



NuScale Small Modular Reactor (SMR)

INPRO Dialogue Forum on
Challenges in Small Modular

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Acknowledgement and Disclaimer

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NuScale's Mission

NuScale Power provides advanced nuclear technology for the production of electricity and clean water to **improve life for people around**

Who is NuScale Power?

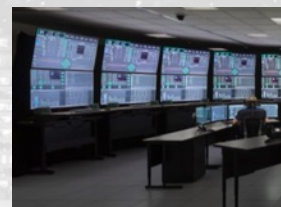
- NuScale Power was formed in 2007 for the sole purpose of completing the design and commercializing a small modular reactor (SMR) – the NuScale Power Module™.
- Initial concept had been in development and testing since the 2000 U.S. Department of Energy (DOE) MASLWR program.
- Fluor, global engineering and construction company, became lead investor in 2011.
- In 2013, NuScale won a \$226M competitive U.S. DOE Funding Opportunity for matching funds.
- >400 patents granted or pending in nearly 20 countries.
- >350 employees in 6 offices in the U.S. and 1 office in the U.K.
- Making substantial progress with a rigorous design review by the U.S. Nuclear Regulatory Commission (NRC).
 - Phase 4 of NRC Review is on schedule for completion December 2019.
- Total investment in NuScale to date ~US\$800M.
- On track for first plant operation in 2026 in the U.S.



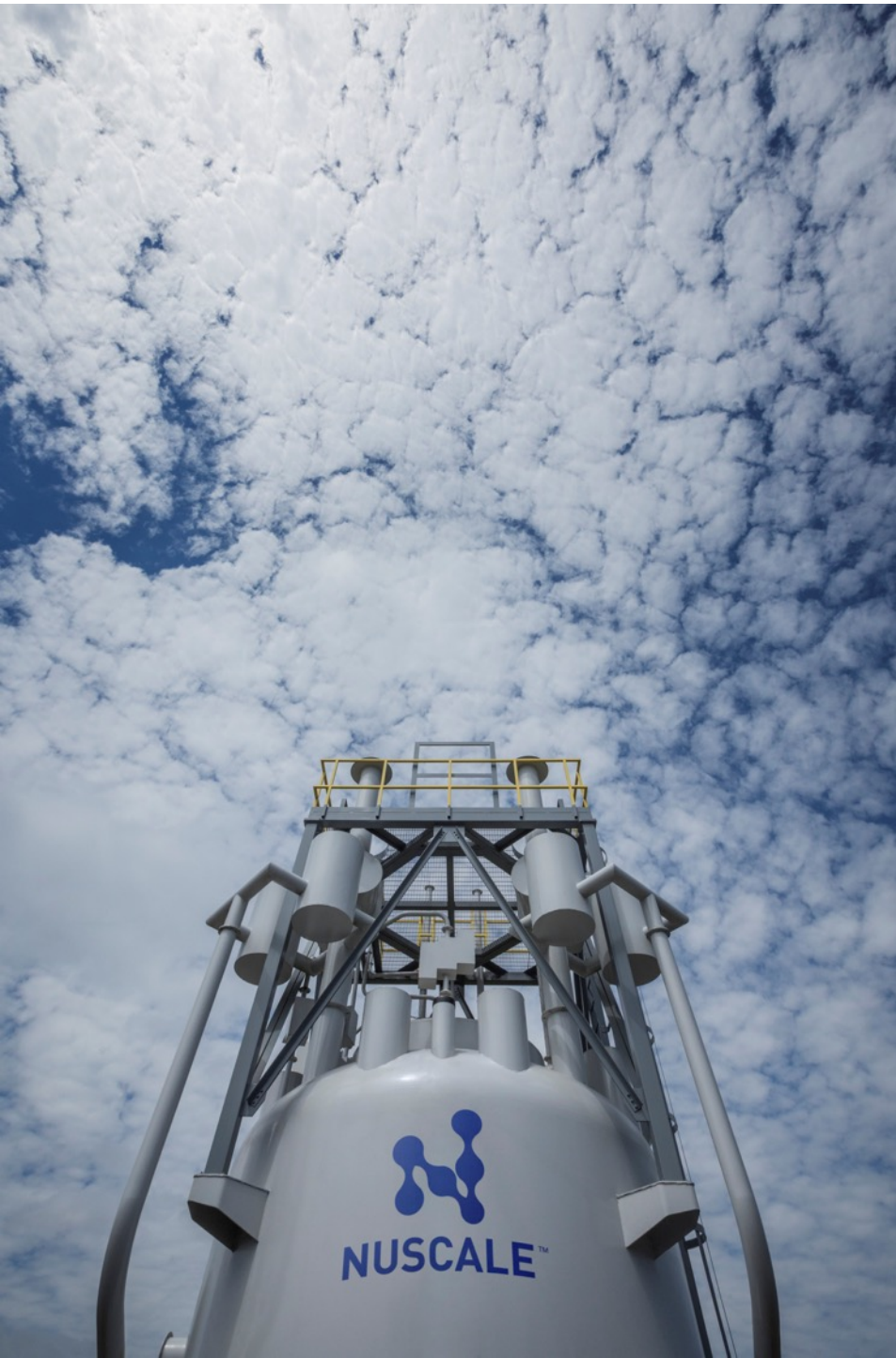
NuScale Eng



One-third s

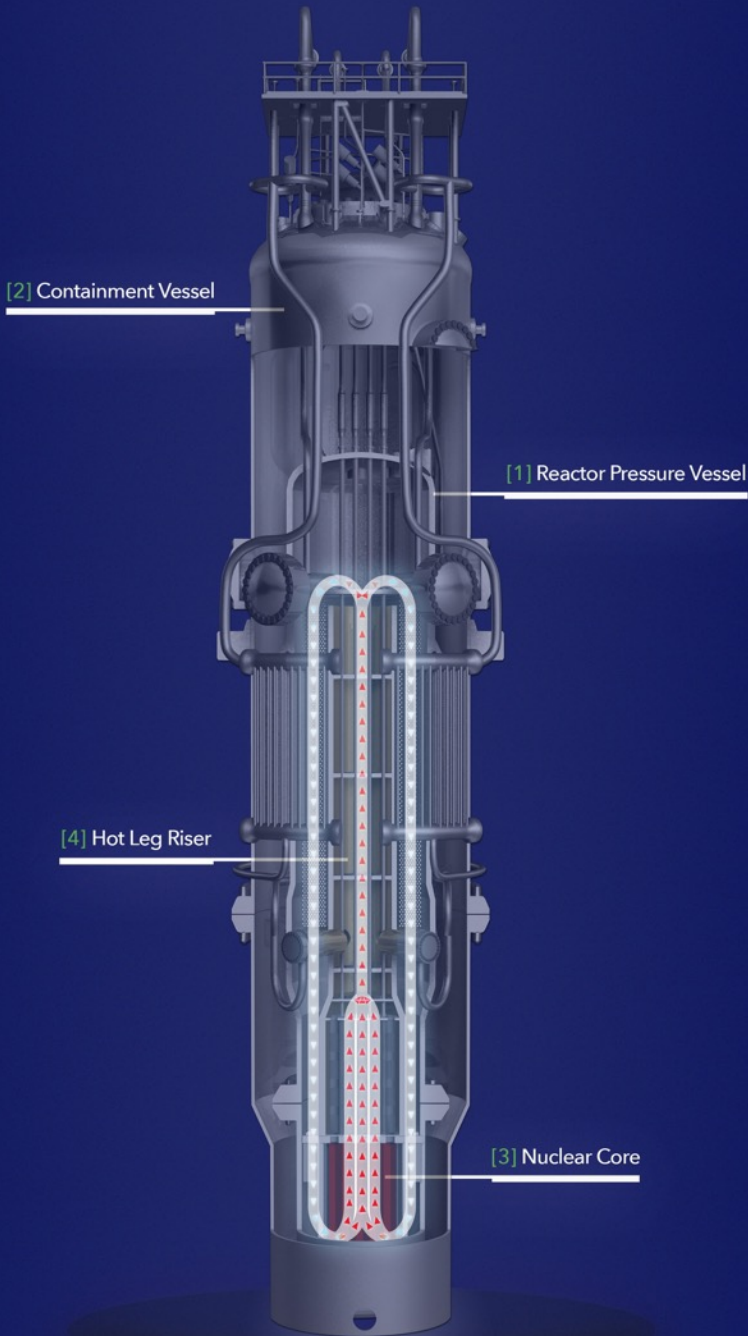


NuScale C



A bold, new en

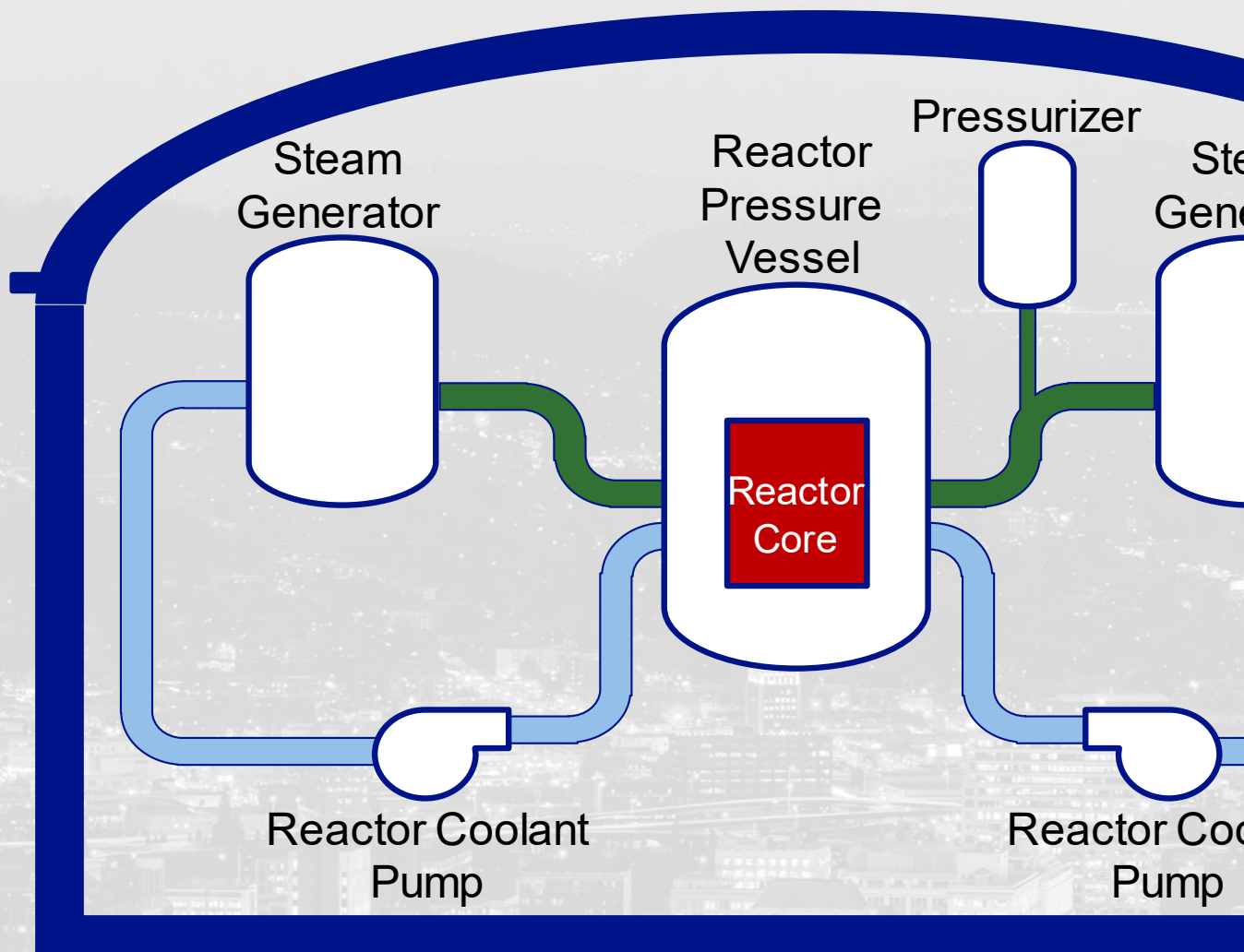
- **Smarter energy** – flexible for multiple applications, integrated with other resources, provide high reliability for mission critical facilities, and baseload power.
- **Cleaner Energy** – 100% carbon free, as clean as wind or solar, and a small footprint.
- **Safer Energy** – should be able to shut down. NuScale's SMR shuts its own power off and cools for an indefinite period with no operator action required and no AC or DC power.
- **Cost Competitive** – the most cost-effective. Less complex than other reactors, faster fabrication and assembly. Components are delivered in a pre-assembled, to-install form. All of this is achieved in a shorter, more predictable time of time.



Core Technology NuScale Power

- A **NuScale Power Module** is a self-contained, factory-built unit that houses the reactor vessel, steam generator, pressurizer, and containment system. This **simple design package** – simple design, no reactor coolant pumps, no other systems and components – is a departure from conventional reactors.
- Each module produces 120 MWe net power.
 - small enough to be factory built, transported and installed
 - dedicated power conversion system
 - flexible, independent operation
 - incrementally added to a plant
 - up to **12 modules** (684 MWe net) total capacity

Typical Pressurized Water Reactor



NuScale Small Modular Reactor

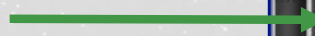
Containment



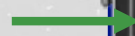
Pressurizer



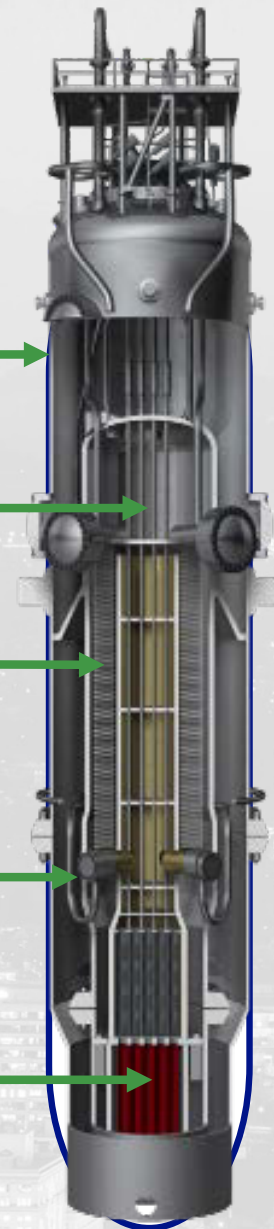
Steam Generators



Reactor Pressure Vessel

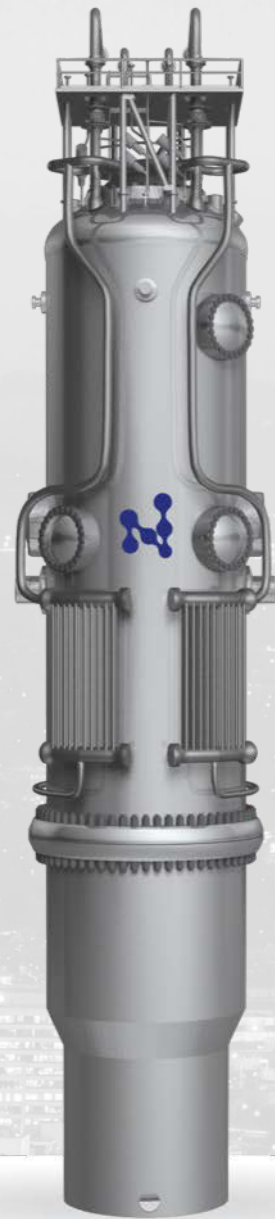


Reactor Core



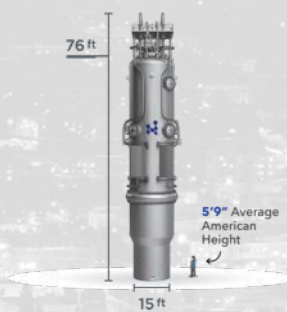
Dimensions

76 ft
(≈23 m)

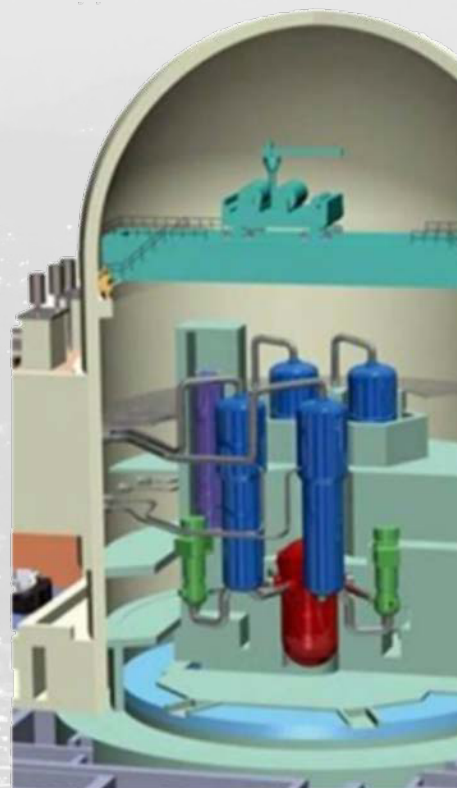


15 ft (≈4.6 m)

Comparison to a Large Pressurized Water Reactor



NuScale Power Module



Typical Large PWR

Simplicity Enhances Safety

Natural Convection for Cooling

- Passively safe - cooling water circulates through the nuclear core by natural convection eliminating the need for pumps

Seismically Robust

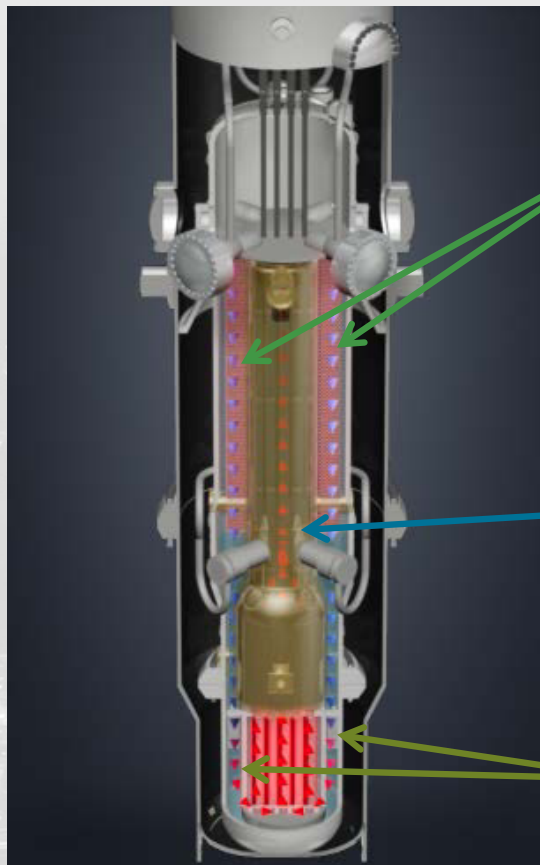
- System submerged in a below-grade pool of water in an earthquake and aircraft impact resistant building

Simple and Small

- Reactor core is 1/20th the size of large reactor cores
- Integrated reactor design - no large-break loss-of-coolant accidents

Defense-in-Depth

- Multiple additional barriers to protect against the release of radiation to the environment



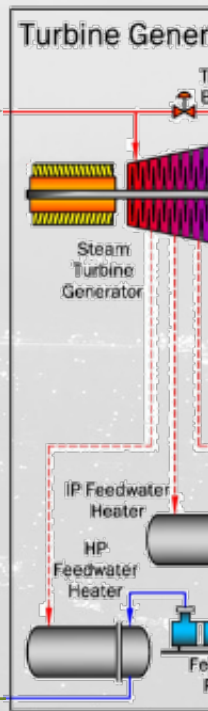
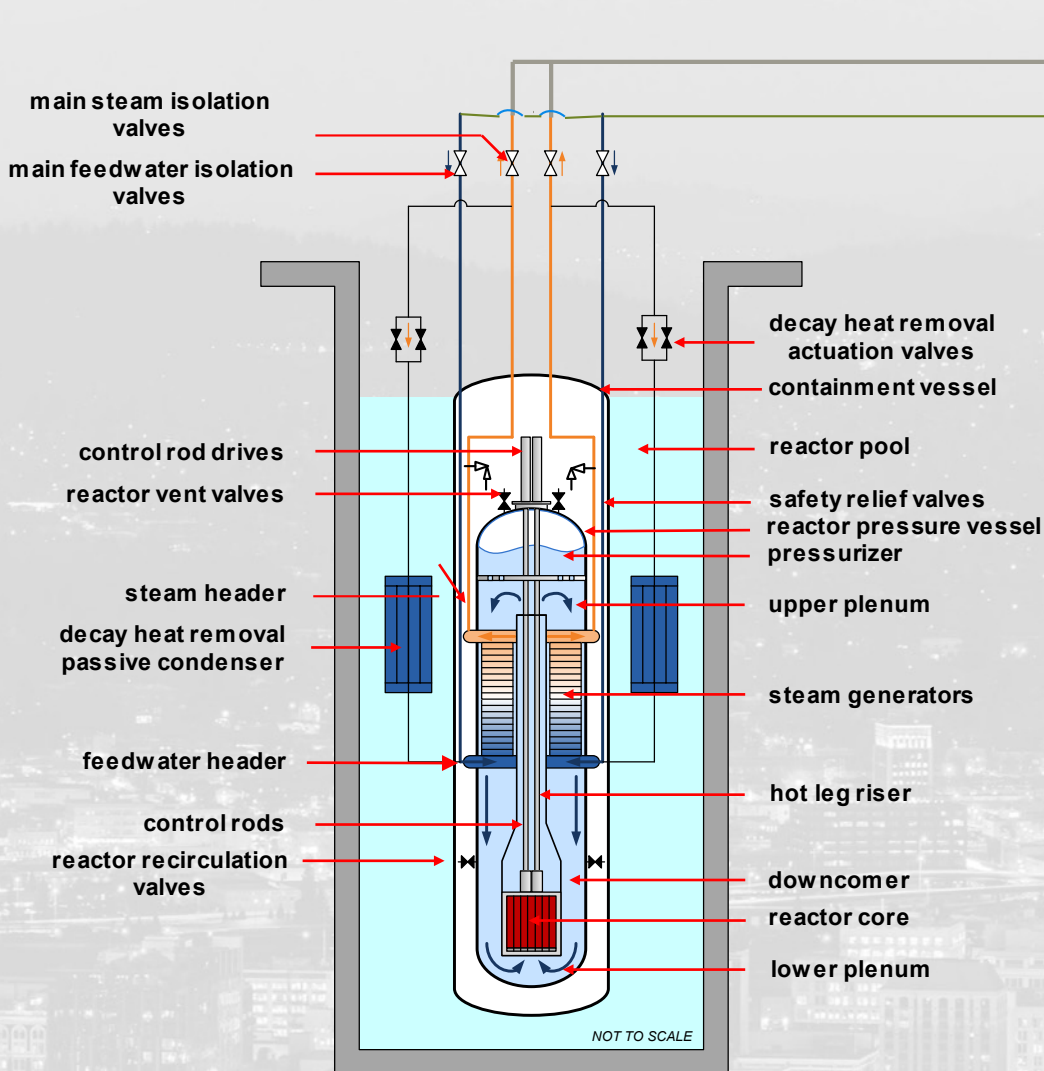
Conduction by the (primary) heat tubes turning water

Convection of primary coolant through chimney

Gravity (density) to bottom vessel circulates

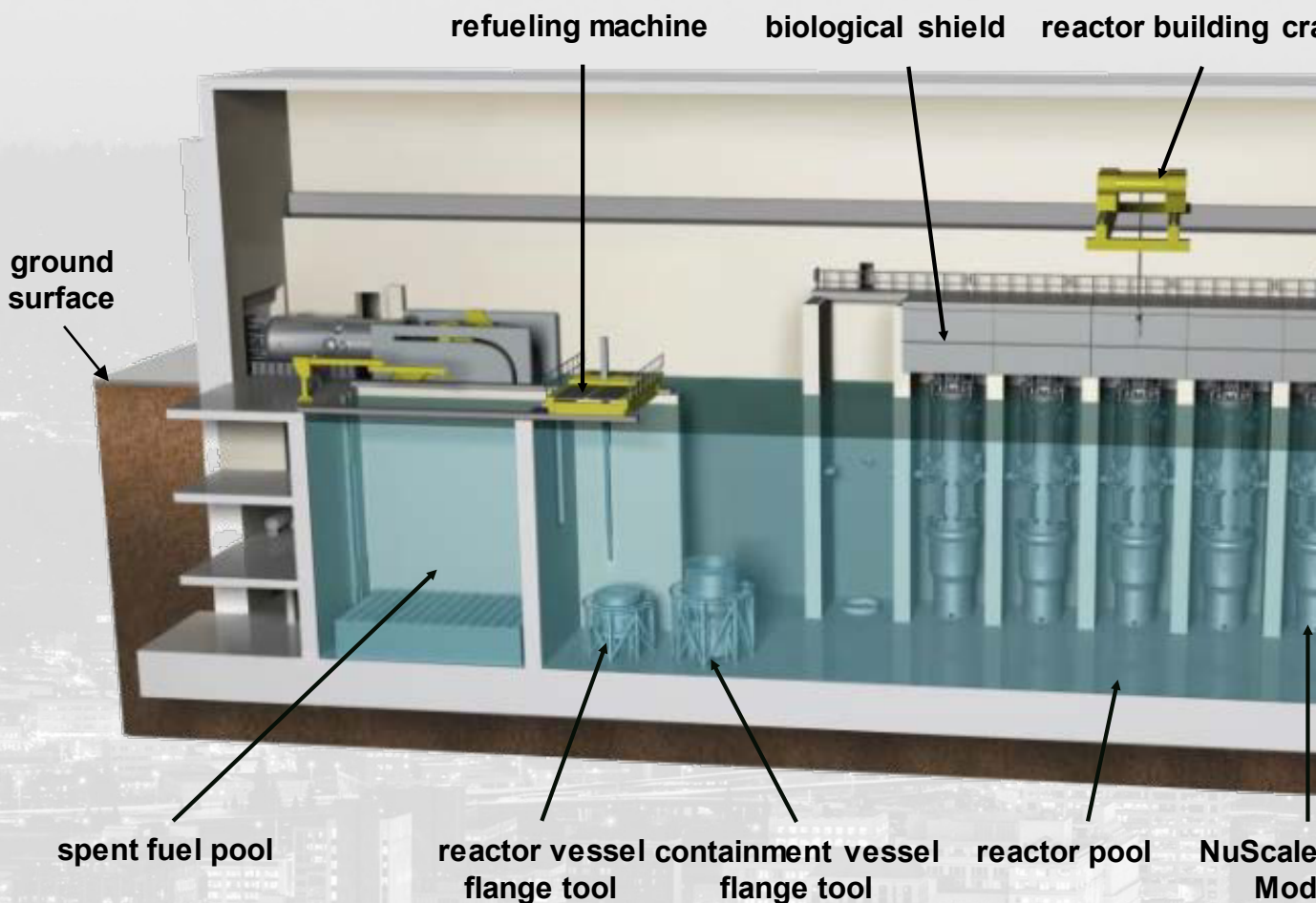
Second-to-none safety case – site boundary Emergency Planning

NuScale Power Train

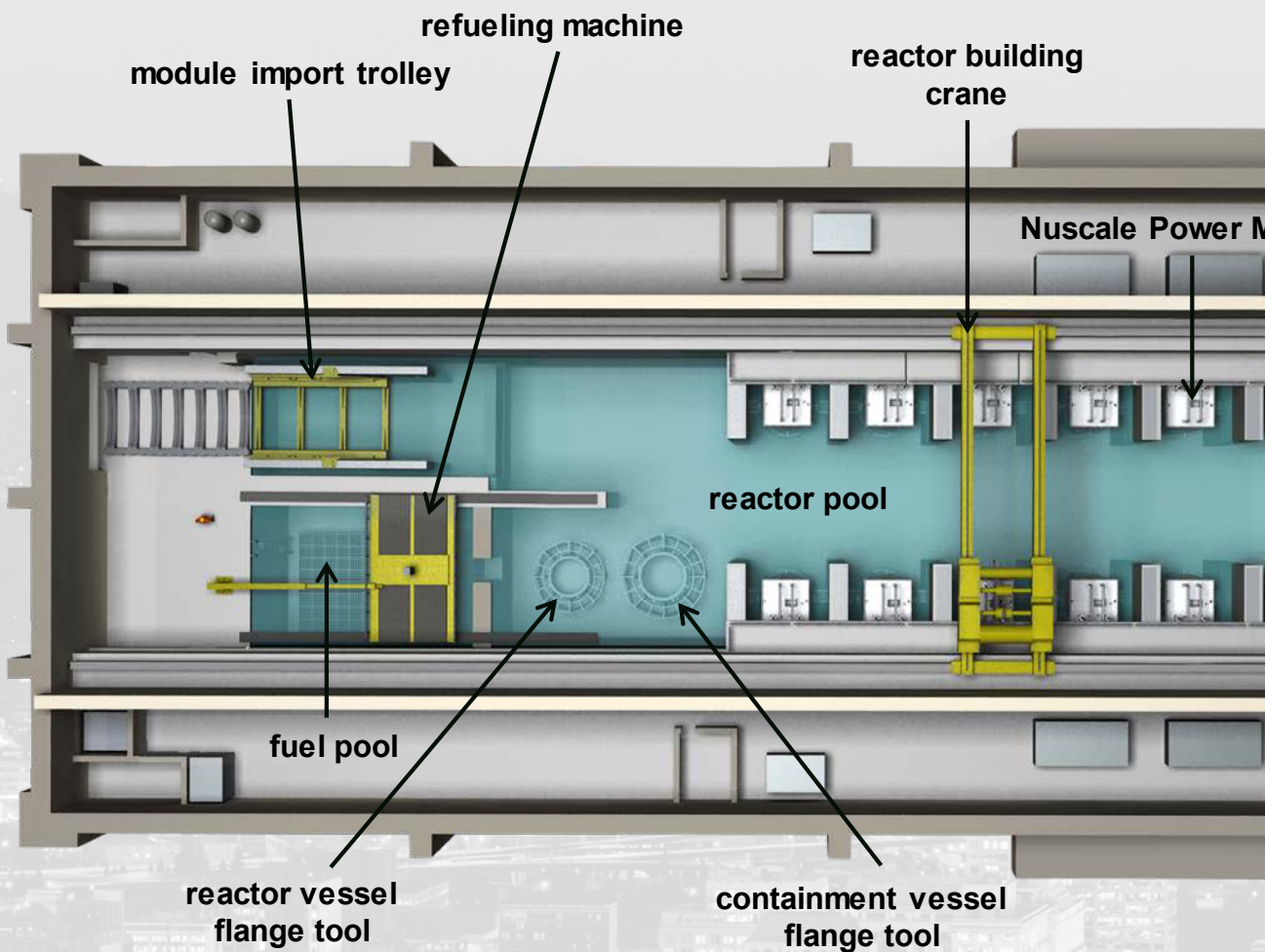


- Each module feeds a power train, eliminating the need for a central power plant
- 100% turbine by volume
- Small, simple components supported by straightforward manufacturing

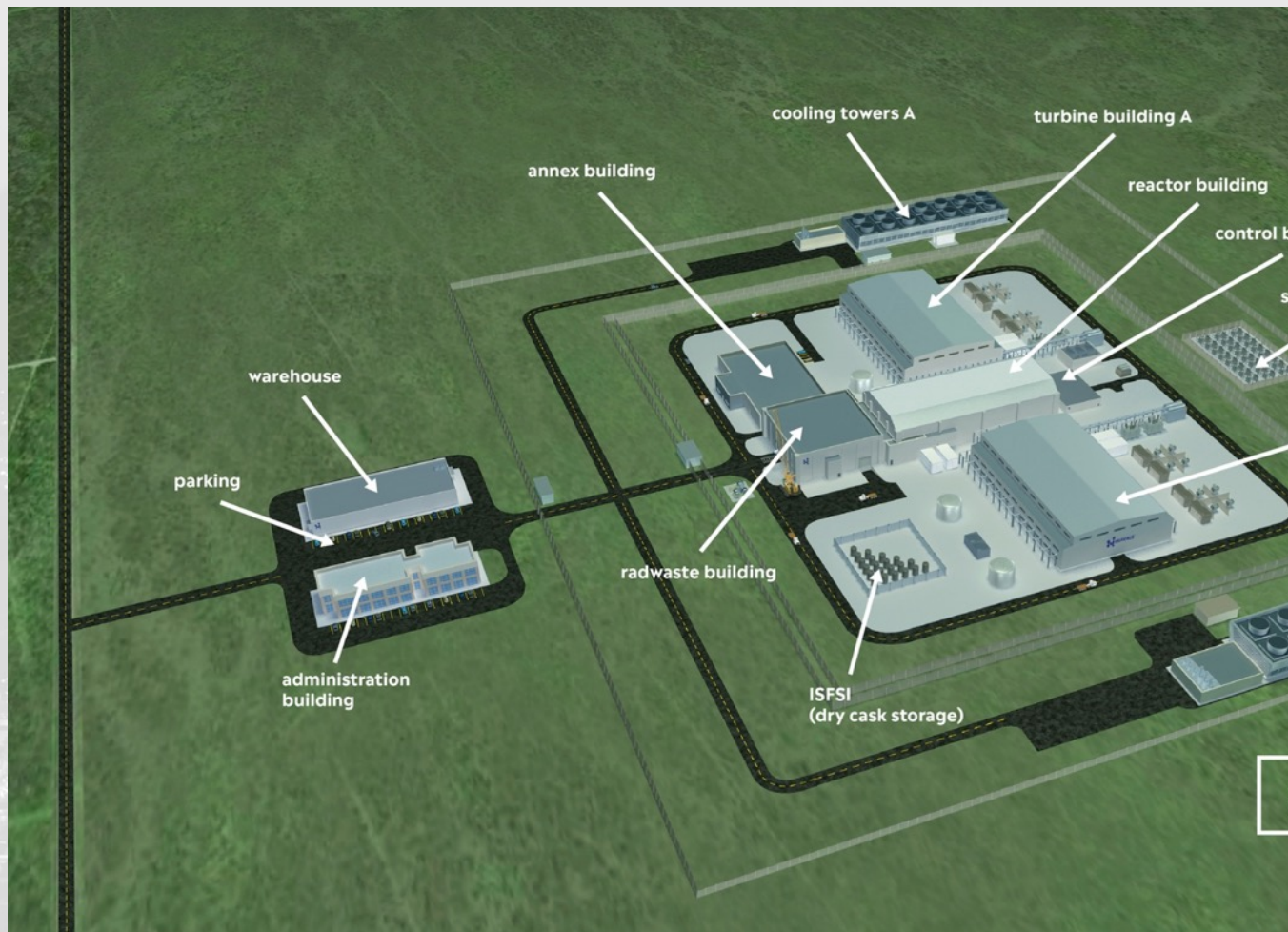
Reactor building houses NuScale Power Module, spent fuel pool, and reactor pool



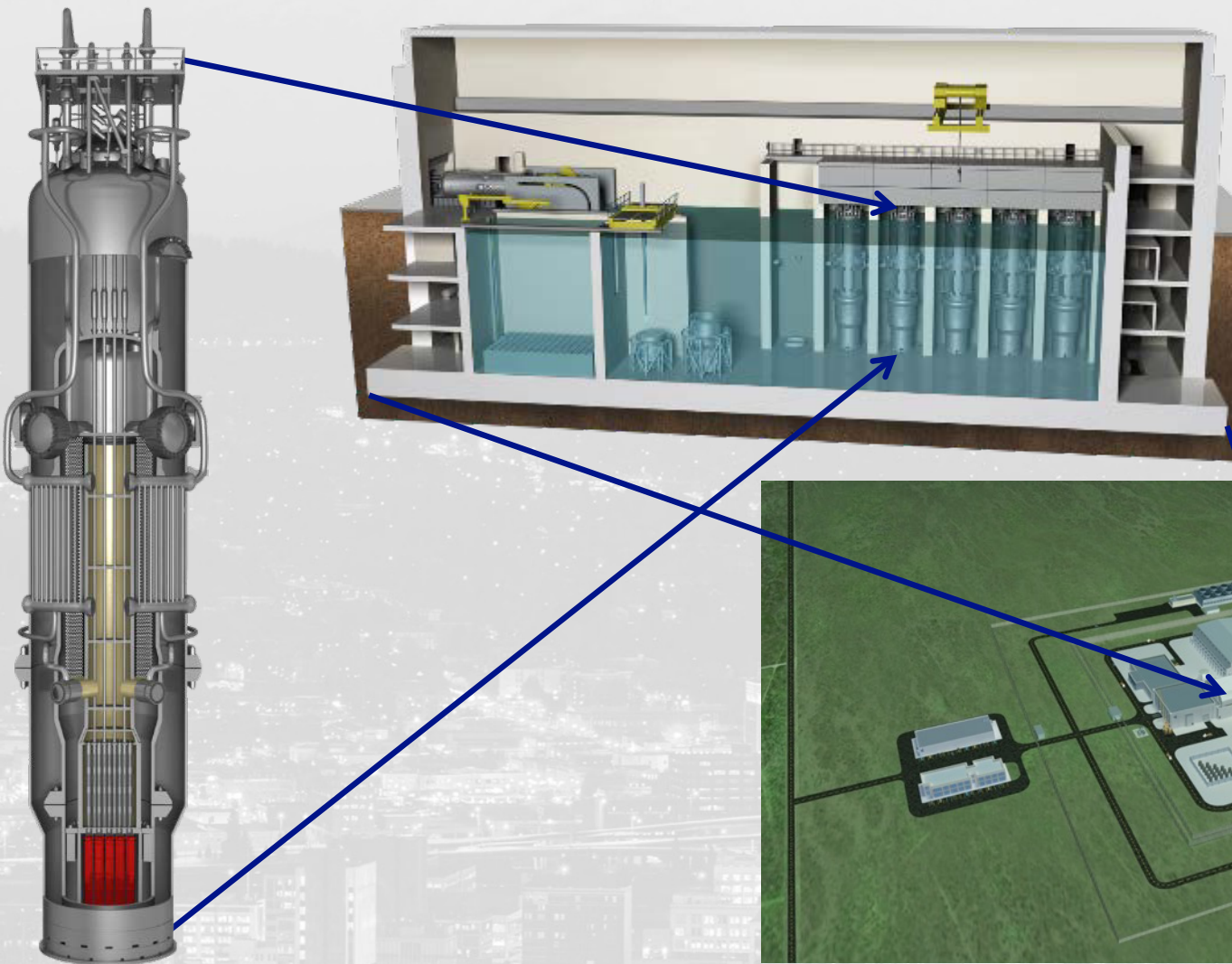
Reactor Building Overhead View



Detailed Plant Site Layout



NuScale Plant Site Overview

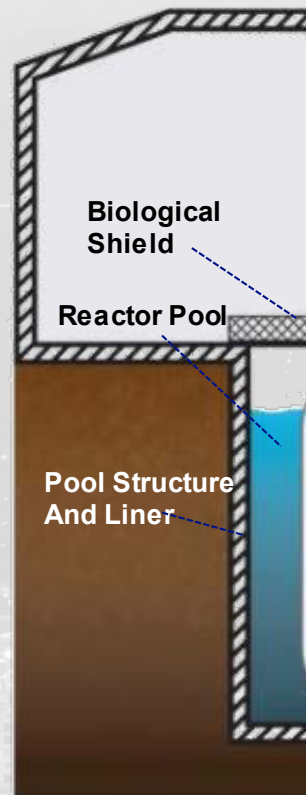
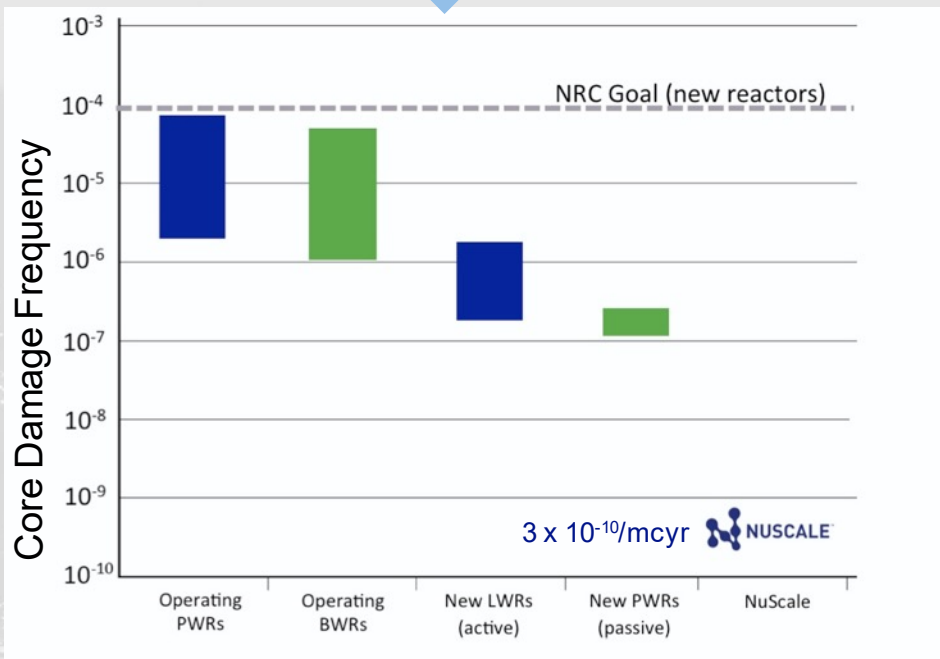


Reducing Plant Risk

Risk = (frequency of failure)

X

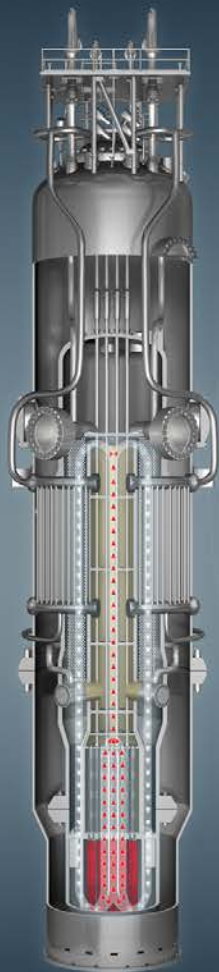
(consequence)



Probability of core damage (Full Power) due to NuScale reactor equipment failures is 1 event per module every ~3 Billion Years

Four additional radioactivity from

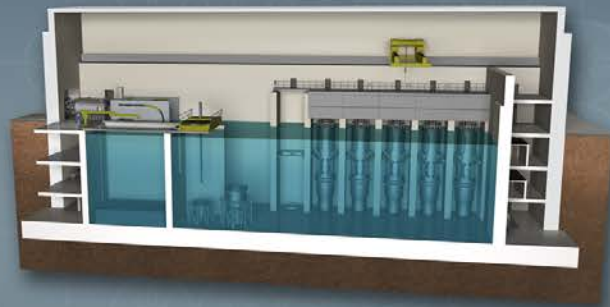
A New Approach to Construction and Operat



Factory
Fabrication



Low carbon, secure
electricity



Housed in a 12 module
reactor building



To the p

NuScale Power
Module™ including
containment and
reactor vessel



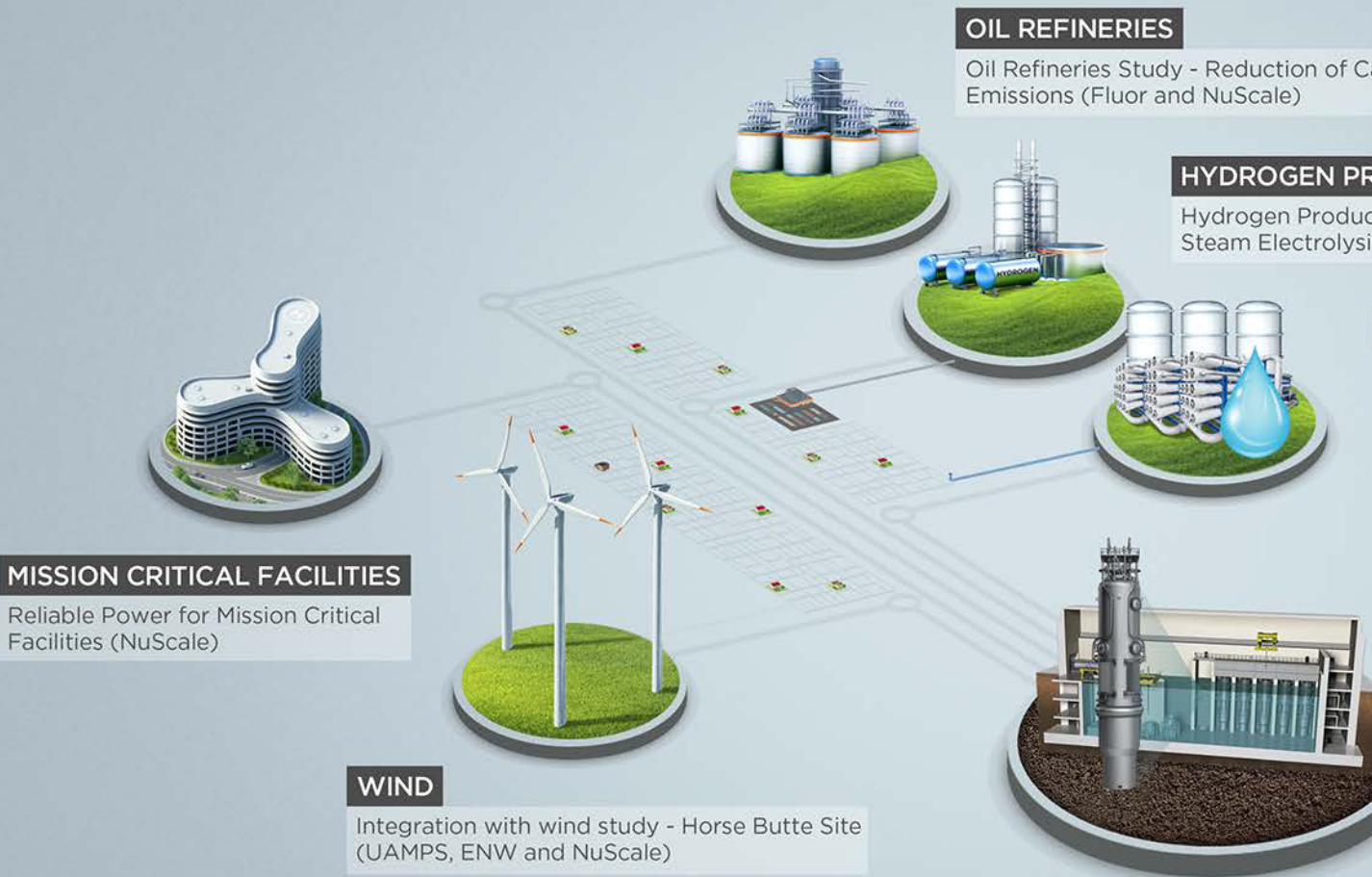
Shipped by truck,
rail or barge



Technology Variants

- **NuScale Integral System** testing at AREVA's INEL facility located at Oregon State University in Corvallis, Oregon
- **Critical Heat Flux** testing at AREVA's facility in Hamilton, Ontario Canada
- **Helical Coil Steam Generator** testing at AREVA's facility SpA in Piacenza, Italy
- **Fuels testing** at AREVA's facility in Richland, Washington
- **Critical Heat Flux** testing at AREVA's facility loop in Karlstein, Germany
- **Control Rod Assembly** testing at AREVA's facility alignment testing at AREVA's facility in Erlangen, Germany
- **Steam Generator** Flow testing at AREVA's facility in Erlangen, Germany
- **Control Rod Assembly** testing at AREVA's facility FIV at AREVA's facility in Le Creusot, France

Beyond Baseload: NuScale Diverse Energy



Reports for associated technical studies are available at: www.nuscalepower.com/technology/technical-publications

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A New Level of Plant Resiliency



Island Mode/Loss of Offsite Power

A single module can power the entire plant in case of loss of the grid; no operator or computer actions, AC/DC power or additional water required to keep the reactors safe



First Responder Power

On loss of the offsite grid, through variable (0% to 100%) steam bypass, all 12 modules can remain at power and be available to provide electricity to the grid as soon as the grid is restored



Resilience to Aircraft Impact

Reactor building is able to withstand aircraft impact as specified by the NRC aircraft impact rule



Cybersecurity

Module and plant protection systems are non-microprocessor based using field programmable gate arrays that do not use software and are therefore not vulnerable to internet cyber-attacks

Reliable Power for Mission Critical Facilities

UTILITY MACROGRID



- Connection to a micro-grid, island mode, and the ability for 100% turbine bypass at a (gross) NuScale plant to assure **120 MWe** and **99.95% reliability over a 60 year life**
 - 60 MWe at 99.98% availability
- Using highly robust power modules and a plant design can provide **clean, abundant, and reliable power** to customers
- Working with utilities and customers

**684 MWe (net)
> 95% Capacity**

NuScale 12-Module Plant



**DEDICATED
MICROGRID
120 MWe (net)
> 99.95%
Availability**

MISSION CRITICAL FACILITY





NuScale Micro-Re

10-50 MWe Micro-NuScale

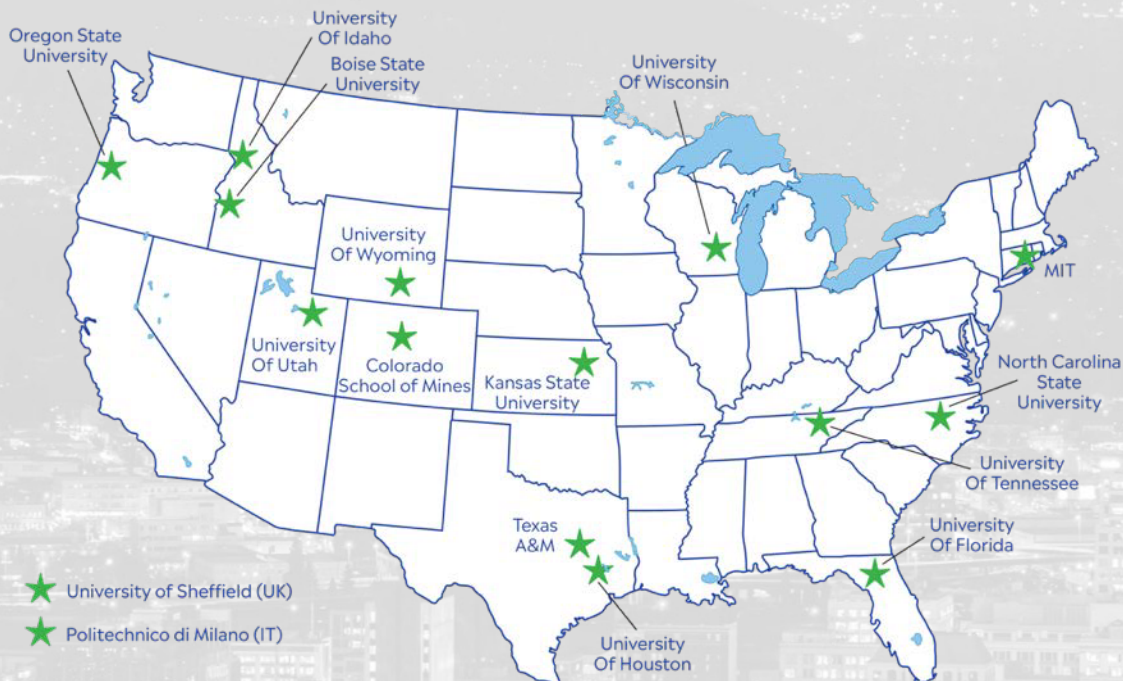
- **Builds on NuScale's existing**
 - Supplying power to commercial
 - Remote and off-grid communities
 - Off-grid industrial facilities
 - Long duration remote mining
 - Stationary / permanent markets
- **Design imperatives include:**
 - Reduced construction time
 - Simplified operations
 - Increased fuel cycle length

1-10 MWe Heat Pipe Reactor

- **Simple and inherently safe reactor concept** that requires rapid deployment, and are full power operation
- **Applications include:**
 - Remote small off-grid communities
 - Transportation delivery limited
 - Remote mining operations
 - Temporary power for disaster relief
 - Power in space

Research Collaborations

- Since 2012, NuScale Power staff has engaged in over 70 research collaborations with external organizations.
- **NuScale has collaborated on approximately \$34 million in external research from DOE-sponsored university and laboratory grants.**

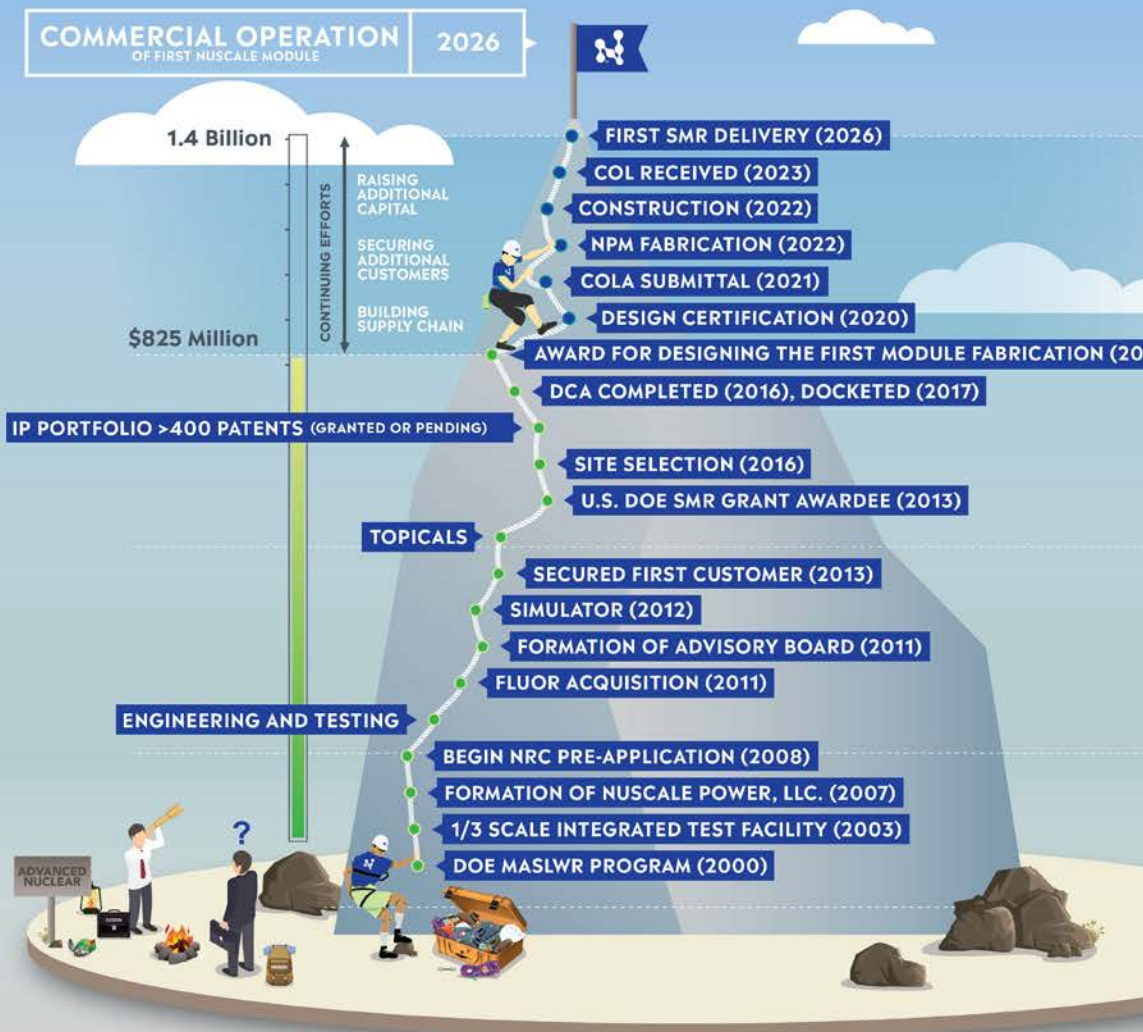


- Collaborations with different commercial laboratories
- International collaborations included research from the Czech Republic, Italy and the UK
- National laboratories have included Idaho (INL), LLNL, Oak Ridge, Pacific Northwest and Sandia (SNL)

Current Progress in Commercialization: Licensing, Supply Chain, and Customers

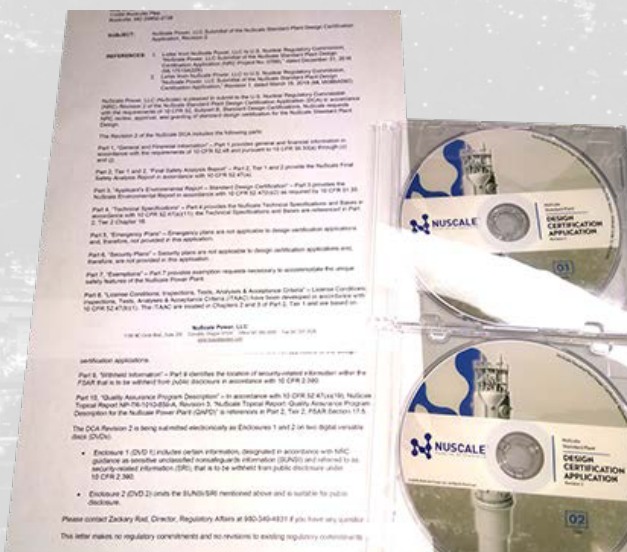


Blazing the Trail to Commercialization



First SMR to Undergo Licensing in the U.S.

- Design Certification Application (DCA) completed in December 2016
- Docketed and review commenced by U.S. Nuclear Regulatory Commission (NRC) in March 2017
- Phase 4 of the NRC review on schedule for completion December 2019. Technical review would be completed.
- NRC has published its review and approval schedule; **to be approved in September 2020**



DCA Statistics

- 12,000+ pages
- 14 Topical Reports
- >2 million labor hours
- >800 people
- >50 supplier/partners
- Over \$500M



Right-sizing the Planning Zone (EPZ)

- NuScale's small core size, inherent safety, defense-in-depth design, and compact footprint **reduced EPZ to the size of a city block**
 - NuScale plants could be sited in areas where population and industrial activity are high and energy is needed most
- **Tennessee Valley Authority (TVA) analysis is demonstrating that sites previously considered unsuitable are possible for SMRs**
 - TVA analysis included a 10-mile EPZ for the River early site permit and NuScale Plant design
 - Shows any accident risk would be limited to within the EPZ
 - Analysis provides basis for a 10-mile EPZ
 - NRC preliminary findings analysis that reduced EPZs are feasible

Reduced Operator Staffing

- **Integrated System Validation (ISV) completed using simulator**
 - Verifies the integrated system that supports safe operation (NUREG-0711)
 - Performance based evaluation of hardware, software, and personnel using trained and licensed operators
 - Operators trained similar to an operating plant license class
 - 12 full-scope, evaluated scenarios over 11 weeks
 - NRC audited ISV activities, no significant open items
 - Demonstrated reduced operator staffing model feasibility
- **Novel regulatory solution to overwrite 50.54(m) with Applicable Requirements certification appendix**





Factory Fabrication

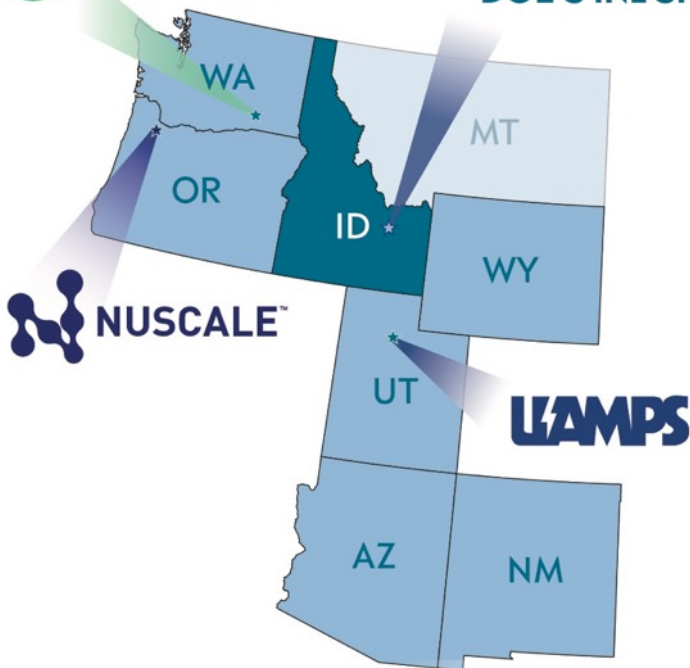
- NuScale Power Modules are produced in a factory and are designed to be installed in the reactor building.
- In 2018, **BWX Technologies** was selected to provide factory fabrication leading to fabricating the Power Modules™.
 - The decision follows a competitive process, with expressed interest from companies based in 10 countries.
 - BWXT and NuScale are working on design optimizing for manufacturing, transportation and reducing NPMs.
- In 2019, **Doosan Heavy Construction Co., Ltd.** signed an MOU for strategic support deployment of Power Modules™.
- Manufacturing trials are underway.

PROGRAM
WIN

Western Initiative for Nuclear

 ENERGY
NORTHWEST

DOE'S INL SITE



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First Deployment Carbon Free Power

- **Utah Associated Municipal Systems (UAMPS)** project to community-owned power throughout the Intermountain West.
- First deployment will be **(720 MWe)** within the Idaho National Laboratory (INL) site, scheduled for **operation in 2026**.
- DOE awarded \$63.3 million to perform site selection, water, and prepare construction license application to NRC for site specific design.
- **Joint Use Modular Plant** INL-DOE will lease one 12-module plant, for re-lease of additional module may be under Purchase Agreement (PPA) to INL.

Let's change the power that changes the world



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