Northwest **Power** and
Conservation Council

January 4, 2017

MEMORANDUM

TO: **Council Members**

FROM: **Gillian Charles, Energy Policy Analyst**

SUBJECT: **Small modular reactor technology, opportunities and potential**

BACKGROUND:

Presenter: Jim Gaston, General Manager – Energy Services Department, Energy Northwest
Christopher Colbert, Chief Strategy Officer, NuScale Power

Summary: Jim Gaston and Christopher Colbert will introduce small modular reactor technology and discuss current opportunities and potential for development in the Pacific Northwest.

Energy Northwest and NuScale are both participants in the Carbon Free Power Project (CFPP), led by the Utah Association of Municipal Power Systems (UAMPS). The CFPP is currently working to site, license and develop a small modular reactor on the Idaho National Laboratory (INL) grounds. Mr. Gaston and Mr. Colbert will discuss the latest developments in this effort, and outline future milestones of importance.

Relevance: As part of the Seventh Power Plan's action item ANLYS-14, the Council is to monitor and track emerging technologies and innovations that hold potential for the future regional power system.

Workplan: Power division work plan, Action A.4.3 – Implement Seventh Power Plan and related Council priorities – Generation Resources – Track emerging technologies and development trends related to generating resources and utility scale storage.

Background: The Seventh Power Plan identified small modular reactors as an emerging technology and alternative to conventional nuclear power plants.

“The emerging small modular reactor (SMR) technology’s smaller size (300 megawatts or less) and modular construction is intended to reduce capital cost and investment risk by utilizing a greater degree of factory assembly, shortening construction lead time, and better matching plant size to customer needs and finances through scaling of multiple units. The smaller plant size of SMRs may also permit greater siting flexibility, load following capability, and cogeneration potential and can benefit system reliability through reduction in “single shaft” outage risk.” Seventh Power Plan, Chapter 13.

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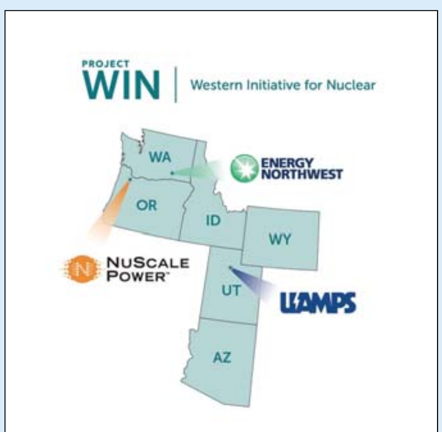
Northwest Power & Conservation Council

Energy Northwest Small Modular Reactor Update

Jim Gaston
General Manager, Energy Services & Development

January 10, 2017

Utah Association of Municipal Power Systems “UAMPS” - Carbon Free Power Project (CFPP)



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Energy Northwest - Background

- Joint Operating Agency – Established 1957
- Current operation and maintenance experience
  - Packwood Hydro – 53 years
  - Columbia Nuclear Generating Station – 33 years
  - Nine Canyon Wind Project – 16 years
  - White Bluffs Solar Demonstration Project – 16 years
  - Tieton Hydro – 3 years
- Operations and maintenance is an expanding business line for Energy Northwest

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CFPP Responsibilities

- UAMPS:
  - Project lead, owner, and licensee
  - Develop power purchase agreements
- NuScale
  - Design development
  - Nuclear plant provider
  - Fluor as EPC contractor
- Energy Northwest
  - Consultant role during development
  - First right O&M service provider

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CFPP Current Project Activity

- Teaming agreement (UAMPS/NuScale/EN) in 2013
- UAMPS Final Site Selection Report complete – August 2016
- Preferred site is Idaho National Laboratory (INL)
- Process of obtaining water rights
  - Study on Hybrid Dry Cooling vs. Wet Cooling
- Finalizing Economic Modeling
- UAMPS decision to proceed to COLA – 1st Qtr 2017

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CFPP Current Project Activity

(Cont'd)

- NuScale submitted Design Certification Application (DCA) to the Nuclear Regulatory Commission (NRC) December 31, 2017
- Energy Northwest
  - Operator Licensing and Accreditation Program

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Overview of Idaho National Laboratory Site

- 889 square miles
- Five campuses
- 111 miles of power line
- 177 miles of paved roads
- 14 miles of railroad tracks
- 584 buildings and structures (3.2 million square feet)
- 3,200 BEA employees
- Multiple missions
- Multiple stakeholders

The Department of Energy's National Nuclear Capability

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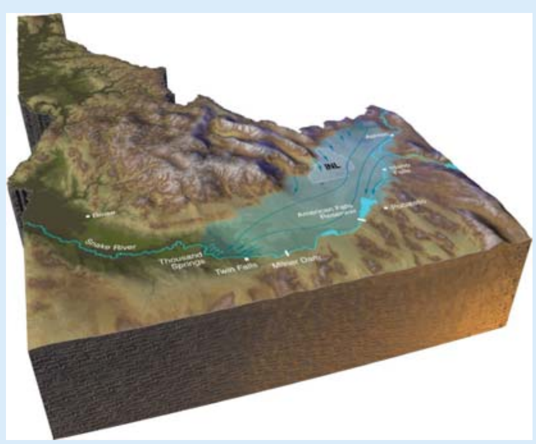
INL Site Characteristics

- DOE land would accommodate siting of a commercial generation facility
- Surface: shallow soil and basalt outcrops
- Water from the Snake River Plain aquifer is 475 feet deep



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Key INL Reactor Site Selection Criteria

1. Subsurface water availability/well depth
2. Volcanic/seismic fault exclusionary zones
3. Maximize distance from INL site boundaries
4. Geotechnical considerations
5. Minimize length of new roads
6. Minimize length of new transmission lines
7. Environmental acceptability (land use, ecology)

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Proposed Siting Locations

Four Acceptable Sites

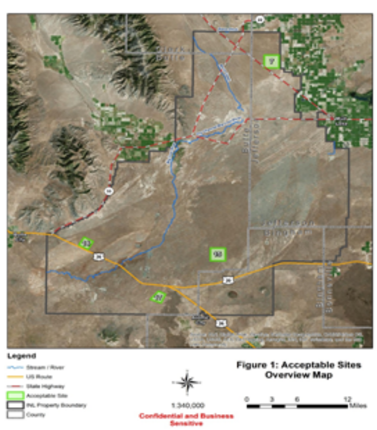

Figure 1: Acceptable Sites Overview Map

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CFFP Milestone Schedule

- NuScale submits Design Certification Application (DCA) – December 31, 2016
- NRC approves Design Certification Application 2020
- UAMPS start Combined Operating License Application (COLA) – Development 2nd Qtr 2017
  - Submit COLA mid 2019
  - NRC issue COLA mid 2022

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CFFP Milestone Schedule (Cont'd)

- Fuel load Module 1 – 3rd Qtr 2025
- CFPP full commercial operation – 2nd Qtr 2027

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Economics

- Cost of Power will be competitive with alternatives
  - Natural gas is the short term exception
- Capital cost $2.5 - 3 billion (570 MW)
- Levelized cost estimate $78 per MWh
- First of a kind project has 10-20% cost add

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New Nuclear in Tri-Cities

- $500,000 Washington Department of Commerce grant awarded to Tri-City Development Council in 2013
- Purpose: Analyze the Hanford site for SMR development
- Contracted with URS Corporation to evaluate the benefits
- Report completed in Fall 2014 (tridec@tridec.org)

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Questions
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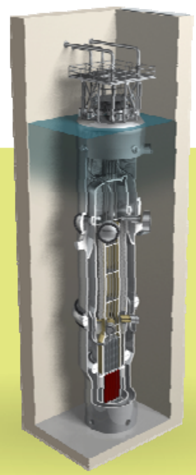

NuScale Overview

Christopher Colbert
Chief Strategy Officer
January 10, 2017

NuScale Nonproprietary

NuScale Power

Acknowledgement & Disclaimer

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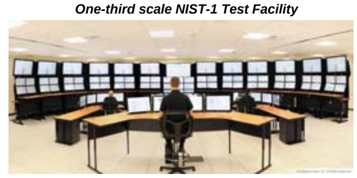
NuScale Power

NuScale Power History/Status

- NuScale technology in development and design since 2000 (DOE) MASLWR program.
- Electrically-heated 1/3-scale Integral test facility first operational in 2003
- Began NRC design certification (DC) pre-application project in April 2008
- Fluor becomes Lead Investor, 2011
- Twelve-reactor simulated control room operational in May 2012 for Human Factors Engineering development
- DOE announced FOA win in 2013 and Cooperative Agreement signed May 2014
  - $217M matching funds
- 330 Patents Granted or Pending in 20 countries
- >400 people currently on project in five offices
- On track to submit DCA to NRC end of 2016.
- Total Fluor/DOE spend will be ~$500MM life-to-end of 2016.

NuScale Engineering Offices Corvallis

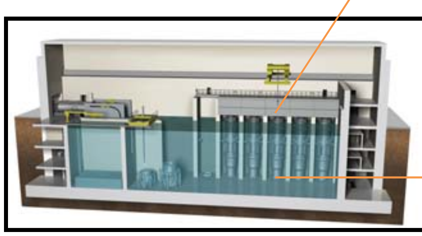
One-third scale NIST-1 Test Facility

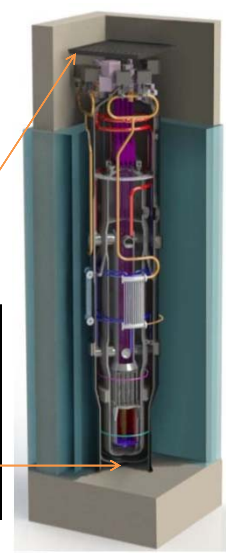


NuScale Control Room Simulator

What is a NuScale Power Module?

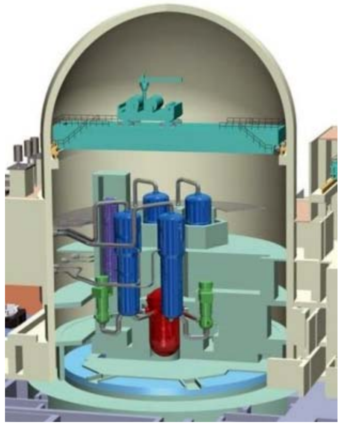
- A NuScale Power Module (NPM) includes the **reactor vessel, steam generators, pressurizer** and **containment** in an integral package that eliminates reactor coolant pumps and large bore piping (no LB-LOCA)
- Each NPM is 50 MWe and factory built for easy transport and installation
- Each NPM has its own skid-mounted steam turbine-generator and condenser
- Each NPM is installed below-grade in a seismically robust, steel-lined, concrete pool
- NPMs can be incrementally added to match load growth - up to 12 NPMs for 600 MWe gross (~570 net) total output





Size Comparison

Typical Pressurized-Water Reactor Containment & Reactor System

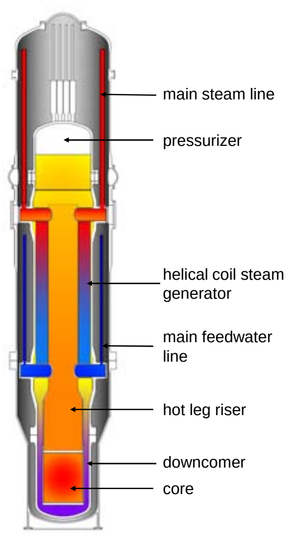


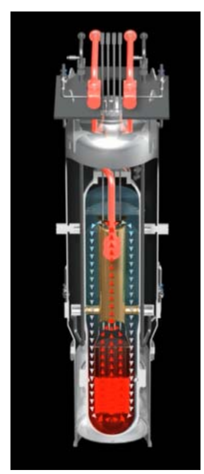
*Source: NRC

NuScale Power Module
Combined Containment Vessel and Integral Reactor System

Normal Operation

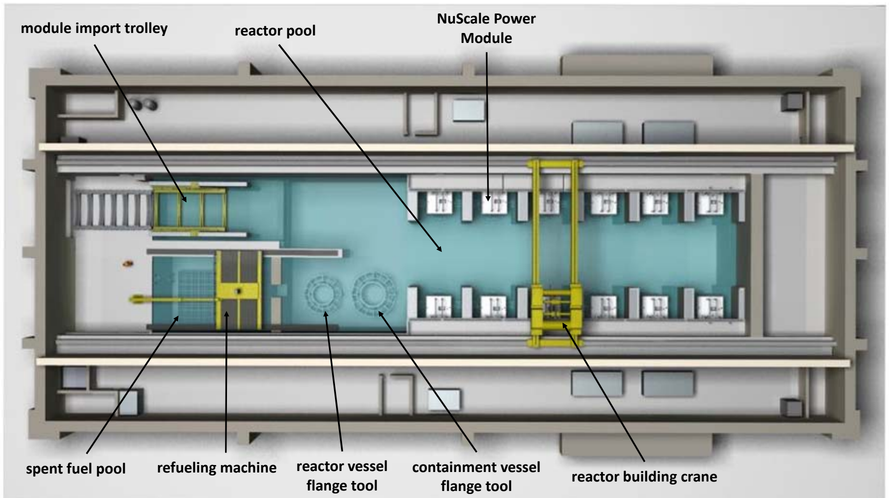
- Primary side
  - natural circulation
  - integral pressurizer
  - No Reactor Coolant Pumps
- Secondary side
  - feedwater plenums
  - two helical steam generators with large surface area per volume to maximize thermal efficiency
  - steam plenums



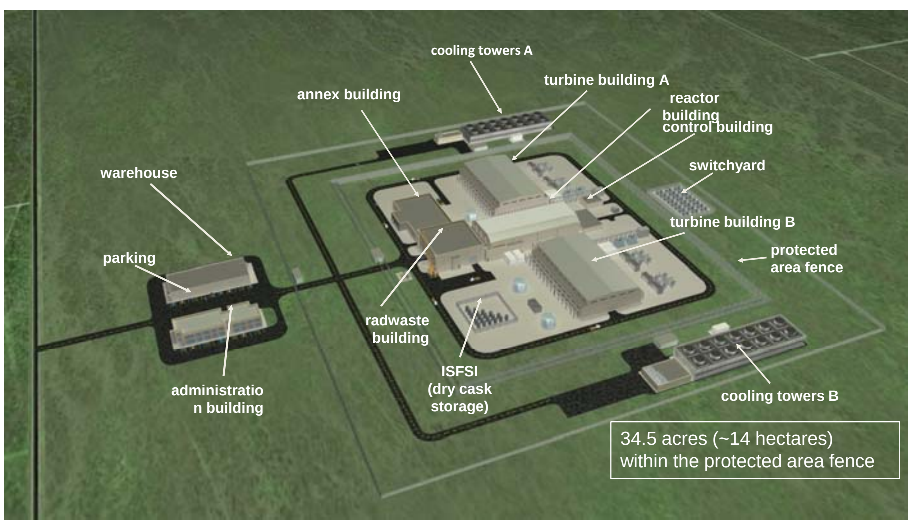


primary coolant flow path

Reactor Building Overhead View



Site Overview

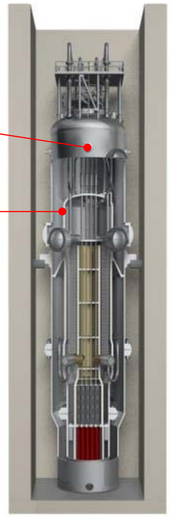


34.5 acres (~14 hectares) within the protected area fence

Containment Design

High Pressure Containment – Enhanced Safety

- Containment volume sized so that core does not uncover following a LOCA (prevents fuel heat-up)
- Large water pool keeps containment shell cool and promotes efficient post-LOCA steam condensation
- Insulating vacuum
  - significantly reduces heat transfer during normal operation
  - requires no insulation on reactor vessel
  - 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



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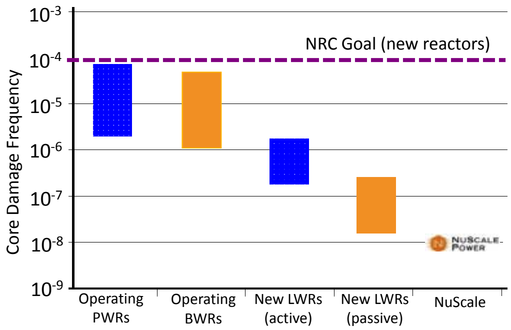
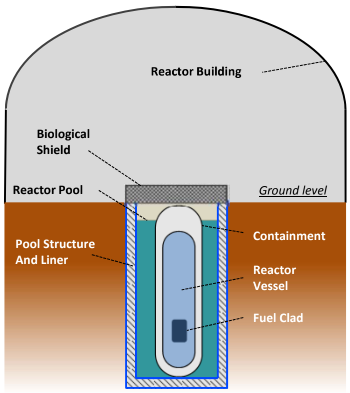
Reducing Plant Risk

Risk = (frequency of failure) X (consequences)





*Probability of core damage due to NuScale reactor equipment failures is **1 in 100,000,000 years***

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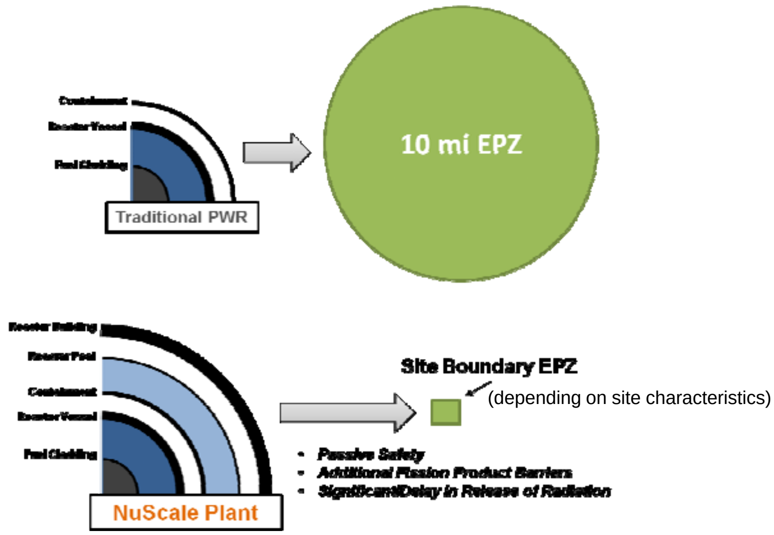
Smaller Emergency Planning Zone (EPZ)



Overview of NuScale Test Programs

NuScale 12-Module Control Room Simulator, Corvallis, Oregon

Cost Competitiveness

- NuScale's power module enables utility companies to "right-size" their power plants for current needs, then add capacity as necessary
- Design simplification enhances safety, reduces maintenance, and improves plant availability
- Off-site fabrication and assembly reduces cost, and components are delivered to the site in "ready-to-install" form
  - as a result, construction occurs in a shorter, more predictable period of time
- The workforce required to construct NuScale power plants are measured in the hundreds, not the thousands
- Our short 3-year construction schedule provides greater assurance that the plant will achieve operation before unforeseen external events impact the schedule
- Projected first plant levelized cost of energy (LCOE) $98/MWhr, and improving

Design Simplification - NSSS

- **Eliminated systems and components**
  - containment spray system
    - spray ring
    - containment penetration
  - containment cooling system
    - containment fans
    - containment coolers (heat exchangers)
    - containment cooling water penetration
  - auxiliary feedwater system
    - safety-related steam and/or electric high pressure pumps
  - ECCS injection and recirculation
    - refueling water storage tank
    - safety-related charging pumps
    - intermediate pressure injection pumps
    - cold leg accumulators
    - low pressure injection/recirculation pumps
    - containment sumps
  - reactor pressure vessel components
    - hot leg and cold leg piping
    - pressurizer surge line
    - pressurizer relief tank
    - reactor vessel insulation
    - primary system insulation
  - residual heat removal components
    - RHR pumps
    - RHR heat exchangers
    - safety-related component cooling water pumps
    - safety-related component cooling water heat exchangers
    - service water pumps
    - service water heat exchangers

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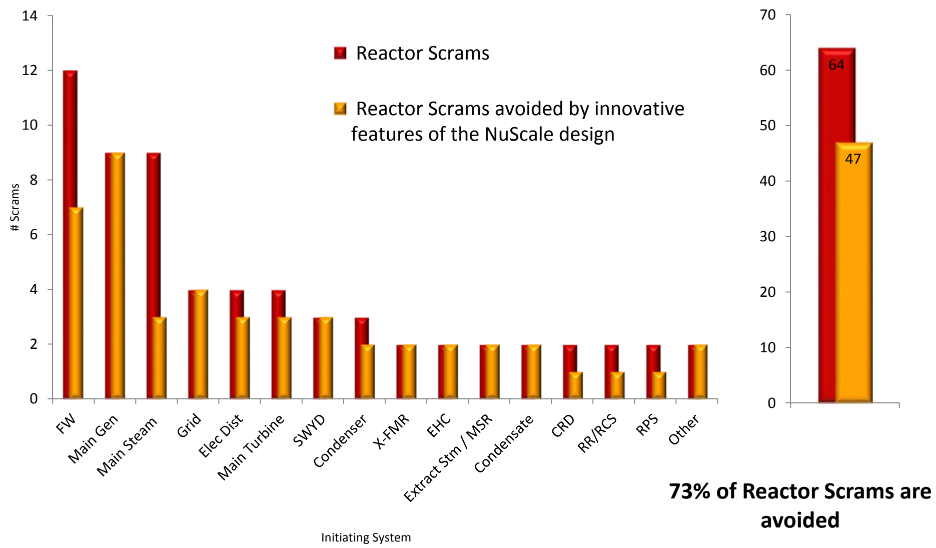
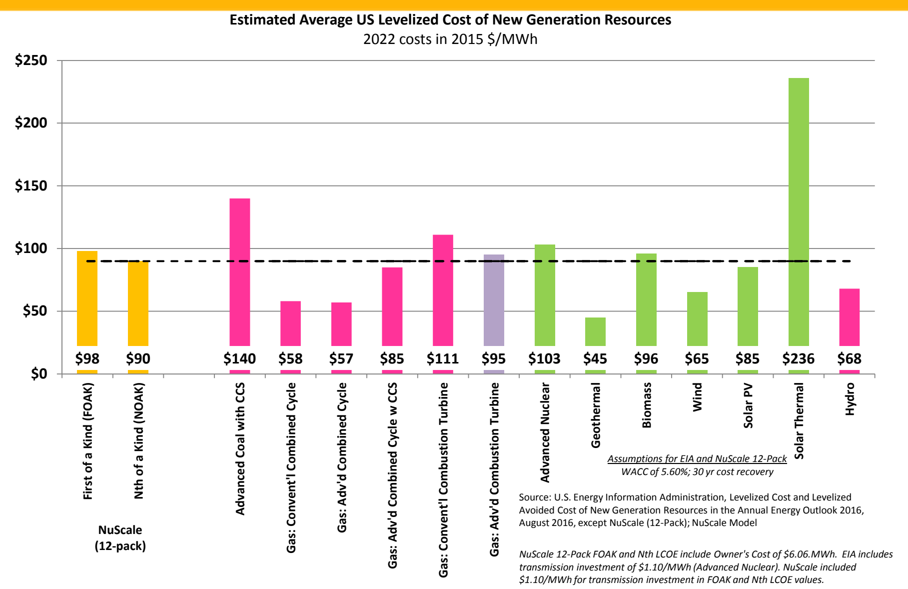
Reliability – U.S. Plant Scrams in 2015



NuScale LCOE in North America



NuScale Diverse Energy Platform

Oil Refineries Study - Reduction of Carbon Emissions *(Fluor and NuScale)*

10-Module Plant coupled to a 250,000 barrels/d refinery

Integration with Wind Study - Horse Butte Site *(UAMPS, ENW and NuScale)*

1-Module dedicated to UAMPS 57.6 MW wind farm

Reliable Power for Mission Critical Facilities *(NuScale)*

12-Module Plant coupled to a 100 MWe Mission Critical Facility

Hydrogen Production Study – High-Temperature Steam Electrolysis *(INL and NuScale)*

6-Module Plant for Emission Free Hydrogen Production

Desalination Study – Sized for the Carlsbad Site *(Aquatech and NuScale)*

8-Module Plant can produce 50 Mgal/d (190K m^3/d) of clean water plus 350 MWe

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