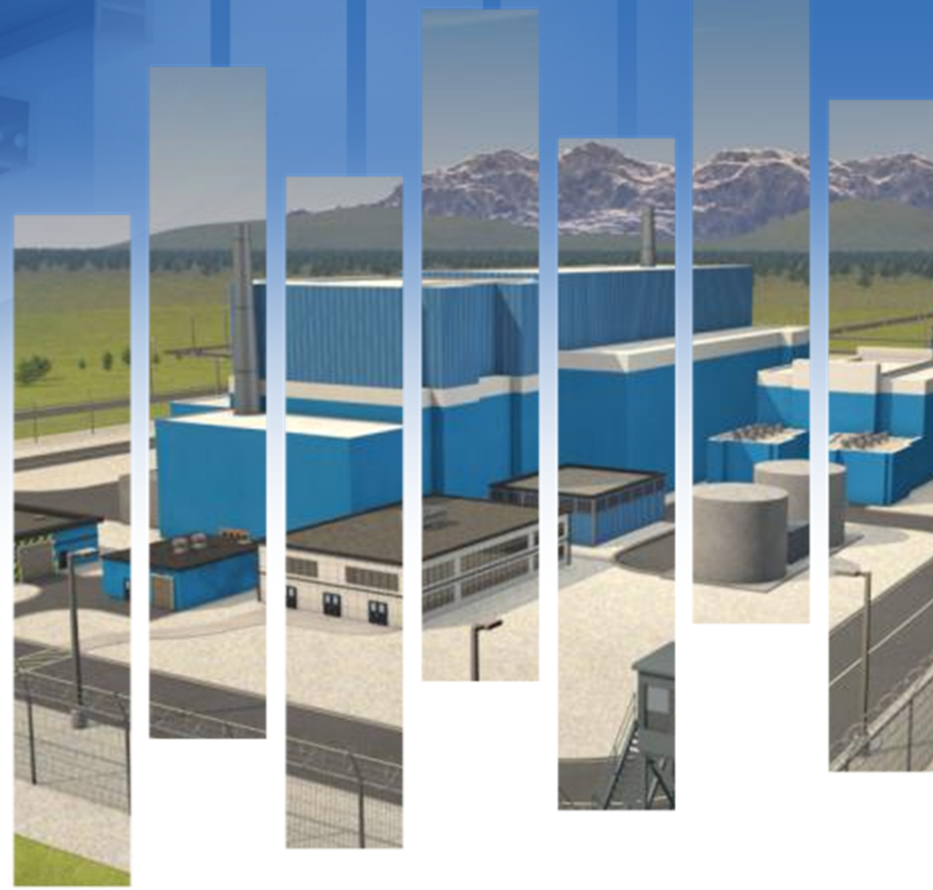


Safety, constructability, and operational performance of the ABWR and ESBWR designs

Douglas McDonald
Vice President, Nuclear Power Plant Sales – Middle East and Africa

IAEA Technical Meeting on Technology Assessment for Embarking Countries
June 24-28, 2013

GE Hitachi Nuclear Alliance

HITACHI

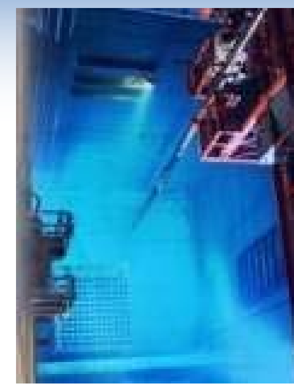
Wilmington, NC
USA

HITACHI

Tokyo,
Japan

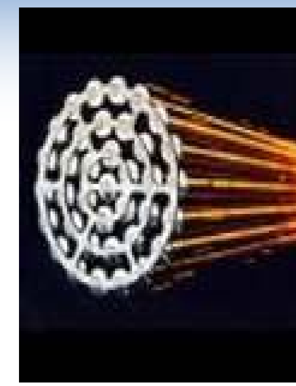
GLE

Wilmington, NC
USA



GNF

Wilmington, NC
Yokosuka, Japan



HITACHI

Peterborough, ON
Canada

- Nuclear Power Plants: ABWR, ESBWR and PRISM
- Nuclear Services

- Uranium Enrichment … Third Generation Technology

- Nuclear Fuel Fabrication ….BWR and CANDU
- CANDU Services
- Fuel Engineering and Support Services

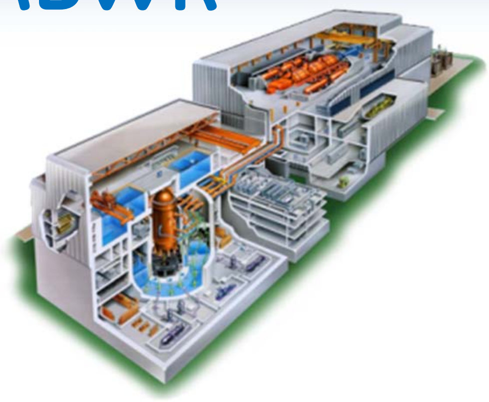
HITACHI

BWRs around the world

84 operating BWRs

GE Hitachi's new reactor portfolio

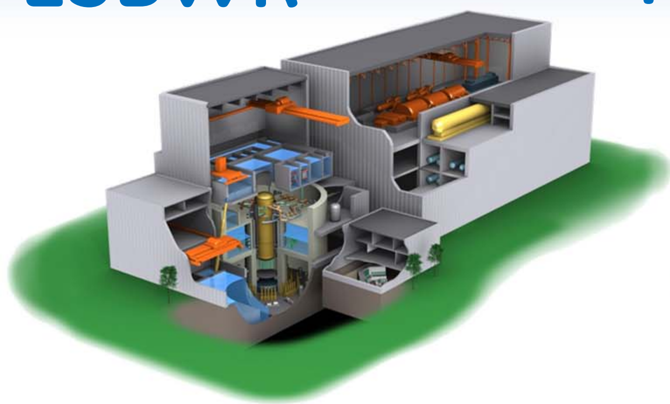
ABWR



Operational Gen III technology

- Lowest core damage frequency of any Generation III reactor
- Extensive operational experience since 1996
- Licensed in US, Taiwan, and Japan

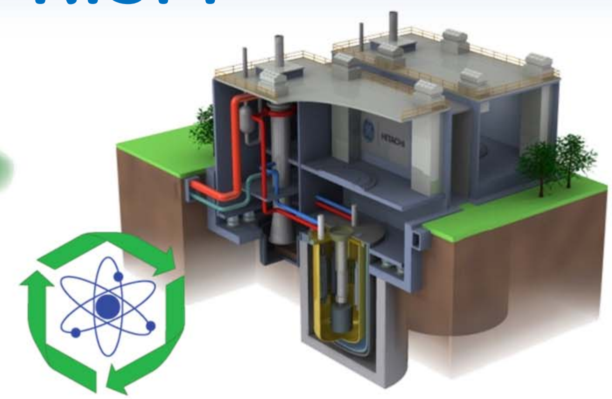
ESBWR



Evolutionary Gen III+ technology

- Lowest core damage frequency of any Generation III+ reactor
- Passive cooling for >7 days without AC power or operator action
- Lowest projected operations, maintenance, and staffing costs[1]
- 25% fewer pumps, valves, and motors than active safety nuclear plants

PRISM

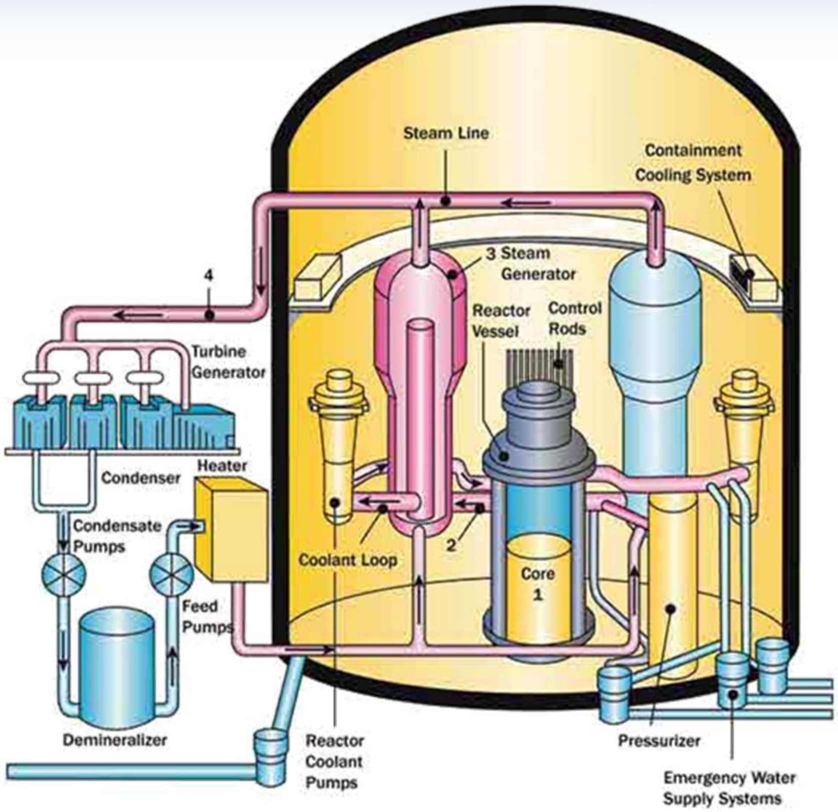


Revolutionary technology with a rich, 40-year heritage

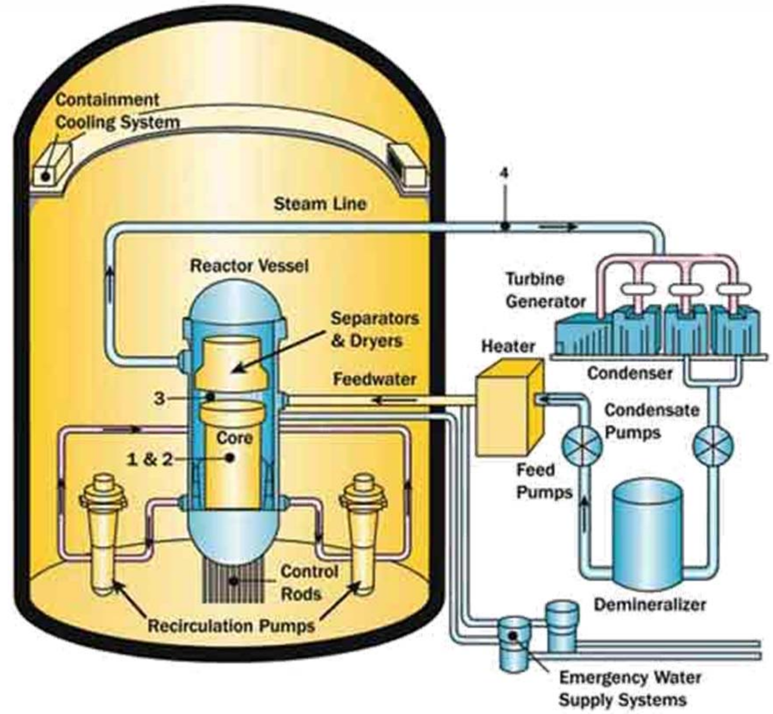
- Passive air-cooling with no operator or mechanical actions needed
- The answer to the used fuel dilemma - can reduce nuclear waste to ~300-year radiotoxicity[2] while providing new electricity generation

1 Claims based on the U.S. DOE commissioned 'Study of Construction Technologies and Schedules, O&M Staffing and Cost, and Decommissioning Costs and Funding Requirements for Advanced Reactor Designs' and an ESBWR staffing study performed by a leading independent firm
2 To reach the same level of radiotoxicity as natural uranium

PWRs and BWRs – the basics



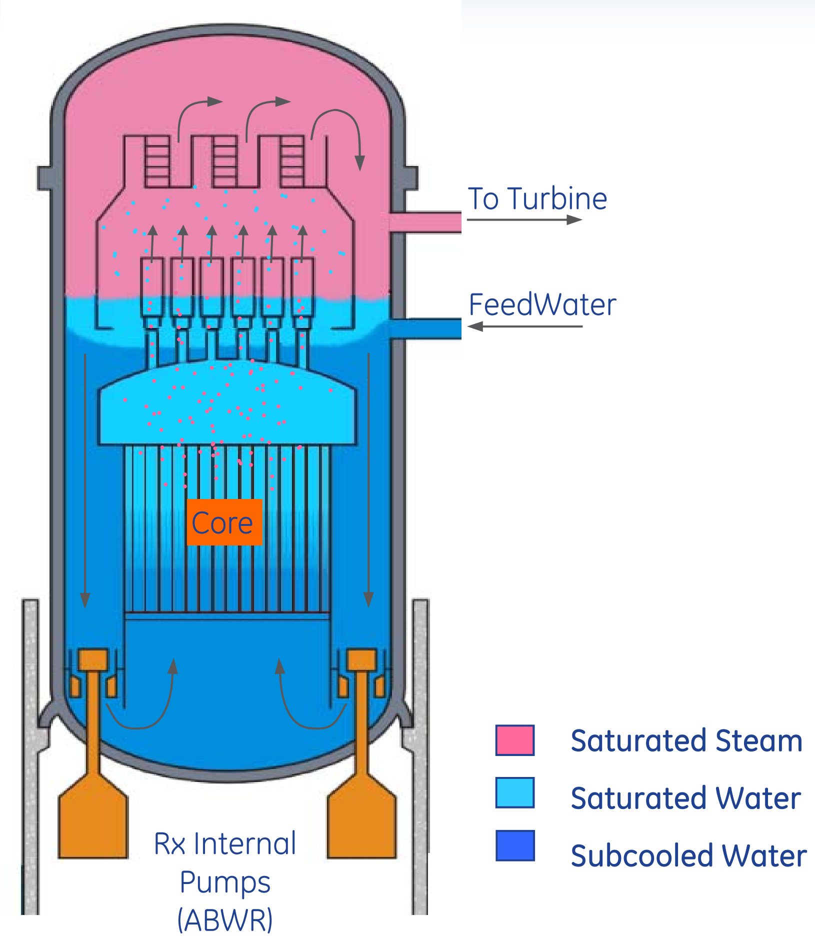
Typical Pressurized Water Reactor



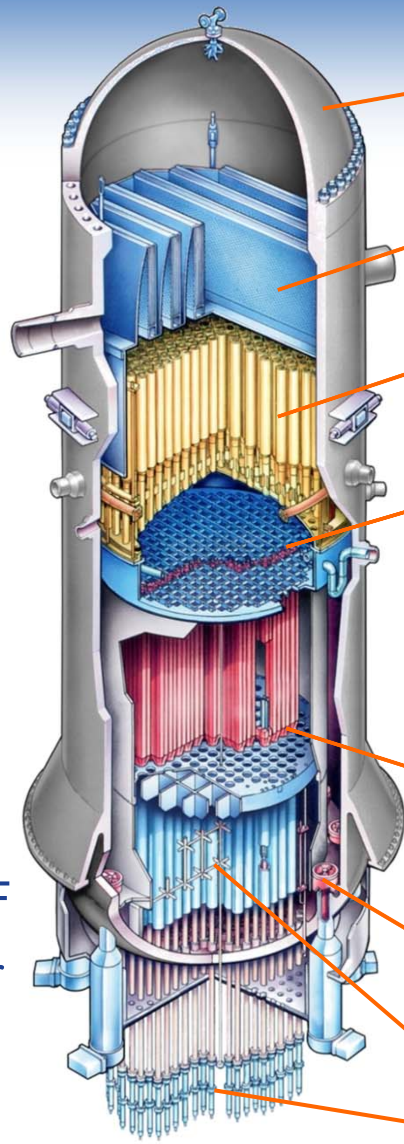
Typical Boiling Water Reactor

Operation of a BWR

- Saturated water/steam mixture cooling fuel
- Direct cycle (No external steam generators)
- Water moderator modified by steam voids (bubbles)



The Boiling Water Reactor



550⁰ F / 288⁰ C

99.9% Steam

420⁰ F / 216⁰ F

100% Water

Reactor Pressure Vessel

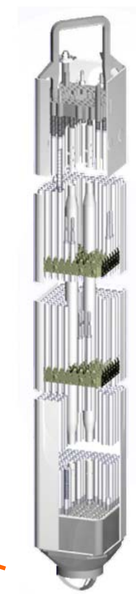
Steam Dryer

Steam Separator

Reactor Internal Pumps (ABWR)

Control Rod Blades

Control Rod Drives



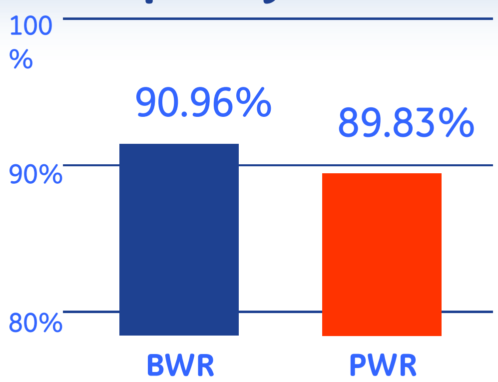
BWR Fuel Assembly

- 90 fuel rods encased in a ‘channel’
- 2 water rods
- part-length rods
- burnable absorbers

HITACHI

A benchmark for operational performance

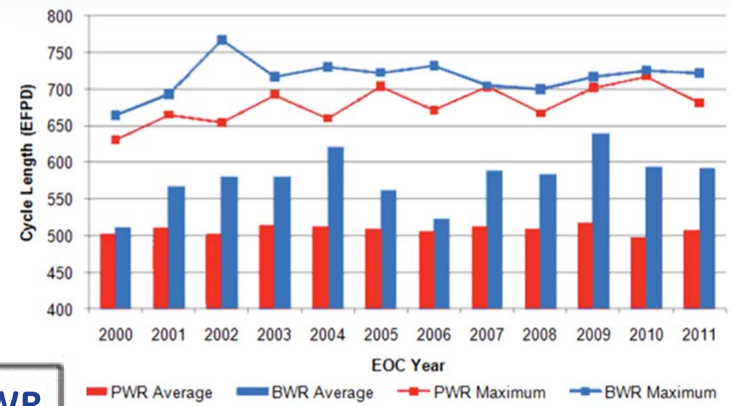
Capacity factors



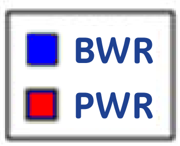
Data represents top quartile for 2002-2012

- **1%** BWR advantage provides **<u>8 additional months</u>** of revenue over 60-year lifetime

Average U.S. Cycle Length Trends



- BWRs – 20 months
- PWRs – 16.7 months

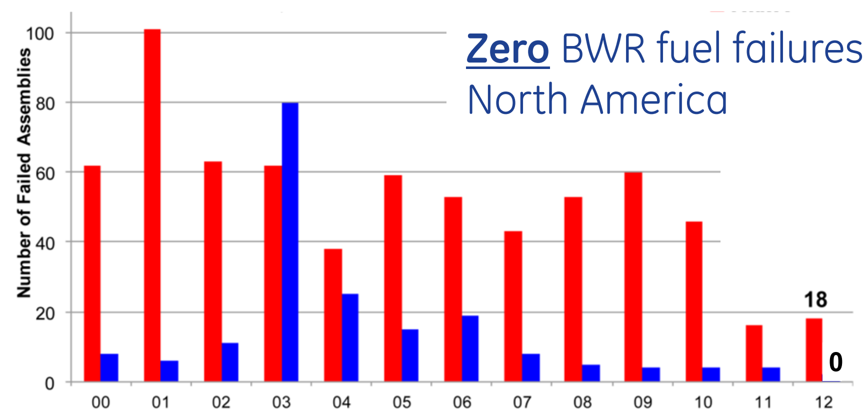


Average Outage length

<u>10 fewer days</u> in BWR outages in North America

2002-2012 N. American outages including inspection, maintenance or repair with refueling

Fuel performance

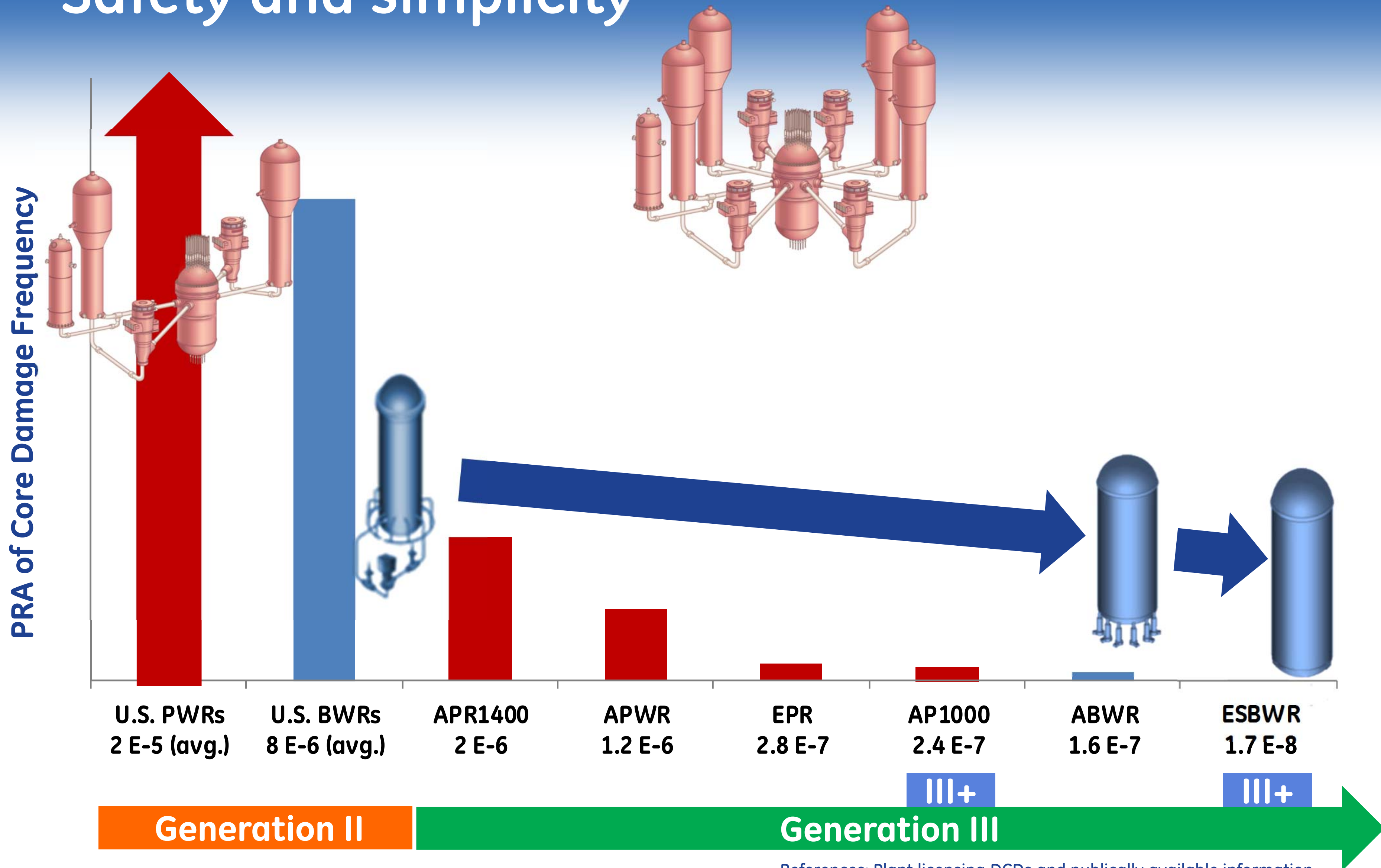


<u>Zero</u> BWR fuel failures in North America

HITACHI

Source: IAEA PRIS Database and 3/2013 EPRI Fuel Reliability Update

Safety and simplicity

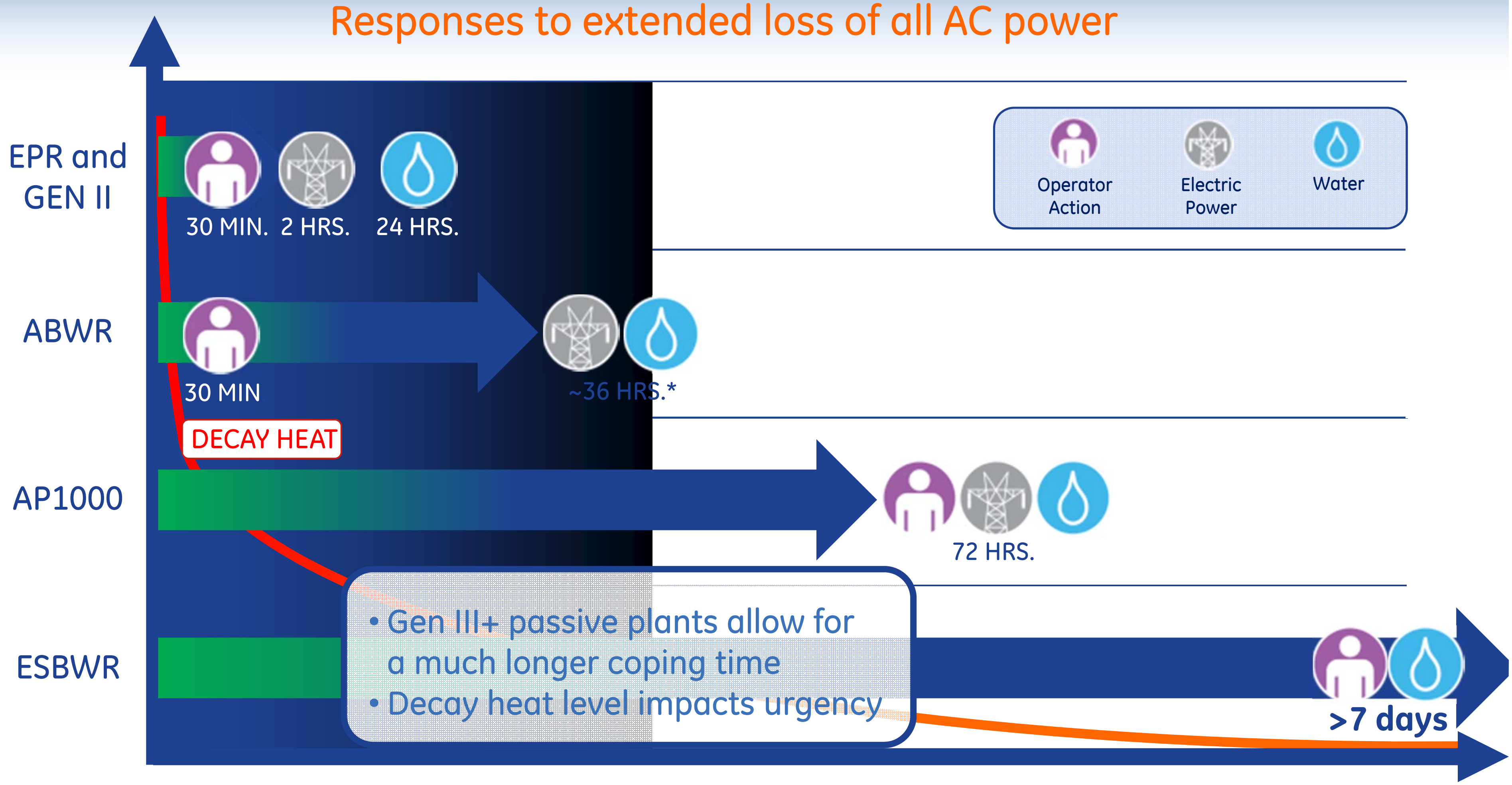


References: Plant licensing DCDs and publically available information
Note: PRA of CDF is represented in at-power internal events (per year)
Note: NSSS diagrams are for visualization purposes only

HITACHI

Responses needed to maintain core cooling

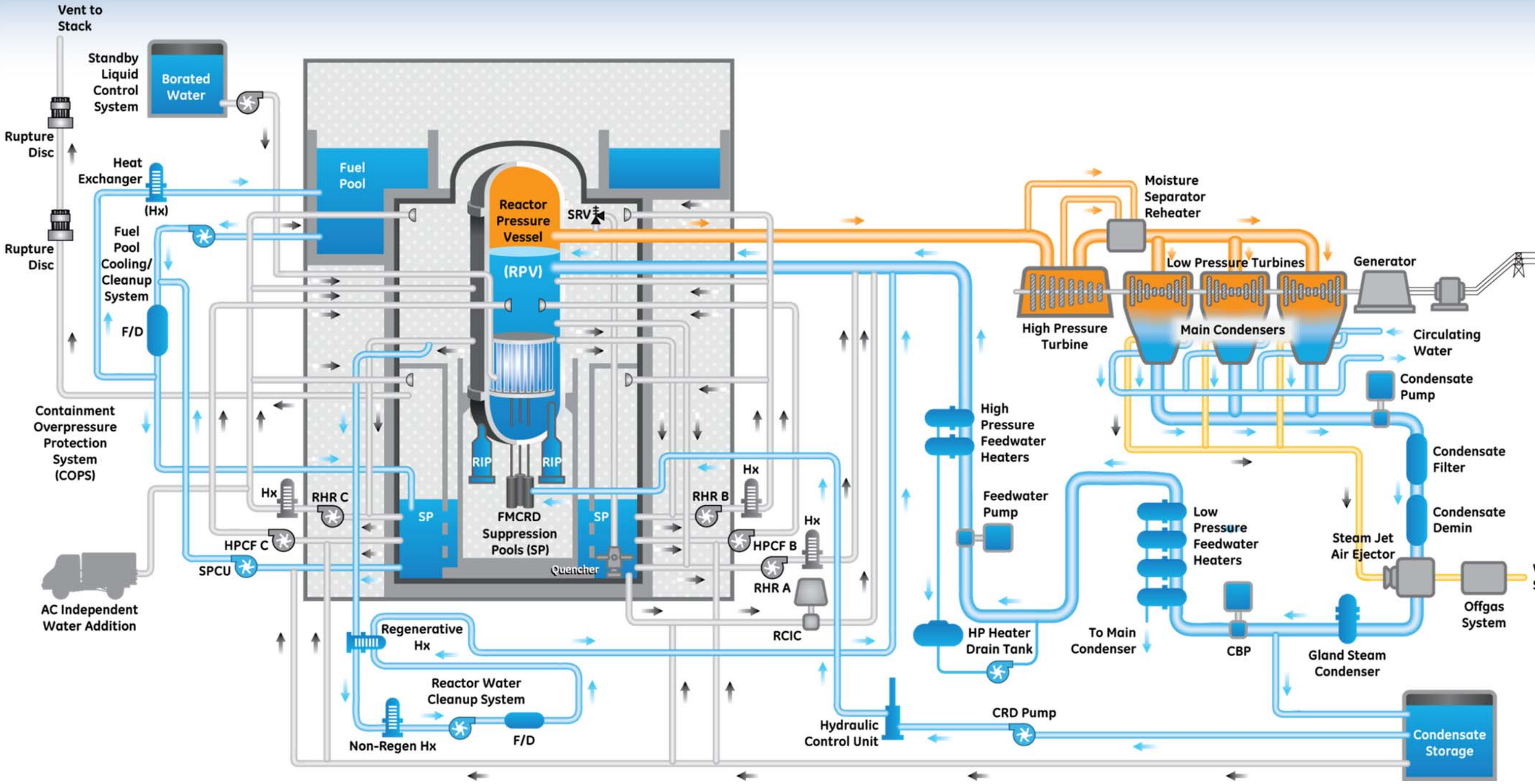
Responses to extended loss of all AC power



*ABWR DCD credits water addition at 8 HRS.
References: AP1000: US DCD rev. 18 Section 8.5.2.1, EPR: US DCD Rev. 1 Section 8.4

HITACHI

Advanced Boiling Water Reactor



HITACHI

ABWR Reactor Specification

3926 Rated MWt/1350 MWe

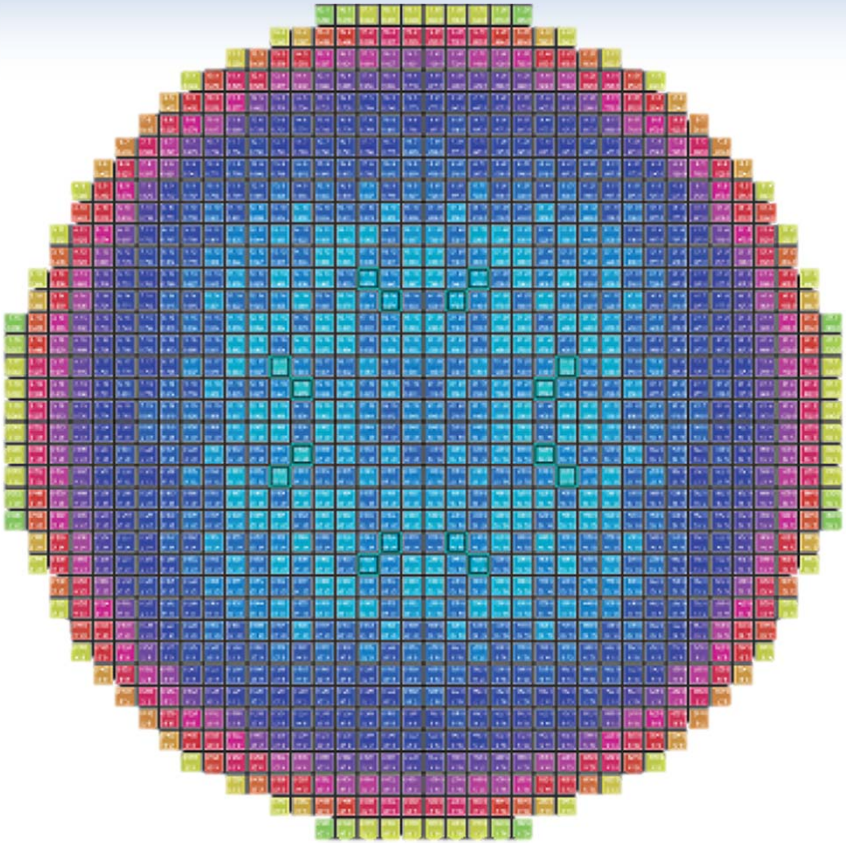
- Can be uprated to 4,300 MWt

872 Fuel Bundles

- N- Lattice (symmetric water gap)
- Active Fuel Length (3.66 m; 12 ft)
- Moderate Power Density (51 kw/liter)

205 Control Blades

- Fine Motion Control Rod Drives (FMCRDs)
    - Reduced Fuel Duty
    - Fast Hydraulic Scram



HITACHI

ABWR Design Objectives

Improved operability

Improved capacity factor

- 12-24 month fuel cycle
- ~95% on a 10 year rolling average

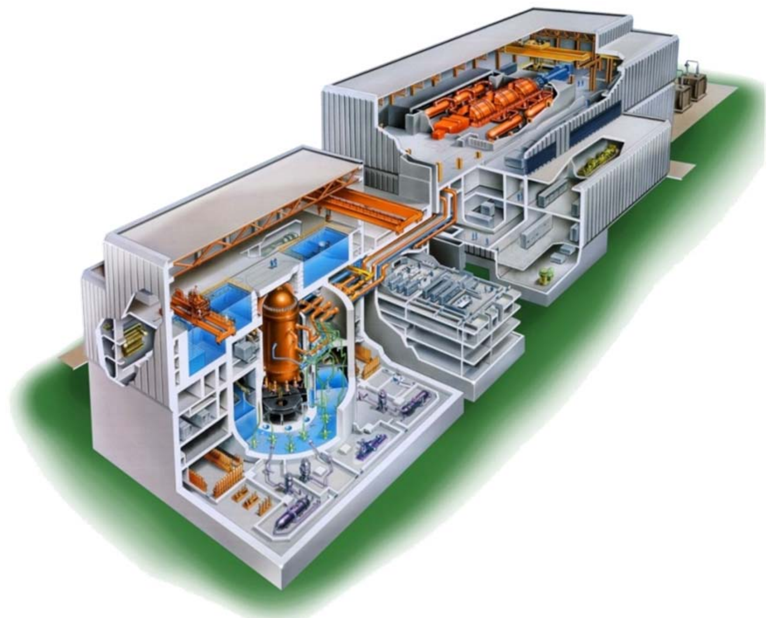
Improved safety and reliability

- No core uncovery during design basis accidents

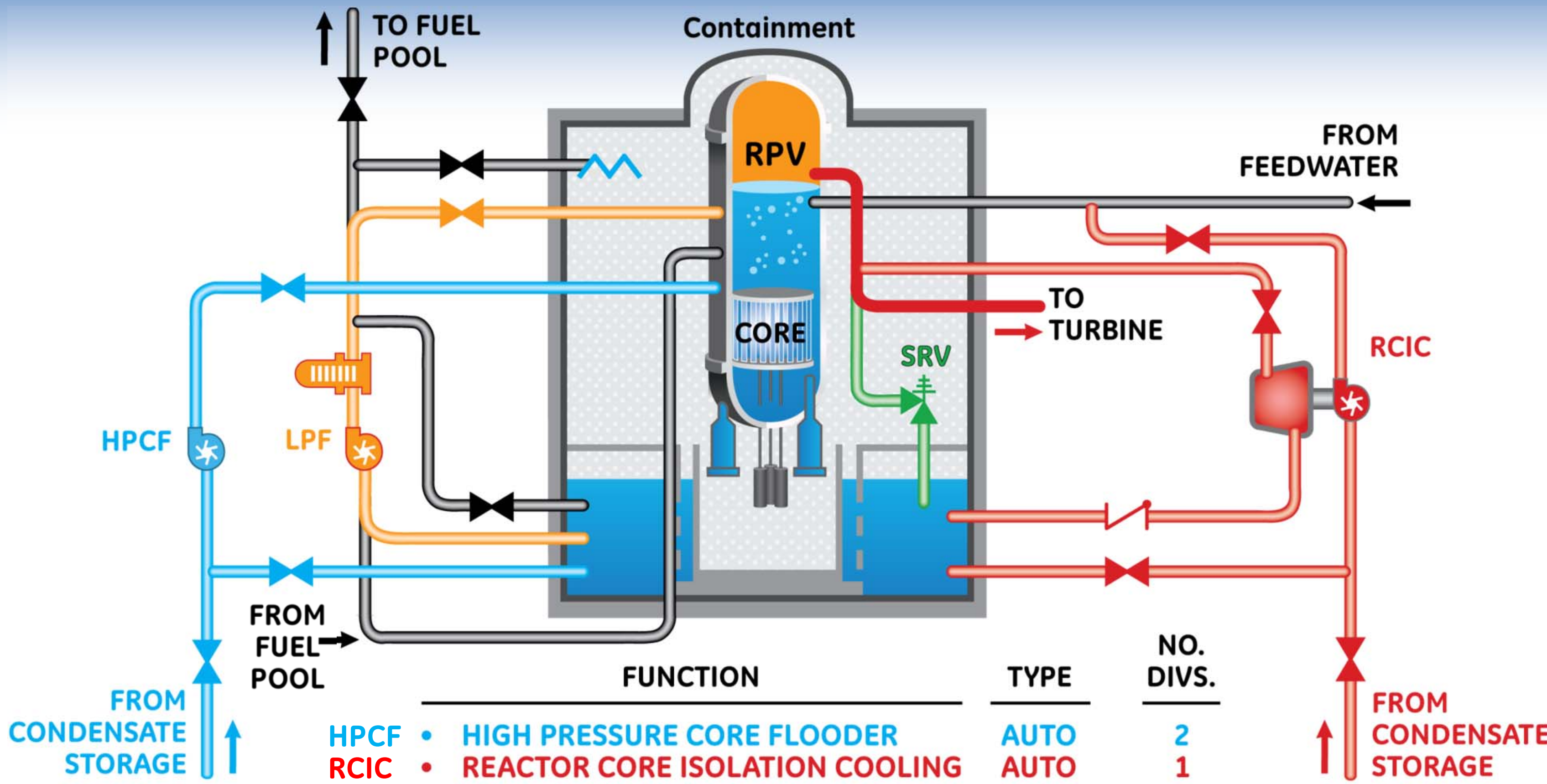
Reduced occupational exposure

Reduced costs

- Predictable Construction Time and Costs
- Operations and Maintenance (O&M)



Emergency Core Cooling System



	FUNCTION	TYPE	NO. DIVS.
HPCF	• HIGH PRESSURE CORE FLOODER	AUTO	2
RCIC	• REACTOR CORE ISOLATION COOLING	AUTO	1
ADS	• AUTOMATIC DEPRESSURIZATION SYS.	AUTO	2
LPF	• LOW PRESSURE FLOODER	AUTO	3
	• SUPRESSION POOL COOLING	AUTO	3
	• WETWELL SPRAY	MAN	2
	• DRYWELL SPRAY	MAN	2
	• SHUTDOWN COOLING	MAN	3
	• FUEL POOL COOLING SUPPORT	MAN	2

HITACHI

Key ABWR differentiators for extreme events

- Separate and passive containment venting to prevent hydrogen explosion

- Reactor depressurization capability for >7 days due to battery segregation and pneumatic controls
- Seismic AC independent water injection into core

ABWR Station Blackout prevention and mitigation

3 x 100% nominal safety divisions

Emergency Diesel Generators

- 3 located in Reactor Building
- Each has a 7-day fuel tank that is buried in a concrete vault outside the Reactor Building

Combustion Turbine Generator

- Air-cooled – Service Water not needed

Safety-related batteries are located in the Control Building - just below the Main Control Room

AC Independent Water Addition (ACIWA) System

- Hard-piped connections to reactor

HITACHI

Recent experience and project status

In Operation	4 Units
Under Construction	4 Units

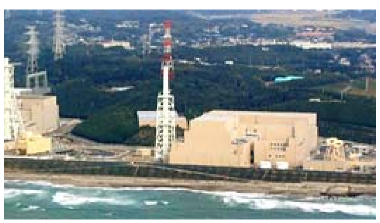
Kashiwazaki-Kariwa 6/7 ABWR

COD 1996/1997

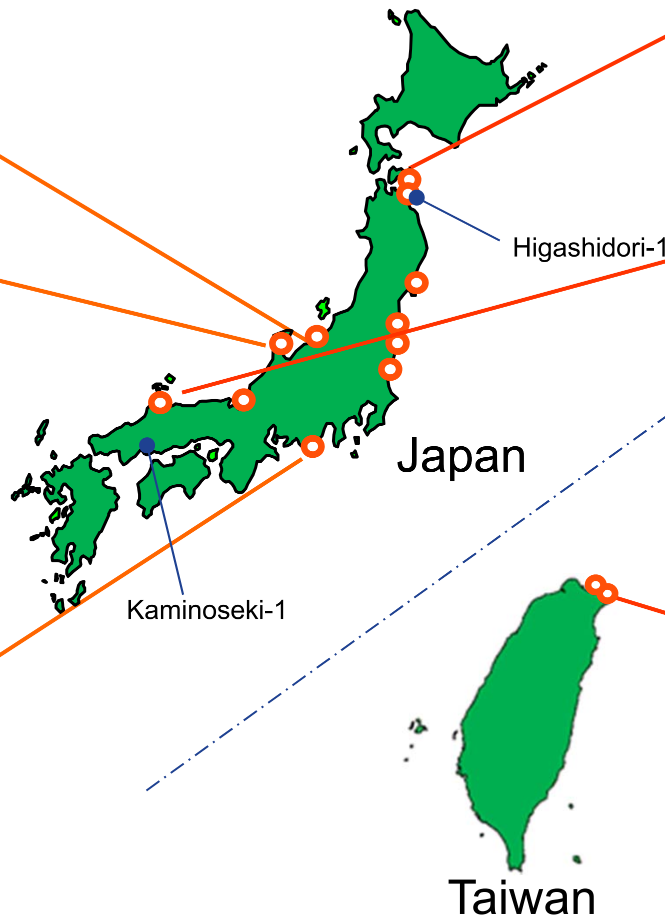
Shika-2 ABWR

COD 2006

Hamaoka-5 ABWR



COD 2005



○ : BWR Power Plant Site

Ohma ABWR

Under Construction
COD TBD

Shimane-3 ABWR

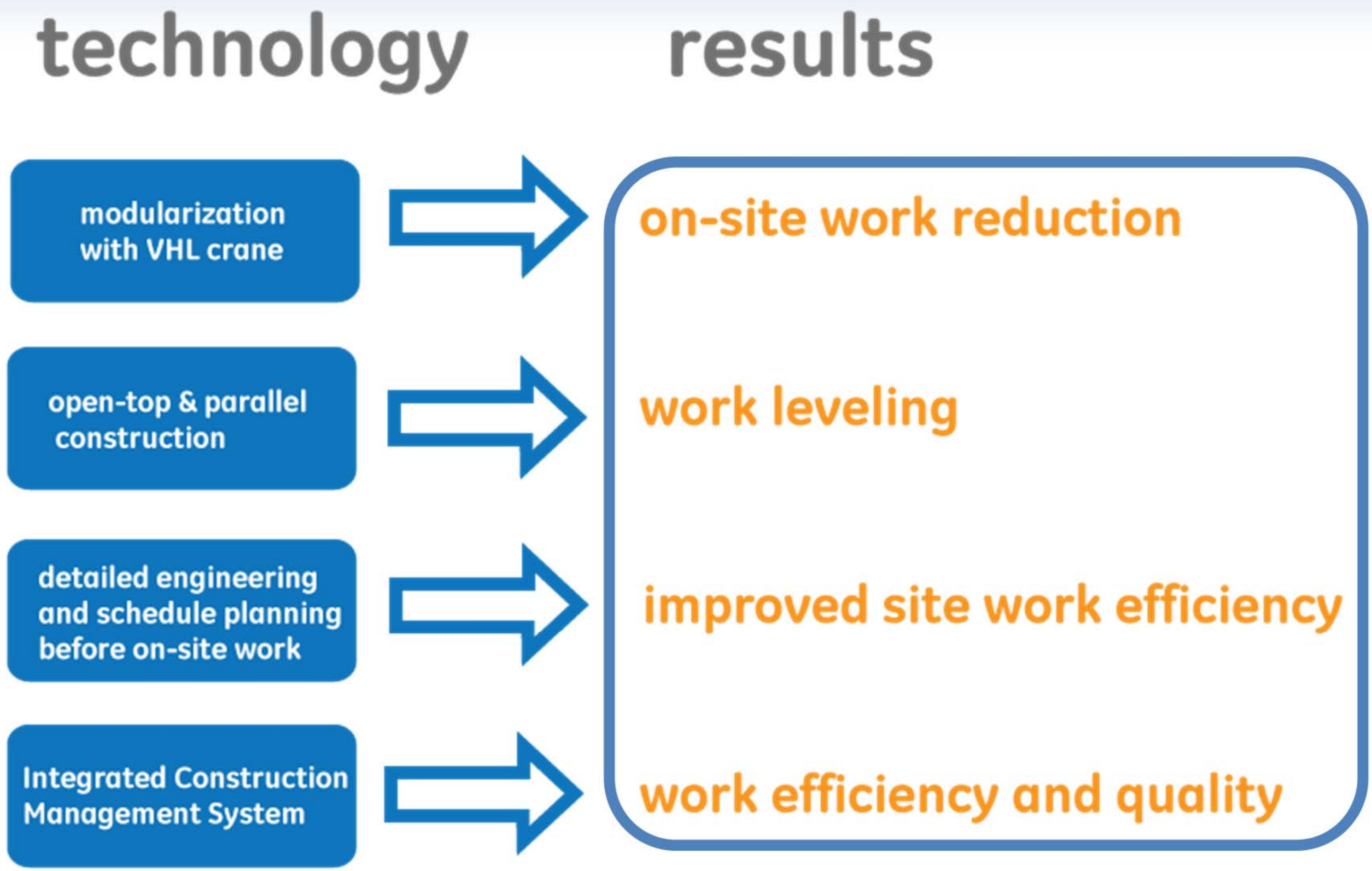
Under Construction
COD TBD

Lungmen-1/2 ABWR

Under Construction
COD 2014 (estimated)

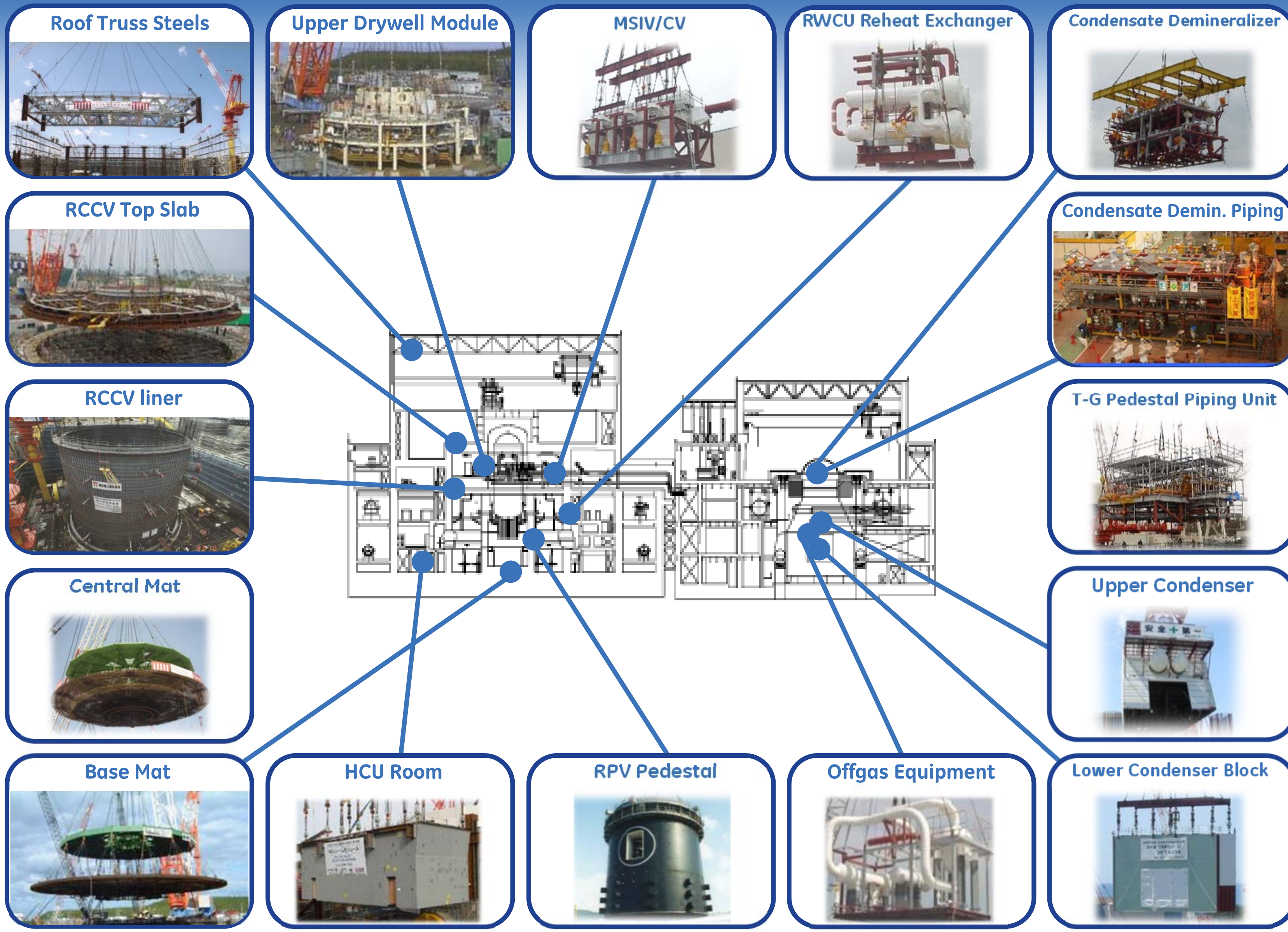
HITACHI

Construction lessons learned: Efficient, repeatable execution model

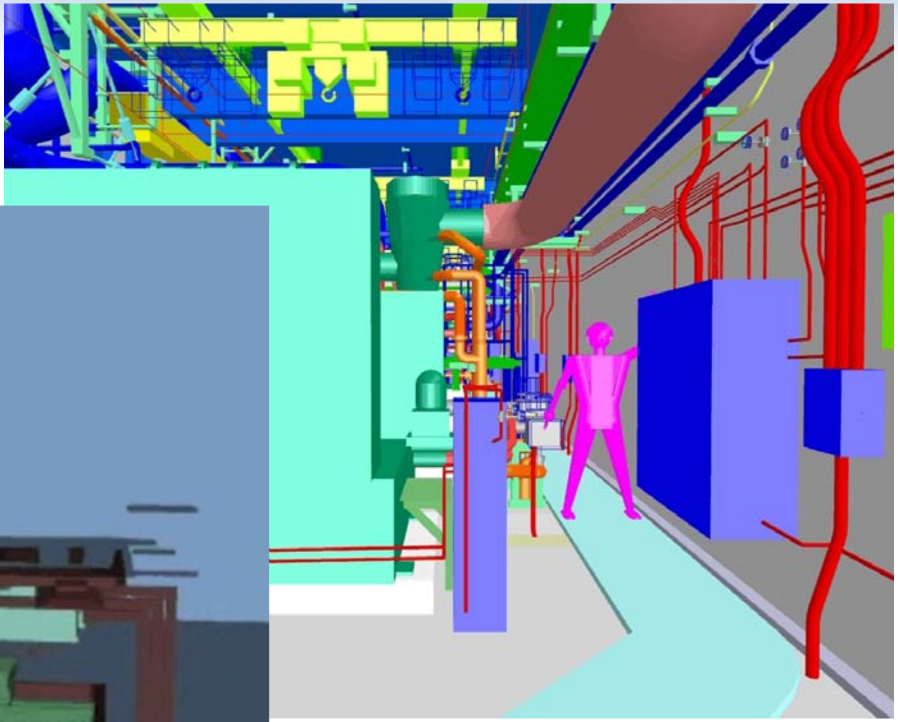


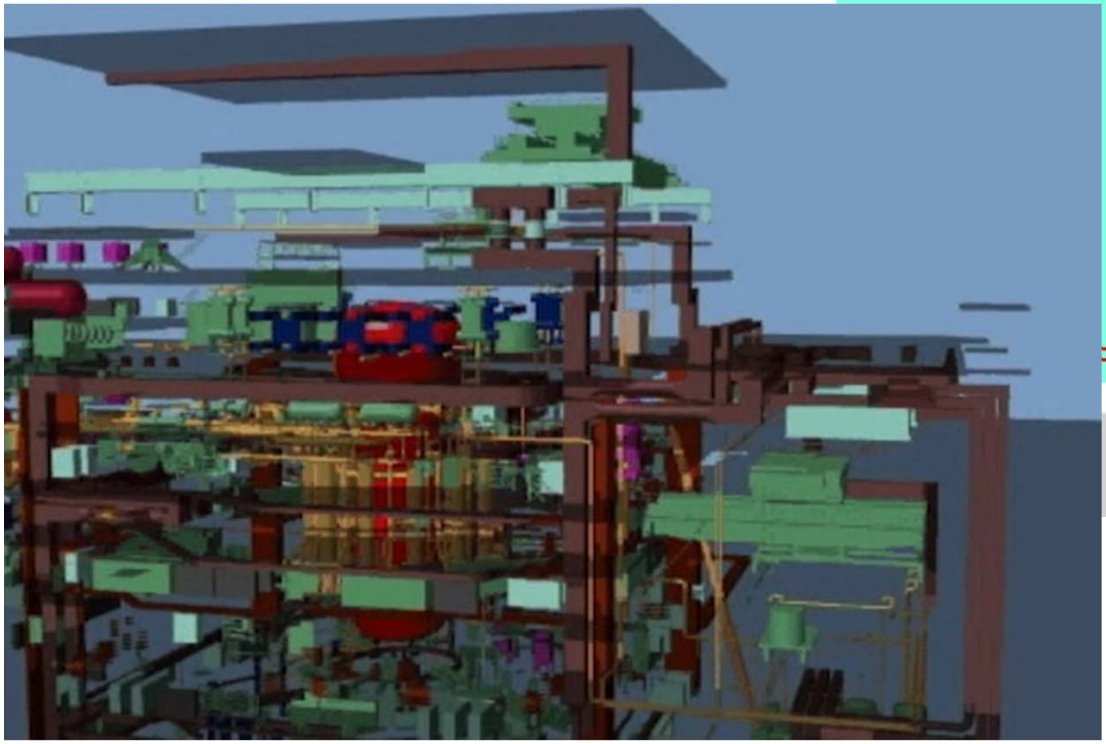
GE HITACHI

ABWR modularization – proven in Japan



Detailed engineering before on-site work





Modularization

Proven experience in operating Gen III plants

RCCV liner

Roof Truss Steel

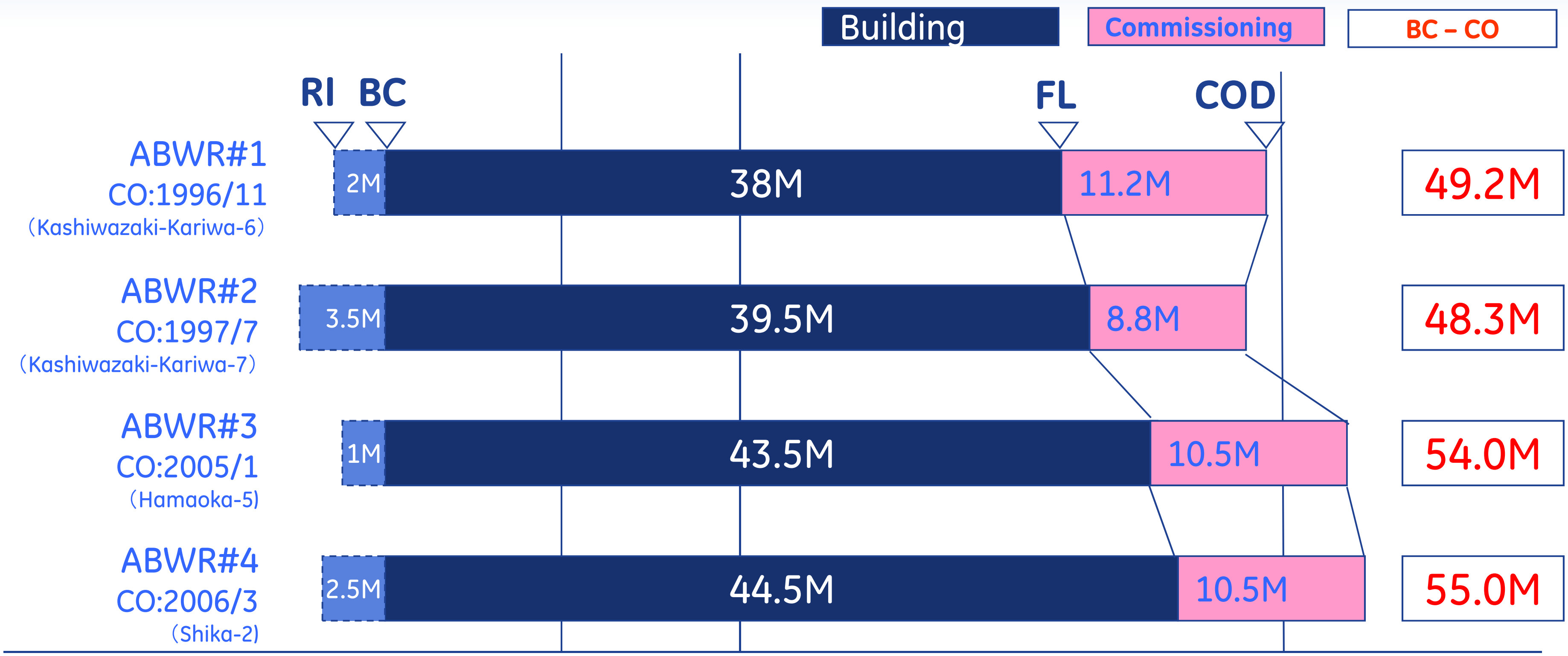
Central Mat

Top Slab

RCCV Rebars

HITACHI

Predictability of Schedule

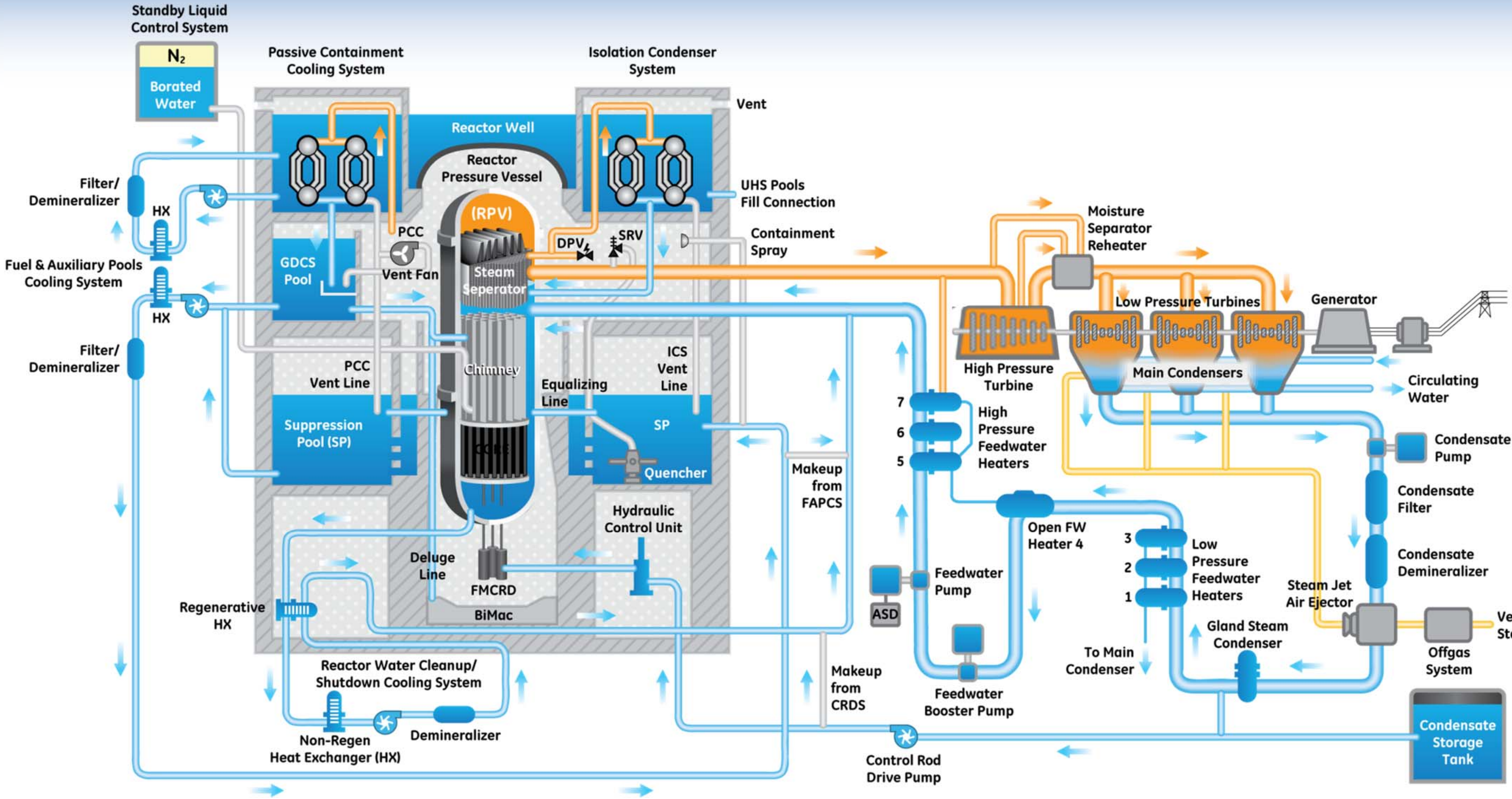


RI : Rock Inspection BC:Start of Basemat Construction FL : Fuel Loading CO: Commercial Operation

HITACHI

North Anna 3 ESBWR

Economic Simplified Boiling Water Reactor



HITACHI

Key plant / reactor characteristics

Parameter	
• Core Thermal Power Output	4500 MWt
• Plant Net Electrical Output[(1)]	1520 MWe
• Reactor Operating Pressure	7.17 MPa (1040 psia)
• Feedwater Temperature[(2)]	216°C (420°F)
• RPV	
— Diameter	7.1 meters (23.3 feet)
— Height	27.6 meters (90.5 feet)
• Reactor Recirculation	Natural Circulation
• Fuel	1132 fuel bundles Shortened length of 3m
• Control blades	269 Fine Motion Control Rod Drives (FMCRDs)

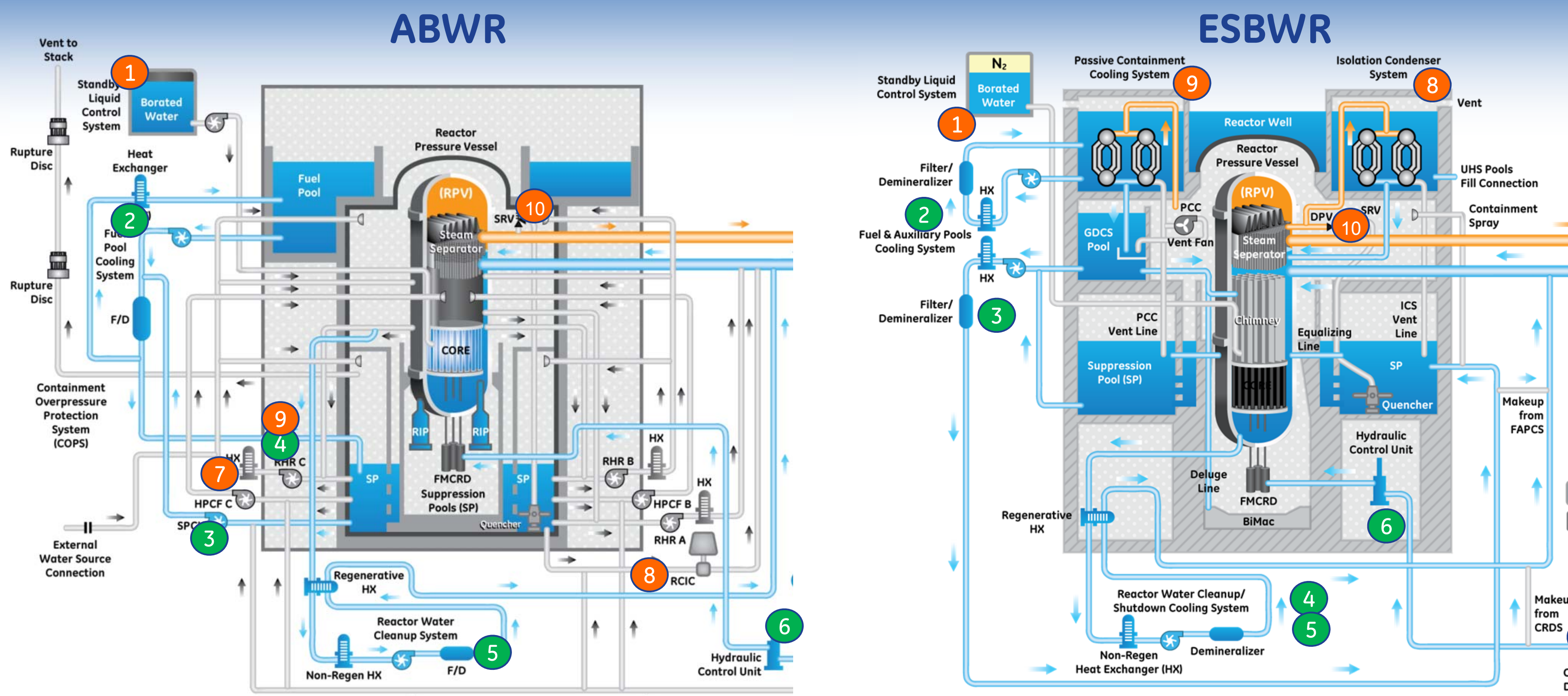
[(1)] Typical (site dependent)

[(2)] Nominal Rated Operation

ESBWR: Economy of Scale and Simpler Design

HITACHI

ABWR to ESBWR evolution: Nuclear Island

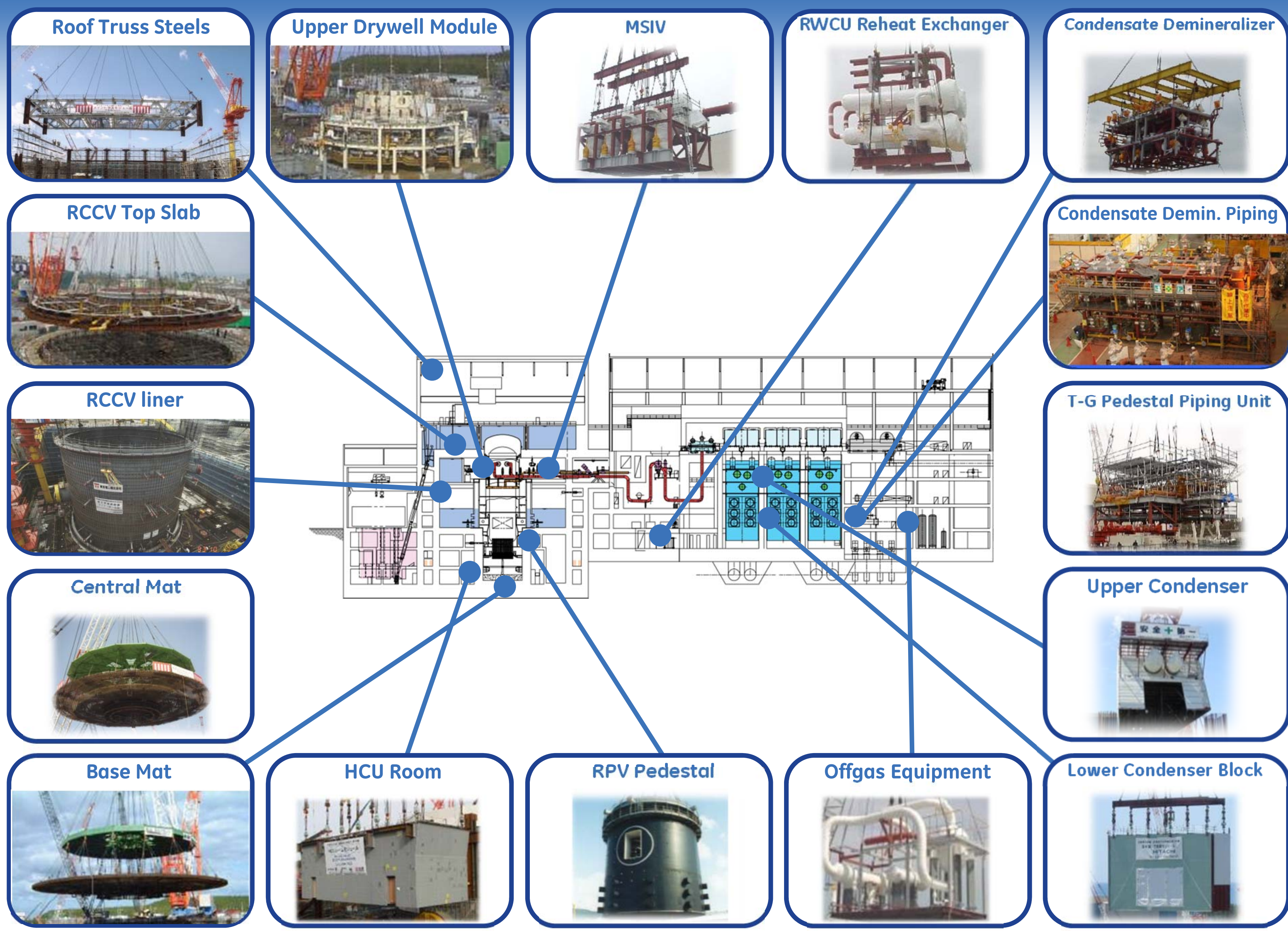


1. Standby Liquid Control System – **simplified** design
2. Fuel and Aux Pool Cooling – **equivalent** designs
3. Suppression Pool Cooling & Cleanup System – **equivalent** capability
4. Residual Heat Removal System – **equivalent** for shutdown cooling
5. Reactor Water Cleanup System – **equivalent** designs
6. Hydraulic Control Unit – **equivalent** design
7. High Pressure Core Flooder – **replaced** by HP CRD makeup
8. Reactor Core Isolation Cooling – **replaced** by Isolation Condenser
9. Residual Heat Removal Containment Spray – **replaced** by PCCS
10. Safety Relief Valves – **Diversified** by Depressurization Valves

Systems are Equivalent or Simplified

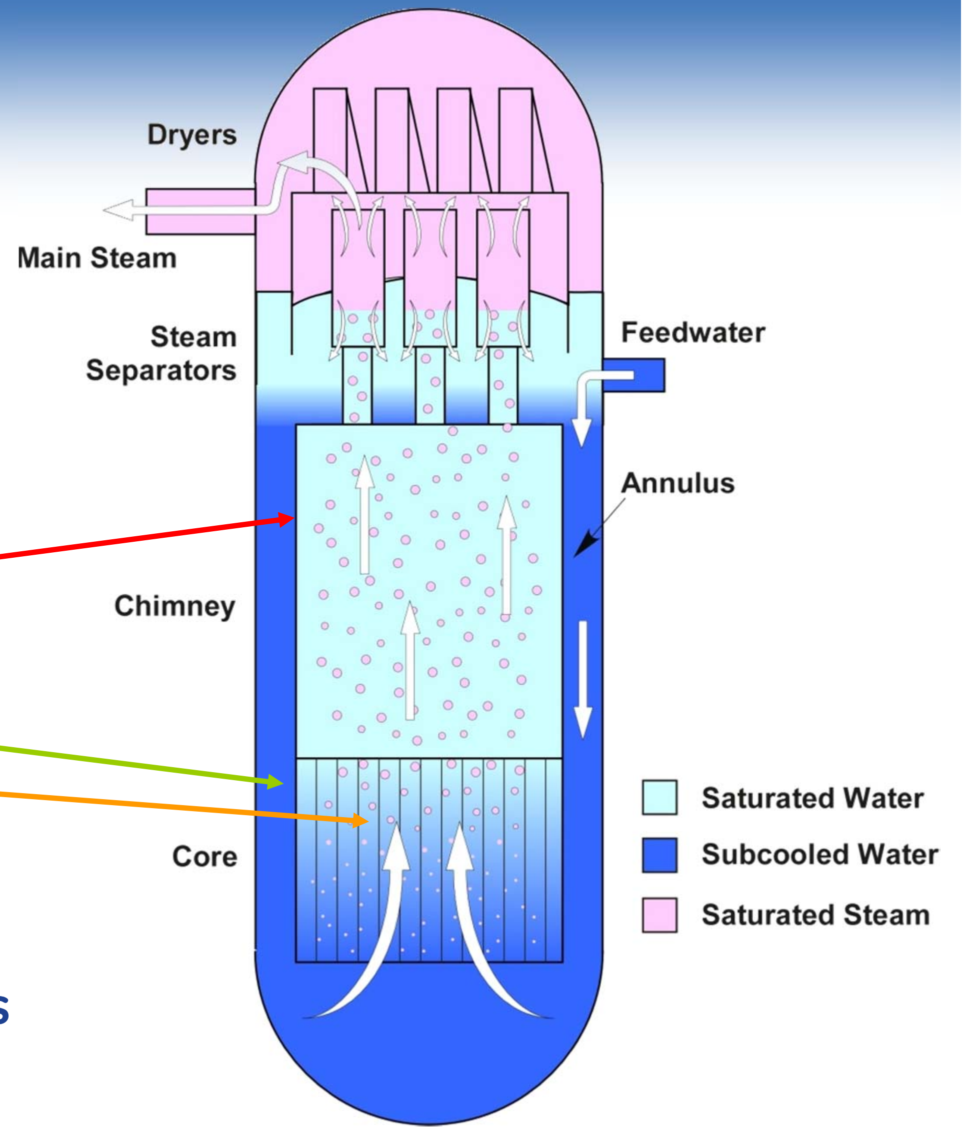
HITACHI

ESBWR modularization – based on ABWR

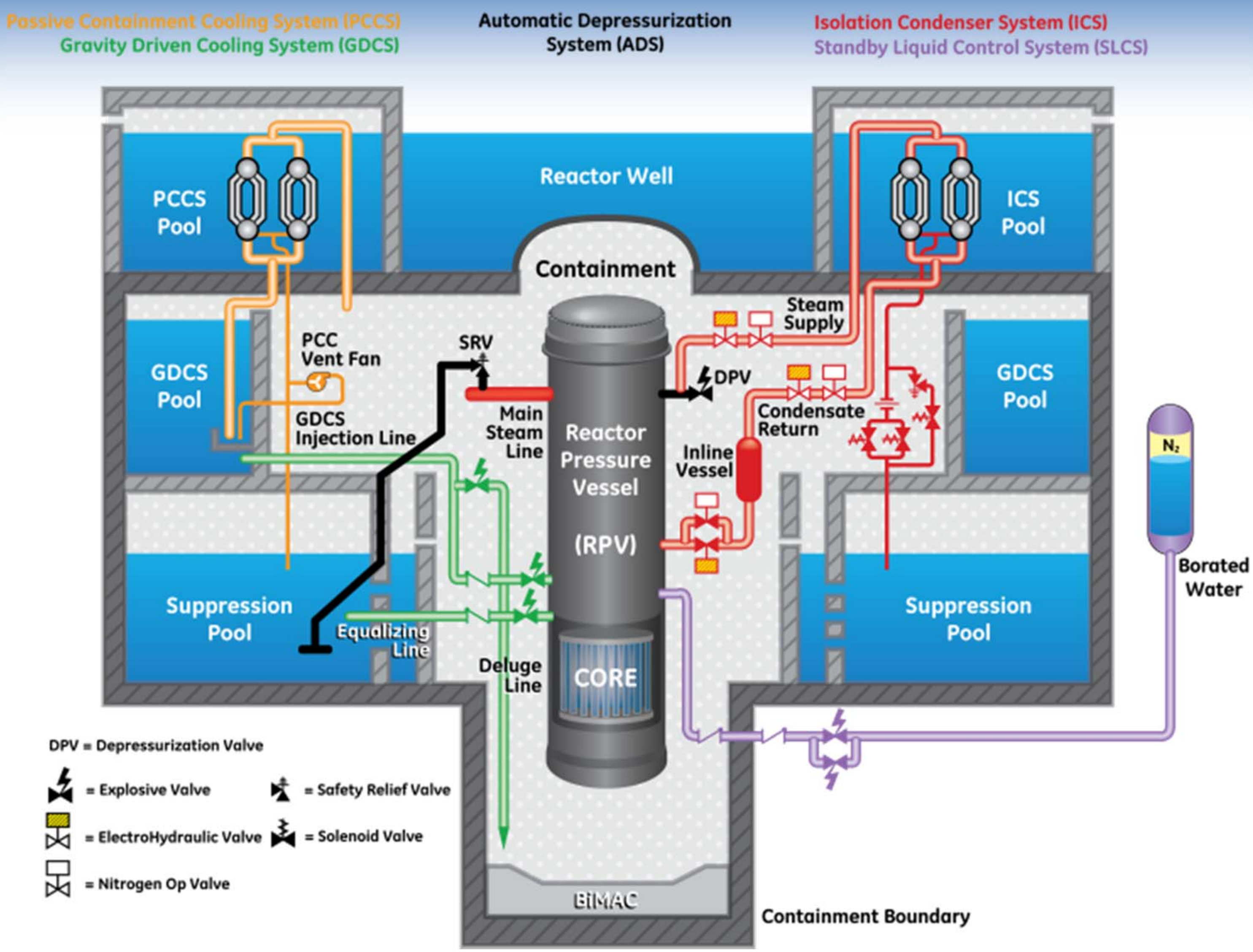


Natural Circulation

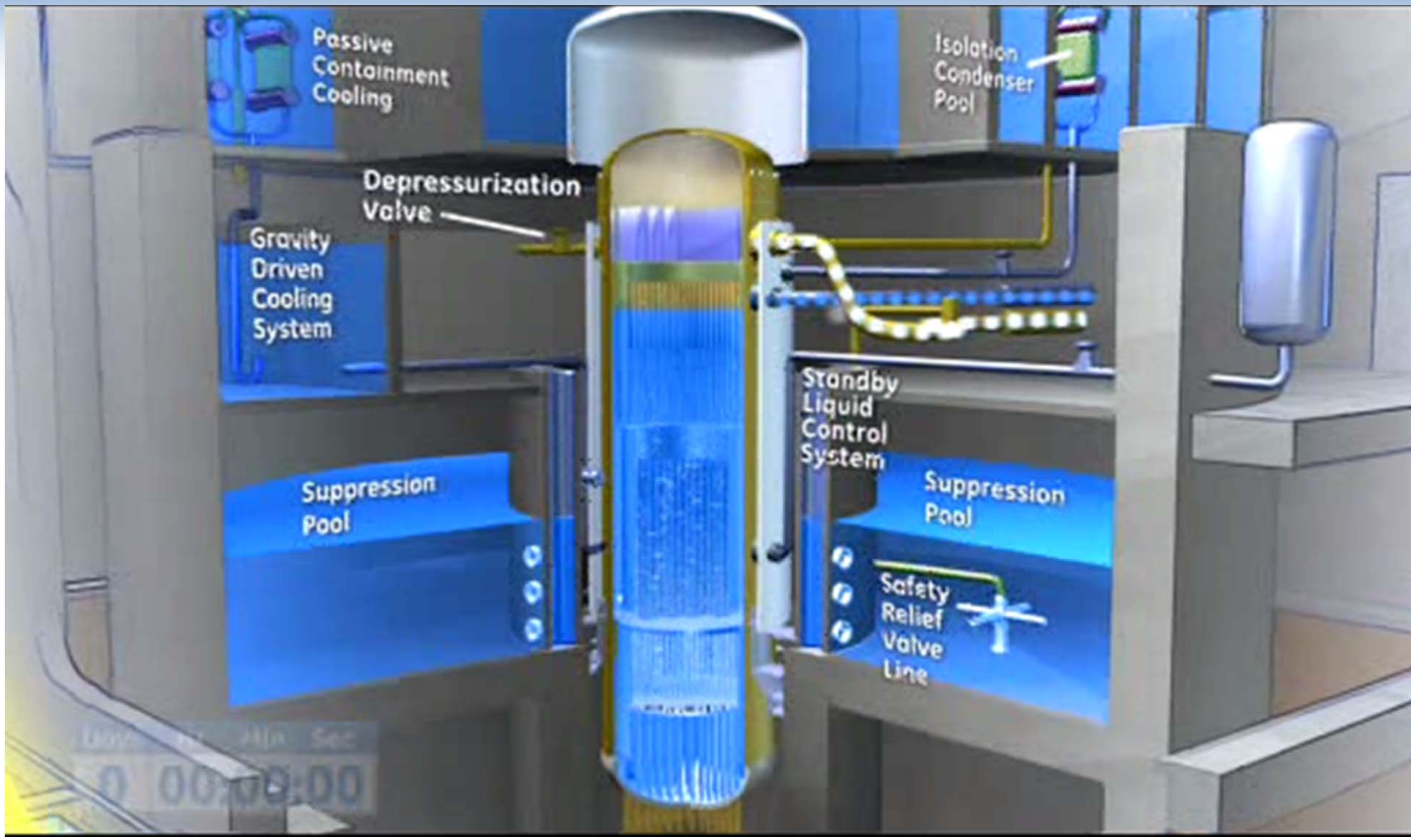
- **Passive safety/natural circulation**
  - Increased volume of water in the vessel
  - Increased driving head
    - Chimney, taller vessel
  - Reduced flow restrictions
    - Open downcomer
    - Shorter core
- **Significant reduction in components**
  - Pumps, motors, controls, Heat Exchangers
- **Power Changes with Feedwater Temperature and Control Rod Drives**
  - Minimal impact on maintenance



ESBWR Passive Safety Systems



ESBWR LOCA response



Isolation Condenser System

- Fully passive – only requires gravity to function and starts automatically (fails in-service if DC power is lost)
- 4 separate systems in reinforced concrete vaults
- Limits reactor pressure (no SRV lifts) and temperature and conserves water inventory following containment isolation
- Steam (heat) rises from reactor to the condenser pool, condenses, then gravity pulls the cool water down into the reactor (closed-loop)

Core cooling

Removes heat from containment

HITACHI

Simple refill actions – even in the worst conditions

Simple refill actions – even in the worst conditions

Simple refill actions – even in the worst conditions

ESBWR … Proven innovation

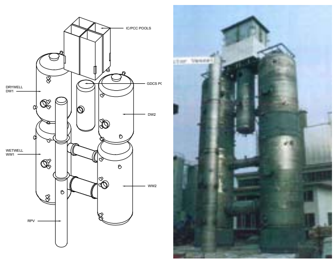
PCCS heat exchanger test

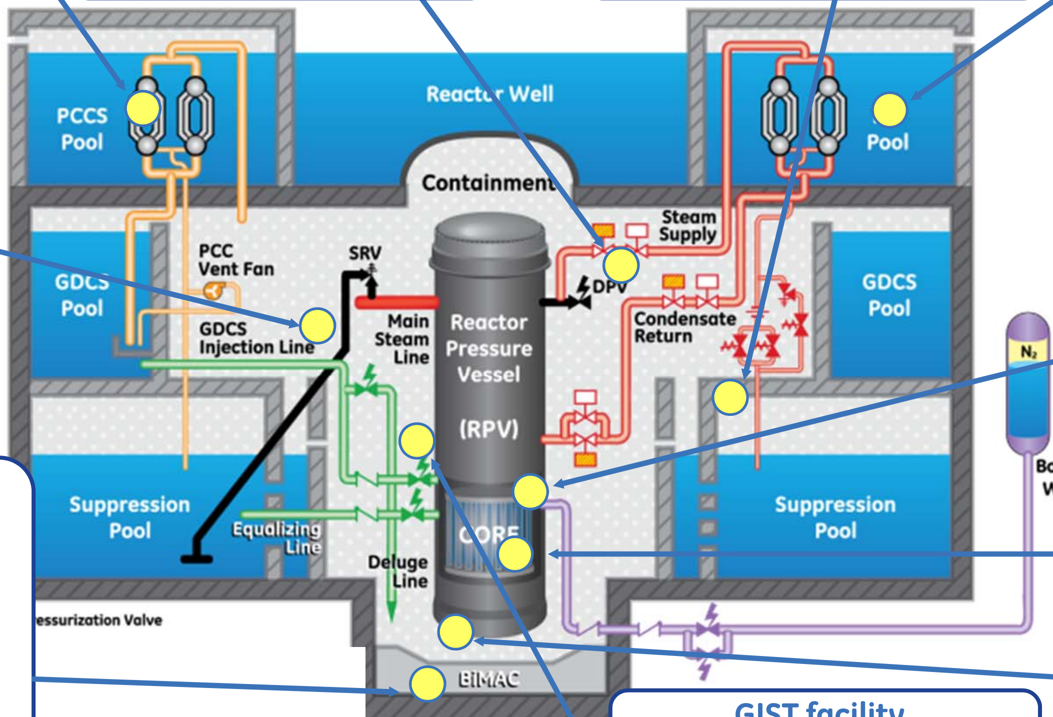
Depressurization Valve test

drywell to wetwell vacuum breaker test

Isolation Condenser Testing

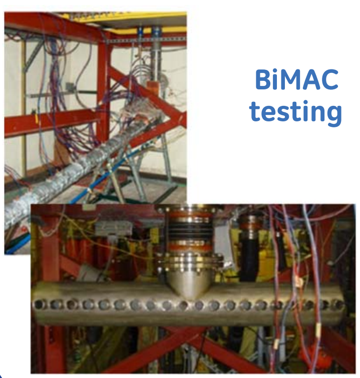
Panda Full Height Containment Test facility



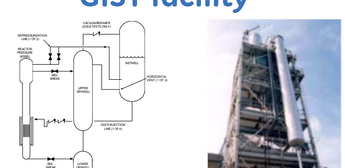


natural circulation proven at Dodewaard

BiMAC testing



GIST facility



FMCRDs from ABWR

fuel – modified GNF2

Operations

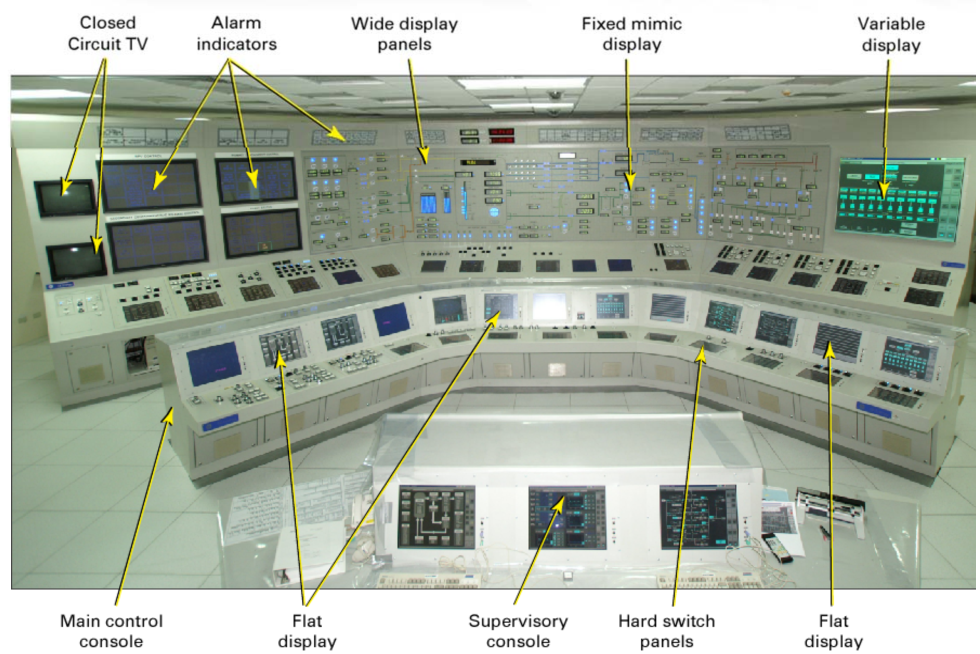
ABWR and ESBWR state-of-the-art operations

Fully Digital Control System

- Fewer components, No drift, less power and heat
- Fault tolerance control
- Four division safety redundancy
- Automated operation
- Surveillance testing greatly reduced

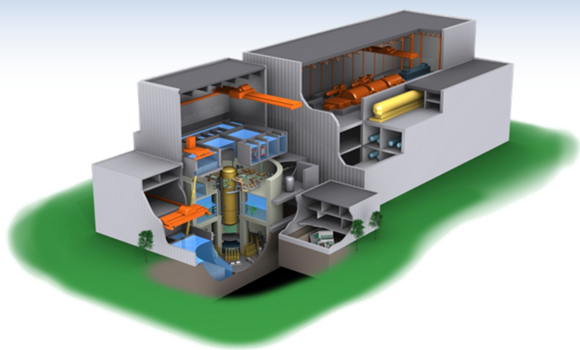
Improved Man-Machine Interface

- Large mimic displays
- Prioritized alarms
- Flat panel controls minimize hard switches
- Human factored displays



GE HITACHI

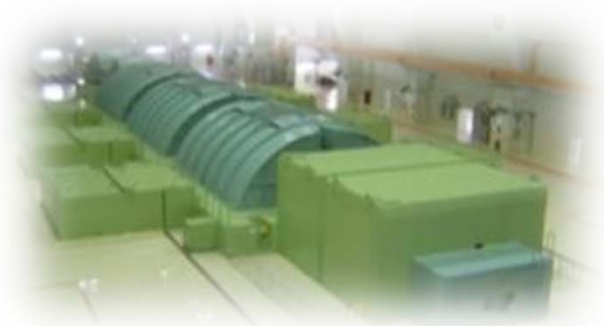
ABWR and ESBWR offer substantial improvements in O&M

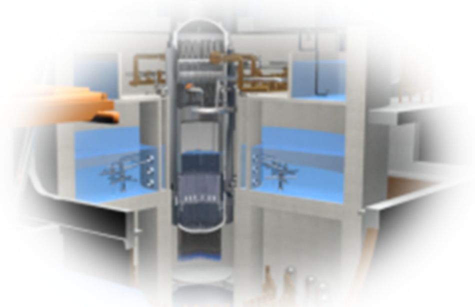


Simplifications in design –
↑ Safety, operations, and reliability
↓ O&M costs

Improvements in plant maintenance –
↑ Easier operations, greater reliability
↓ Maintenance cost and dose

Simpler to operate –
↑ Safety and reliability
↓ Operator actions and transients





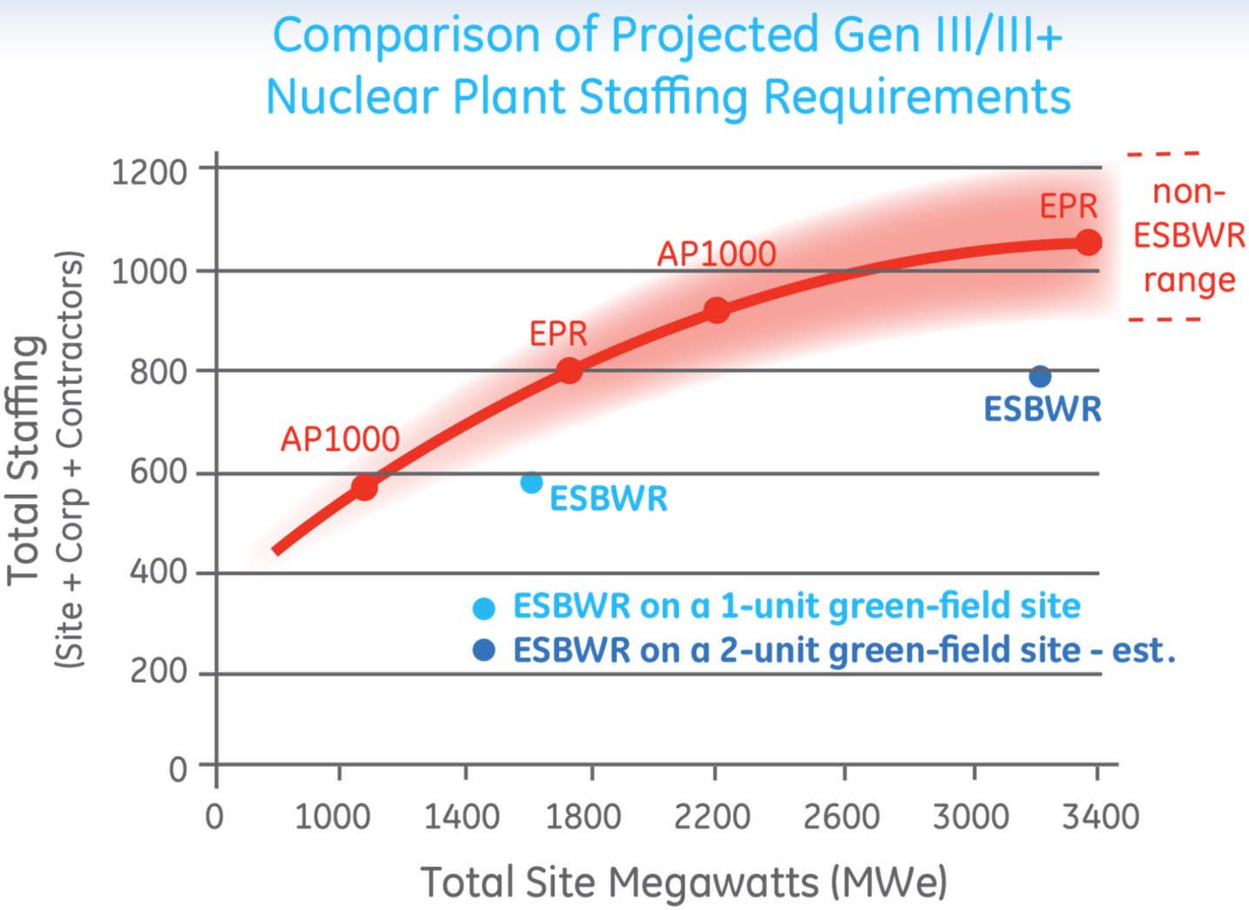
Key component redundancy –
↑ Maintenance flexibility
↓ Operational transients

Lower radiation exposure –
↑ Outage efficiency and FME reduction
↓ Occupational dose and rad waste costs

Passive safety (ESBWR) –
↑ Safety and plant simplification
↓ Maintenance costs and dose

HITACHI

Best in-class O&M



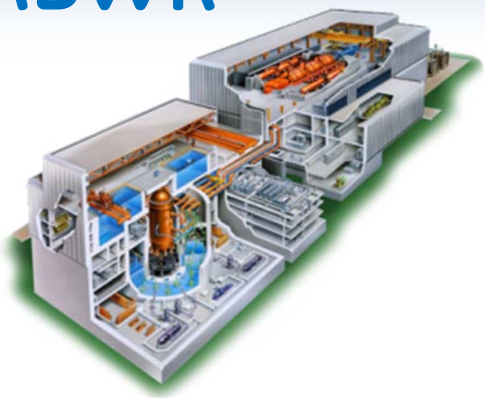
ESBWR requires significantly fewer plant personnel than any other Generation III/III+ design.

- A direct reflection of the ESBWR's simpler design
- Allows for a higher percentage of local workforce
- Fewer ex-pats results in direct cost savings

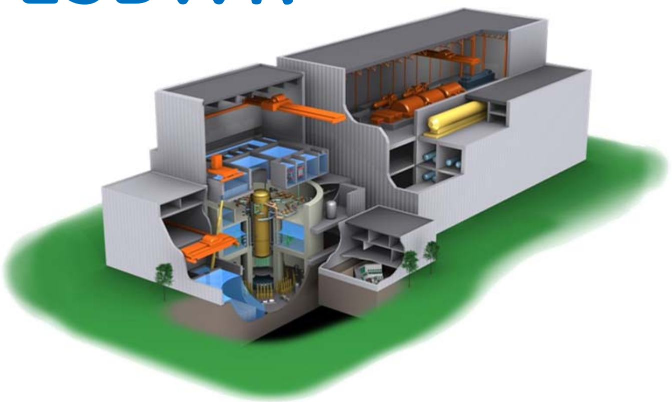
HITACHI

Source: An ESBWR staffing study performed by a leading independent firm

ABWR



ESBWR



Safe.

Simple.

Smart.

1 Based on the industry standard measure of reactor safety - core damage frequency
2 Claims based on the U.S. DOE commissioned 'Study of Construction Technologies and Schedules, O&M Staffing and Cost, and Decommissioning Costs and Funding Requirements for Advanced Reactor Designs' and an ESBWR staffing study performed by a leading independent firm

HITACHI