GE-Hitachi Nuclear Energy Submission for the Federal Inquiry into the Prerequisites for Nuclear Energy in Australia

September 16, 2019

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GE-Hitachi Nuclear Energy (GEH) welcomes the opportunity to provide a submission to the Standing Committee on Environment and Energy's inquiry into the prerequisites for nuclear energy in Australia. This submission provides an overview of reactor technology developments by GEH that can deliver greater capability, improved reactor performance and safety outcomes.

GE

For more than 125 years, GEH's controlling parent, General Electric Company (GE) has been an industry leader. GE's vast installed base across aviation, power, healthcare and renewable energy keeps GE intimately involved in the daily operations of GE's customers around the world. Today, GE additionally leads new paradigms in additive manufacturing, materials science and data analytics.

GE has built a local presence, a strong brand, and deep customer relationships in more than 180 countries. GE is proud to serve as a true partner in growth and development — offering resources and experience, investing in local talent and supply chains, and bringing other partners along with it.

The GE Power and GE Renewables businesses create the energy technologies of the future and improve the power networks that millions depend on today. GE's equipment generates a third of the world's electricity. GE's technology equips 90% of power transmission utilities worldwide, and 40% of the world's energy is managed by GE software. GE believes an "all of the above approach" and a diversified portfolio of leading positions in power technologies that limit greenhouse gas emissions – including nuclear power, and wind – will be required to sustain its current position. GE provides offerings from GE Gas Power Systems, GE Steam Power, GEH, GE Grid Solutions, GE Energy Consulting, GE Power Conversion, GE Energy Storage, GE Renewable Energy, and GE Power Services.

GE in Australia

GE began operations in Australia in 1896 with the provision of traction equipment and engineering services for the Brisbane tramway and has been active in Australia ever since. Today, GE technology and people thrive as contributors to Australia's healthcare, aviation, defense, power, renewables, and additive-manufacturing industries.

Nuclear Energy

Nuclear energy is an invaluable energy source which has made a major contribution to meeting the worlds energy need. Some of the benefits are outlined below.

Low Emissions Energy

While renewables sources like hydro, wind and solar have a low carbon footprint, each has its own challenges and collectively cannot address climate change alone. It takes a mix of energy sources to address this challenge. For its part, nuclear is an important and large source of clean, baseload electrical power around the globe. There are sufficient global uranium supplies to fuel many more nuclear plants, and there is a huge opportunity to recycle used nuclear fuel to extract the significant remaining energy content and improve its environmental efficacy. According to the World Nuclear Association, nuclear power facilities generate ~11% of the electricity worldwide (~6% by renewables), yet nuclear generates ~30% of the world's carbon-free power. The Nuclear Energy Institute (NEI) shows that in the U.S. nuclear energy generates ~19% of the electricity (~17% by renewables), yet provides 55% the U.S. carbon-free electricity (~45% from renewables).

Grid Stability

Nuclear is an excellent, stable, baseload source with load-following capabilities that provide positive contributions to any electrical grid, while at the same time providing clean energy. It can be integrated with renewables to address issues created by too much renewables penetration on a grid, which can be seen in a phenomenon known as the "Duck Curve" or "Duck Billed Platypus Curve". This phenomenon has been seen in places such as California where significant solar electric capacity has been installed, and some other significant redundant source must be available to back solar up. The additional source of power is needed to rapidly ramp up to meet evening demand after the sun goes down, producing a graph that resembles the silhouette of a duck. To address this phenomenon, nuclear would be a good redundant clean energy source and can help provide ramp-up capabilities for the evening hours. It is interesting to note that Germany, which abandoned nuclear in favor of wind and solar after Fukushima, is now adversely impacting the electrical grids of neighboring countries. It should also be noted that Germany's emissions have risen at times, despite increased reliance on renewables, partly because the backup power is largely generated by coal. This constrains Germany's ability to meet its commitments under the Paris Accord.

Energy Density

Nuclear is energy dense with high capacity factors and efficient use of land and materials. Depending on siting location, capacity factors for solar are 15-30% and for wind are 30-50%; however, the capacity factors for nuclear are not weather or time of day dependent and are on the order of 80-90%. Compared to nuclear, solar uses 60 times more land per installed megawatt than nuclear and wind uses 300 times more than nuclear. Also, compared to nuclear, solar requires 15 times more tons of materials per TWh than does nuclear, and wind requires 10 times more. While all three of these energy sources generate emissions-free electricity, it is clear that energy density for nuclear is far superior when the aforementioned factors are combined.

Competitive

The competitiveness of nuclear energy depends on many factors, such as availability and cost of other fossil fuels, wind and sun regimes, subsidies, etc. Nuclear does have costs that other sources do not have, such as strong regulations. Moreover, nuclear accounts for additional costs that other sources are not required to account for such as decommissioning. Nuclear must continue to strive to be competitive and adapt to the changing electricity markets. For example, nuclear creates many direct technical jobs and indirect support jobs in a community, but the relatively large staff levels at nuclear plants can significantly impact the cost of electricity. The global nuclear industry is responding with Advanced Reactors and Small Modular Reactors (SMRs). According to Third Way, a Washington, D.C. based public policy think tank, there are 81 advanced nuclear reactor projects under development in 20 countries outside of the United States and Canada, where there are 56 more, and Third Way suggests the "Global market for nuclear reactors is expected to average at least $75 B annually." These technologies will help the industry adapt by making nuclear power affordable to a wider group of customers based on size, reducing equipment cost by operating at lower pressures in many cases, increasing passive safety features, reducing emergency planning zones, utilizing load following, reducing staffing, etc.

Other Benefits

Nuclear has many other benefits besides generating electricity. The heat from nuclear reactors can be used for process heat (e.g. hydrogen), desalination, district heating, etc. Similarly, Nuclear is also used for medical imaging, specialized cancer treatments and medical equipment sterilization. Nuclear radiation is likewise used to treat food and kill bacteria, insects and parasites that cause illness. Finally, Nuclear can also be used for transportation such as submarines and space ships, untethering them from the need to be fueled.

GE's Nuclear Business

GE Hitachi Nuclear Energy

Based in Wilmington, N.C., GEH is a world-leading provider of advanced reactors and nuclear services. Established in June 2007, GEH is a global nuclear alliance created by GE and Hitachi, Ltd. of Japan to serve the global nuclear industry. The nuclear alliance executes a single, strategic vision to create a broader portfolio of solutions, expanding its capabilities for new reactor and service opportunities. The alliance offers customers around the world the technological leadership required to effectively enhance reactor performance, power output and safety. GE was one of the first reactor Original Equipment Manufacturers (OEMs), and GEH has the benefit, taking into account its GE legacy, of over 60 years of global nuclear project experience. GE was instrumental in engineering, designing, procuring, manufacturing, and constructing over 80 nuclear power plants globally; providing over 70 GW of electricity, including approximately 30 percent of those operating nuclear plants in the U.S. GE first built the 30 MWe BWR in Vallecitos, California as a prototype in only two years, receiving the first atomic power license from the then U.S. Atomic Energy Commission, and becoming the first privately owned and operated nuclear power plant to deliver electricity to the grid in 1957. Then GE built the 180 MWe Dresden 1 BWR for Commonwealth Edison, the first private commercial nuclear power plant.

GEH Nuclear Plant Projects

The GEH Nuclear Plant Projects (NPP) business offers various nuclear technologies, including gigawatt scale boiling water reactors (BWRs), i.e. ABWR and ESBWR and Small Modular Reactors (SMRs) including a the BWRX-300 and the Gen IV reactor, PRISM. Additional information is provided on BWRX-300 and PRISM below. In addition to these reactor design offerings, GEH has been offering and providing engineering and other types of help to many of the new start-up type reactor vendors with a full range of expertise, services and infrastructure.

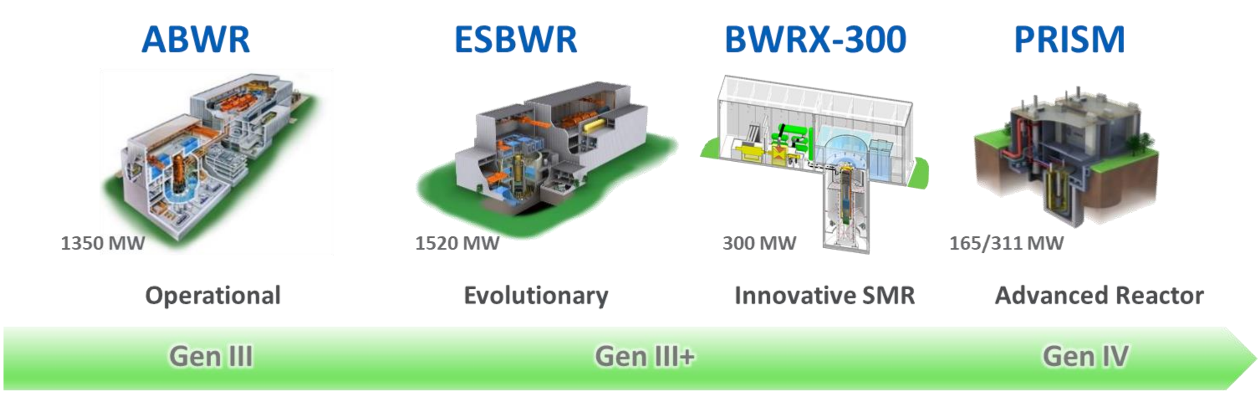

Figure 1: GEH's Stable of Reactors

Global Nuclear Fuel

Co-located in Wilmington is Global Nuclear Fuel (GNF), a world-leading supplier of boiling water reactor fuel and fuel-related engineering services. GNF is a GE-led joint venture with Hitachi, Ltd. GNF has manufacturing facilities in Wilmington, North Carolina and Kurihama, Japan. GNF has been providing the most reliable and efficient fuel in the nuclear industry for over 60 years. While focused on BWR fuel up to the present, GNF now intends to develop and fabricate additional fuel types for advanced reactors.

GEH Input to Response to the South Australian Nuclear Fuel Cycle Royal Commission

GEH previously submitted a response to the Nuclear Fuel Cycle Royal Commission, which researched nuclear with various inputs and provided a report to the Governor of South Australia in 2016. GEH's 156 page written input, "GEH Response to Nuclear Fuel Cycle Royal Commission, August 6, 2015", can be found here: http://nuclearrc.sa.gov.au//app/uploads/2016/03/GE-Hitachi-Nuclear-Energy-07-08-2015.pdf

Additionally, Dr. Eric Loewen, GEH Chief Consulting Engineer, participated in the Nuclear Fuel Cycle Royal Commission public session on October 30, 2015, while also providing an overview of GEH's PRISM technology and Advanced Recycling Centre. Relevant GEH information can be found here:

Video: http://nuclearrc.sa.gov.au/videos/low-carbon-energy-generation-options-30102015-8am/

Transcript: http://nuclearrc.sa.gov.au//app/uploads/2016/02/LOEWEN-Eric-948-969.pdf

BWRX-300

The BWRX-300 is a ~300 MWe water-cooled, natural circulation Small Modular Reactor (SMR) design with passive safety systems. It is the tenth evolution of the Boiling Water Reactor (BWR) and represents the simplest, yet most innovative BWR design since GE began developing nuclear reactors in 1955.

The BWRX-300 is based on the U.S. NRC-licensed, 1,520 MWe ESBWR and is designed to provide clean, flexible, baseload electricity generation that is competitive with the levelized cost of electricity of natural gas fired plants. The overnight capital cost is projected to be US$1B for FOAK (first of a kind) and US$675M for NOAK (nth of a kind) implementations.

Benefits and Features

- World class safety: designed to eliminate loss-of-coolant accidents (LOCA) enabling simpler passive safety
- Cost competitive: projected to have up to 60% less capital cost per MW when compared with typical water-cooled SMR
- Passive cooling: designed to allow steam condensation and gravity allow to cool the reactor for a minimum of 7 days without power or operator action
- Quick Deployment: Deployable as early as 2028, thanks to proven know-how and construction techniques

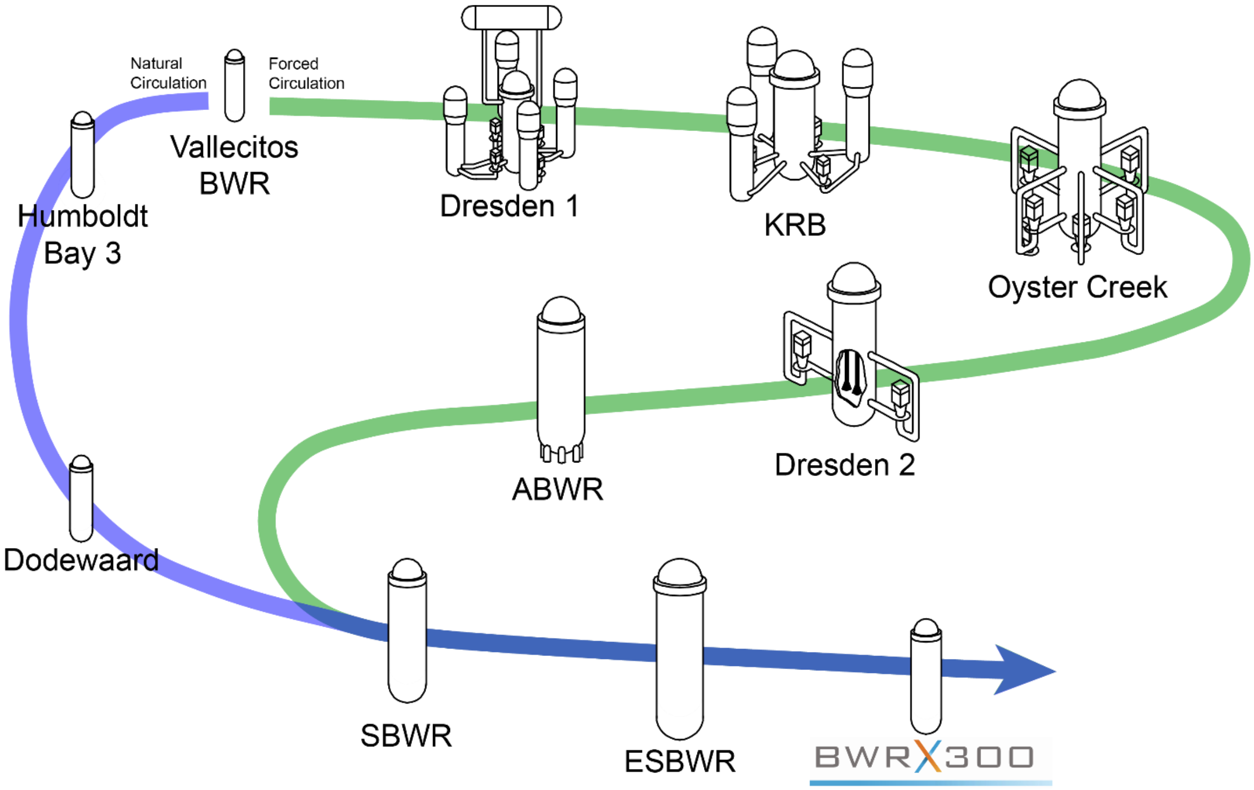

Figure 2: Boiling Water Reactor Evolution to BWRX-300

A Dramatic Reduction in Scale and Complexity

The BWRX-300 utilizes the ESBWR's 30+ year development basis to help future plants operate smarter, faster and on a less costly basis.

Compared to the ESBWR, the BWRX-300 prides itself on achieving about a 90 percent volume deduction in plant layout. Notably, the innovative SMR is designed to reduce building volume by about 50 percent per MW, which should account for 50 percent less concrete per MW. The 1,520 MWe ESBWR has approximately 160,000 m^3 of safety related concrete while the BWRX-300 has only 15,500 m^3. The BWRX-300 will significantly improve the next generation of reactors due to its affordability and advantageous size.

As a "smart reactor", BWRX-300 uses natural circulation and passive cooling isolation condenser systems to promote simple and safe operating rhythms. In the global race for advanced nuclear, the BWRX-300 sets itself apart with its proven, less complicated processes.

Proven Technology

It should be noted that most of the nuclear-related technology and components used in the BWRX-300 either have had many years of proven operation experience or have undergone significant testing and licensing as part of the ESBWR program. Moreover, the various construction technologies incorporated into the BWRX-300 design adopt advanced concrete solutions and innovative techniques that have been proven in the oil and gas, tunneling and power industries. GEH continues to focus on reducing cost and schedule in order to enable the BWRX-300 to compete with natural gas combined cycle power plants and to help position nuclear plants generally to remain a vital part of the future power generation mix.

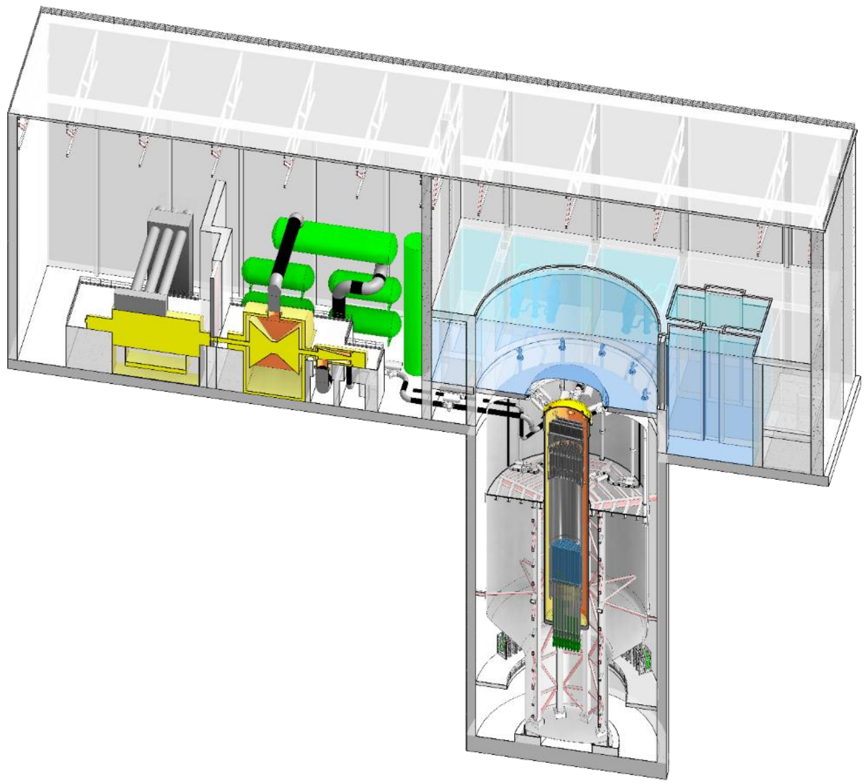

Figure 3: BWRX-300 Plant and Reactor Vessel

PRISM

PRISM is a sodium fast reactor (SFR) that is based on the EBR-II reactor which had 30 years of successful operating experience at Argonne National Lab - West in Idaho, U.S. PRISM has a long development history and can be utilized for power generation and high temperature heat applications. Additionally, when combined with electrometallurgical processing, PRISM can recycle light water reactor (LWR) UNF, changing it from a liability into an asset generating emissions-free power.

As a successor to the successful 30-year Experimental Breeder Reactor II (EBR-II) program in Idaho, and with almost four decades of its own development on the books, no other single U.S. advanced reactor technology has more licensing, testing, design, or operation basis than PRISM. GE's early work on sodium-cooled power reactor systems began in 1946 with establishment of the Knolls Atomic Power Laboratory (KAPL), building the S1G liquid sodium-cooled Naval prototype reactor, followed by construction and operation of the sodium fast test reactor Southwest Experimental Fast Oxide Reactor (operated from 1969 to 1972). The PRISM design was initiated by GE in the early 1980s. After the initial GE program, subsequent studies were conducted under a DOE program which formed the basis for DOE to select the PRISM concept as the reference design for the DOE Advanced Liquid Metal Reactor (ALMR) Program. The ALMR Program resulted in the preparation of the PRISM Preliminary Safety Information Document (PSID), which was submitted to the U.S. Nuclear Regulatory

Commission (NRC) for review and approval. The NRC then published NUREG-1368, *Pre-application Safety Evaluation Report (PSER) for the PRISM Liquid Metal Reactor* and provided feedback that there were no obvious impediments to licensing PRISM. During the ALMR Program alone, approximately 1.8 million man-hours were expended to develop technical and commercial cost data for PRISM. Building on that legacy, GEH has continued to improve GE's pioneering reactor design and to work on commercialization efforts.

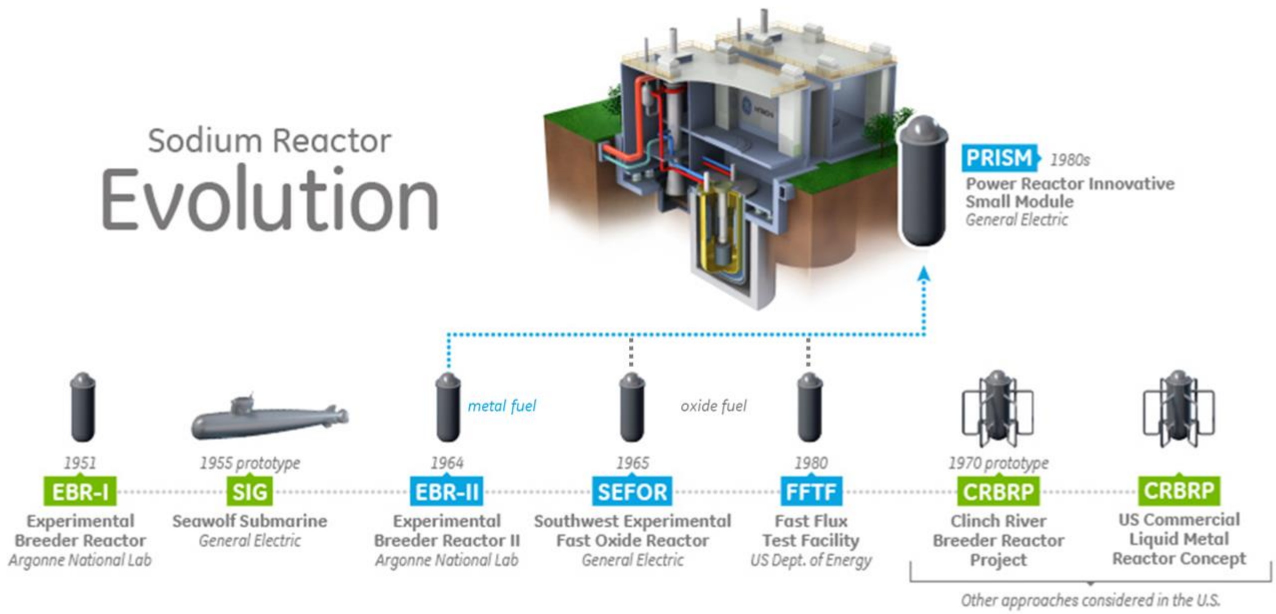

Figure 4: Sodium Fast Reactor Evolution to PRISM

Most recently, in November 2018, the DOE awarded GEH a contract to utilize PRISM as a basis to support the conceptual design, cost/schedule estimate and safety framework activities for a proposed fast spectrum Versatile Test Reactor (VTR). The DOE's intentions are to develop and build the VTR by 2026 in order to provide the U.S. the necessary fast neutron irradiation and high temperature capabilities critical for the development of innovative nuclear fuels, materials, instrumentation and sensors associated with the wide array of advanced reactors expected to be developed. The VTR will further demonstrate certain aspects of PRISM and will provide a good reference for any customer interested in deploying PRISM.

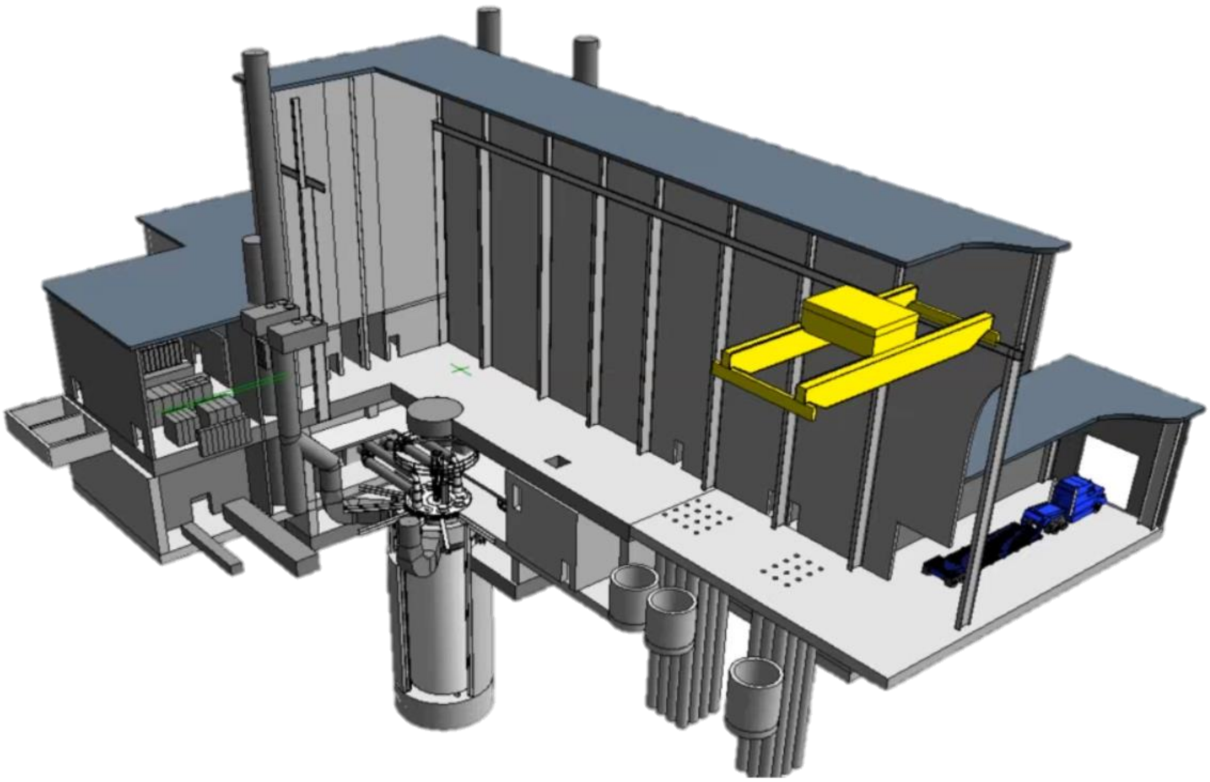

Figure 3: Versatile Test Reactor based on PRISM

PRISM Attributes and Benefits

- Sodium cooled fast reactor … Generation IV technology
- 165 and 311 MWe options … flexible output levels
- Compact pool-type reactor/atmospheric pressure … designed to eliminate Loss of Coolant Accident (LOCA)
- Air cooling for decay heart removal … passive safety
- Proven metallic fuel … inherent safety
- Superheated steam … improved thermal cycle efficiency
- High temperatures (500°C) … process heat applications
- Modular design … improved quality & construction efficiency
- 99% fuel utilization … fuel recycling

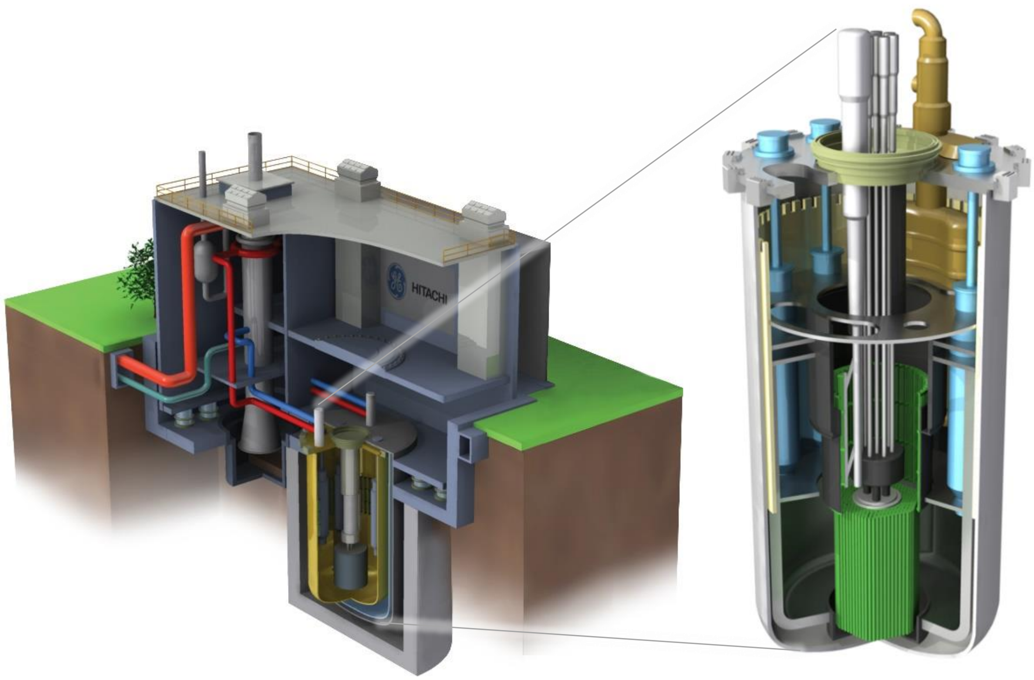

Figure 5: PRISM Power Block and Reactor Vessel

Table 1: PRISM Performance Parameters

Parameter	**Mod A (Mod B differences)**
Net Electrical Output	165 MW_e (311 MW_e)
Primary System	Pool, forced flow
Core Thermal Power	471 MW_{th} (840 MW_{th})
Core Outlet Temperature	500°C
Core Inlet Temperature	352°C
Primary Pumps	4 Electromagnetic
Intermediate Heat Exchangers	2 Sodium to Sodium
Intermediate System	Two Sodium Loops
IHX Sodium Inlet	301°C
IHX Sodium Outlet	462°C
Intermediate Pumps	2 Electromagnetic
Steam Generator	Single unit, helical coil, counter flow
Power Cycle	Superheated Rankine
Shell-Side/Tube-Side	Sodium/Steam