Mission, Role, and Capabilities of US National Laboratories in the Nuclear Field

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International Nuclear Atlantic Conference: Nuclear New Horizons – Fueling our Future

www.inl.gov

Idaho National Laboratory

Nuclear Energy Contributions to the US

AVOIDS
547.5 MILLION
METRIC TONS OF
CARBON EMISSIONS
EACH YEAR

+

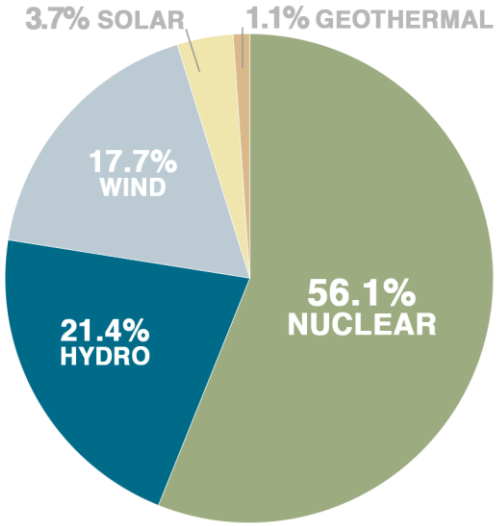
PREVENTS
315,000 SHORT TONS
OF **NOx**

AND

374,000 SHORT TONS
OF **SO_2**
EMISSIONS

—AVERAGE—
CAP FACTOR
>90%
SINCE 1999

CLEAN ENERGY CONTRIBUTION



CONTRIBUTES
$10 BILLION IN FEDERAL
AND **$2.2 BILLION IN STATE**
TAXES EACH YEAR

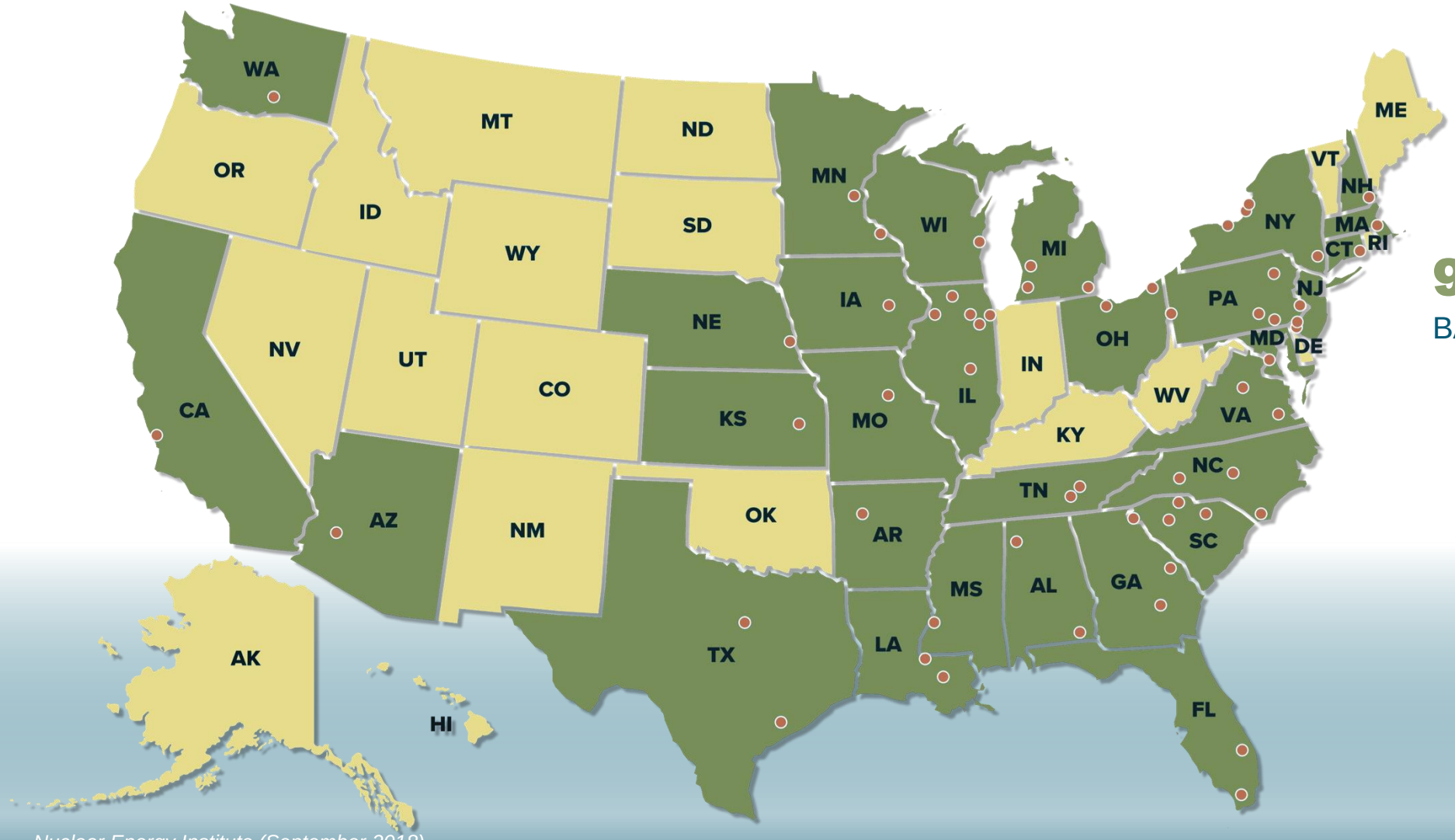
SUPPORTS
475,000
JOBS

SAVES CONSUMERS
AN AVERAGE OF
6%
ON ELECTRICITY BILLS

ADDS
$60 BILLION
TO THE COUNTRY'S
GDP

After Nuclear Energy Institute (2018)

U.S. Nuclear Power Plants – Current Fleet



96
REACTORS
ACROSS 58 SITES

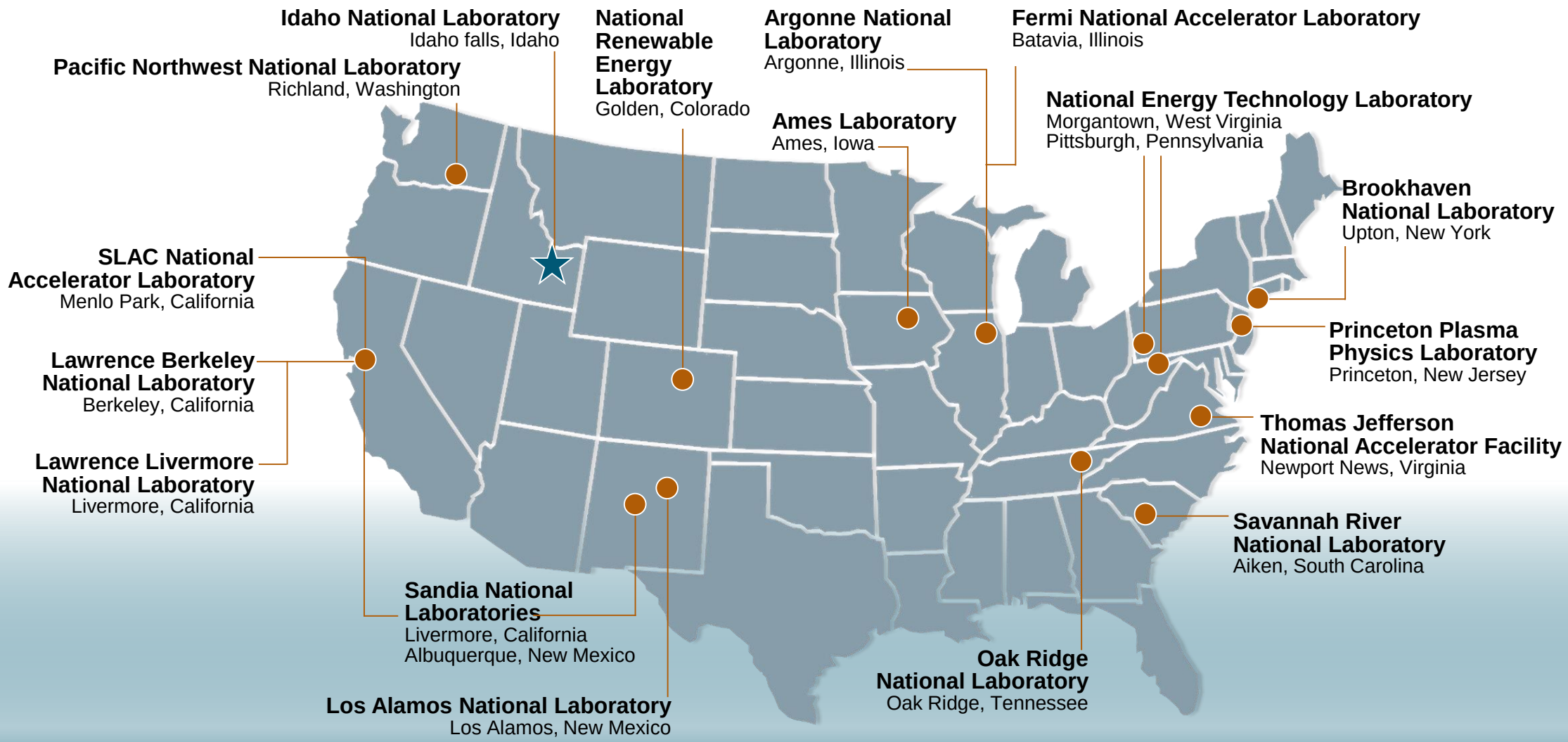
99,635 MWe
BASELOAD CAPACITY

804.9 BILLION
KILOWATT-HOURS IN 2017

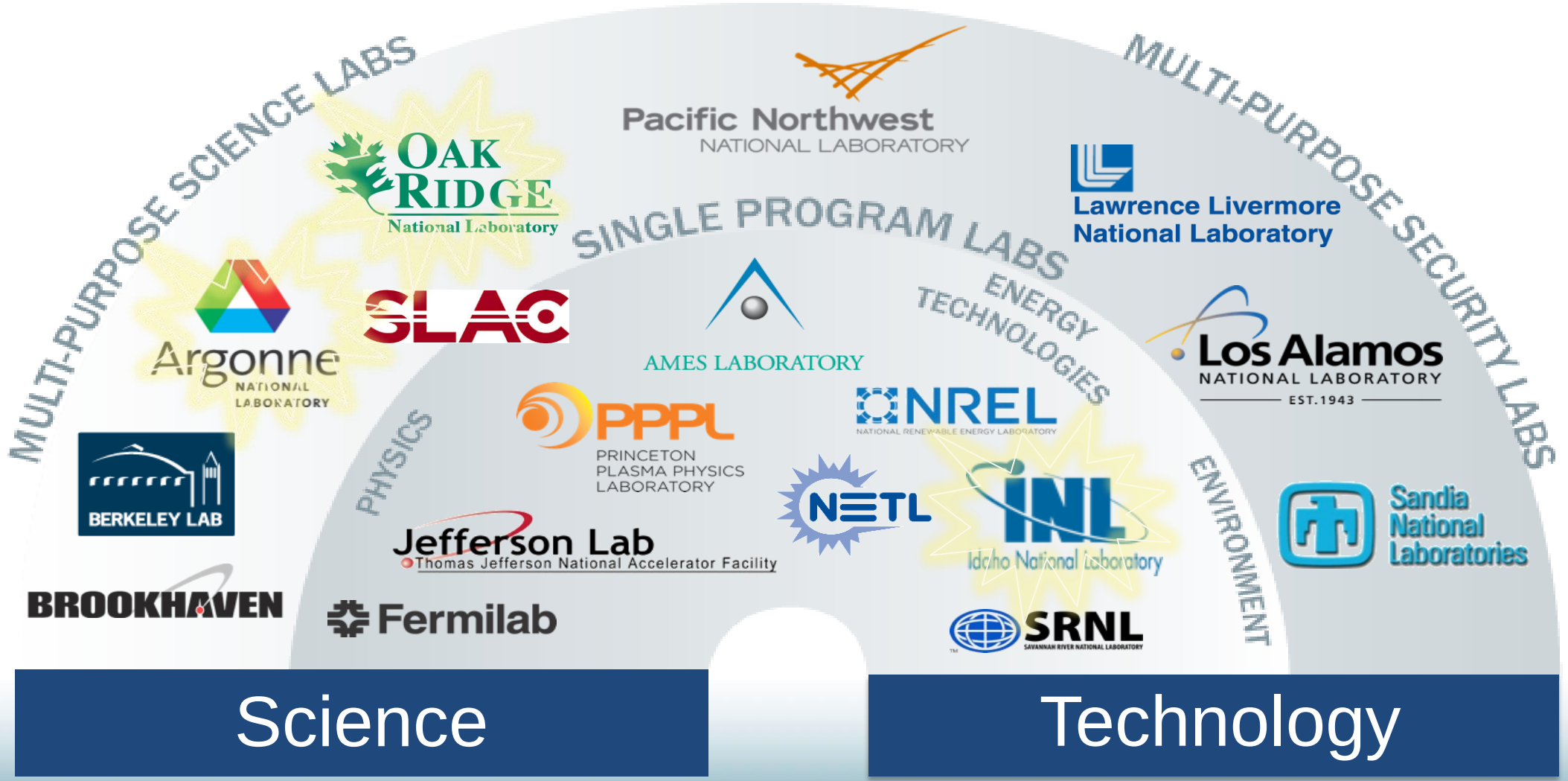
92.2%
CAPACITY FACTOR
IN 2017

Nuclear Energy Institute (September 2018)

Department of Energy National Laboratories



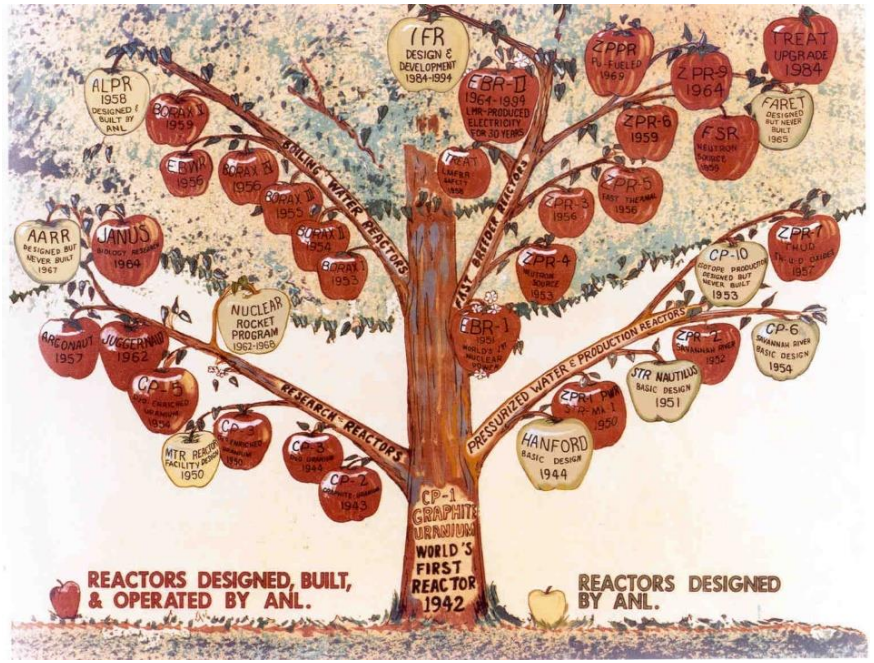
DOE Executes its Missions through Diverse National Labs

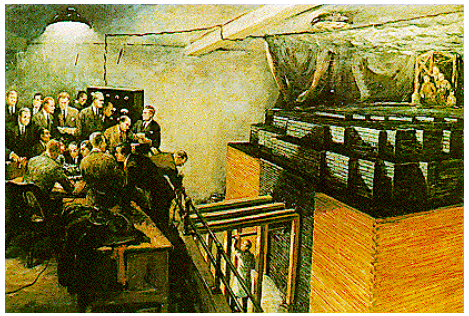


Our National Laboratories – Ames • Argonne • Brookhaven • Fermi • Idaho • Jefferson • Lawrence Berkeley • Lawrence Livermore • Los Alamos • National Energy Technology • National Renewable Energy • Oak Ridge • Pacific Northwest • Princeton Plasma Physics • Sandia • SLAC National Accelerator • Savannah River

ARGONNE'S NUCLEAR PROGRAM BUILDS ON PIONEERING ACHIEVEMENTS

- Argonne's heritage dates back to Enrico Fermi and the first controlled chain reaction (CP-1)
- Argonne pioneered thermal and fast reactors, as well as fuel recycling technologies
- Seminal work on reactors and fuel cycle technologies
- Our mission today is to advance the safe, secure use of nuclear energy and management of nuclear materials
  - Incorporating science and technology advances in the development, design, and operation of nuclear energy systems



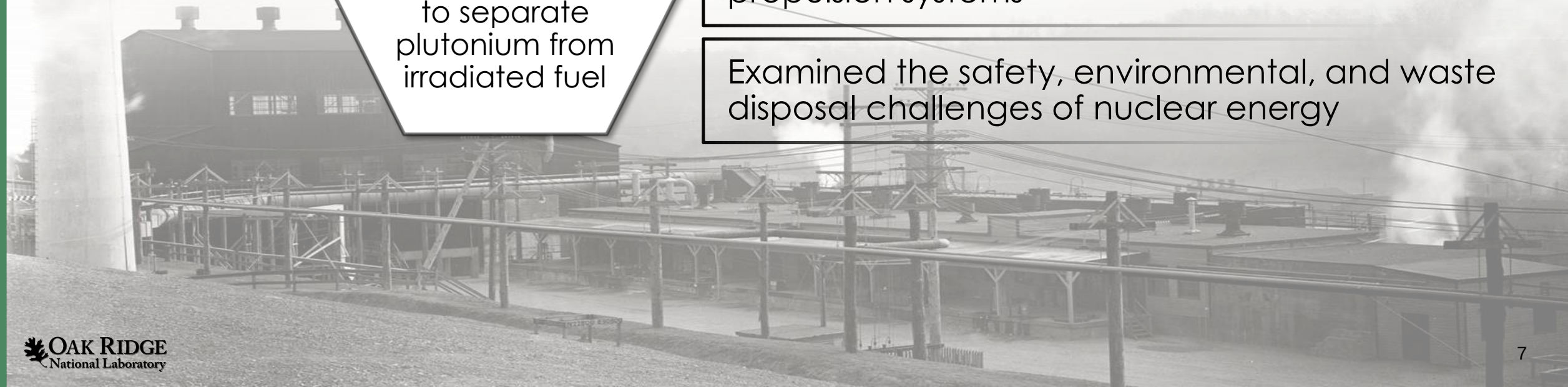


Oak Ridge National Laboratory evolved from the Manhattan Project into a leading NE Laboratory

The Clinton Pile was the world's first continuously operated nuclear reactor

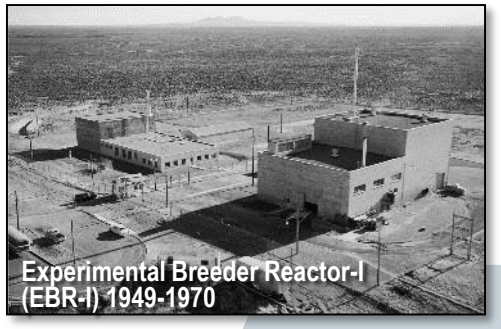
Chemical processing techniques were developed to separate plutonium from irradiated fuel

- Designed, built, and operated 12 experimental reactors
- Developed techniques for nuclear fuel reprocessing
- Contributed to the design of naval nuclear propulsion systems
- Examined the safety, environmental, and waste disposal challenges of nuclear energy

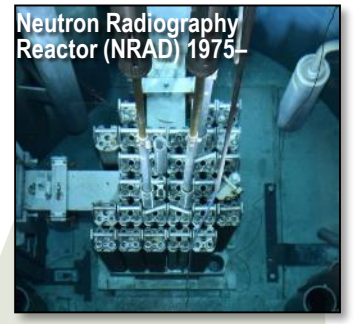


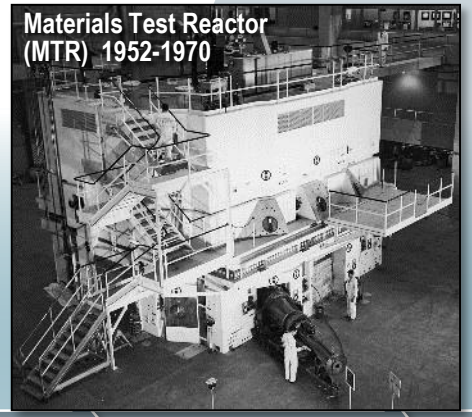
INL's Beginning as National Reactor Testing Station

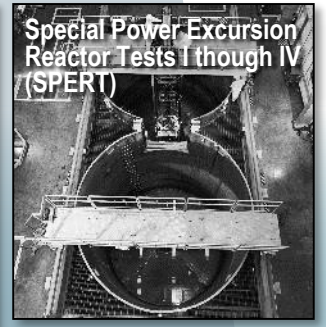
- Established in 1949 on 890 square miles of remote federal land
- Argonne's EBR-I was the first reactor for the nation's new test bed
- Materials Test Reactor followed soon after to provide irradiation testing of fuels and materials for other reactors in planning stages

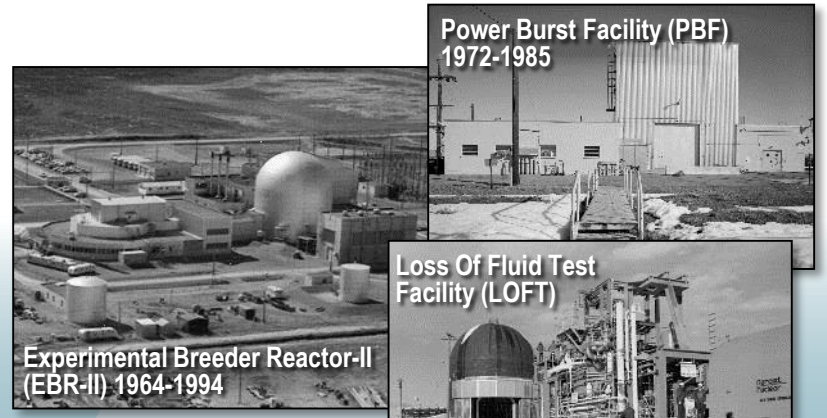


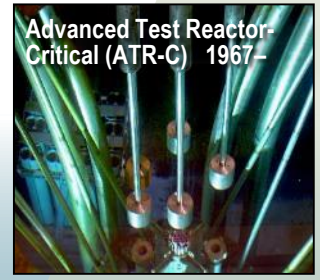
- Additional reactor concepts explored transient and other safety testing to help validate safety codes
- Thermal hydraulic systems testing











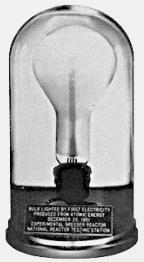
1949 1950s 1960s 1970s 1980s 1990s 2000s 2010s

The Idaho National Laboratory – 70 Years of Groundbreaking Nuclear Energy R&D

International Intellectual Leadership

Building a Laboratory

National Reactor Testing Station



1949

INEL
Idaho National Engineering Laboratory

Energy Mission – Reactor Science, Safety and Sustainability Solutions

1974

INEEL
Idaho National Engineering and Environmental Laboratory

Environmental Management Mission

1997

Argonne NATIONAL LABORATORY

INL
Idaho National Laboratory

INEEL & ANL-W combined to create the new Idaho National Laboratory

- **Nuclear Energy**
- **National and Homeland Security**
- **Energy and Environment**

2005

- **Advancing Nuclear Energy**
- **Securing & Modernizing Critical Infrastructure**
- **Enabling Clean Energy Systems**

2019

National Labs have many capabilities related to nuclear energy

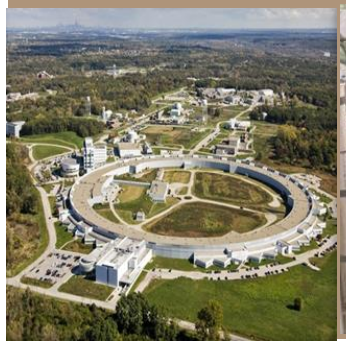
- Reactor and fuel cycle physics
- Reactor design
- Reactor safety analysis
- Neutron activation analysis
- Radiochemistry
- Post-irradiation examination
- Sensors, instrumentation and diagnostics
- Actinide science
- Waste form development and performance assessment
- Modeling and simulation
- Separations science and technology
- Neutron scattering
- Materials design
- Heavy elements
- Materials in extreme environments
- Fuel design, testing, and qualification
- Medical isotopes development and production
- Transportation
- Etc.

Specialized Nuclear Energy Facilities (examples)

Argonne National Laboratory

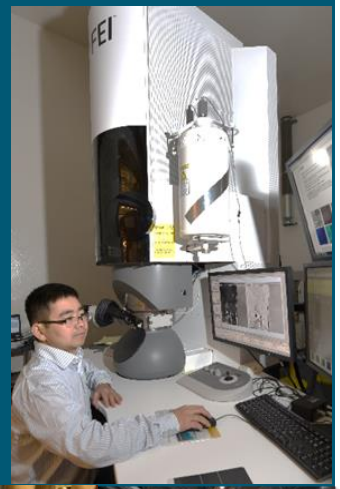
FACILITIES

- Engineering development laboratories
- Radiological laboratories
- Thermo-hydraulics loops
- Intermediate Voltage Electron Microscope
- Advanced Photon Source
- Argonne Leadership Computing Facility
- Argonne Tandem Linear Accelerator System
- Argonne Low Energy Accelerator Facility



Idaho National Laboratory

- Advanced Test Reactor
- Transient Reactor Test Program
- Hot Fuel Examination Facility
- Irradiated Materials Characterization Laboratory



Oak Ridge National Laboratory

- HFIR was constructed in the 1960s to meet national need for production of transuranic isotopes
  - Peak thermal flux: 2.5 × 10^{15} neutrons/cm^2/s at 85 MW (1.6× ILL, >3× all other research reactors outside Russia)
- HFIR was equipped with 4 horizontal beam tubes to support neutron scattering experiments
  - 2007: New cold neutron source with brightness comparable to the world's best
- Primary HFIR missions today:
  - Thermal and cold neutron scattering
  - Isotope production (rapidly growing)
  - Materials irradiation
  - Neutron activation analysis
  - Fundamental physics

Department of Energy Office of Nuclear Energy

The Office of Nuclear Energy (NE) mission is to advance nuclear power to meet the nation's energy, environmental, and national security needs.

Under the guidance of three research objectives, NE resolves barriers to technical, cost, safety, security, and proliferation resistance through early-stage research, development, and demonstration to:

- Enhance the long-term viability and competitiveness of the existing U.S. reactor fleet.
- Develop an advanced reactor pipeline.
- Implement and maintain national strategic fuel cycle and supply chain infrastructure.

Summary of DOE LWR Technologies

- **LWR Sustainability** program focusing on Materials Research, Risk-Informed Systems Analysis, and Plant Modernization
- **Nuclear Energy Enabling Technology** with advanced sensors for monitoring; addressing cyber threats to the nuclear industry
- **Training** with Human Factors, instrumentation and controls, statistics expertise, control room prototypes, and full scale simulators
- **High Performance Computing** to support modeling and simulation for LWRs
- **LWRs nuclear simulation tools** include predicting performance of existing LWR, modeling transient flow in T-H networks, simulating component aging and damage evolution events, etc.

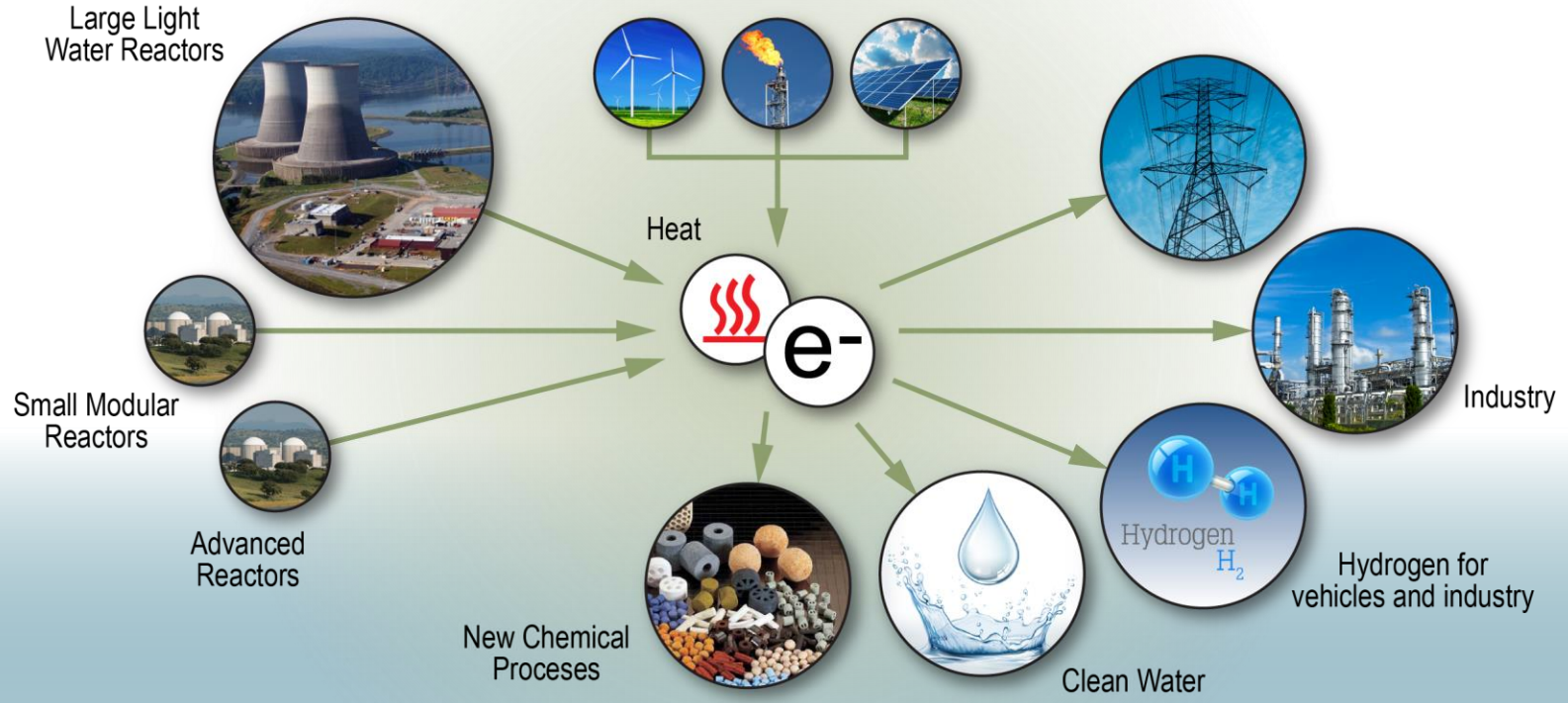
Future Energy System: Integrate Energy Sources and Demands to Maximize Flexibility and Economic Performance While Ensuring Reliability and Resilience

Today

Electricity-only focus

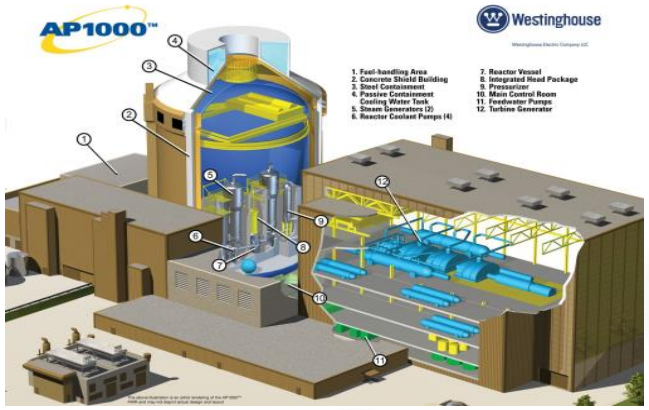
Future

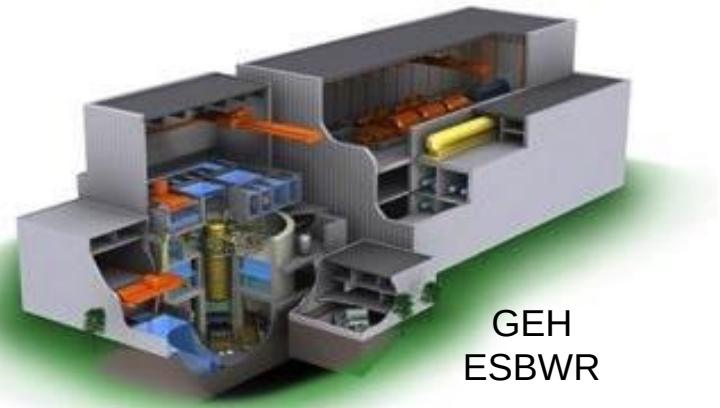
Integrated grid system that leverages contributions from nuclear fission beyond electricity sector



Flexible generators, Advanced processes, Revolutionary design

Continuum of Innovations

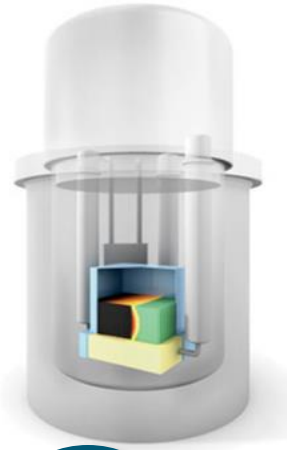




GEH
ESBWR

Advanced Non-LWRs

- Hi-temp gas
- Liquid metal
- Molten salt

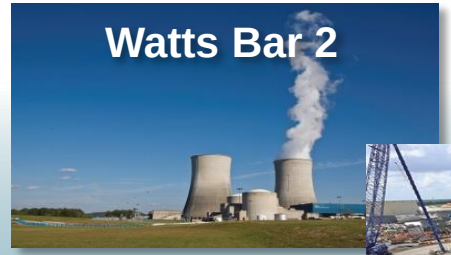


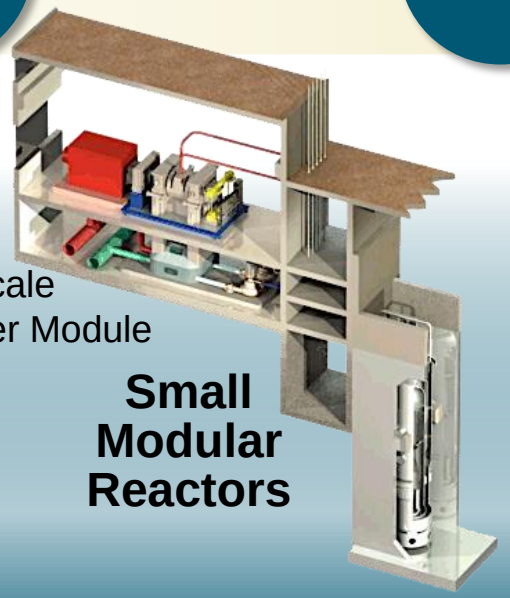
2016

2020

2025

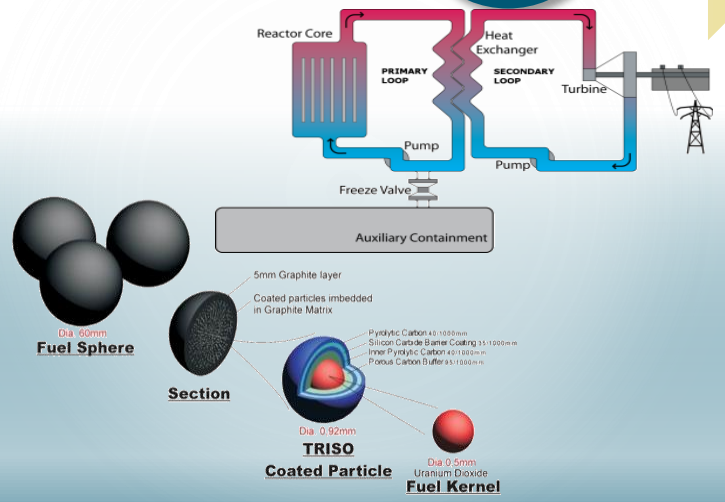
2030





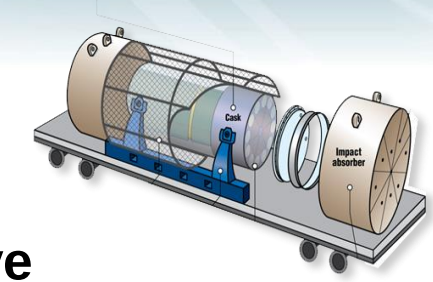
NuScale
Power Module

Small Modular Reactors



Enabling Micro-Reactors (vSMR)

- **Factory built, transportable, 2-20 MW, inherently safe, reliable power**
- **Working through a successful demonstration can resolve uncertainties in the advanced reactor licensing and deployment processes at a reduced cost**
- **Successful deployment in key markets (space, defense, remote off-grid) can open up broader commercial markets**
- **Applications beyond electricity**
- **Potential advantages for integration with intermittent sources**



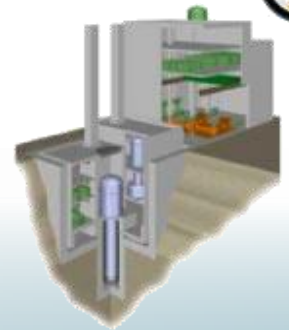
OKLO

HolosGen™

BATTERY
Local Modular Energy

STARCORE NUCLEAR

TOSHIBA Micro Nuclear



Key features and use-cases:

- **Defense applications:**
  Uninterrupted mobile power; potentially no cyber vulnerabilities; heat and power to support various operational needs
- **Commercial applications**
  Support for remote communities, mining sites, etc. Features similar to Defense applications, but with emphasis on economics

USNC ULTRA•SAFE•NUCLEAR

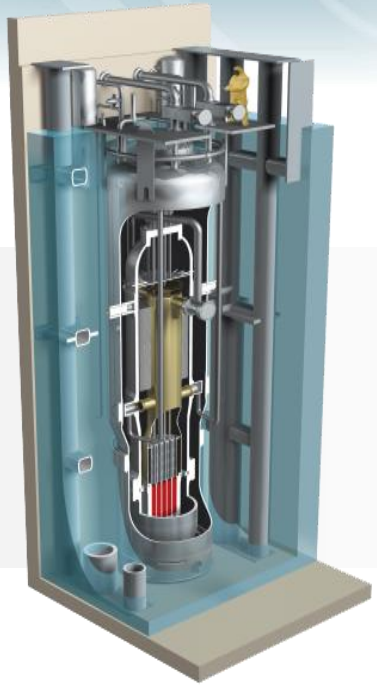
HITACHI

GENERAL ATOMICS

HALEU Feedstock and Fuel Production

- **High-Assay Low Enriched Uranium (HALEU): ~20% enrichment**
- **Initiate recovery of material from irradiated naval fuels and EBR-II spent fuel, and reestablish domestic enrichment**
- **Initiate operations to support advanced reactor start-up cores**

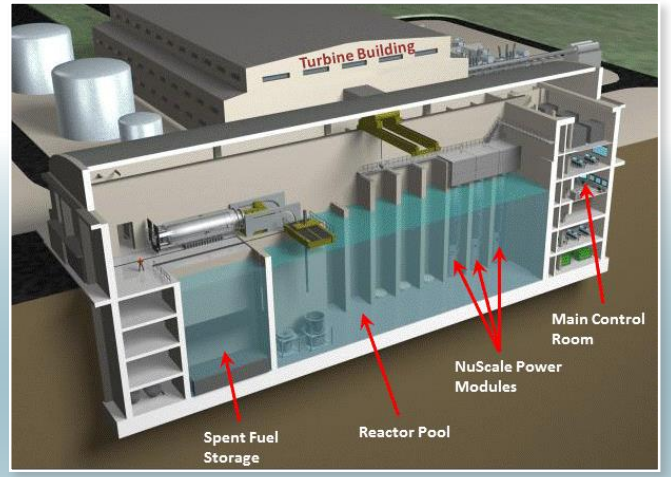
Enabling Small Modular Reactors (SMRs)



INL

- **works with all vendors**
- **works with industry on SMR technology development and deployment**
- **supports DOE in deploying SMRs**

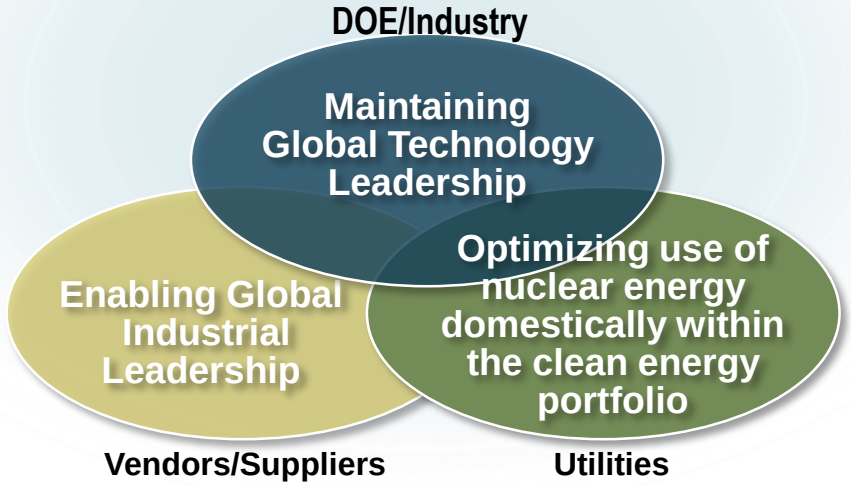
  - UAMPS entered a site use agreement with DOE with intent to build a NuScale SMR on the INL site
  - Utah Associated Municipal Power Systems (UAMPS) is a not-for-profit group of 45 community owned power systems in 8 western states
  - DOE-ID discussing a Power Purchase Agreement (PPA)
  - Joint Use Modular Plant (JUMP) to enable accelerated demonstration, validation, and wide-scale deployment



3-D view of Six NuScale Modules

GAIN

Gateway for Accelerated Innovation in Nuclear



In parallel, create private-public partnership and funding approach, engage industry on technology needs and focus advanced reactor R&D on common technology needs, innovative designs, and reducing cost of advanced nuclear energy systems.

Idaho National Laboratory · Argonne National Laboratory · Oak Ridge National Laboratory

NSUF

Nuclear Science User Facilities

Mission:

- Provide access to network of unique nuclear energy R&D capabilities at no cost to user link intellectual capital with nuclear research infrastructure to fulfill mission of DOE-NE
- Established in 2007 as DOE Office of Nuclear Energy's first and only user facility
- Partner facilities to date: 11 universities + 4 Universities in Center for Advanced Energy Studies (University of Idaho, Boise State University, Idaho State University, University of Wyoming), 7 national laboratories, 1 industrial, 1 international affiliate

August 15, 2019: The National Reactor Innovation Center Established at INL

1 2 3 4 5 6 7 8

Proof-of-Concept ***Proof-of-Performance*** ***Proof-of-Operations***

R&D to Address Technical Feasibility

- Materials and Fuels
- Validated predictive modeling and simulation capabilities
- Experimental Capabilities

Establish Performance of Nuclear Technologies

- Validation data
- Irradiation and transient testing
- Irradiated materials characterization

Demonstration Platform to Address Economic/ Operational Feasibility

- Sites for demonstration
- Licensing Support
- Integrated energy systems support

115TH CONGRESS
2D SESSION

S. 97

AN ACT

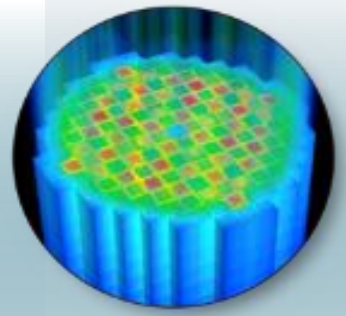
To enable civilian research and development of advanced nuclear energy technologies by private and public institutions, to expand theoretical and practical knowledge of nuclear physics, chemistry, and materials science, and for other purposes.

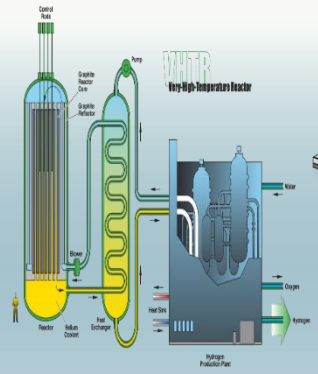
"SEC. 958. ENABLING NUCLEAR ENERGY INNOVATION.

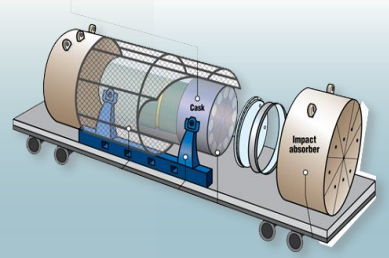
"(a) NATIONAL REACTOR INNOVATION CENTER.—

There is authorized a program to enable the testing and demonstration of reactor concepts to be propose

funded, in whole or in part, by the private sector.







NuScale Power™


INL
Idaho National Laboratory