



**NUSCALE**<sup>™</sup>  
Power for all humankind

## **NuScale Power – Design and Safety**

June 3, 2021

Presented to:

4th Virtual Annual Meeting on ASEAN  
Network on Nuclear Power Safety  
Research

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# NuScale’s Mission

NuScale Power provides scalable advanced nuclear technology for the production of electricity, heat, and clean water to improve the quality of life for people around the world.

We will achieve this mission by providing technology that is:



SMARTER



CLEANER



SAFER, and



COST COMPETITIVE

## 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 was 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
- 2013 - NuScale won a competitive U.S. DOE Funding Opportunity for matching funds, and has been awarded over \$300M in DOE funding since then.
- >400 employees in 5 offices in the U.S. and 1 office in the U.K.
- Total investment in NuScale to date is greater than (US) \$1B. Over 560 patents granted or pending in 20 countries; ASME N-Stamp.
- First project in Idaho (2029 COD); MOU's with several potential customers worldwide.
  - Potential projects being pursued in U.S., UK, Canada, eastern Europe, Middle East, southeast Asia, and Africa.



*NuScale Engineering Offices Corvallis*



*One-third scale NIST-1 Test Facility*



*NuScale Control Room Simulator*

# 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.
- NuScale received standard design approval in September 2020.
- Final rule publication date: March 22, 2022

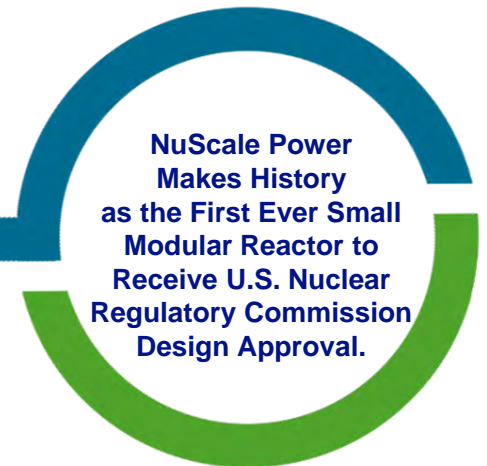


## DCA Statistics

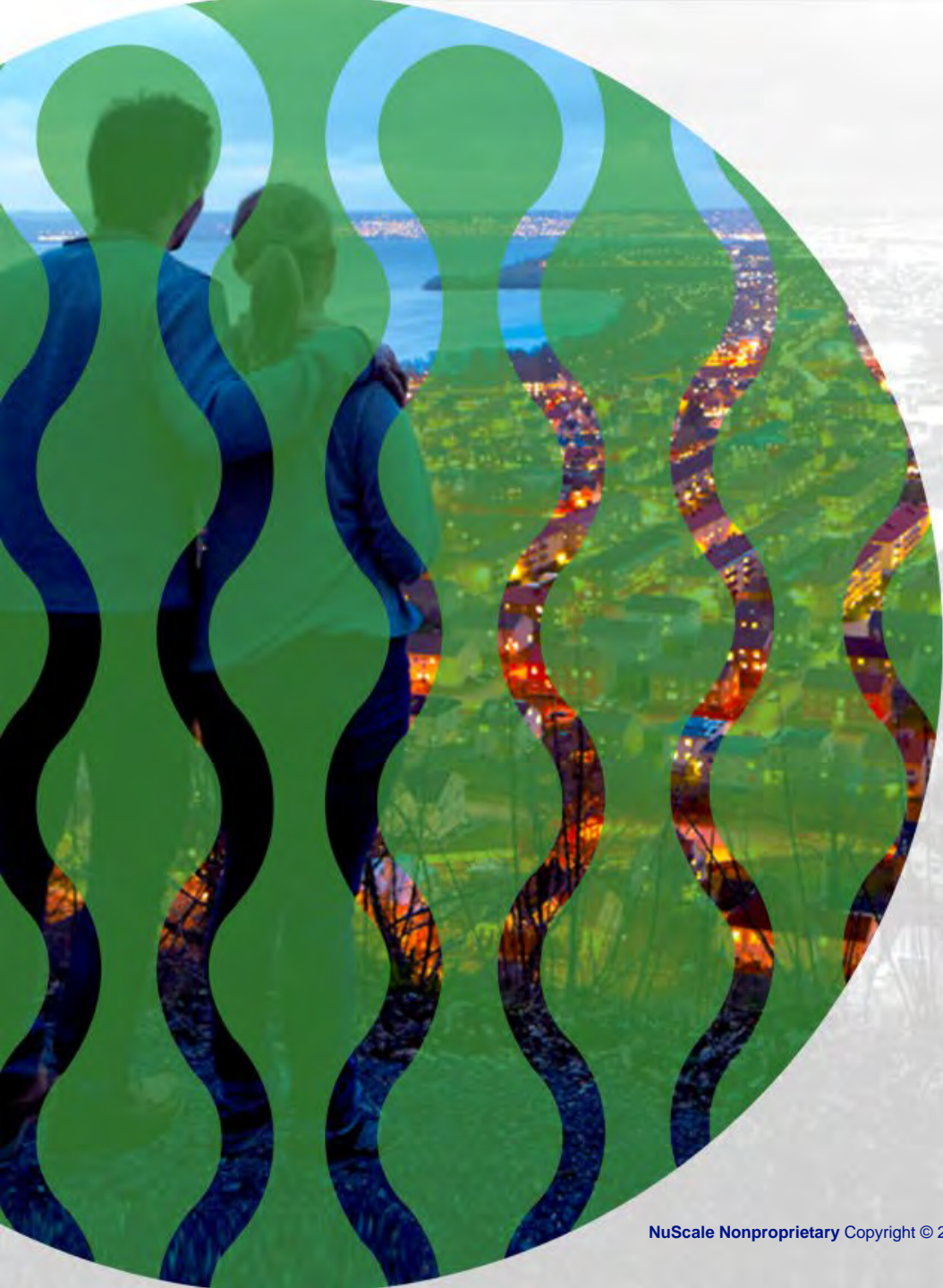
- 12,000+ pages
- >2 million labor hours
- >50 supplier/partners
- 14 Topical Reports
- >800 people
- Over \$500M

## DCA Review Statistics

- 42 month review
- ~2 Million pages of supporting information
- > \$70M in NRC fees
- > \$200M NuScale in-house costs

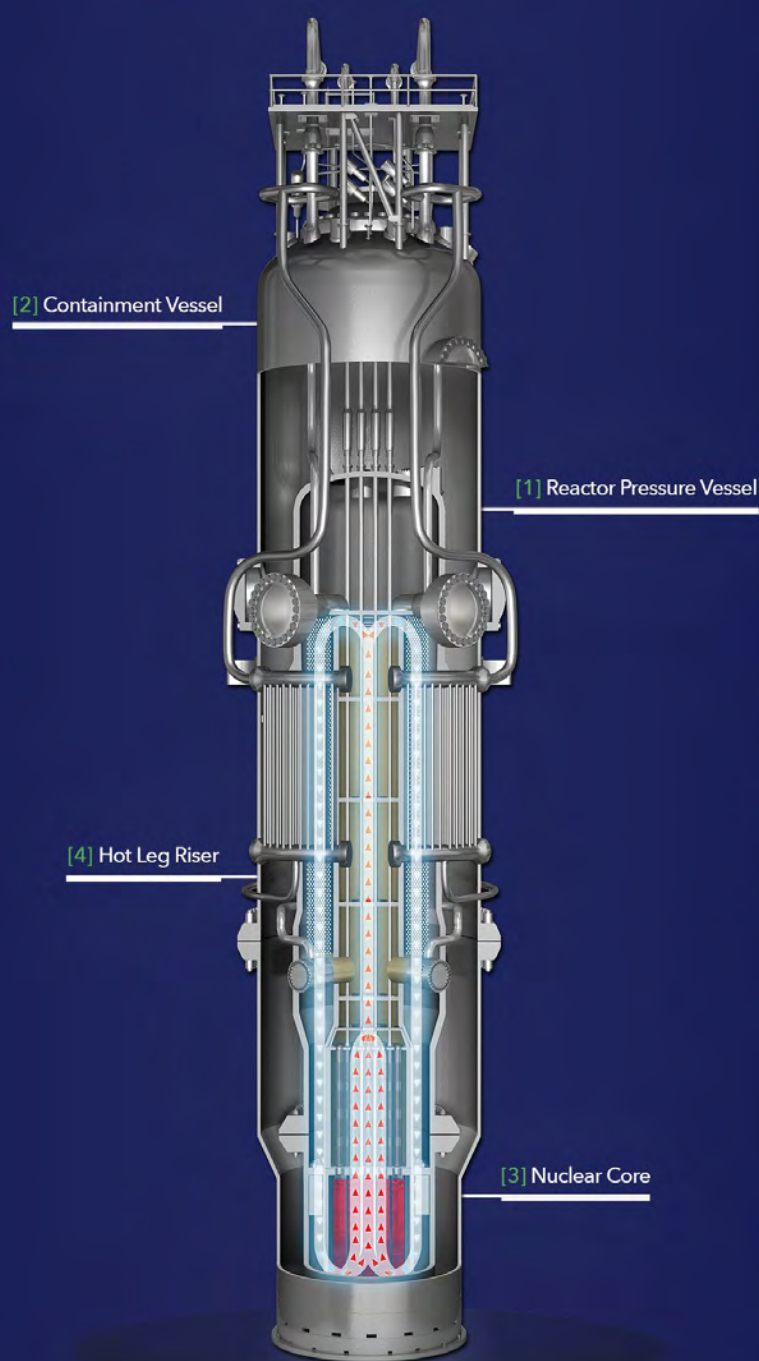


**NuScale Power  
Makes History  
as the First Ever Small  
Modular Reactor to  
Receive U.S. Nuclear  
Regulatory Commission  
Design Approval.**



# SMARTER

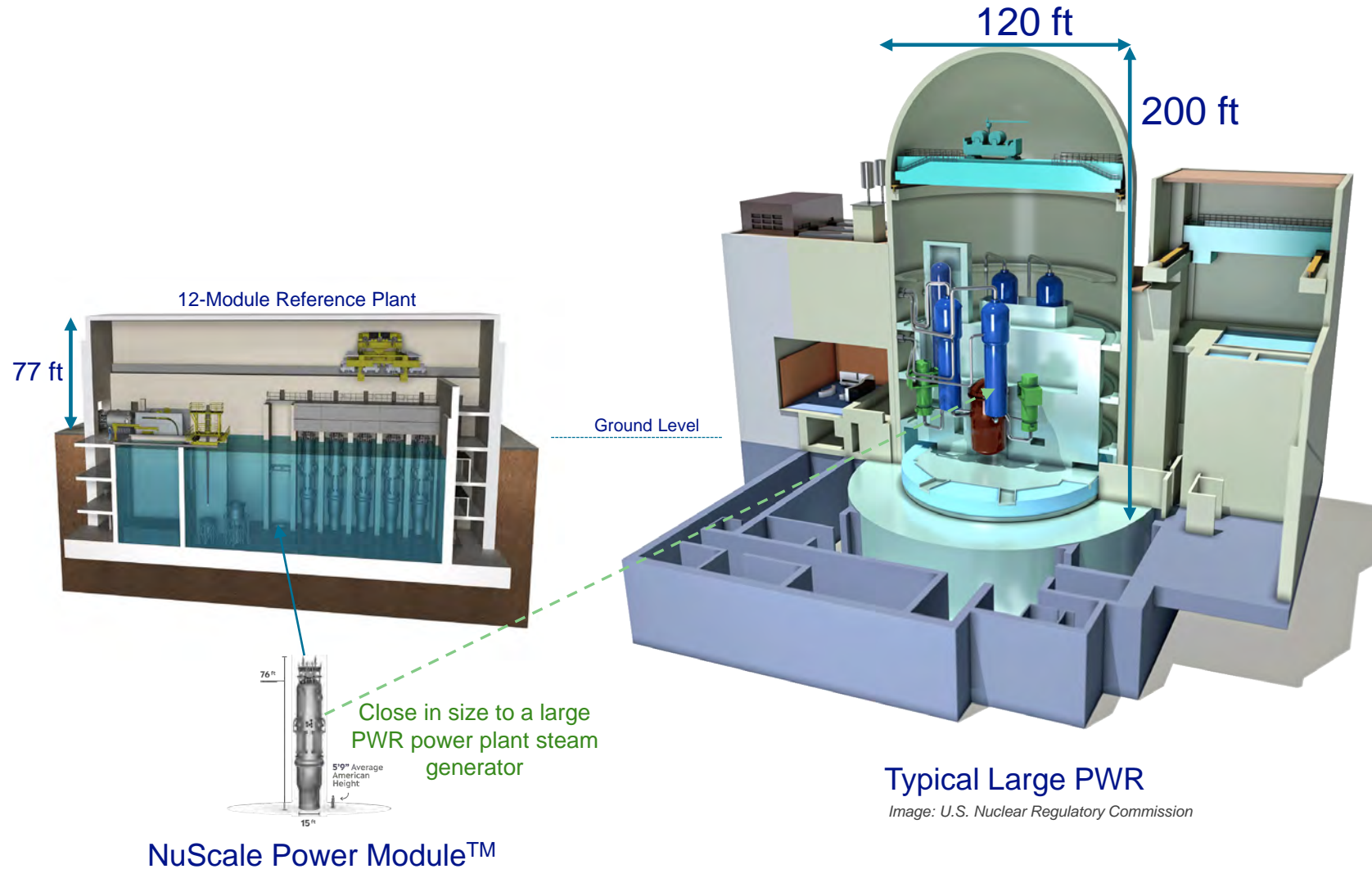
*Ingenuity is Powering the Future*



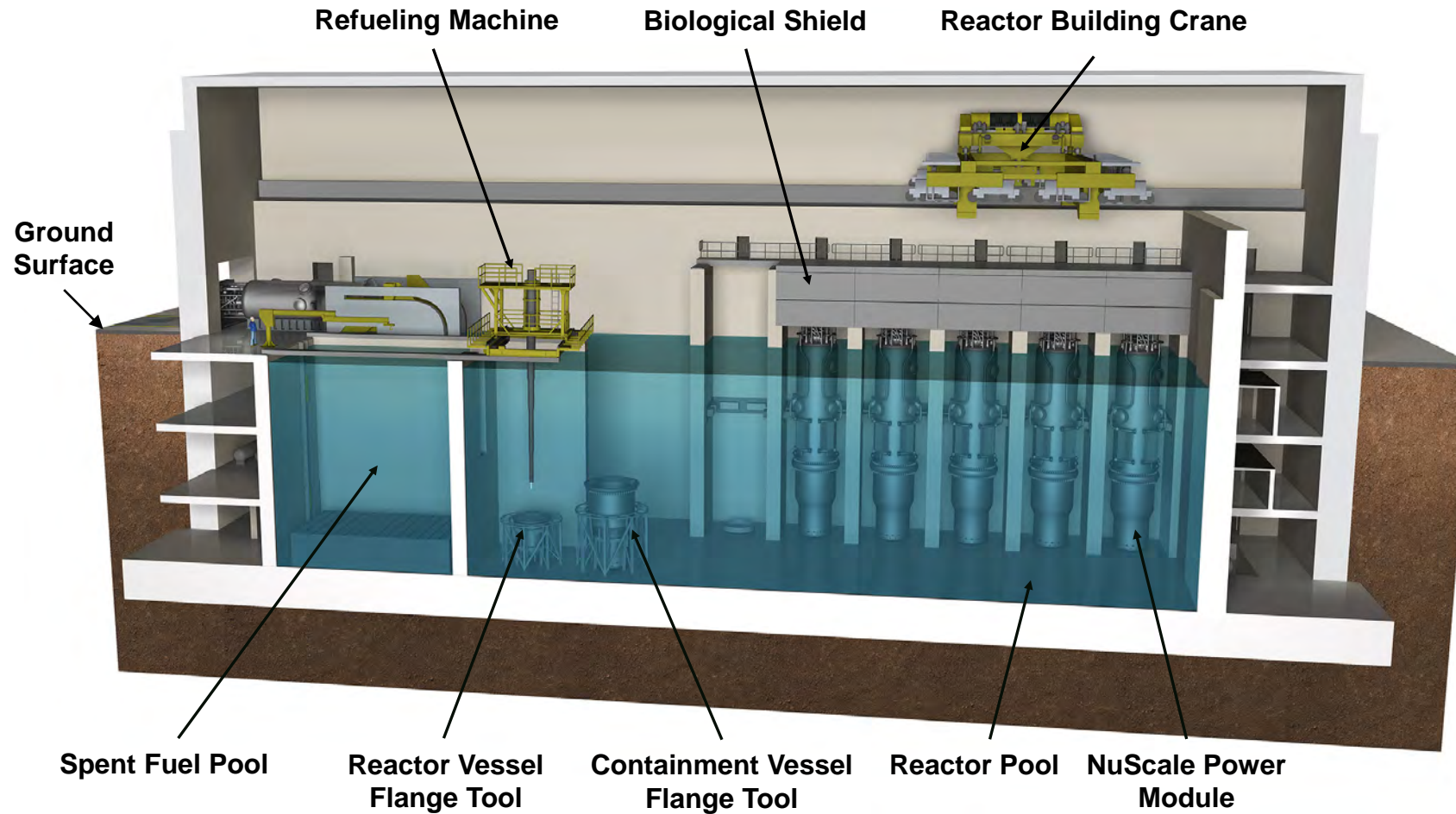
## Core Technology: NuScale Power Module

- A NuScale Power Module™ (NPM) includes the reactor vessel, steam generators, pressurizer, and containment in an integral package
- Simple design that eliminates reactor coolant pumps, large bore piping and other systems and components found in large conventional reactors
- Each module produces up to 77 MWe
  - Small enough to be factory built for easy transport and installation
  - Dedicated power conversion system for flexible, independent operation
  - Incrementally added to match load growth
  - 12 module plant – up to 924 MWe gross
  - 6 module plant – up to 462 MWe gross
  - 4 module plant – up to 308 MWe gross

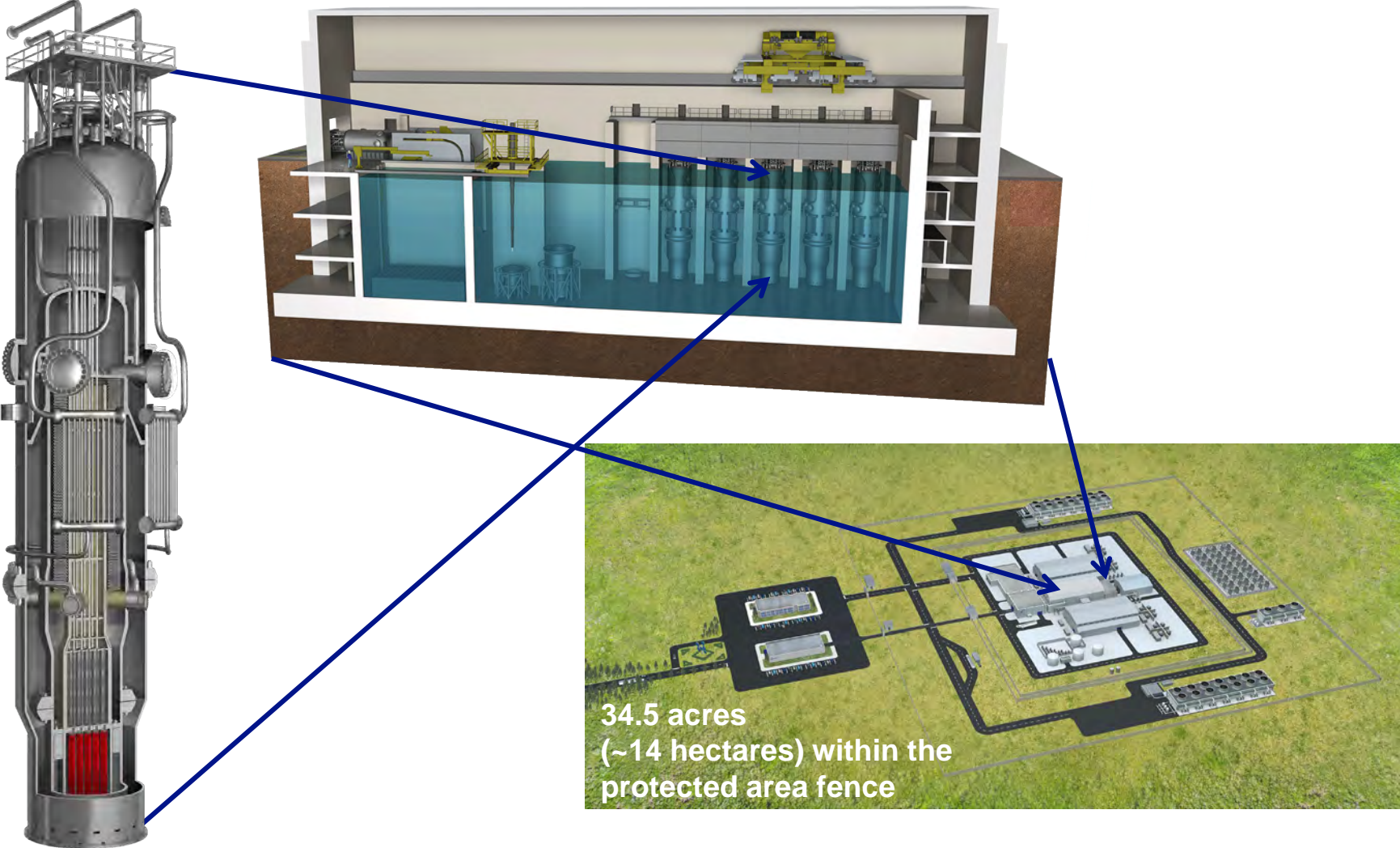
# Comparison to a Large Pressurized Water Reactor (PWR)



# Reactor Building Houses NuScale Power Modules™, Spent Fuel Pool, and Reactor Pool

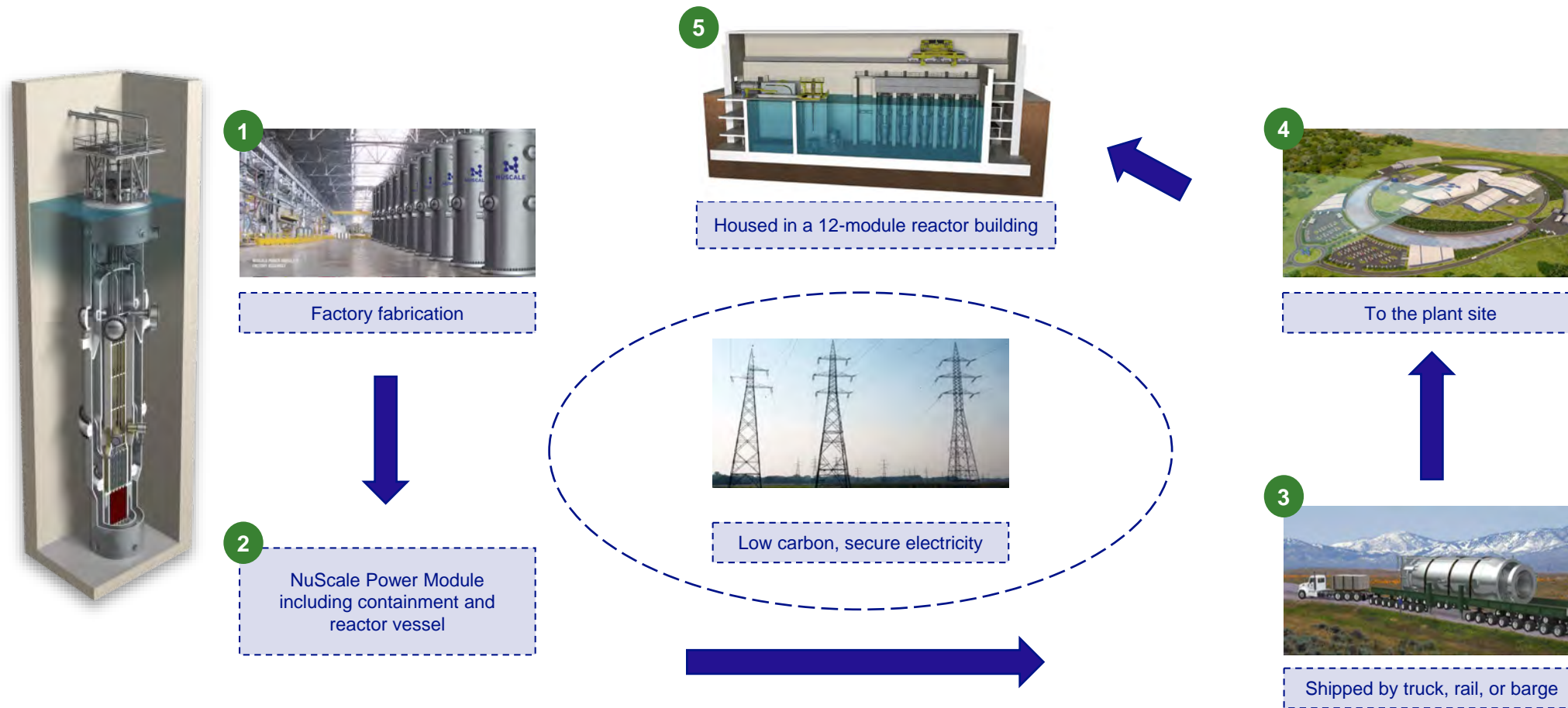


# NuScale Plant Site Overview



# A New Approach to Construction and Operation

NuScale has revolutionized the nuclear supply chain with modular manufacturing of NPM units in-house that are shipped to sites





# CLEANER

*100% Carbon-Free Energy and Heat*

## Helping Utilities Meet Clean Energy Goals

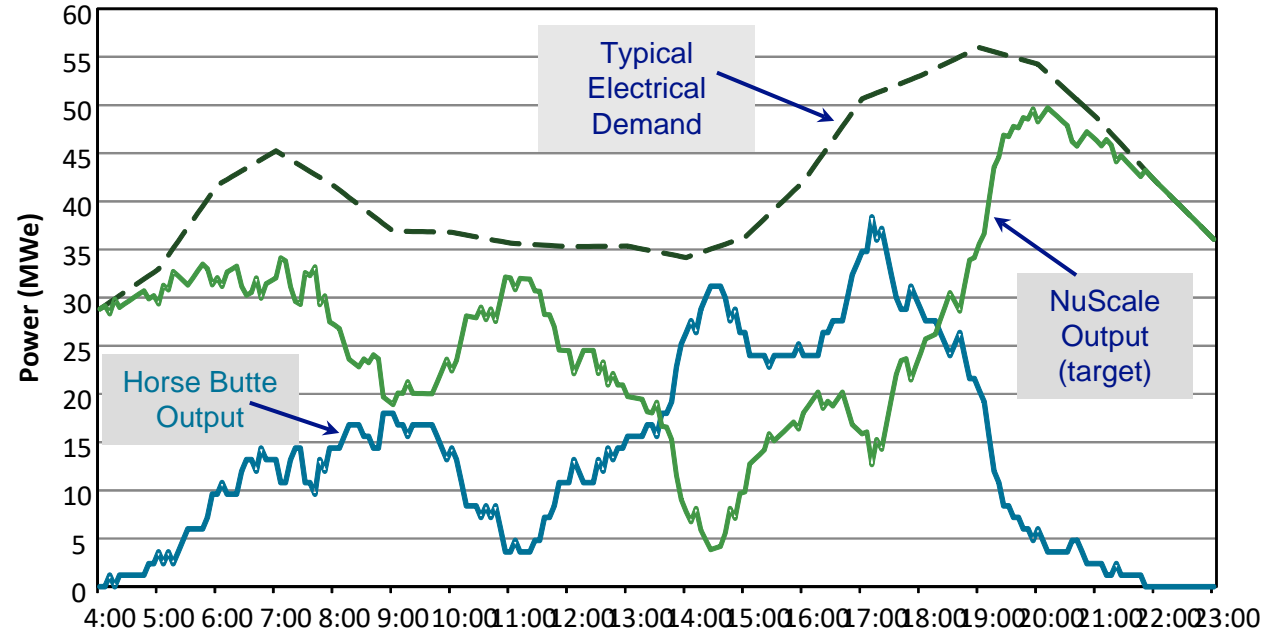
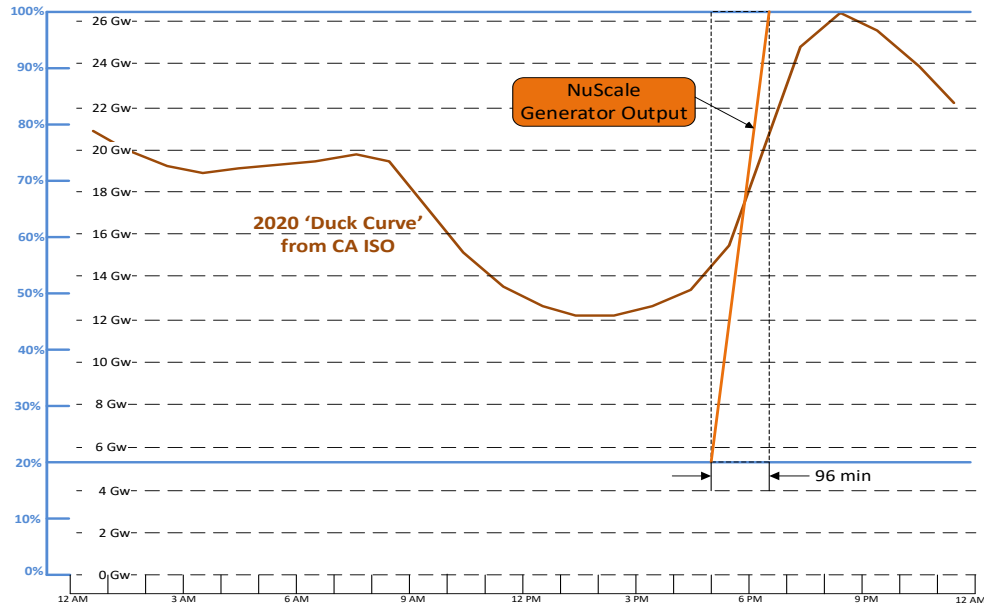
- Providing carbon-free flexible power to balance the grid allowing increased penetration of renewable power such as wind and solar.
- Providing highly reliable, scalable, and cost-effective carbon-free power for repurposing fossil-fuel power plants and retaining personnel.

When energy sources are evaluated over their entire life cycle, from mining of materials and fuel, to construction, and eventual D&D and waste storage - nuclear energy has a carbon footprint lower than solar PV and about the same as wind.



**NUSCALE™**

# Integrating Renewables: Load Follow Strategies



NuScale plant is designed to work with renewables, including being able to ramp up power quickly enough to meet high evening demand when solar ramps down.

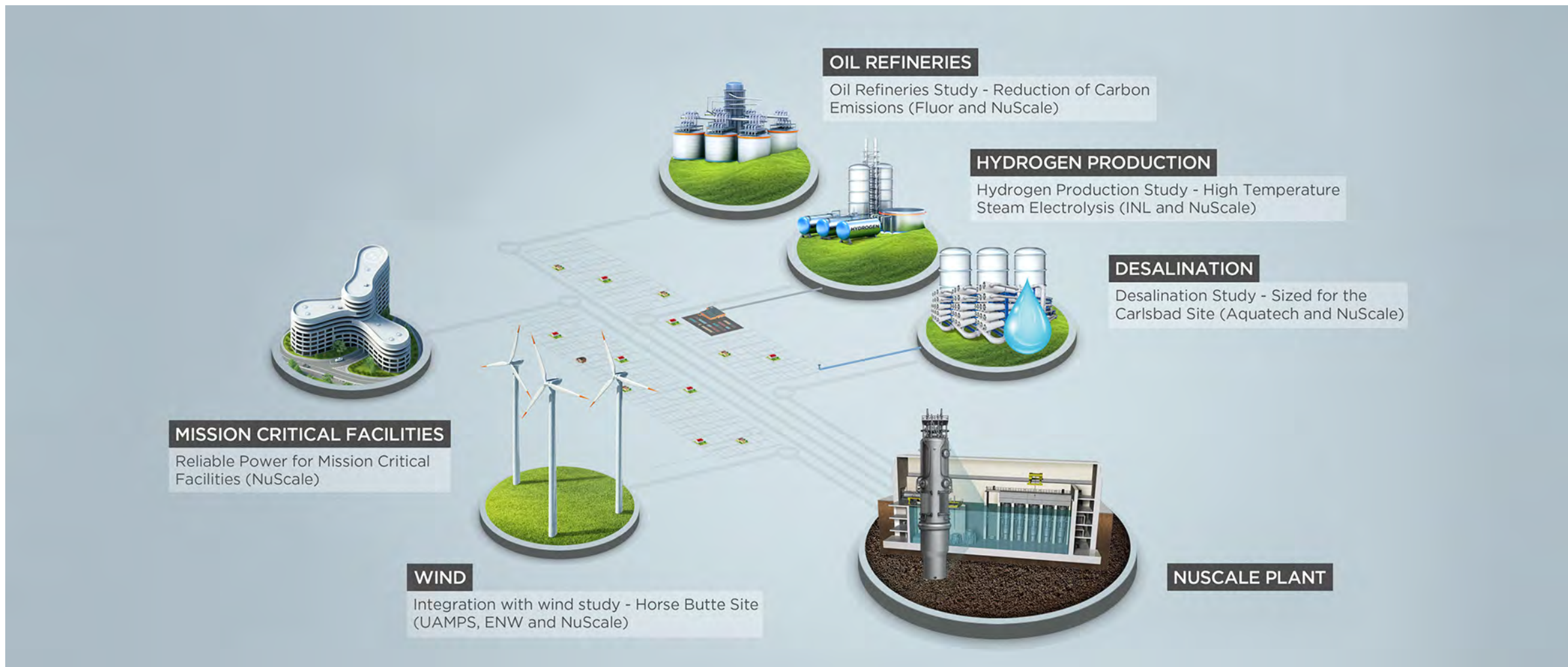
NuScale design meets or exceeds EPRI Utility Requirements Document (URD), Rev. 13, load following and other ancillary service requirements.

# Repurposing Coal Power Plant Sites



- A NuScale plant can be built on an existing coal power plant site
  - 12-module NuScale plant has a small land footprint of around 30 acres
- Some coal plant infrastructure can be repurposed and reused, such as:
  - Cooling water delivery systems, demineralized water, potable water, site fire protection, switchyard, and buildings (e.g., administrative, training, warehouse)
- Capital cost savings could be approximately \$100M depending on site
- Preservation of local tax base; continued economic benefit to community

# Beyond Baseload Electricity



Reports for associated technical studies are available at: [www.nuscalepower.com/technology/technical-publications](http://www.nuscalepower.com/technology/technical-publications)

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## Cost-Competitive, Carbon-Free Hydrogen Production

- Hydrogen has the capability to help decarbonize both the electricity and transportation sectors by being used for energy storage or as a fuel for hydrogen fuel-cell vehicles, trains, ships, and airplanes.
- Most hydrogen today is produced by fossil fuels and is not carbon-free.
- NuScale's innovative technology is ideal for producing clean hydrogen in a cost-competitive manner:
  - A single NuScale module can produce 2,053 kg/hour of hydrogen, or **50 tons/day** – enough hydrogen to power 38,000 fuel cell vehicles or 1,500 long-haul fuel cell trucks annually
  - Hydrogen produced by a high temperature steam electrolysis system using heat and electricity from a NuScale module is forecasted to be **cost competitive with green hydrogen** (produced from renewable electricity)



# SAFER

*Safety First, Second to None*

# 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

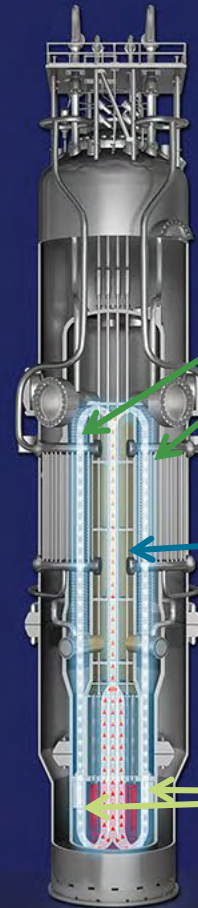
- System submerged in a below-grade pool of water in an earthquake and aircraft impact resistant building.

## 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** – the water heated by the nuclear reaction (primary water) transfers its heat through the walls of the tubes in the steam generator, heating the water inside the tubes (secondary water) and turning it to steam. This heat transfer cools the primary water.

**Convection** – energy from the nuclear reaction heats the primary water causing it to rise by convection and buoyancy through the riser, much like a chimney effect.

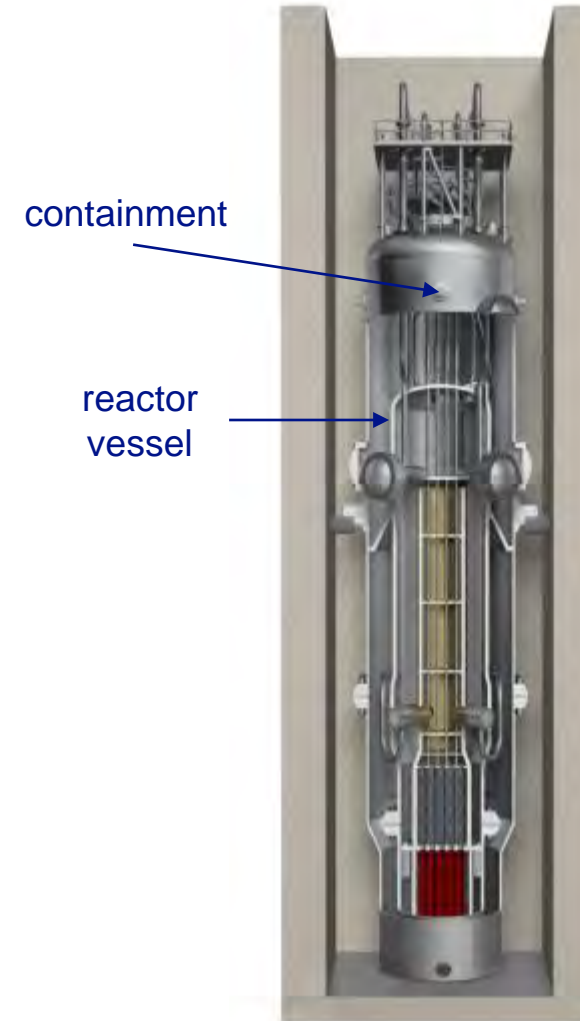
**Gravity / Buoyancy** – colder (denser) primary water “falls” to bottom of reactor pressure vessel, and the natural circulation cycle continues.

**Second-to-none safety case – site boundary Emergency Planning Zone capable**

# Containment Design

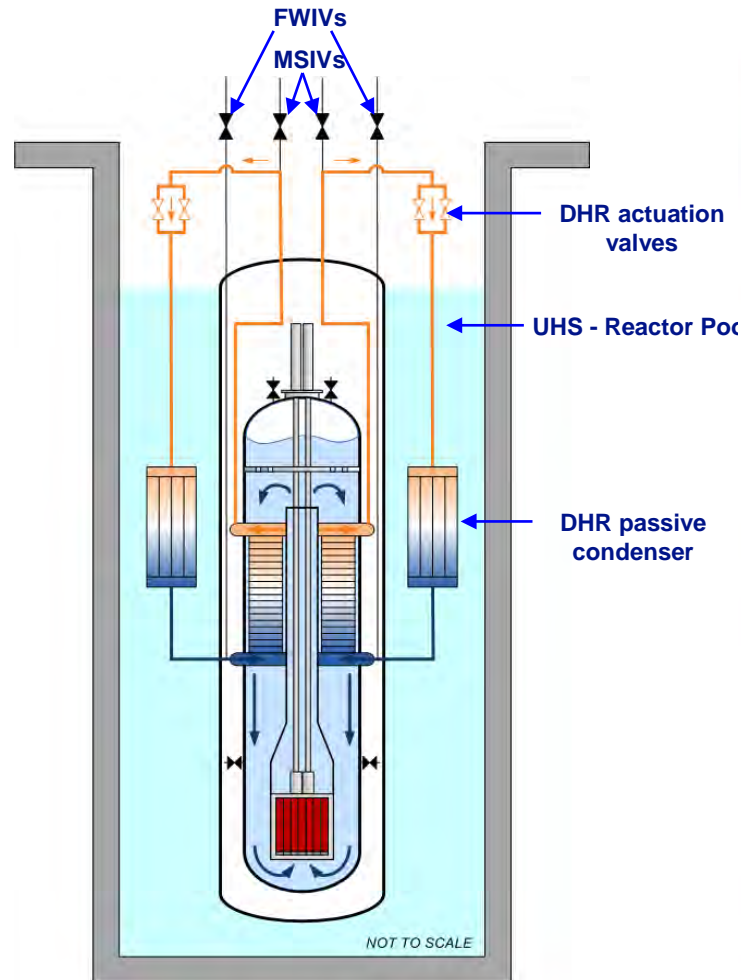
## Evacuated Containment—Enhanced Safety

- **Containment volume sized so that core does not uncover following a LOCA**
- **Large reactor pool keeps containment shell cool and promotes efficient post-LOCA steam condensation**
- **Insulating vacuum**
  - Significantly reduces convection heat transfer during normal operation
  - Eliminates requirement for insulation on the reactor vessel, thereby minimizing sump screen blockage concerns (GSI-191)
  - Improves LOCA steam condensation rates by eliminating air
  - Prevents combustible hydrogen mixture in the unlikely event of a severe accident (i.e., little or no oxygen)
  - Reduces corrosion and humidity problems inside containment



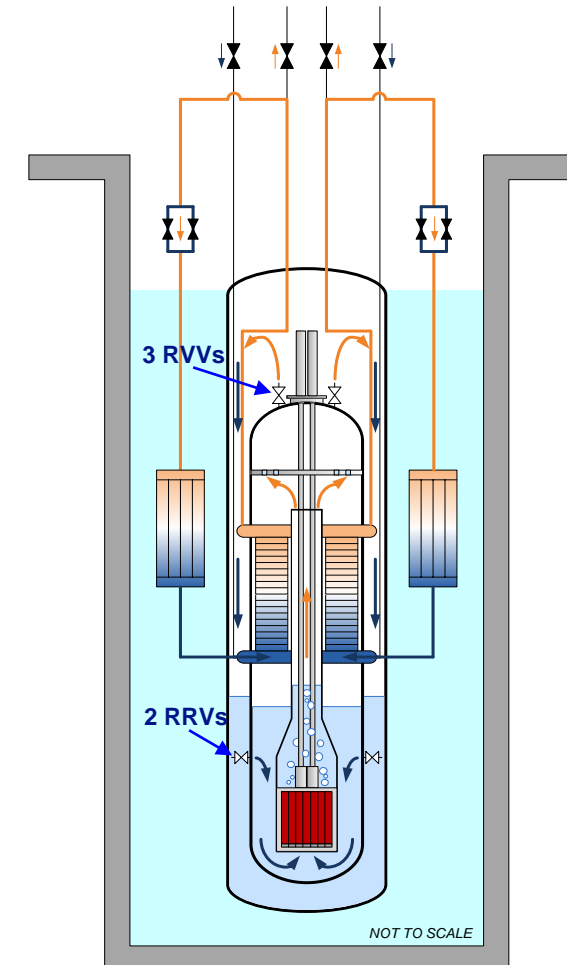
# Decay Heat Removal System

- **Two, 100% redundant trains of DHRs per NuScale Power Module.**
  - Each train has an independent heat exchanger.
  - Each train has two DHRs Actuation Valves.
  - Operation of only one valve, in only one of the trains is sufficient to remove all core decay heat.
- **DHRs Actuation Valves**
  - No electrical power required to open the valves.
  - Automatically opened by:
    - An actuation signal, or
    - Loss of power to the valve



## Emergency Core Cooling System (ECCS)

- During ECCS operation, reactor coolant is vented as steam into containment through the Reactor Vent Valves (RVVs).
- Because the containment is in direct contact with the UHS, the steam condenses on the inside surface of the containment vessel.
- The condensate collects in containment and flows back into the RPV through the Reactor Recirculation Valves (RRVs).
- The condensate is then heated again by the core to produce steam that is once again vented through the RVVs. This is a closed boiling-condensing cycle.

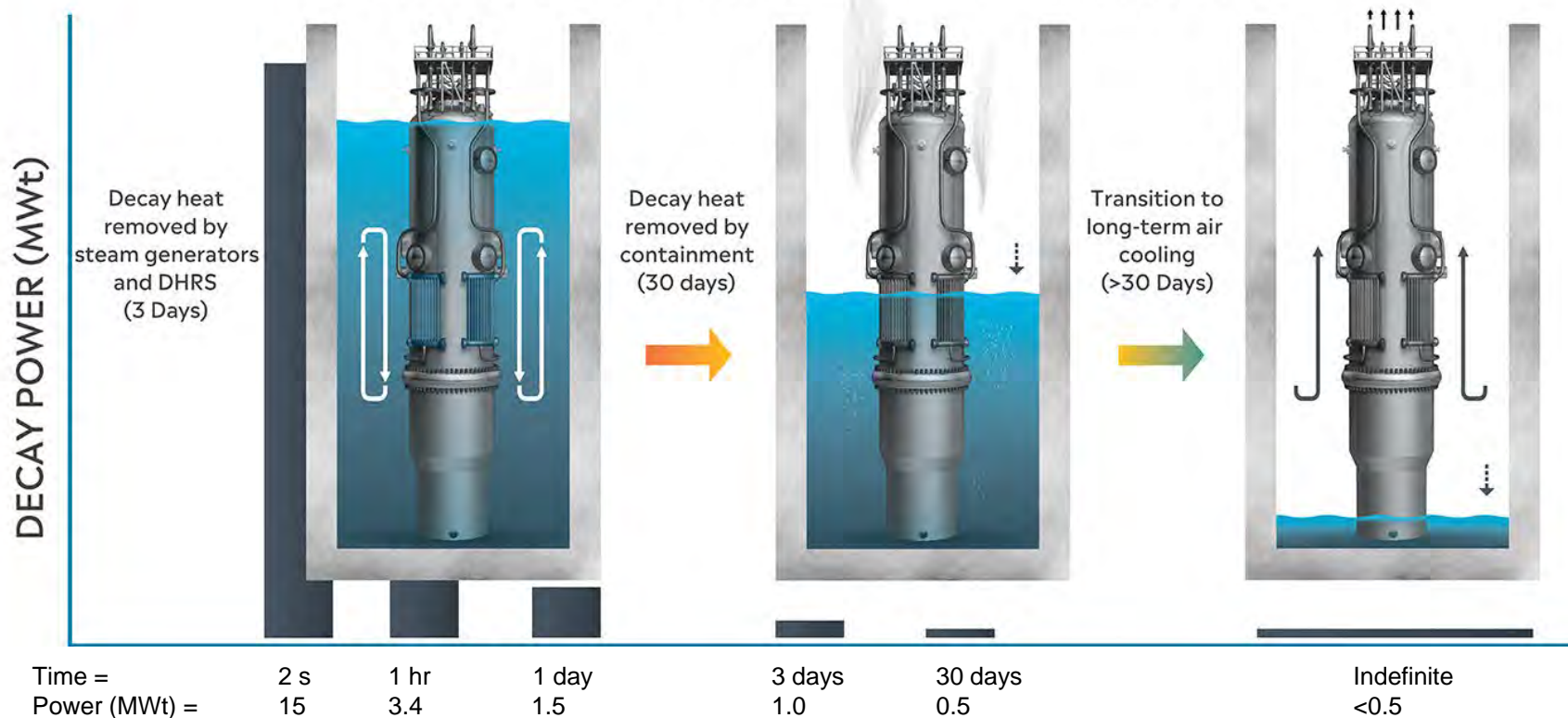


# Innovative Advancements to Reactor Safety

*Nuclear fuel cooled indefinitely without AC or DC power\**



• No Pumps • No External Power • No External Water



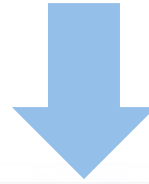
\*Alternate 1E power system design eliminates the need for 1E qualified batteries to perform ESFAS protective functions – Patent Pending

## PRA Models Maintained with Design

- PRA in development for ~6 years
- ~ 20 staff, includes severe accident analyses
- Modeling done using SAPHIRE and MELCOR (and NRELAP5)
- PRA models periodically updated to reflect design changes
  - Approximately two or three times per year
- All operating modes and all hazards
  - full-power internal-events
  - low-power/shutdown
  - internal fire
  - internal flood
  - high winds and hurricanes
  - seismic
  - other external events

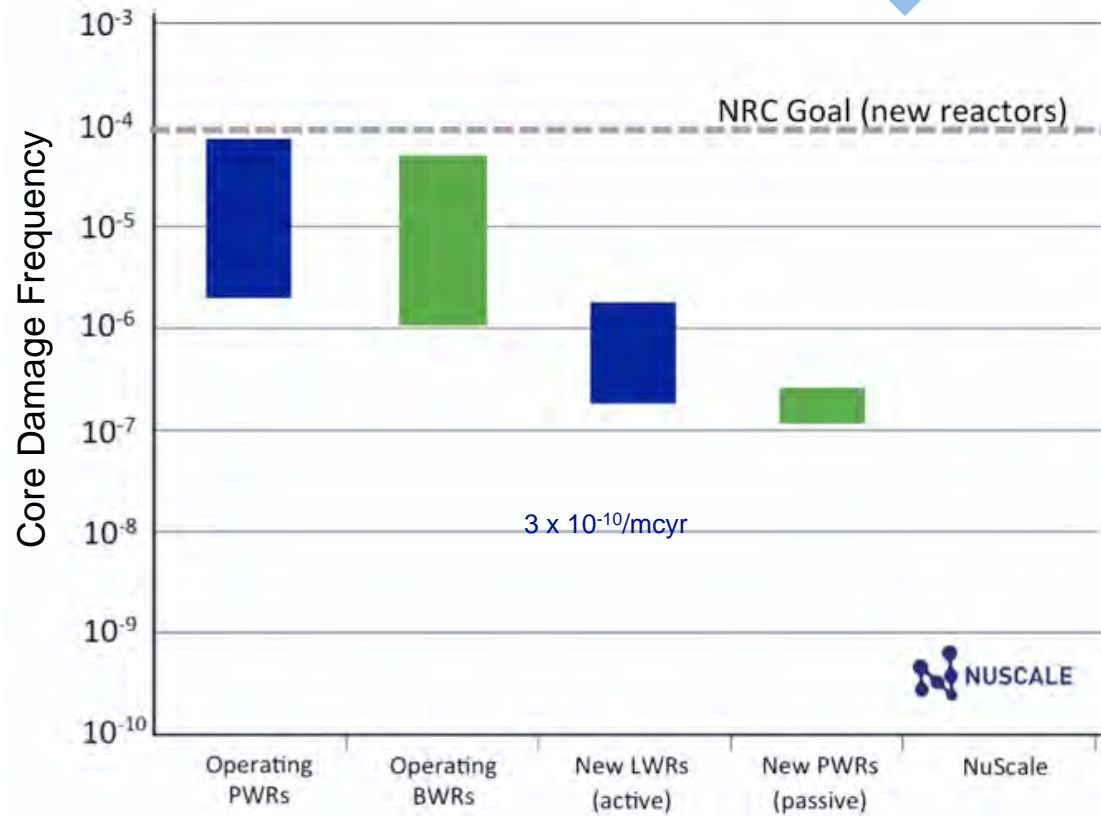
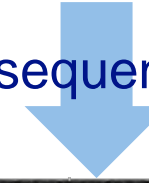
# Reducing Plant Risk

**Risk = (frequency of failure)**

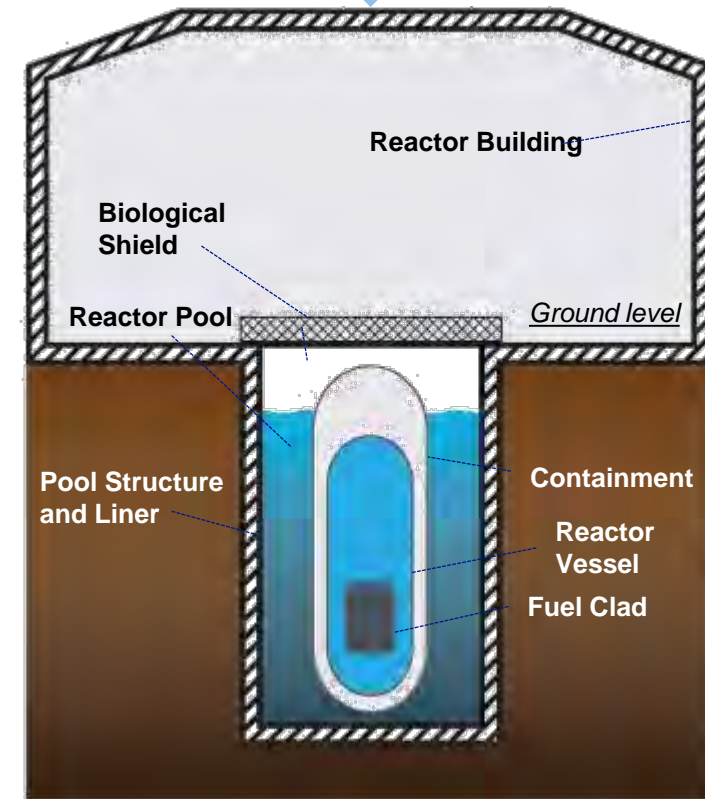


X

**(consequences)**



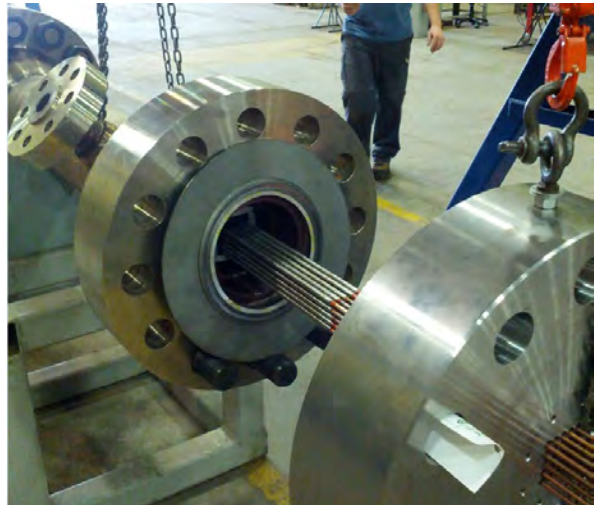
*Probability of core damage (full power, internal events) due to NuScale reactor equipment failures is 1 event per module every ~3 Billion Years.*



*Four additional barriers to release of radioactivity from a NuScale plant.*

## Technology Validation

- NuScale Integral System Test (NIST-1) facility located at Oregon State University in Corvallis, Oregon
- Critical Heat Flux testing at Stern Laboratories in Hamilton, Ontario Canada
- Helical Coil Steam Generator testing at SIET SpA in Piacenza, Italy
- Fuels Mechanical Testing at AREVA's Richland Test Facility (RTF) in Richland, WA, USA
- Critical Heat Flux testing at AREVA's KATHY loop in Karlstein, Germany
- Control Rod Assembly (CRA) drop / shaft alignment testing at AREVA's KOPRA facility in Erlangen, Germany
- Steam Generator Flow Induced Vibration (FIV) testing at SIET SpA in Piacenza, Italy
- Steam Generator Inlet Flow Restrictor Test at Alden Laboratory, Holden, MA, USA
- ECCS Valve Proof of Concept and Demonstration Tests, Target Rock, NY, USA

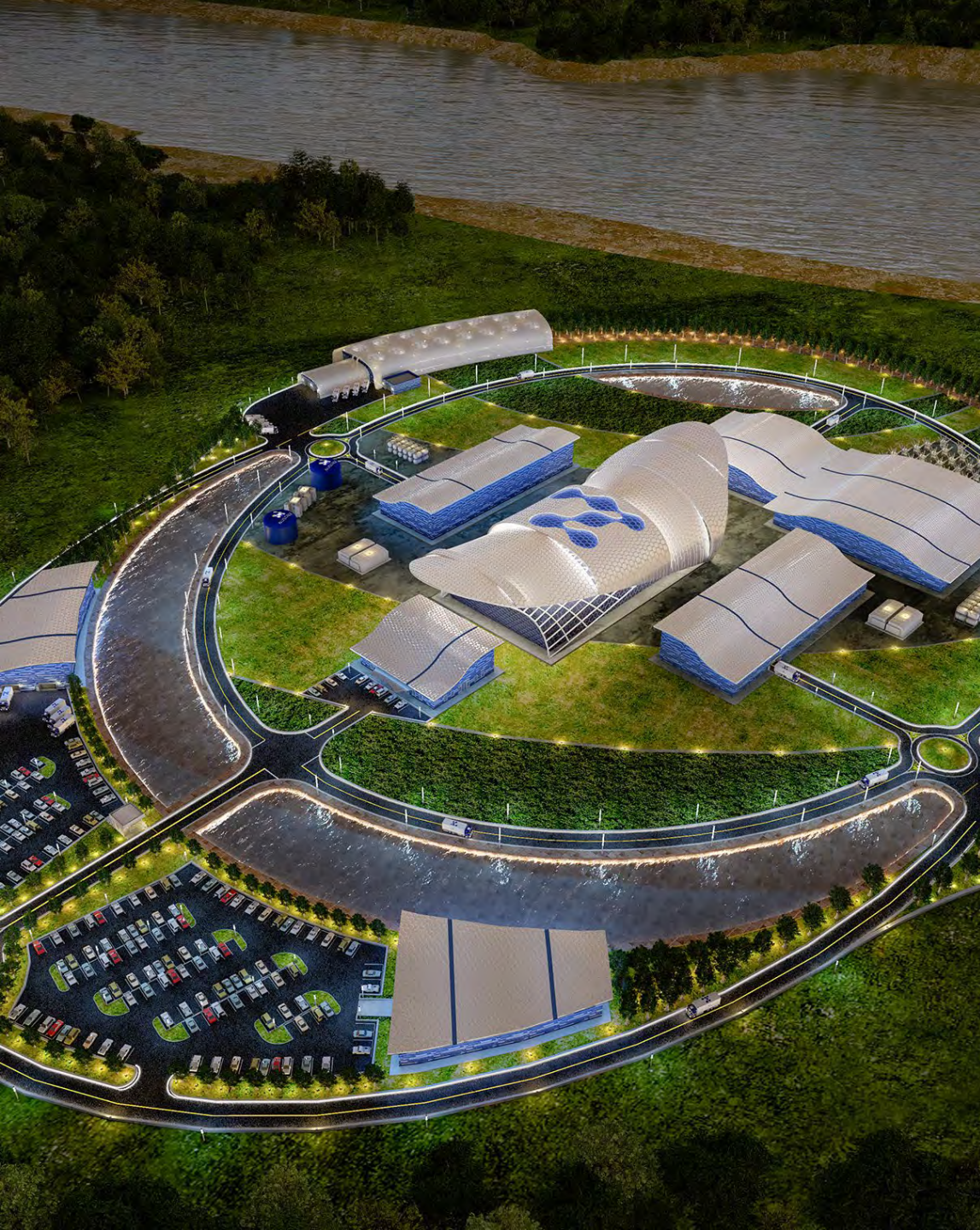


## Right-sizing the Emergency Planning Zone (EPZ)

- NuScale's small core size and exceptional safety, defense-in-depth make the case for a reduced EPZ to the site boundary.
  - This means that NuScale Plants could be sited closer to population and industrial centers – where energy is needed most
- Tennessee Valley Authority (TVA) Demonstrates Site Boundary EPZ Possible for SMRs
  - TVA analysis adds information on Clinch River early site permit application using NuScale Plant design
  - Shows any accident radiological impact would be limited to within site boundary
  - Analysis provides basis for exemption from 10-mile EPZ in regulatory breakthrough
- NRC Emergency Preparedness Rule for SMRs is out for public comment



Image courtesy of Third Way Nuclear Reimagined



## Unique Transmission System Integration

- The NuScale Plant is the only commercial nuclear power plant approved by the NRC that does not require connection to the grid or “1E” power for safety.
- This permits “off-grid” operation
  - A very important feature for providing reliable power and process heat to industrial applications.
- Siting at “end of line”; distributed generation applications, coal plant repowering; and for district heating.

NuScale’s technology is the only U.S. NRC approved design with this capability

# A New Level of Plant Resiliency

## Features and Capabilities Not Found in Other Nuclear Plants

## Climate Adaptation



### Black-Start and Island Mode Following Loss of Offsite Power

A single module can be Black-Started and 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 Natural Events

Reactor modules and fuel pool located below grade in a Seismic Category 1 Building

- Capable of withstanding a Fukushima type seismic event
- Capable of withstanding hurricanes, tornados, and floods.



### 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.



### Electromagnetic Pulse (EMP/GMD)

Resilience to solar-induced geomagnetic disturbances (GMDs) and electromagnetic pulse (EMP) events beyond current nuclear fleet.

# Reliable Power for Mission Critical Facilities

## UTILITY MACROGRID



- Connection to a micro-grid, island mode capability, and the ability for 100% turbine bypass allows a 924 MWe (gross) NuScale plant to assure **154 MWe net power at 99.95% reliability over a 60-year lifetime**
  - 77 MWe at 99.98% availability
- Using highly robust power modules and a multi-module plant design can provide **clean, abundant, and highly reliable power** to customers
- Working with utilities and customers to achieve “Five 9s”

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

## NuScale 12-Module Plant



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

## MISSION CRITICAL FACILITY





# COST COMPETITIVE

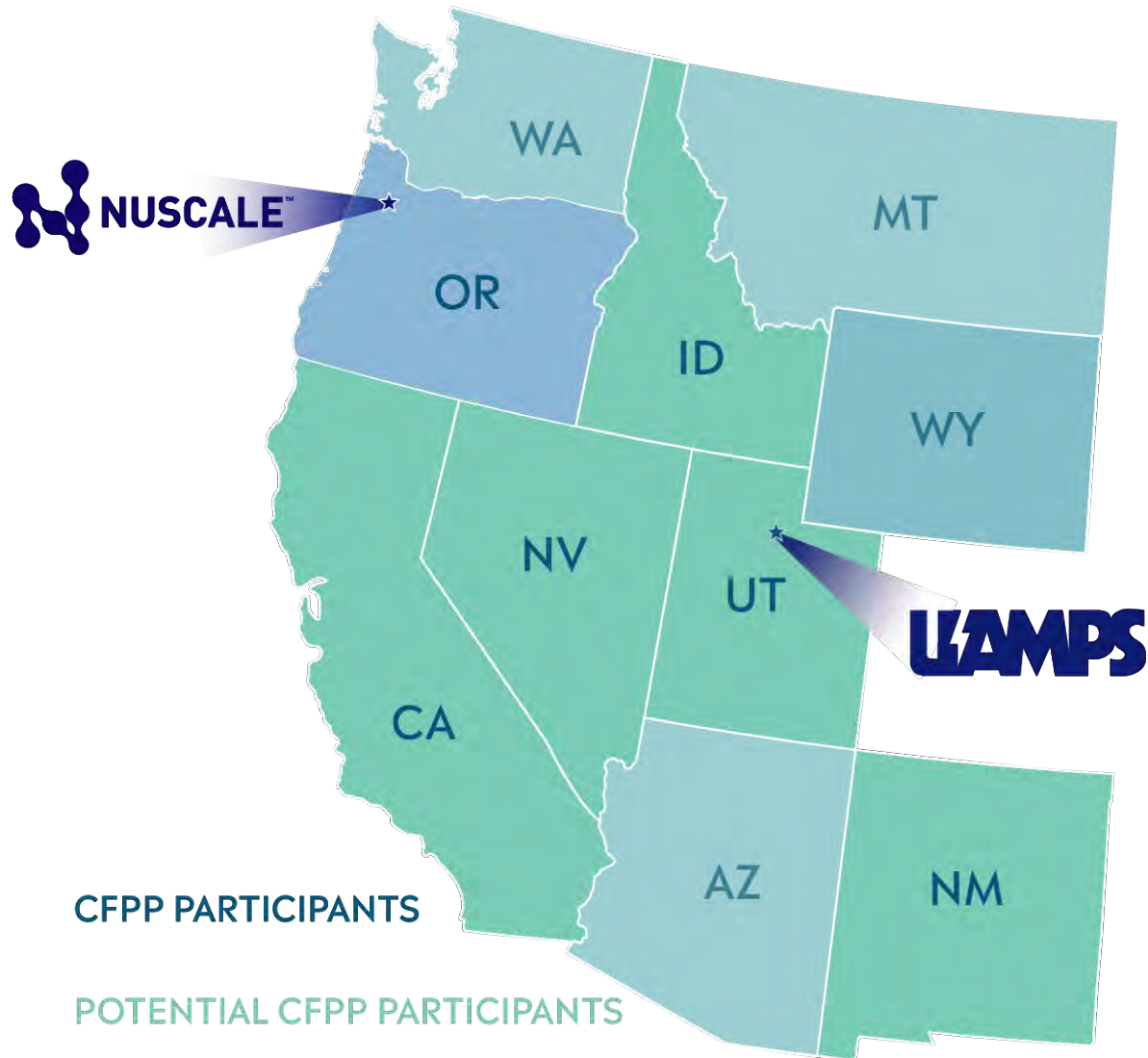
*Operational sensibility meets financial responsibility*



## What Makes NuScale Different than Conventional Nuclear Power Plants?

- Much Simpler Design with Fewer and Smaller Components
  - New level of safety and resilience
  - New level of operational flexibility meets much broader market needs
  - Leverages economies of small and scalable
- Factory Fabrication of Entire Power Module greatly reduces site construction time
- Teamed early with an experienced Engineering, Procurement, Construction firm to advise on construction process
- Expect ~80% design completion before construction starts
  - Higher fidelity cost estimates
  - Reduces likelihood of schedule delays
- Leverages existing supply chain by using conventional fuel and materials
- Key innovative features tested at full scale





## First Deployment: UAMPS Carbon Free Power Project

- **Utah Associated Municipal Power Systems (UAMPS) provides energy services to community-owned power systems throughout the Intermountain West**
  - 48 members in Utah, California, Idaho, Nevada, New Mexico and Wyoming.
  - 27 members are **CFPP participants** in Utah, California, Idaho, Nevada, New Mexico
  - Discussions with **potential CFPP participants** in Montana, Wyoming, Arizona and Washington.
- **First commercial deployment of the NuScale plant will be at the Idaho National Laboratory (INL) as part of the UAMPS Carbon Free Power Project**
- **In January 2021, UAMPS and Fluor signed a cost-reimbursable development agreement to provide estimating, development, design and engineering services to develop the site-specific cost estimates for deployment of the NuScale technology at the INL site.**

## Acknowledgement and Disclaimer

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