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**GE Hitachi Nuclear Energy**

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Revision B

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# **BWRX-300 UK Generic Design Assessment (GDA) Chapter E1: Introduction**

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## **EXECUTIVE SUMMARY**

GE-Hitachi Nuclear Energy, Americas, LLC has entered into the Generic Design Assessment (GDA) process up to Step 2 with the BWRX-300 new nuclear power plant design. As the tenth evolution of the Boiling Water Reactor (BWR), the BWRX-300 represents the simplest, yet most innovative BWR design since General Electric began developing nuclear reactors in 1955.

As part of the GDA process, there is a requirement to submit both an environment case and a safety case. The environment case, consisting of the Preliminary Environmental Report (PER) and supporting information (with reference to other GDA submissions such as the Preliminary Safety Report), provides claims and arguments, and confidence that evidence can be provided in the future, to demonstrate that the BWRX-300 meets United Kingdom regulatory requirements and expectations, and uses Best Available Techniques to prevent or minimize harm to people and the environment.

The PER draws upon learning from previous GDAs and successful deployment of BWR technology around the world, to demonstrate that the design has been optimised to reduce environmental impacts to As Low As Reasonably Achievable throughout the whole lifecycle. The PER is informed by regulatory guidance and decision documents, supplemented by regulatory engagement, to ensure regulatory expectations for GDA Step 2 are fulfilled.

This introductory chapter concisely summarises the content and structure of the PER and supporting information, as well as providing information about the Requesting Party, an overview of the BWRX-300 design and how the design has evolved since initial conception of the BWR.

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**ACRONYMS AND ABBREVIATIONS**

<b>Acronym</b>	<b>Explanation</b>
ABWR	Advanced Boiling Water Reactor
BWR	Boiling Water Reactor
CRD	Control Rod Drive
EA	Environment Agency
ECCS	Emergency Core Cooling System
ESBWR	Economic Simplified Boiling Water Reactor
FMCRD	Fine Motion Control Rod Drive
GDA	Generic Design Assessment
GE	General Electric
GEH	GE-Hitachi Nuclear Energy Americas, LLC
GT	Gamma Thermometer
IC	Isolation Condenser
ICS	Isolation Condenser System
LOCA	Loss of Coolant Accident
NRW	Natural Resources Wales
ONR	Office for Nuclear Regulation
PER	Preliminary Environmental Report
PSR	Preliminary Safety Report
RB	Reactor Building
RP	Requesting Party
RPV	Reactor Pressure Vessel
RSR	Radioactive Substances Regulation
SBWR	Simplified Boiling Water Reactor
SC	Safety Class
SMR	Small Modular Reactor
SRV	Safety Relief Valve
UK	United Kingdom
U.S.	United States

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**REVISION SUMMARY**

Revision #	Section Modified	Revision Summary
A	All	Initial Issuance
B	All	Update for end of GDA Step 2 consolidation

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# 1 INTRODUCTION

## Purpose

This Preliminary Environmental Report (PER) forms part of the Generic Design Assessment (GDA) submission to the United Kingdom (UK) regulatory bodies for a single unit of the GE-Hitachi Nuclear Energy, Americas, LLC (GEH) BWRX-300 Small Modular Reactor (SMR). The Environment Agency (EA) and Natural Resources Wales (NRW) have outlined guidance about the information that should be provided, to be able to assess the environmental impacts of this proposed SMR during construction, operation, and decommissioning. This guidance is presented in “New nuclear power plants: Generic Design Assessment guidance for Requesting Parties,” (Reference 1-1).

## Scope

GEH, as the Requesting Party (RP), are only undertaking Steps 1 and 2 of the GDA process at this time. The PER forms a major part of the suite of documents that support Step 2, which allow for an assessment of the fundamentals of the design by the regulatory bodies against the regulatory requirements and expectations. This is to ensure that there are no environmental protection shortfalls that could prevent the SMR from being acceptable for deployment at sites in England and Wales.

## Document Structure

As part of the Step 2 submission, this chapter provides the following information:

- An introduction to the PER chapters and supporting information that form part of the PER
- Details about the RP, including their experience of reactor design and plants in service
- A brief history of the design, identifying predecessor plant and main design changes from this plant
- A simple outline description of the design, including schematics

NEDC-34141P, “BWRX-300 UK GDA Environmental Strategy,” (Reference 1-2) highlights the scope of each of the chapters and any exclusions, in line with the requirements of Step 2 of the GDA. The scope of design assessment is limited to that described in NEDC-34154P, “BWRX-300 UK GDA Design Reference Report,” (Reference 1-3).

### 1.1 Preliminary Environmental Report Organisation

The PER is comprised of the following core chapters:

#### Chapter E1: Introduction

A summary document that provides a brief overview of the RP, how the design has evolved from previous BWR iterations, the current design and unique features of the BWRX-300, and a summary of the PER chapters and supporting information.

#### Chapter E2: Generic Site Description

NEDO-34219, “BWRX-300 UK GDA Chapter E2: Generic Site Description,” (Reference 1-4) describes the generic site characteristics that envelope suitable sites for the deployment of the BWRX-300 in the UK. It also describes any environmental characteristics and constraints that are used to inform the radiological dose assessment.

#### Chapter E3: Management Arrangements and Responsibilities

NEDO-34220, “BWRX-300 UK GDA Chapter E3: Management Arrangements and Responsibilities,” (Reference 1-5) provides information on the management system(s) and how management responsibilities for the GDA are allocated within the organisational structure

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of the RP. Discussion surrounding the environmental objectives and principles and how management arrangements and responsibilities contribute towards sustainability are provided.

### **Chapter E4: Information about the Design**

NEDO-34221, "BWRX-300 UK GDA Chapter E4: Information about the Design," (Reference 1-6) provides concise descriptions of the systems, plants, and processes of the BWRX-300 that are required for safe power generation. A particular focus is placed on those that have a bearing on both radioactive and non-radioactive waste generation, treatment, measurement, assessment, and disposal. Those that have conventional environmental impacts and produce hazardous substances are also described.

### **Chapter E5: Radioactive Waste Management Arrangements**

NEDO-34222, "BWRX-300 UK GDA Chapter E5: Radioactive Waste Management Arrangements," (Reference 1-7) outlines the radioactive waste management arrangements for the BWRX-300. It identifies all sources of radioactive waste that are to be generated during operation and decommissioning, and identifies how they will be managed, segregated, and disposed to approved waste receivers, in line with relevant regulatory expectations and good practice.

### **Chapter E6: Demonstration of Best Available Techniques Approach**

NEDO-34223, "BWRX-300 UK GDA Chapter E6: Demonstration of Best Available Techniques Approach," (Reference 1-8) details how decisions relating to the design of systems that have potential environmental impacts have been made. It is a requirement to demonstrate the application of Best Available Techniques to the BWRX-300 design. A number of high-level claims have been substantiated with arguments (as part of the Claims, Arguments, Evidence approach – noting that at Step 2 only Claims and Arguments are required).

### **Chapter E7: Radioactive Discharges**

NEDO-34224, "BWRX-300 UK GDA Chapter E7: Radioactive Discharges," (Reference 1-9) provides high-level estimates of all authorised radioactive aqueous and gaseous discharges under normal operating conditions, including anticipated operational occurrences. It describes the sources of these wastes and their discharge routes.

### **Chapter E8: Approach to Sampling and Monitoring**

NEDO-34225, "BWRX-300 UK GDA Chapter E8: Approach to Sampling and Monitoring," (Reference 1-10) describes the design and arrangements for how aqueous and gaseous discharges are to be monitored, measured, and sampled in line with UK regulatory requirements. It includes general locations and provisions, demonstrating that the installation of a broad range of sampling and monitoring equipment can be accommodated by the design.

### **Chapter E9: Prospective Radiological Assessment**

NEDO-34226, "BWRX-300 UK GDA Chapter E9: Prospective Radiological Assessment," (Reference 1-11) provides an assessment of the predicted radiation doses to both the public and non-human species arising from any planned radioactive effluent discharges to the atmosphere and aquatic environment.

### **Chapter E10: Other Environmental Regulations**

NEDO-34227, "BWRX-300 UK GDA Chapter E10: Other Environmental Regulations," (Reference 1-12) describes the applicability of non-radioactive environmental regulations to the BWRX-300 design. It identifies how it complies with the UK environmental regulations relating to water use and abstraction, discharge to surface water and groundwater, operation of installations and medium combustion plants, Control of Major Accident Hazard substances, and fluorinated greenhouse gases and ozone-depleting substances.

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### 1.1.1 Supporting Documentation

The core chapters are supported by several additional important sources of information that demonstrate how the BWRX-300 design aligns with the UK regulations. These are:

#### **Environmental Strategy**

The Environmental Strategy (Reference 1-2) defines the scope and suite of deliverables that collectively form the PER.

#### **Integrated Waste Strategy**

NEDO-34228, “BWRX-300 UK GDA Integrated Waste Strategy,” (Reference 1-13) identifies strategies for the management of all potential wastes, both radioactive and conventional, arising through all phases of the plant lifecycle, demonstrating compliance with the UK regulations. It also demonstrates how the design is aligned with sustainability principles, such as the United Nations Sustainable Development Goals.

#### **Alignment with Sustainability, the Radioactive Substances Regulation (RSR): Objective and Principles & Generic Developed Principles**

NEDC-34231P, “BWRX-300 UK GDA Alignment with Sustainability, RSR Objective and Principles & Generic Developed Principles,” (Reference 1-14) predominantly demonstrates how the BWRX-300 design aligns with the RSR objective and principles, and generic developed principles. It briefly describes sustainability alignment. It is used to signpost to relevant GDA submissions as part of both the PER and Preliminary Safety Report (PSR).

#### **Demonstration of Disposability for Higher Activity Radioactive Wastes (including Spent Fuel)**

NEDC-34229P, “BWRX-300 UK GDA Demonstration of Disposability for Higher Activity Radioactive Wastes (Including Spent Fuel),” (Reference 1-15) summarises information relating to the types of higher activity wastes that may arise from the BWRX-300, to enable Nuclear Waste Services to provide their expert view on the disposability of these wastes. It also justifies that aspects of the UK Advanced Boiling Water Reactor (ABWR) disposability assessments are valid for the BWRX-300 and poses alternative disposability arguments, where necessary.

#### **Analysis of Environmental Discharge Data for US Nuclear Power Plants**

NEDC-34279P, “BWRX-300 UK GDA Analysis of Environmental Discharge Data for US Nuclear Power Plants,” (Reference 1-16) demonstrates experience of United States (U.S.) BWRs operating on a maximum recirculation basis. These data support the arguments made in PER Chapter E6 (Reference 1-8) and PER Chapter E7 (Reference 1-9).

### 1.1.2 Interfaces with the Preliminary Safety Report

The PER is supported by the PSR, a suite of safety-related documentation, which has been prepared for assessment by the Office for Nuclear Regulation (ONR). The PER makes reference to various common topics within the PSR, some of which present similar information for assessment. The ONR assesses these from a safety perspective, rather than from an environmental impact perspective. These include:

- NEDO-34164, “BWRX-300 UK GDA Chapter 2: Site Characteristics,” (Reference 1-17) (related to PER Chapter E2)
- NEDO-34174, “BWRX-300 UK GDA Chapter 11: Management of Radioactive Waste,” (Reference 1-18) and NEDO-34198, “BWRX-300 UK GDA Chapter 26: Interim Storage of Spent Fuel,” (Reference 1-19) (both related to PER Chapter E5)

A list of interfaces with the PSR can be found in the Environmental Strategy (Reference 1-2).

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### 1.1.3 Forward Action Plans

Where applicable, each PER chapter and the supporting documentation includes a Forward Action Plan in its Appendix, describing future commitments and actions that will require consideration, for example, during design development or prior to Site License Application. These forward actions are also presented in NEDC-34274P, “BWRX-300 UK GDA Forward Action Plan”, (Reference 1-20), which provides an overview of all commitments and actions that have been identified during GDA Step 2.

### 1.2 Requesting Party

GEH was established in 2007 after General Electric (GE) and Hitachi combined their power businesses to form a strategic global alliance. This has brought together over 60 years of nuclear reactor design expertise and a history of delivering reactors, fuels, and services globally from GE, with proven experience in advanced modular construction from Hitachi, to effectively enhance reactor performance, power output, and safety.

GE began developing nuclear reactors in 1955, with their first nuclear power plant starting operations in 1957. Since the 1960s, GE and Hitachi have been involved in the design, development, construction, and maintenance of Boiling Water Reactors (BWRs) around the world, as described in 005N9751, “BWRX-300 General Description,” (Reference 1-21). The GNF2 fuel that is to be employed in the BWRX-300 has been designed by GE and has been manufactured by them for over 50 years. It is deemed to be one of the most reliable and efficient fuels available in the industry.

Although GEH is the RP, the organisation is also the reactor technology vendor and responsible for design control of the power block. GEH provides engineering and technical services to the current fleet of operating BWRs for the:

- Power block and balance of plant equipment
- Plant life extension
- Power uprates
- Performance services
- Spare and renewal parts
- Outages and inspections

GEH also provides services for spent fuel storage.

GEH has proven experience, knowledge, and capability to design, manufacture, and furnish technical assistance and hardware for the construction, startup, and servicing of the BWRX-300. GEH will provide technical assistance for the construction of any future plant.

It is expected that the design and construction management teams of any future operator will provide oversight of design and construction activities prior to transitioning from the design/construction phase to the operational phase.

### 1.3 Design History and Evolution

Since the construction and successful operation of the first BWR nuclear plant in 1957 (the 5 MWe Vallecitos plant located near San Jose, California), the GE BWR design has undergone a series of evolutionary changes with each one incorporating greater levels of simplification. The design has been simplified in two key areas – the reactor systems and the containment design. Table 1-1 describes the evolution of the BWR, adapted from NEDC-34137P, “BWRX-300 UK GDA Design Evolution,” (Reference 1-22).

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### 1.3.1 Reactor Systems

The first GE BWR in commercial operation, Dresden 1, was based upon a dual steam cycle, not a direct steam cycle that characterises all later generation BWRs. Steam was generated in the reactor, then flowed to an elevated steam drum and a secondary steam generator before making its way to the turbine. The first step in BWR simplification was the elimination of the external steam drum. This was achieved by introducing two technical innovations – an internal steam separator and a dryer. The practice of design simplification has been repeated over and over.

The first large direct steam cycle BWRs, such as Oyster Creek, appeared in the mid-1960s and were characterised by the elimination of the steam generators and the use of five external recirculation loops. Later, reactor systems were further simplified by the introduction of internal jet pumps. These pumps sufficiently boosted recirculation flow so that only two external recirculation loops were needed. This change first appeared in the Dresden-2 BWR/3 plant. BWR/4, BWR/5, and BWR/6 designs continued the path to simplification.

The use of reactor internal pumps in the ABWR design represented another large step in the process of simplification. By using pumps attached directly to the vessel itself, the jet pumps, and the external recirculation systems, with all the associated pumps, valves, piping, and snubbers, were eliminated.

A total of 67 BWRs have been operated by GEH and their predecessors, across the US, Europe, and Asia. The ABWR is the most recent iteration of the BWR that has been employed for commercial power operation (classed as a Generation III+ reactor). It has operated successfully for the last 25 years in Asia but has not been deployed elsewhere. A successful GDA was completed by Hitachi-GE, supported by its UK subsidiary Horizon Nuclear Power Ltd., for a UK variant of the ABWR (the UK ABWR). The UK ABWR was granted Design Acceptance Confirmation by the ONR, and a Statement of Design Acceptability by the EA, supported by NRW in December 2017. Construction of the UK ABWR did not come to fruition.

The Economic Simplified Boiling Water Reactor (ESBWR), and its smaller predecessor, the Simplified Boiling Water Reactor (SBWR), simplified the design further with the use of a taller vessel and a shorter core to achieve effective natural recirculation flow without the use of any pumps.

The BWRX-300 is continuing the advances of the SBWR and ESBWR by using the same tall vessel design to achieve effective natural circulation flow, but it is designed without the need for a shorter core. This allows the BWRX-300 to use the same fuel bundle designs that are currently in use in the operating GEH BWR fleet (e.g., GNF2). Challenges to the system are minimised by the large water inventory above the core in the Reactor Pressure Vessel (RPV), as described in the BWRX-300 General Description (Reference 1-21). The evolution of the GE BWR design is shown in Figure 1-1.

### 1.3.2 Primary Containment

The first BWR containments were spherical “dry” structures. Dry spherical and cylindrical containments are still used today in Pressurised Water Reactor designs. The Mark I containment used for BWR/3 and most BWR/4 plants was the first of the pressure suppression containment designs. The Mark I design has a characteristic “inverted” light bulb configuration for the steel drywell surrounded by a steel torus housing the large pool of water for pressure suppression. The conical Mark II design used for some late BWR/4 and BWR/5 plants is a less-complicated arrangement, allowing simplified construction. The Mark III containment design in BWR/6 plants represented a further improvement in simplicity; the containment structure is a right-circular cylinder that is easy to construct while providing access to equipment and space for maintenance activities.

Generation III+ reactors, such as the ABWR and ESBWR, utilise a pressure suppression containment design that allow for a smaller size and the ability to accommodate rapid

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depressurisation of the RPV. The ABWR containment is smaller than the Mark III containment because the elimination of the recirculation loops translates into a more compact containment and Reactor Building (RB). The ESBWR containment is similar in design to the ABWR but is larger to accommodate the passive Emergency Core Cooling System (ECCS) systems.

The BWRX-300 has returned to the dry containment configuration because Isolation Condensers (ICs) manage RPV pressure and safety relief valves have been eliminated. The containment is small and simple and is achieved with surface-mounted integral RPV isolation valves to rapidly isolate flow from a downstream pipe break. This minimises pressure and temperature buildup in the containment. The Isolation Condenser System (ICS) is used to remove energy from the RPV rather than directing that energy into a suppression pool, (BWRX-300 General Description, (Reference 1-21)).

### 1.4 BWRX-300 Design Overview

The BWRX-300 is a designed-to-cost 300 MWe water-cooled natural circulation SMR utilising simple natural phenomena-driven safety systems. It is the tenth generation of the BWR and represents the simplest design since GE began developing nuclear reactors. It is an evolution of the U.S. Nuclear Regulatory Commission licensed 1,520 MWe ESBWR, utilising proven in-use systems and materials, commercial off-the-shelf components, and design pressures and temperatures within the range of existing BWRs.

The BWRX-300 utilises the already-licensed GNF2 fuel (designed and manufactured by GE) which is currently in use globally and used by the majority of the existing BWR fleet. The core lattice configuration provides more shutdown margin as desired for reload design to accommodate variations in burnup histories imposed by load following. The reactor lattice configuration and fuel element design for the BWRX-300 are similar to those employed in operating BWRs around the world. The BWRX-300 fuel handling and refuelling process is essentially unchanged from historical BWR practice.

A “Defense in Depth” concept is employed as the primary means of preventing accidents and mitigating the consequences of accidents if they do occur. Multiple layers of defense are employed to maximise radiation protection and safety. These layers include both physical barriers (such as fuel cladding, the reactor coolant pressure boundary, and primary containment vessel) and features, functions, and practices to minimise the challenges to these physical barriers.

The types of radioactive waste/effluent discharges during normal operations are well understood for BWRs. This iteration of the reactor incorporates decades of lessons learned from the operating fleet to minimise these amounts. A maximum recirculation philosophy is applied as far as reasonably practicable, which is based upon recent operational experience in the U.S., presented in Analysis of Environmental Discharge Data for US Nuclear Power Plants (Reference 1-16).

An overview of the BWRX-300 major systems is provided in Figure 1-2.

#### 1.4.1 Unique Design Features

Though mostly aligned with traditional BWR design, the BWRX-300 includes several design features that simplify the design and support reduced costs (BWRX-300 General Description, (Reference 1-21)). These features include:

- **Integral RPV isolation valves**

The BWRX-300 RPV is equipped with isolation valves, which are integral to the RPV, that rapidly isolate a ruptured pipe to help mitigate the effects of a Loss Of Coolant Accident (LOCA). All large fluid pipes with RPV penetrations are equipped with double isolation valves that are integral to the RPV.

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- **No Safety Relief Valves (SRVs)**

SRVs have been eliminated from the BWRX-300 design. The large capacity ICS in conjunction with the large steam volume in the RPV provide overpressure protection. The ICS also acts as the ECCS, utilising natural circulation. Historically, BWR SRVs have been the most likely cause of a LOCA but have been eliminated from the BWRX-300 design.

- **Dry containment**

The BWRX-300 has a dry containment. This has been proven to effectively contain the releases of steam, water, and fission products after a LOCA.

- **Designed-to-cost**

The BWRX-300 has been designed with cost and constructability in mind from the start, beginning with a simplified system layout that requires fewer safety systems and safety-related pools of water. This concept has also been adapted to fit with commercial building standards and cost and labor-efficient construction techniques for underground structures. The design has been optimised for constructability by adopting a strategy for modularisation.

- **Use of commercial off-the-shelf equipment**

Due to its smaller size, the BWRX-300 has been designed to use more commercial off-the-shelf equipment than previous BWRs. For instance, the turbine and generator models have been used on many fossil plant projects such as combined-cycle combustion turbine sites and can be used for this plant with small modifications. This leads to lower cost.

### 1.4.2 Key Design Development Advantages

A summary of the key design development advantages of the BWRX-300 are provided below, with many related to the unique design features, adapted from BWRX-300 UK GDA Design Evolution (Reference 1-22):

- Reduced LOCA risk
- Passive safety design compared with the historic active design
- Design simplification supports increased reliability (fewer components and less pipework)
- Flexible energy generation
- Reduced requirement for operator control or intervention
- Modularisation with constructability integrated into the design
- Designed in accordance with internationally accepted codes, standards, and guidance to support international deployment
- Design pedigree, building upon previous BWR designs
- Use of many proven technologies (e.g., GNF2 fuel, core design)

### 1.4.3 Key Specifications

The key specifications of the BWRX-300 compared with its most recent predecessors are provided in Table 1-2, adapted from the BWRX-300 General Description (Reference 1-21).

PER Chapter E4 (Reference 1-6) provides further information on the main plants, structures, and systems that form part of the BWRX-300 generic design. This is supported by design information provided in the PSR.

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**Table 1-1: Evolution of the GE Boiling Water Reactor**

<b>Product Line</b>	<b>First Commercial Operation Date</b>	<b>Representative Plant/Characteristics</b>
BWR/1	1960	Dresden 1 – Initial commercial size BWR
BWR/2	1969	Oyster Creek – Plants purchased solely on economics. Large direct cycle. Isolation condensers.
BWR/3	1971	Dresden 2 – First jet pump application. Improved ECCS: spray and flood capability.
BWR/4	1972	Vermont Yankee – Increased power density (20%)
BWR/5	1978	Tokai 2 – Improved ECCS. Valve flow control.
BWR/6	1981	Kuosheng 1 – Compact control room. Solid-state nuclear system protection system.
Advanced BWR	1996	Kashiwazaki-Kariwa 6 – Reactor internal pumps. Fine motion control rod drives. Advanced control room, digital and fiber optic technology. Improved ECCS: high/low pressure flooders.
Economic Simplified BWR	-	Natural circulation. Passive ECCS.
BWRX-300	-	LOCA mitigation. RB built from second generation steel-concrete composition modules.

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**Table 1-2: Comparison of Key Features**

Feature	ABWR	ESBWR	BWRX-300
Plant Type	Direct Cycle BWR	Direct Cycle BWR	Direct Cycle BWR
Gross Electrical Output	~1,350 MWe	~1,600 MWe	~300 MWe
Reactor Thermal Output	3,926 MW <sub>th</sub>	4,500 MW <sub>th</sub>	870 MW <sub>th</sub>
Reactor Coolant Recirculation	Reactor Internal Pumps	Natural Circulation	Natural Circulation
Reactor Operating Pressure	7.2 MPa (abs)	7.2 MPa (abs)	7.2 MPa (abs)
Reactor Vessel	Extensive use of forged rings	Extensive use of forged rings	Extensive use of forged rings; integrated isolation valves
RPV Diameter (ID)	7.1 m	7.1 m	4 m
RPV Height (Inside)	21.0 m	27.6 m	26.0 m
Fuel Type	GE14	GNF2e	GNF2
Number of Fuel Bundles	872	1,132	240
Control Blade Type	Cruciform B <sub>4</sub> C or Hf	Cruciform B <sub>4</sub> C or Hf	Cruciform B <sub>4</sub> C or Hf
Control Rod Drive (CRD) Type	FMCRD	FMCRD	FMCRD
Number of Control Rods	205	269	57
Steam Conditioning	AS-2B Steam Separators Chevron Steam Dryer	AS-2B Steam Separators Chevron Steam Dryer	AS-2B Steam Separators Chevron Steam Dryer
Primary Containment Vessel Type	Reinforced Concrete Containment Vessel	Reinforced Concrete Containment Vessel	Steel-plate Composite Containment Vessel
Emergency Core Cooling System	3-Divisional	Passive	Passive
Isolation Makeup	Reactor Core Isolation Cooling System	Isolation Condensers, Passive	Isolation Condensers, Passive
Shutdown Cooling	3-Division Residual Heat Removal System Safety-related	Non-Safety related	Safety Class (SC) 3
Primary Containment Vessel Cooling System	3-Division Residual Heat Removal System	Passive	Passive
Emergency AC Power	3 Safety-related diesel generators	Non-Safety related	Two SC3 diesel generators

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Feature	ABWR	ESBWR	BWRX-300
Control & Instrumentation	Digital, Multiplex, Fiber Optics, Multiple Channel	Digital, Multiplex, Fiber Optics, Multiple Channel, Diverse Analog DL4a System	Digital, Multiplex, Fiber Optics, Multiple Channel, Diverse Analog DL4a System
In-Core Monitor Calibration	Traversing In-core Probe System	Fixed, In-Core Gamma Thermometers (GTs)	Fixed, In-Core GTs
Control Room	Operator Tasked-Based	Operator Tasked-Based	Operator Tasked-Based

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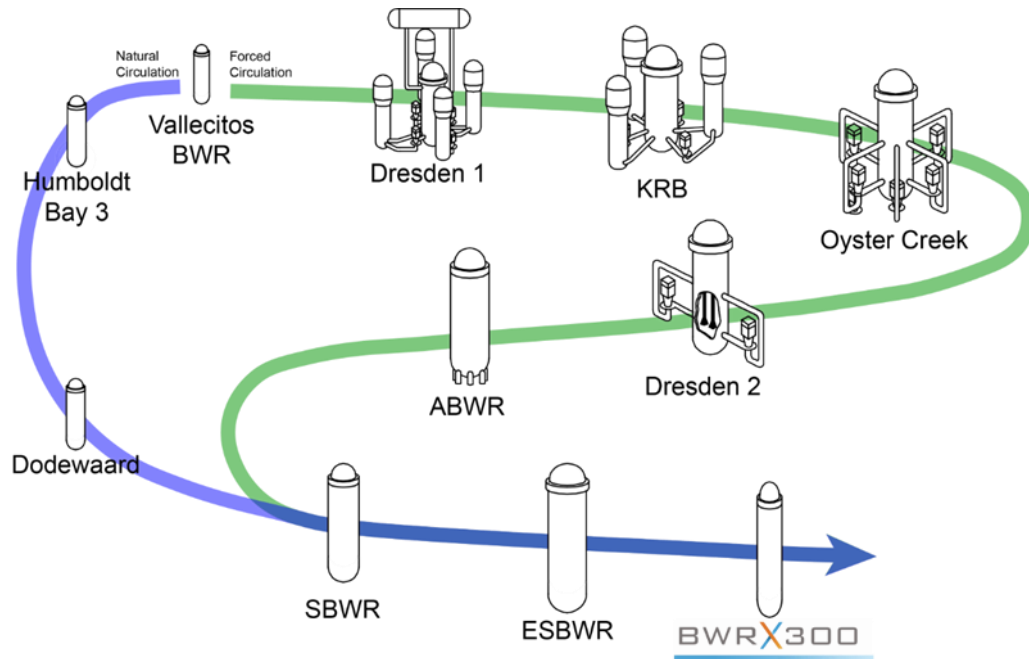
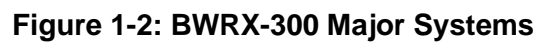


Figure 1-1: Boiling Water Reactor Design Evolution



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### 1.5 References

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