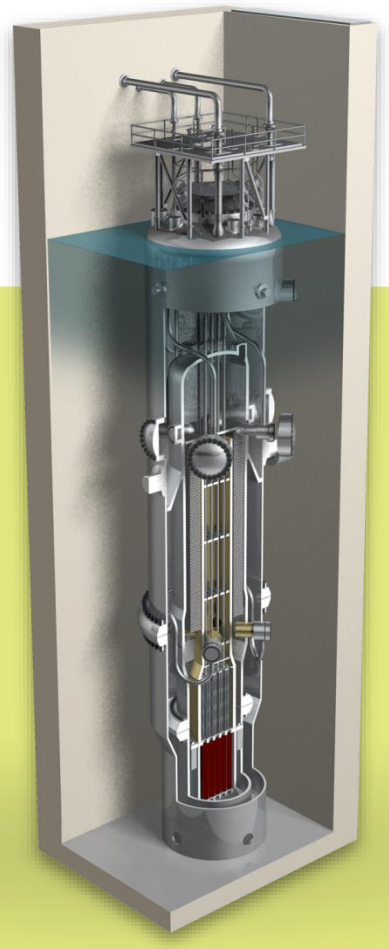


NuScale Power SMR: Supporting the Future with Clean Energy

Southern States Energy Board

December 7, 2016

Nils Breckenridge
NuScale Power LLC
Business Development

NuScale Power™

Acknowledgement & Disclaimer

This material is based upon work supported by the Department of Energy under Award Number DE-NE0000633.

NuScale is Born!

- 2005-2007 DOE Commercialization Program
  - Numerous practical modifications to design; 3 Key Patents; Becoming "Investment Ready"
- July 2007 - NuScale is Born!
  - Founders: Lorenzini CEO; Reyes CTO
- February 2008 - Began NRC design certification (DC) pre-application project
- September 2008 – Kiewit Power Constructors and High Bridge Associates – The Economics Work Too!
- December 2009 - NY Times Full Page Article - Increased Media Interest
- March 2011 - Fukushima Event

2008 - NuScale at Bank Building on 2nd Street, Corvallis

NuScale Power™

NuScale Grows

- October 2011 - Fluor becomes NuScale's Strategic Partner - Acquires majority interest.
- May 2012 - First 12-reactor Control Room Simulator in the world became operational in for Human Factors Engineering development
- April 2013 – NuScale Announces its Triple Crown of Nuclear Safety™. - another world's first
- July 2013 – Program WIN -Western Initiative for Nuclear
- December 2013 - DOE announced FOA win and Cooperative Agreement signed May 2014
  - $217M matching funds

NuScale Control Room Simulator

From a concept to a product

NuScale Today

- More than 600 people currently on project with Offices in:
  - Business Offices: Portland, OR; London, UK; Idaho Falls, ID
  - Engineering Offices: Corvallis, OR; Charlotte, NC; Richland, WA
  - Licensing Office, Rockville, MD
- Fluor/DOE have invested > $500MM life-to-date
- NuScale has teamed with AREVA, ARES, Rock Creek Innovations, Ultra Electronics and Enercon
- Major Testing Facilities in US, Canada, Italy, France and Germany
- 340 Patents Granted or Pending in 20 countries

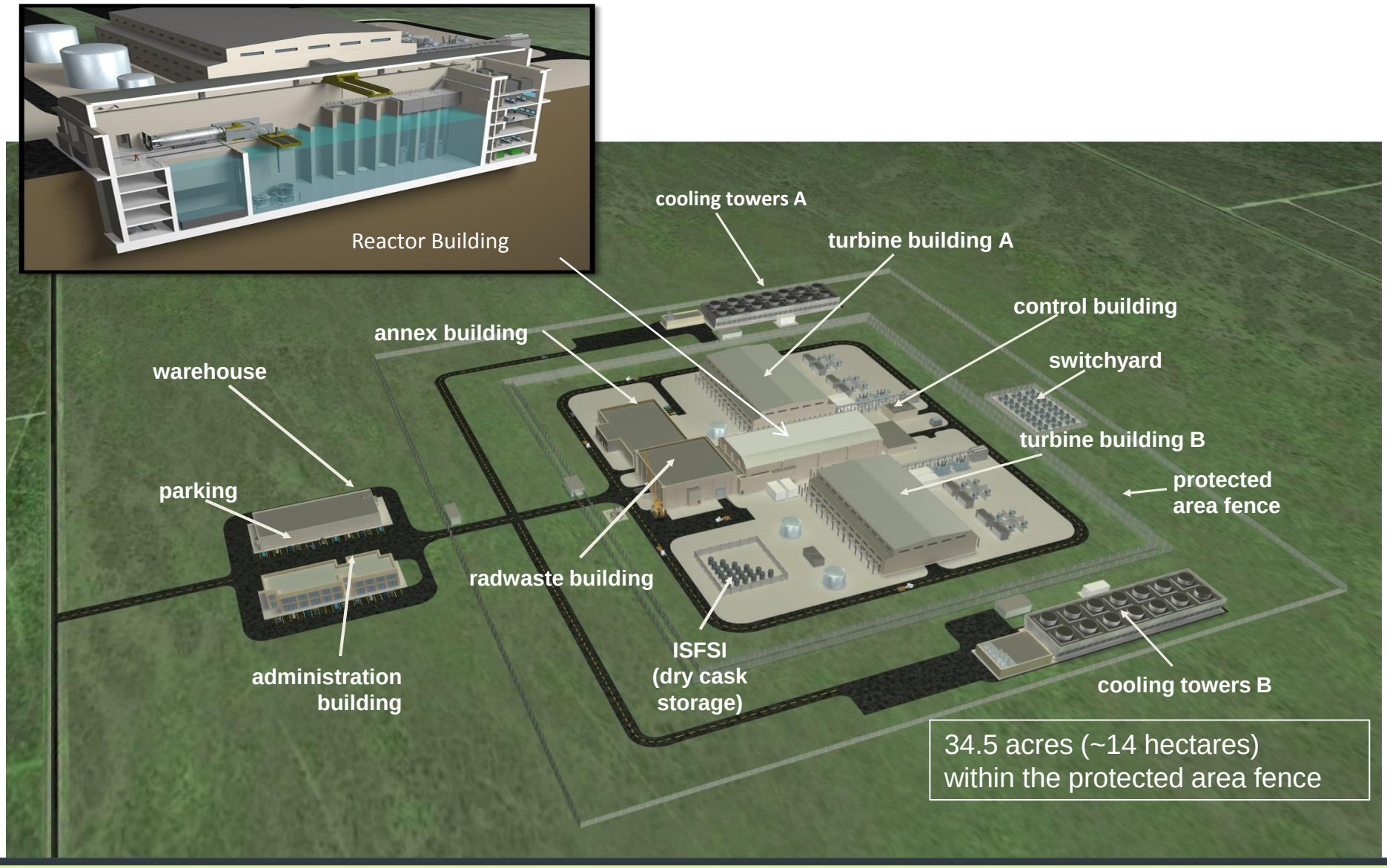
NuScale Engineering Offices Corvallis

A Total of 48 Design Certification and FOAKE Test Programs

to the industry leader in SMR technology

NuScale Power™

Site Layout



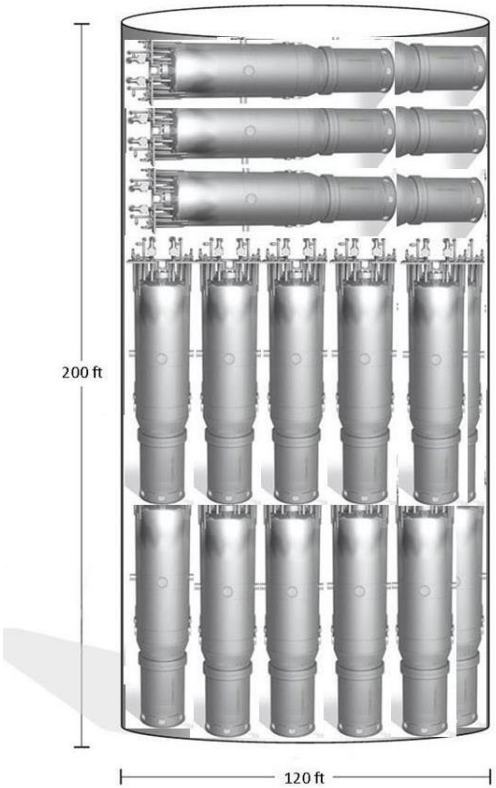
34.5 acres (~14 hectares) within the protected area fence

NuScale Power™

An Integral Small Modular Reactor

Comparison size envelope of new nuclear plants currently under construction in the United States

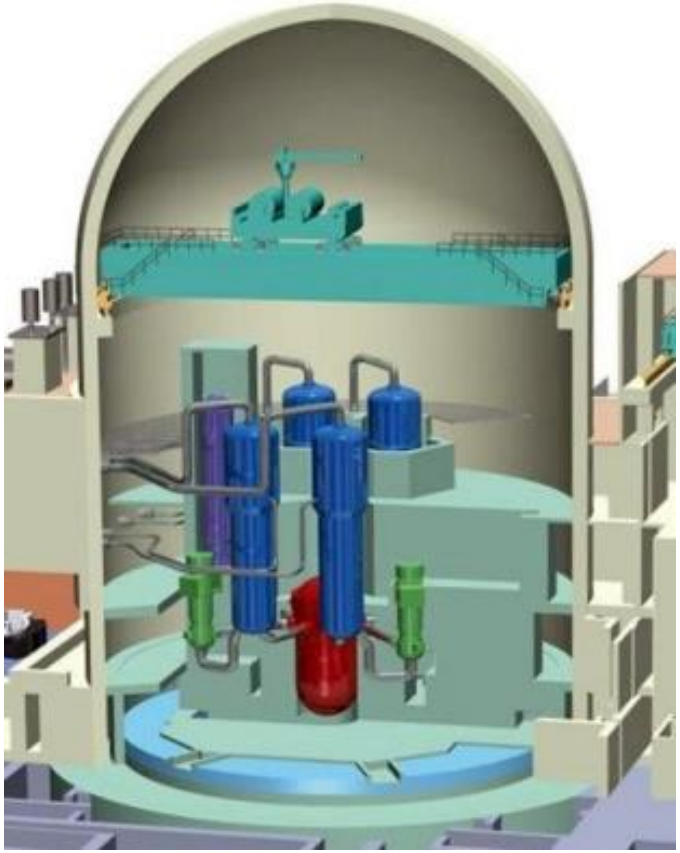
126 NuScale Power Modules



Containment

NuScale's combined containment vessel and reactor system

Typical Pressurized Water Reactor



*Source: NRC

Size Matters

NuScale Power™

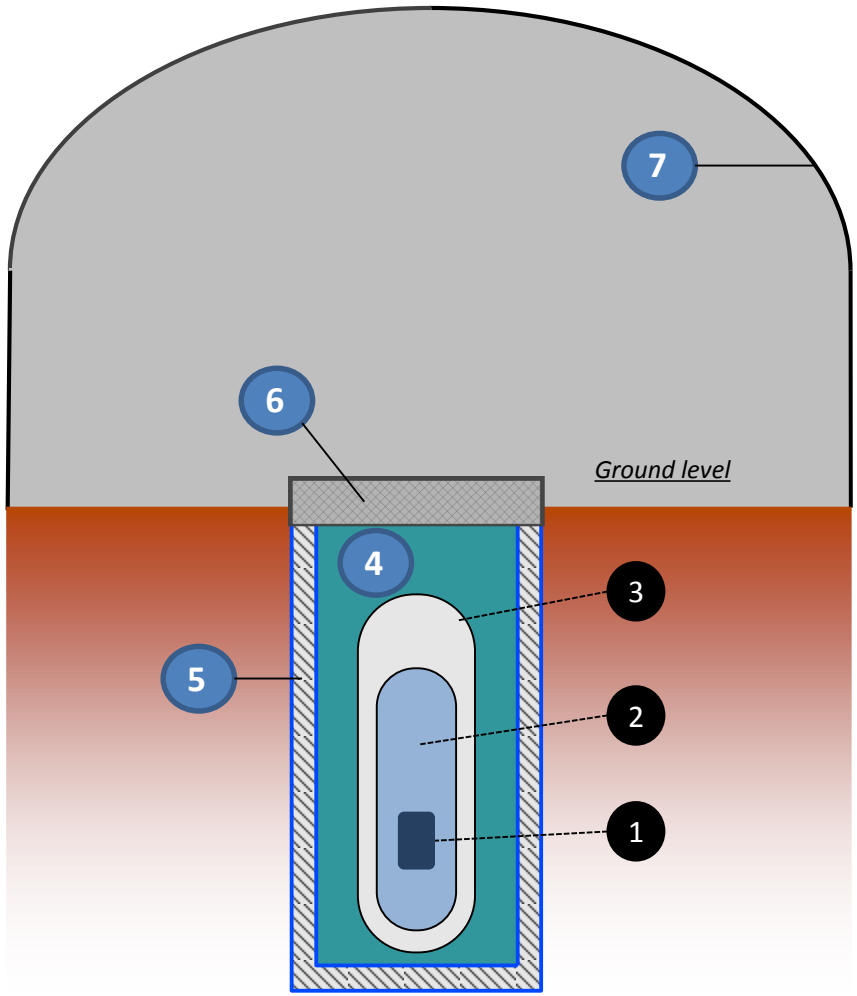
More Barriers Between Fuel & Environment

Conventional Designs

1. Fuel Pellet and Cladding
2. Reactor Vessel
3. Containment

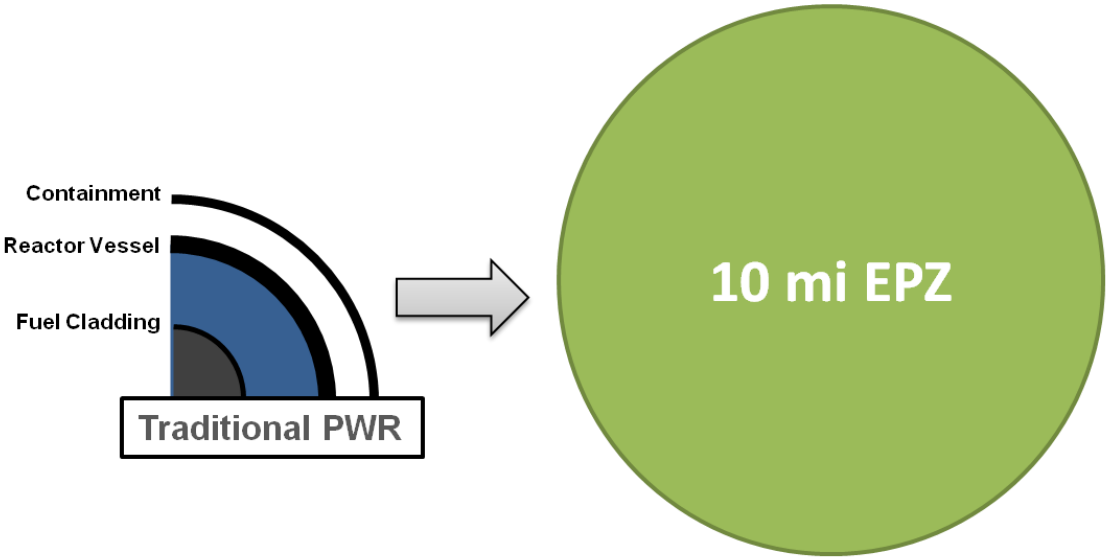
NuScale's Additional Barriers

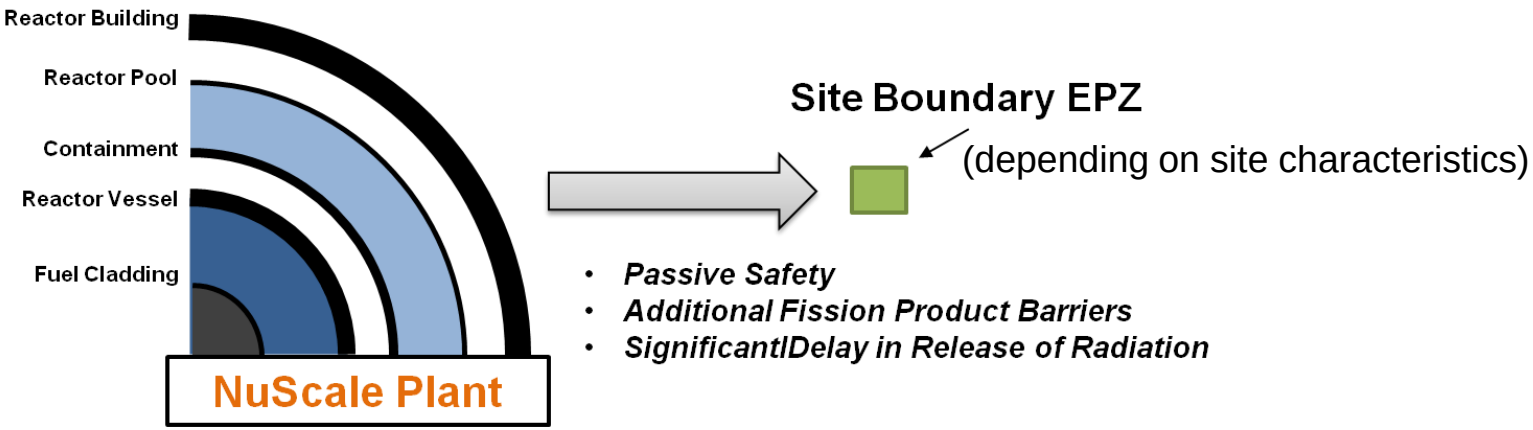
4. Water in Reactor Pool
5. Stainless Steel Lined Concrete Reactor Pool
6. Biological Shield Covers Each Reactor
7. Reactor Building



Safety, Safety, Safety

Smaller Emergency Planning Zone (EPZ)



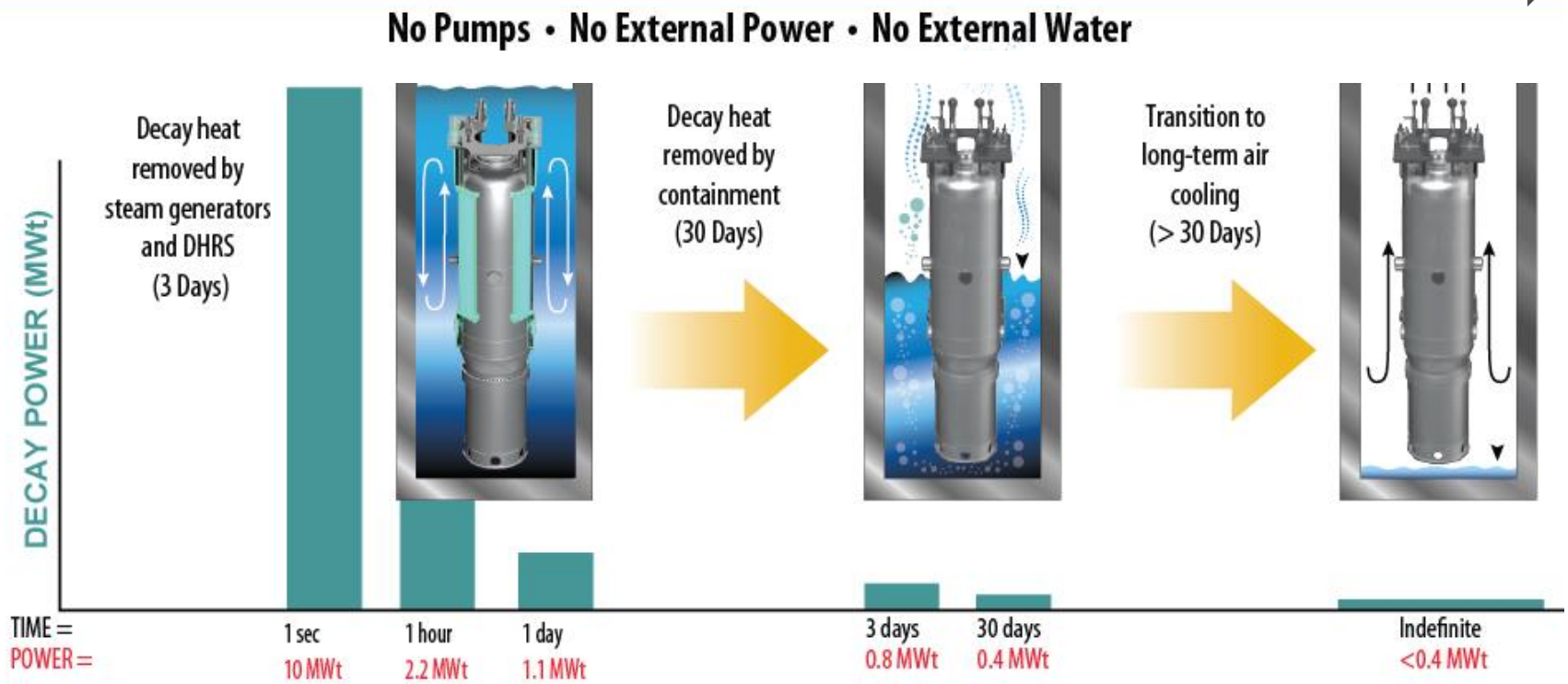


- *Passive Safety*
- *Additional Fission Product Barriers*
- *SignificantlDelay in Release of Radiation*

Innovative Advancements to Reactor Safety

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

WATER COOLING → **BOILING** → **AIR COOLING**



- ***30 days is a minimum based on very conservative estimates.***

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

Triple Crown of Safety

NuScale Power™

NuScale Fuel—(NuFuel HTP2 ™)

- Standard 17 X 17 PWR Fuel Assembly
- Half height
- 37 FA's/core
- Enriched ~3.7%
- ~ 4% MTU of 1000MW core
- RFO 24-month cycle
- ~1/3 core replaced
- MOX capable
- Areva design and fabrication, Richland, Washington

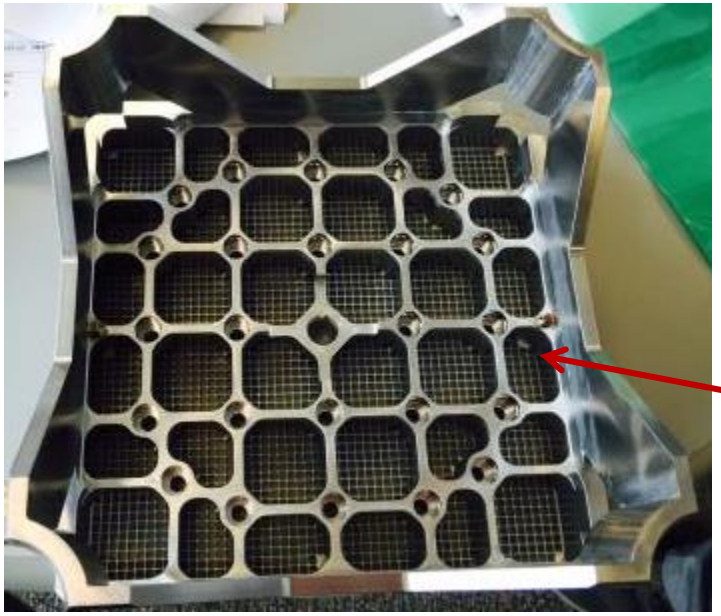
Fuel Mechanical and Hydraulic Testing

Objectives:

- Measure fuel mechanical and hydraulic performance
- Employ prototypic NuScale fuel assemblies with AREVA HTP/HMP grid technology

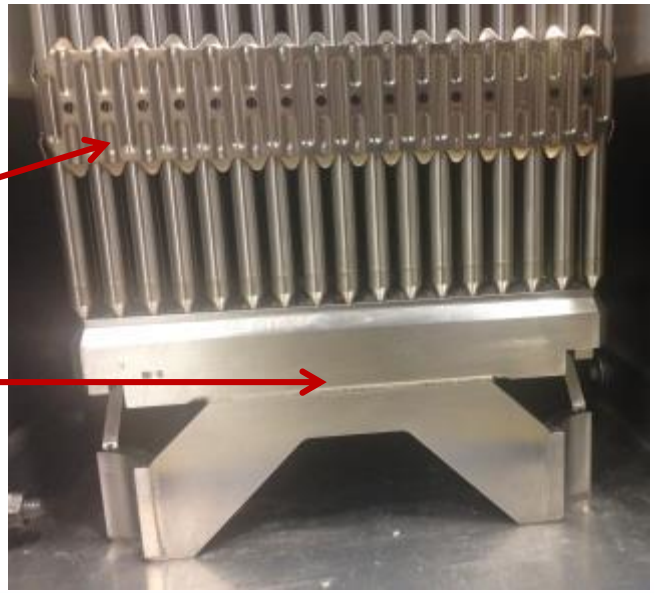
Top Nozzle

HTP Grid



HMP Grid

Fuel Guard Inlet



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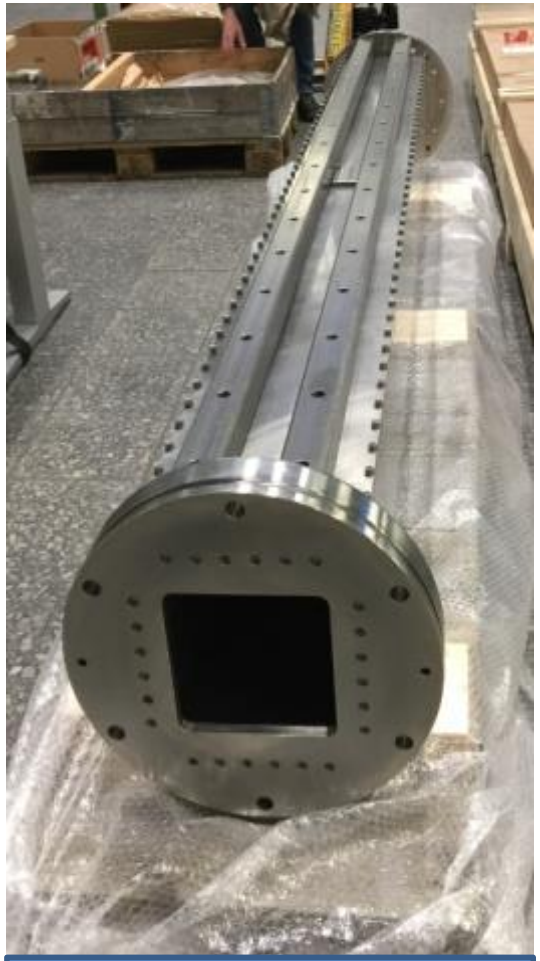
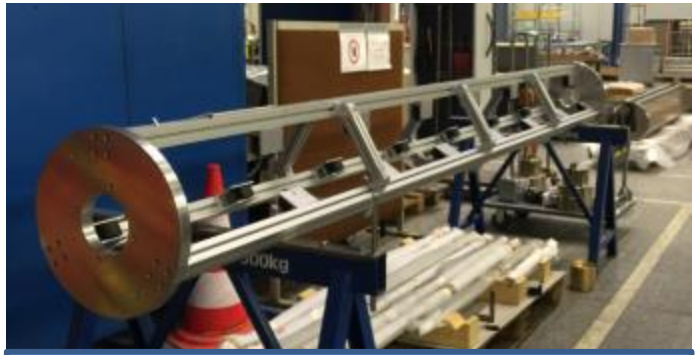
CRA and Drive Shaft Drop Alignment Test Hardware



Fuel Assembly Housing

Support Beam



Counterweight Guide Assembly

Guide Tube/Card Housing

NuScale Power™

NuScale RPV Head Ingot Being Forged

- 150 inches diameter
- 30 inches high
- 142,000 pounds



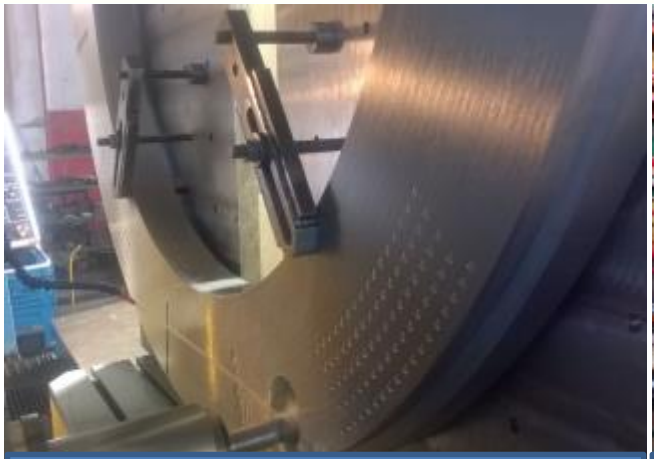

Images Provided courtesy of Sheffield Forgemasters International Ltd

Machining of the NuScale RPV Head

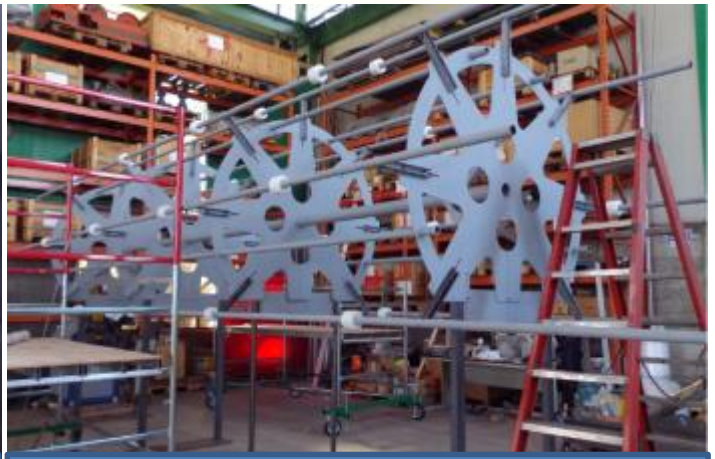
Images provided courtesy of Sheffield Forgemasters International Ltd

SG Flow Induced Vibration (FIV) Test Hardware

Tube Supports



Machining of Tube Sheet



Tube Bending Rig

Vessel Head

Tube Bending

NuScale Power™

NRC Design Certification
and
Commercialization Plan and Status

NRC Licensing Status

- Design Certification Docket Opened in 2009 (NRC starts charging)
  - Significant interactions begin in 2014
- Visits include
  - Tour of NIST Facility
  - Tour of upper module mockup
  - Multi-hour simulator demonstration of plant transient response
  - In-depth meetings with NuScale management and technical staff
- ACRS July 2015
- NRC NRO upper management August 2015
- NRC QA inspection of NIST August 2015
- NRC I&C and Electrical subject matter branch management and key technical staff December 2015
- Human Factors Engineering January 2016
- Office of New Reactors March 2016
- NRC Readiness Assessment review September 2016

Design Certification to be submitted December 2016

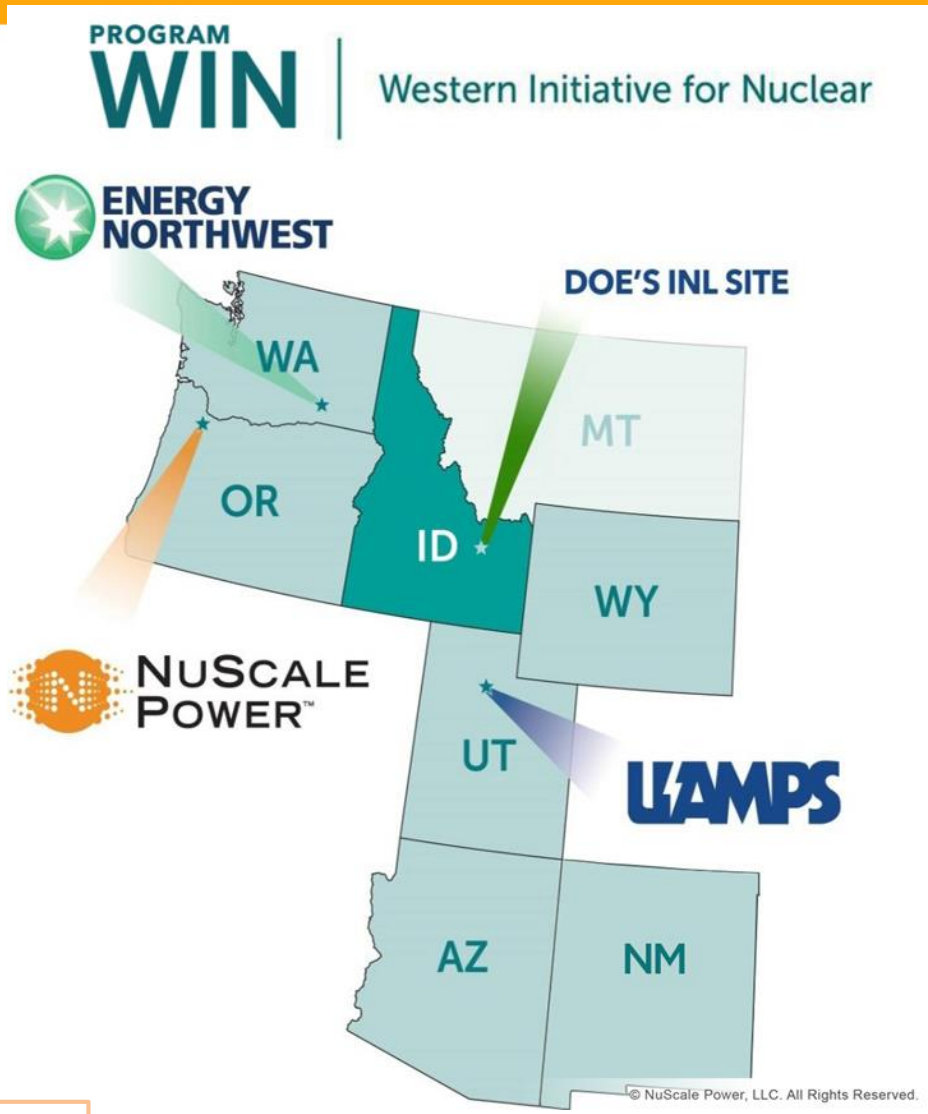
NuScale Power Design Certification Application

Greater than 10,000 pages

NuScale Power™

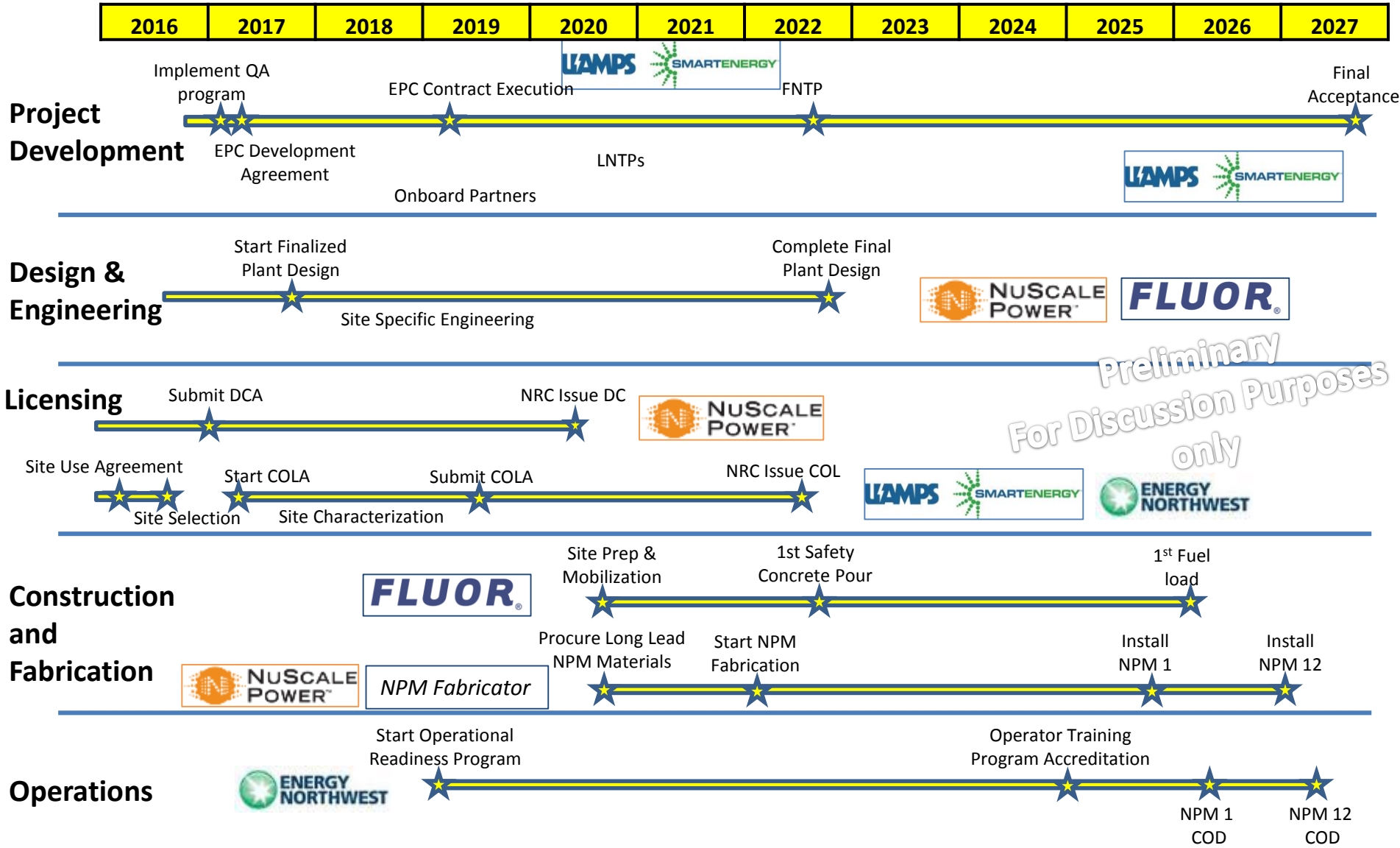
First Deployment: UAMPS CFPP

- Utah Associated Municipal Power Systems (UAMPS) Carbon Free Power Project (CFPP) will be first deployment, sited somewhere in Idaho.
- Site selection underway
- DOE INL site use agreement
- NRC COLA commitment
- UAMPS consists of 44 members serving load in 7 western states.
- 37 UAMPS members are subscribers in CFPP

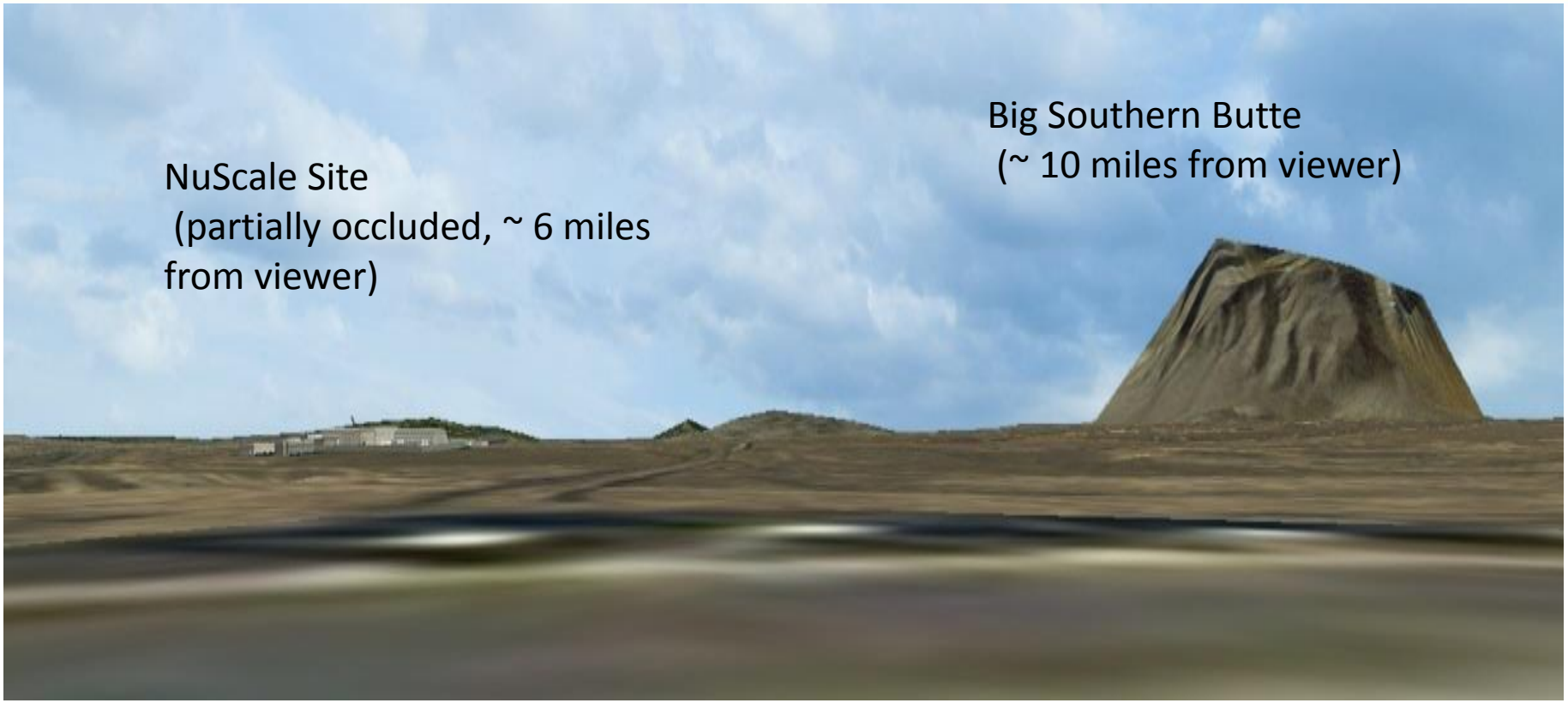


A Groundbreaking Project

UAMPS CFPP Project Schedule



View of Site From Lost River Rest Stop



Southeast *Viewing direction* *South*

Keeping a low profile

NuDEP

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

NuScale Power™

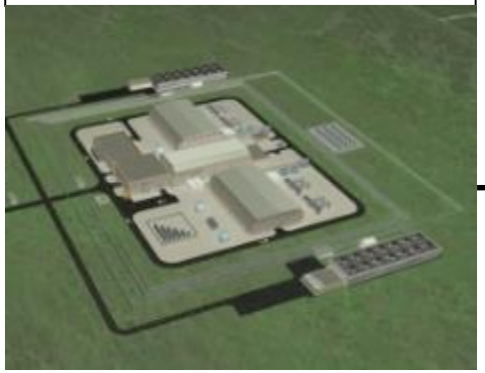
Redundant Array of Independent Reactors (RAIR)

- Highly reliable power is required for Mission-Critical Facilities.
  - **Hospitals, Data Centers, Government Facilities, banking or retail systems**
  - **Security systems, telecommunications, air traffic control**
  - **Safety systems for conventional Nuclear Plants**
- Process failure can cause significant financial or reputational damage to the organization or may impact national security or safety

UTILITY MACROGRID

570 MWe net
> 95% Capacity

NuScale 12-Module Plant



DEDICATED MICROGRID
95 MWe net
> 99.99% Availability

MISSION CRITICAL FACILITY

Security of Supply

NuScale Power™

Financials

Construction Cost Summary

Overall EPC Overnight Plant Costs

($1,000,000)

ITEM	2014 Dollars
Power Modules (FOAK Cost plus Fee, Transportation, & Site Assembly)	$ 848
Home Office Engineering and Support	$ 144
Site Infrastructure	$ 60
Nuclear Island (RXB, RWB, MCR)	$ 538
Turbine Island (2 buildings with 6 turbines each)	$ 350
Balance of Plant (annex, cooling towers, etc)	$ 225
Distributables (Temp. Bldgs., Field Staff, Const. Equip., etc.)	$ 545
Other Costs	$ 185
Total Overnight Price	**$ 2,895**

$ 5,078 per kWe net

Note: Delivered costs shown are in 2014 $'s.

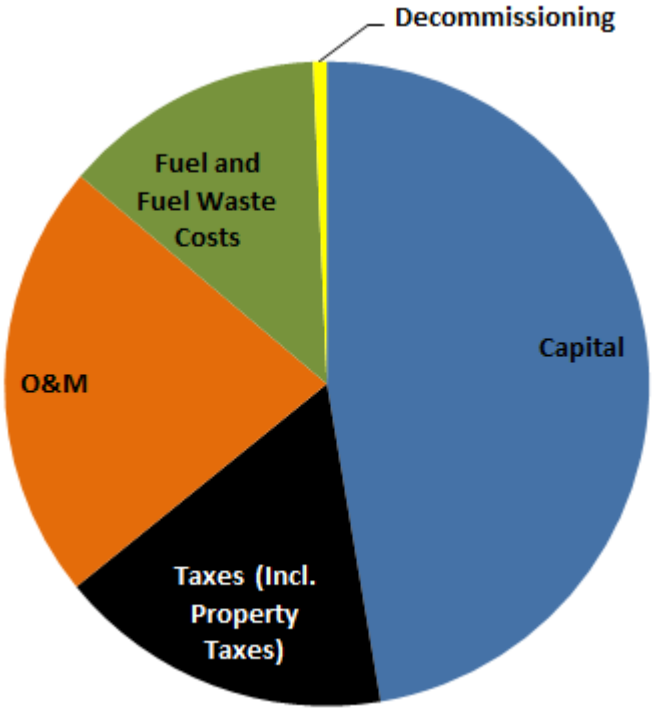
NuScale Power™

NuScale Levelized Cost of Electricity (LCOE)

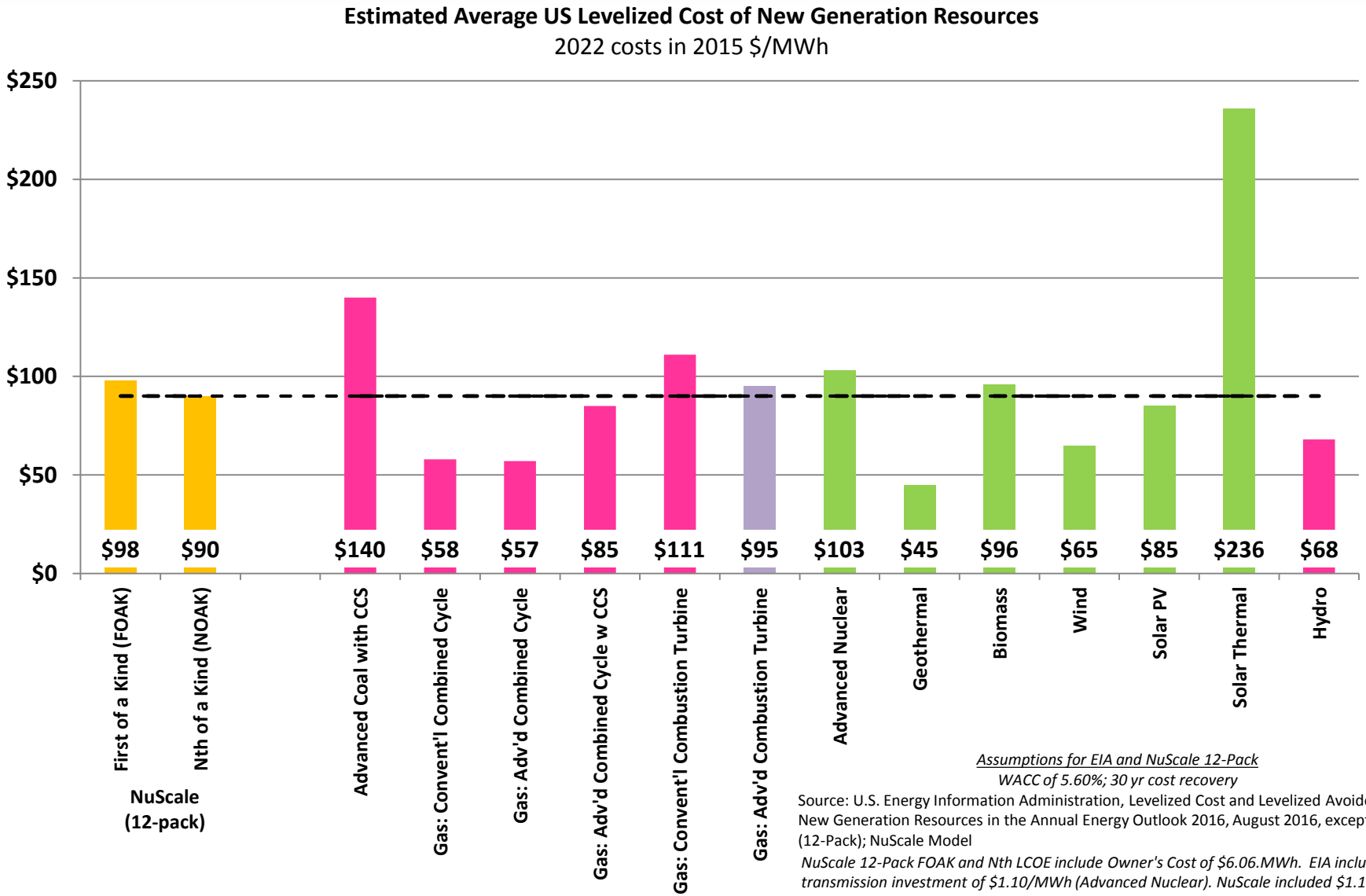
NuScale LCOE results of $96-$106/MWhr (2016 $'s)

Key Assumptions:

- Financing is 55% debt (@5.5%) and 45% equity (@10.0%).
- Modeled as a 40 year project life, but the plant is designed for 60 years
- Excludes owner's costs such as:
  - HR and management infrastructure, central office
  - COLA, permits, NRC and ITAAC inspections, and legal fees
  - Switchyard
  - Owner's project development costs
  - Owner's engineering services (post-COLA)
  - Owner contingency
- Including an estimate of owners costs would add ~ $6/MWhr



The Challenge - LCOE in North America



Assumptions for EIA and NuScale 12-Pack
WACC of 5.60%; 30 yr cost recovery

Source: U.S. Energy Information Administration, Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2016, August 2016, except NuScale (12-Pack); NuScale Model

NuScale 12-Pack FOAK and Nth LCOE include Owner's Cost of $6.06.MWh. EIA includes transmission investment of $1.10/MWh (Advanced Nuclear). NuScale included $1.10/MWh for transmission investment in FOAK and Nth LCOE values.

Note: EIA projects 2022 Henry Hub spot natural gas prices of approx. $4.35/mmbtu (2015 Dollars) (Annual Energy Outlook 2016)

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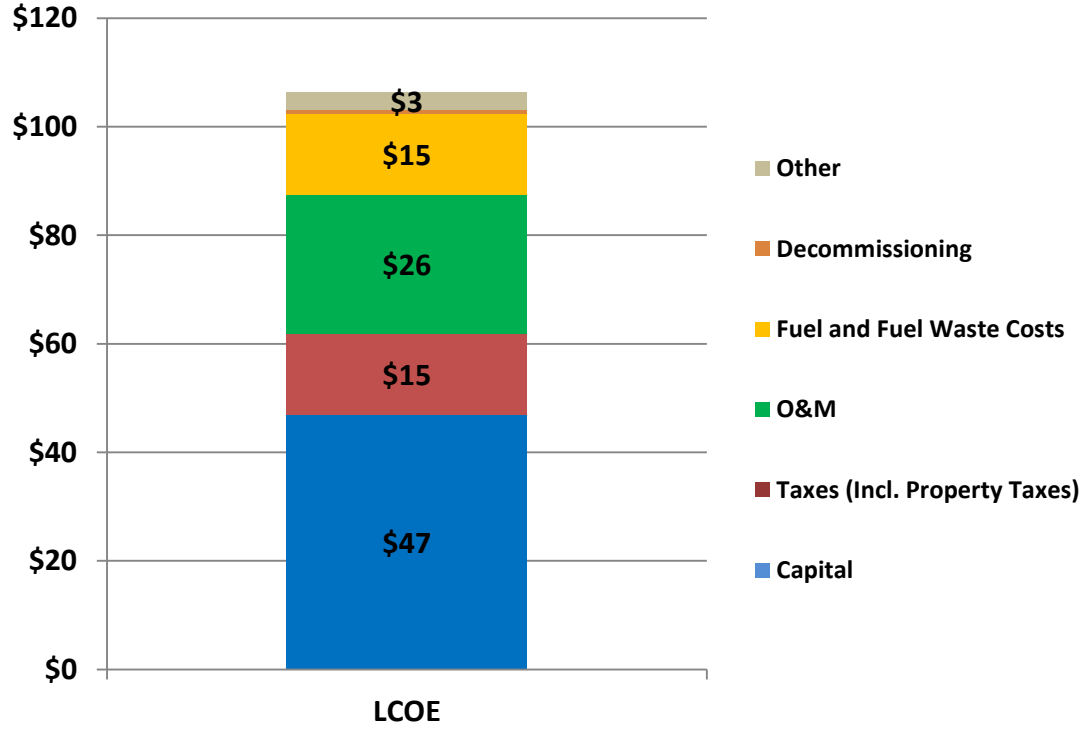
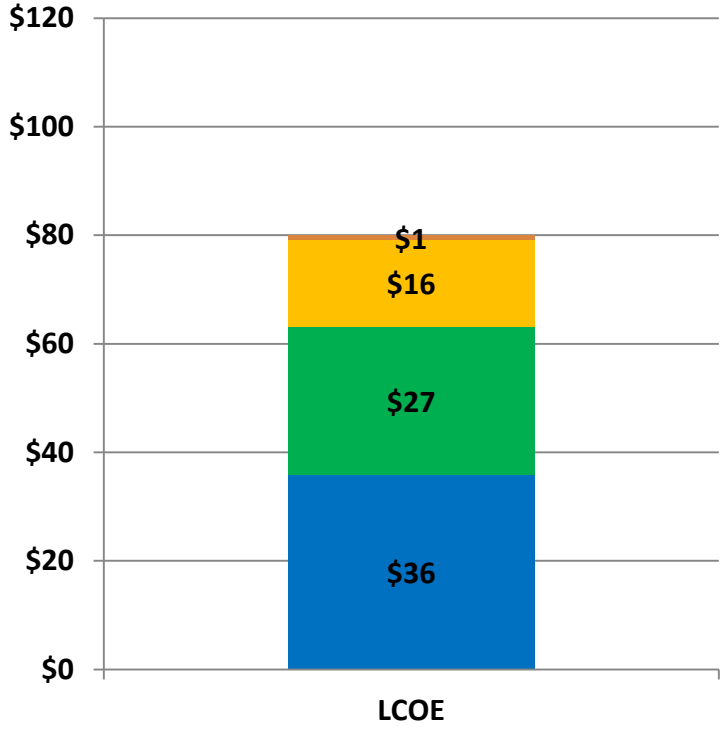
NuScale LCOE Breakdown

Levelized Cost in 2016 US Dollars per MWh





FOAK with Regulated Utility Financing (IOU)

- 55% debt at 5.5%, 45% equity at 10%

$ 106 USD/MWh

FOAK with Municipal Financing

- 100% debt at 4.12%, no equity

$ 80 USD/MWh

Note: Capital costs reflect the Fluor SE estimate completed in 2014.

What Could SMRs mean?

- Strengthens the region's position as the hub for nuclear innovation
- Creates slipstream for other regional SMR projects
- Project can create ~1000 construction jobs at peak, for duration of 2-3 years
- Full-time plant employment ~360 at average annual salaries $85K
- Establishes the region as a desired location for SMR supply chain members
- Indirect economic benefits and associated job multipliers

Phase I: Economic Impact Summary Results Nuclear Power Plant Construction			
Impact Type	Employment	Labor Income	Industry Sales
Direct Effect	1,000	$1,143,677,418	$2,800,000,000
Indirect Effect	3,987	$123,494,919	$353,692,045
Induced Effect	7,821	$243,927,035	$620,061,282
Total Effect	12,808	$1,511,099,372	$3,773,753,328
Multiplier	**1.54**	**1.32**	**1.35**

Source: Idaho Department of Labor's analysis of the impact of the UAMPS SMR project on Idaho Falls

What is Needed to Ensure Success?

- Need a committed owner/buyer(s) – will ultimately drive site selection decision for the project
- Project will need to demonstrate sufficient need for/use of generated power
- Suitable plant economics/investment profile (e.g. long-term PPA's)
- Supportive local and state permitting processes
- Sufficient capable facility workforce and community interest
- Economic development support
  - Economic Development Studies
  - Policy Support

Executive Order, The White House, 3/19/15

- **FACT SHEET: Reducing Greenhouse Gas Emissions in the Federal Government and Across the Supply Chain**
- **40% cut in CO2 emissions across Government agencies**
- **30% of energy must come from "alternative technologies" which include SMR's**
- Sec. 3. Sustainability Goals for Agencies. In implementing the policy set forth in section 1 of this order and to achieve the goals of section 2 of this order, the head of each agency shall, where life-cycle cost-effective, beginning in fiscal year 2016, unless otherwise specified:
- (e) include in the alternative energy portion of the clean energy target established in subsection (b) of this section alternative energy as defined in section 19(c) of this order and associated with the following actions, where feasible:
- (i) installing thermal renewable energy on site at Federal facilities and retaining corresponding renewable attributes or obtaining equal value replacement RECs where applicable;
- (ii) installing combined heat and power processes on site at Federal facilities;
- (iii) installing fuel cell energy systems on site at Federal facilities;
- (iv) utilizing energy from new small modular nuclear reactor technologies;
- (v), (vi), (vii)

- https://www.whitehouse.gov/the-press-office/2015/03/19/executive-order-planning-federal-sustainability-next-decade

6650 SW Redwood Lane, Suite 210
Portland, OR 97224
503.715.2222

1100 NE Circle Blvd., Suite 200
Corvallis , OR 97330
541.360.0500

11333 Woodglen Ave., Suite 205
Rockville, MD 20852
301.770.0472

6060 Piedmont Row Drive South, Suite 1000
Charlotte, NC 28287

http://www.nuscalepower.com

The Element of Nu

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