

Test body (0.5m I.D.)





Obtained validation data

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Summary

- Nuclear power is an important source of low-carbon electricity, and SMR is a key innovative technology for achieving carbon neutrality.
- Hitachi-GE and GE Hitachi are developing the highly economical small BWR, BWRX-300, under the global alliance. BWRX-300 addresses societal requirements for safety, economics and site flexibility.
- Standard design by utilities and GE Hitachi is underway, progressing toward deployment in multiple countries including licensing in Canada, USA, UK and Poland. Hitachi-GE is supporting GE Hitachi.
- The reactor has been awarded strategic status by the EU Commission SMR Industry Alliance for advanced support throughout the union. Also, Polish regulator and government issued General Opinion and Decision in Principle for 6 Polish sites. GE Hitachi applied for UK GDA. GDA stage 2 is on-going.

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END

Features of BWRX-300 Small Modular Reactor

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