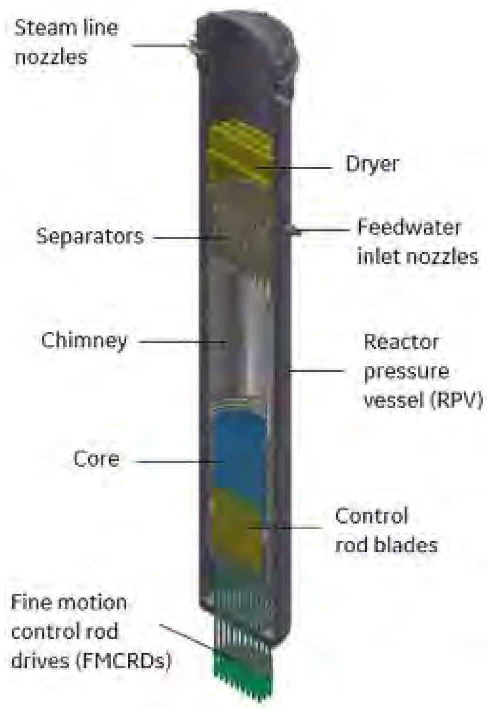
BWRX-300 (GE-Hitachi Nuclear Energy, USA and Hitachi-GE Nuclear Energy, Japan)



MAJOR TECHNICAL PARAMETERS	
Parameter	**Value**
Technology developer, country of origin	GE-Hitachi Nuclear Energy, United States and Hitachi-GE Nuclear Energy, Japan
Reactor type	Boiling water reactor
Coolant/moderator	Light-water / light-water
Thermal/electrical capacity, MW(t)/MW(e)	870 / 270-290
Primary circulation	Natural circulation
NSSS Operating Pressure (primary/secondary), MPa	7.2 / Direct Cycle
Core Inlet/Outlet Coolant Temperature (°C)	270 / 287
Fuel type/assembly array	UO_2 / 10x10 array
Number of fuel assemblies in the core	240
Fuel enrichment (%)	3.40 (avg) / 4.95 (max)
Core Discharge Burnup (GWd/ton)	49.5
Refuelling Cycle (months)	12-24
Reactivity control mechanism	Rods and Solid Burnable Absorber (B_4C, Hf, Gd_2O_3)
Approach to safety systems	Fully passive
Design life (years)	60
Plant footprint (m^2)	8400
RPV height/diameter (m)	26 / 4
RPV weight (metric ton)	485
Seismic Design (SSE)	0.3g
Fuel cycle requirements / Approach	Open fuel cycle utilizing standard BWR fuel
Distinguishing features	Natural circulation BWR utilizing RPV isolation valves and isolation condenser system that enable dry containment and elimination of safety relief valves
Design status	Pre-licensing initiated in UK, Canada, US

1. Introduction

The BWRX-300 is a design-to-cost 300 MW(e) water-cooled, natural circulation SMR utilizing simple, natural phenomena driven safety systems. It is the 10th generation of the Boiling Water Reactor (BWR) and represents the simplest, yet most innovative BWR design since the General Electric began developing nuclear reactors in 1955. The BWRX-300 is an evolution of the U.S. NRC-licensed 1520 MW(e) ESBWR. The design has been developed with a strict adherence to a philosophy which follows the IAEA Defense-in-Depth guidelines.

2. Target Application

The target applications of BWRX-300 include base load electricity generation, load following electrical generation within a range of 50% to 100% power, district heating and process heat up to 287ºC. It is designed to provide clean, flexible energy generation that is cost competitive with natural gas fired plants.

3. Main Design Features

(a) Design Philosophy

Evolved from the licensed ESBWR, the BWRX-300 design optimizes the cost of construction, operation, maintenance, staffing and decommissioning.

(b) Nuclear Steam Supply System

The BWRX-300 is designed utilizing the proven supply chain of the ABWR and the natural phenomena driven safety features from the ESBWR, for its primary circuit, or nuclear boiler system. Components in this system include the Reactor Pressure Vessel (RPV), fine motion control rod drives (FMCRDs), control blades, chimney, separators, and dryer. The RPV and the chimney height are scaled optimally to the thermal output and natural circulation of the BWRX-300. The nuclear boiler system delivers steam from the RPV to the turbine main steam system; and delivers feedwater from the condensate and feedwater system to the RPV. It also provides overpressure protection of the reactor coolant pressure boundary (RCPB).

(c) Reactor Core

The BWRX-300 contains 240-bundles utilizing currently available, industry proven GNF2 fuel. The core lattice configuration has equal spacing on the control rod and non-control rod sides which provides increased shutdown margin that can accommodate variations in burnup imposed by load following. GNF2 fuel bundles contain a 10x10 array of 78 full length fuel rods, 14 part length fuel rods and two large central water rods. The fuel bundles are arranged in a near cylindrical configuration located inside a core shroud. The coolant flows upward through the core. The BWRX-300 reactor core comprises fuel assemblies, control rods, and nuclear instrumentation.

(d) Reactivity Control

Reactivity control is provided by control rods loaded with either B_4C or Hf neutron absorbers and burnable neutron absorber loaded in the fuel rods. The control rods are moved using the FMCRDs that are successfully deployed in the ABWR and part of the ESBWR design. FMCRDs have two independent means of moving the control rods–motor driven fine control for reactivity control during normal operation and hydraulic rapid insertion during a scram.

(e) Reactor Pressure Vessel and Internals

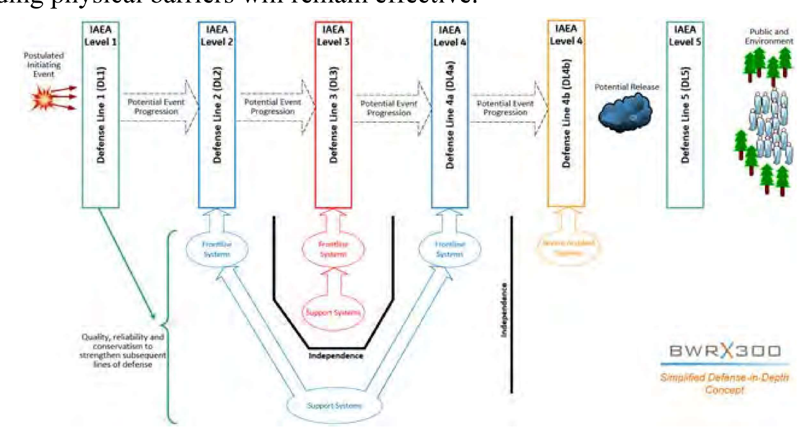
The BWRX-300's RPV assembly consists of a pressure vessel with removable head, internal components and appurtenances. The major reactor internal components include the core, core plate, top guide, control rod guide tube, control rod drive housings, and orificed fuel supports, chimney, steam separator, and steam dryer assembly.

(f) Reactor Coolant System

The reactor coolant system (RCS) is natural circulation driven and provides cooling of the reactor core in all operational states and all postulated off normal conditions. The BWRX-300 leverages natural circulation modelling and operational information from the ESBWR and the Dodewaard BWR in the Netherlands. The relatively tall RPV permits natural circulation driving forces to produce abundant core coolant flow.

4. Safety Features

The basic BWRX-300 safety design philosophy is built on utilization of inherent margins (e.g., larger structure volumes and water inventory) to eliminate system challenges and can easily accommodate transients. Natural driven phenomena safety-related systems mitigate accidents without the need for AC power. The BWRX-300 defence-in-depth (D-in-D) concept uses Fundamental Safety Functions (FSF) to define the interface between the defense lines and the physical barriers. In a given plant scenario, if the FSFs are performed successfully, then the corresponding physical barriers will remain effective.

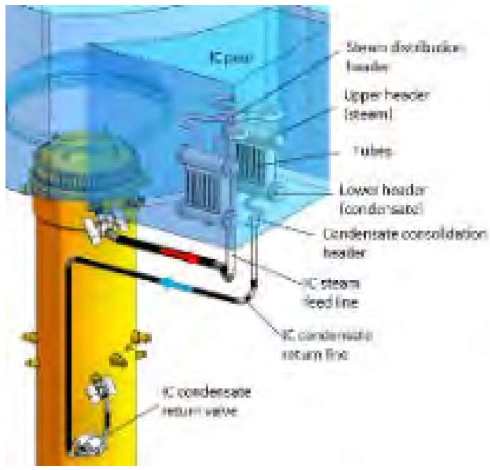


(a) Engineered Safety System Approach and Configuration

There are two passive cooling systems for BWRX-300. The first is the isolation condenser system (ICS) which removes decay heat after a reactor isolation event. The other is the passive containment cooling system (PCCS) which removes the decay heat and maintains the containment within its pressure limits for design basis accidents.

(b) Decay Heat Removal System

The ICS removes decay heat after any reactor isolation during power operations and provides overpressure protection in accordance with ASME BPV code, Section III, Class 1 equipment. The ICS consists of three independent loops, each containing a heat exchanger, with capacity of 33 MW(t). The ICS tubes condense steam from the RPV on the inside surface and transfer heat on the outside surface to the IC pool which is vented to the atmosphere. This steam condensation and gravity allow BWRX-300 to cool itself for a minimum of 7 days without power or operator action.



(c) Containment System

The containment surrounds the RPV, FMCRDs, piping systems and isolation valves. The design pressure and temperature of the containment are within values used in the operating BWR fleet, the ABWR and ESBWR. The RPV isolation vales limit the steam released to the containment during a postulated large break LOCAs to the point that the suppression pool utilized in almost all previous BWRs is not needed. Postulated small break LOCAs are copped by the ICS, PCCS and dry containment for a minimum of 72 hours without AC power or operator action. The PCCS is a passive system consisting of several low-pressure, heat exchangers in the containment. The heat in the containment is transferred to the reactor cavity pool which is located above the containment upper head and is filled with water during normal operation. The reactor cavity pool is vented to the atmosphere. The PCCS heat exchangers are always in service when the reactor is operating.

5. Plant Safety and Operational Performances

The D-in-D approach utilized in the BWRX-300 results in an internal event cord damage frequency less than 10^{-7} per year and a large release frequency less than 10^{-8} per year. The lessons learned and best practices of the BWR fleet have been applied to the BWRX-300 with the expected available factor greater than 95%. The BWRX-300 is capable to operate under the load following range of 50 to 100% with a ramp rate of 0.5% per minute. Normal manpower during operation is expected to be 75 people for all shifts. Cycle lengths between 12 and 24 months can be accommodated with refuelling durations between 10 and 20 days.

6. Electrical Systems

The BWRX-300 electrical system is a completely integrated power supply and transmission system for the power plant. It is divided into subsystems based on safety classification. Each subsystem has appropriate levels of hardware and software quality for the systems it powers, to provide reliable power to various plant electrical loads, and a transmission path for the main generator to the utility switchyard/grid.

7. Instrumentation and Control Systems

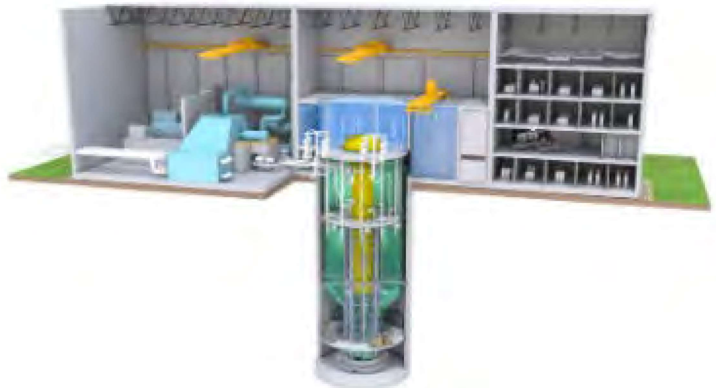
The BWRX-300 I&C system (also referred to as the Distributive Control and Information System or "DCIS") is a completely integrated control and monitoring system for the power plant. The I&C comprises three main platforms. Each platform has appropriate levels of hardware and software quality (corresponding to the systems they control), and provides control, monitoring, alarming and recording functions.

8. Plant Layout Arrangement

The reference site for BWRX-300 fits within a 170 m x 280 m footprint, which includes the power block, switchyard, cooling tower, site office, parking lot, warehouse, and other supporting facilities.

(a) Reactor Building

The reactor building extends below grade where the primary containment and RPV mostly reside. The refuelling floor is above grade level. The Reactor Building contains all of the safety related components in the plant. The underground construction of the reactor building utilizes proven techniques in the mining and shaft sinking industries to minimize the use of concrete and engineered backfill.



(b) Balance of Plant

The balance of plant of BWRX-300 includes the turbine building, radwaste building, control building and yard. The turbine receives high-quality dry steam directly from the RPV, the condenser system cooled by the ultimate heat sink and the feedwater system that returns the coolant into the reactor. The balance of plant also has process systems composed of the plant service water system (PSWS), the component cooling water system (CCW), the makeup water system (MWS), the condensate storage and transfer system (CSTS), and the chilled water system (CWS).

9. Design and Licensing Status

Licensing activities for the BWRX-300 have been initiated in three countries. Pre-licensing application activities are underway in the United States. A combined Phase 1 and 2 Vendor Design Review is underway in Canada. In the UK, the BWRX-300 completed a BEIS-funded Mature Technology evaluation. One of the design goals is also to be able of being licensed internationally with initial operation dates in 2027 and 2028.

10. Fuel Cycle Approach

The BWRX-300 has the same open fuel cycle as operating BWRs. During every refuelling outage, 15% to 25% of the bundles in the core are replaced fresh fuel. Fresh fuel stays in the core for several cycles until it is discharged. When removed from the core, used fuel is stored in the fuel pool inside the reactor building for six to eight years when it is then transferred to storage casks that can be removed from the reactor building and stored outside.

11. Waste Management and Disposal Plan

The BWRX-300 utilizes the lessons learned and best practices from the decades of operational experience of the BWR fleet in waste management and disposal. Waste minimization is one of the focus areas during the design phase to ensure that the unit has minimal environmental impact. Waste that is generated will be segregated for optimal treatment, storage and final disposal. Gaseous wastes will be removed from the steam system by steam jet air ejectors and passed through charcoal beds for absorption.

12. Development Milestones

2017	Conceptual design started
2018	BEIS funded Mature Technology Evaluation the UK ONR
2019	Pre-application activities initiated with the US NRC
2020	Combined Phase 1 and 2 Vendor Design Review initiated with CNSC in Canada
2022	First construction permit applications expected to be submitted
2024	Start of construction for first unit expected
2027	Commercial operation of first unit expected