



EESI

Environmental and
Energy Study Institute

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The State of Play for Nuclear Energy in the United States

Wednesday, April 19, 2023

About EESI



Non-partisan Educational Resources for Policymakers

A bipartisan Congressional caucus founded EESI in 1984 to provide non-partisan information on environmental, energy, and climate policies

Direct Assistance for Equitable and Inclusive Financing Program

In addition to a full portfolio of federal policy work, EESI provides direct assistance to utilities to develop “on-bill financing” programs

Commitment to Diversity, Equity, Inclusion, and Justice

We recognize that systemic barriers impede fair environmental, energy, and climate policies and limit the full participation of Black, Indigenous, people of color, and legacy and frontline communities in decision-making

Sustainable Solutions

Our mission is to advance science-based solutions for climate change, energy, and environmental challenges in order to achieve our vision of a sustainable, resilient, and equitable world.

Polycymaker Education

Briefings and Webcasts



Live, in-person and online public briefings, archived webcasts, and written summaries

Climate Change Solutions



Bi-weekly newsletter with everything policymakers and concerned citizens need to know, including a legislation and hearings tracker

Fact Sheets and Issue Briefs



Timely, objective coverage of environmental, clean energy, and climate change topics

Social Media (@EESIOnline)



Active engagement on Twitter, Facebook, LinkedIn, and YouTube



U.S. DEPARTMENT OF
ENERGY

Office of
NUCLEAR ENERGY

DOE Office of Nuclear Energy 2023 Outlook

Dr. Kathryn (Katy) Huff

Assistant Secretary for Nuclear Energy, Department of Energy

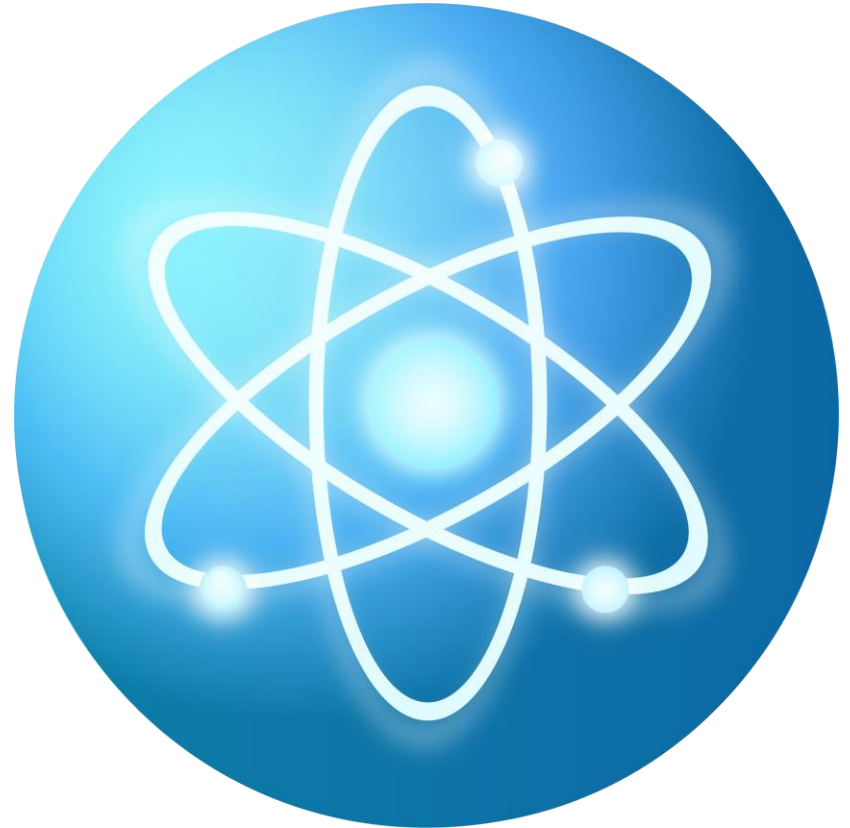
April 19, 2023

Mission

To advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs

Priorities

- Keep existing U.S. nuclear reactors operating.
- Deploy new nuclear reactors.
- Secure and sustain our nuclear fuel cycle.
- Expand international nuclear energy cooperation.



Enable continued operation of existing U.S. nuclear reactors

Nuclear power is **carbon-free energy.**

It's the **largest source of carbon-free electricity** in the United States!



18%

of **all electricity** generated in the U.S.



47%

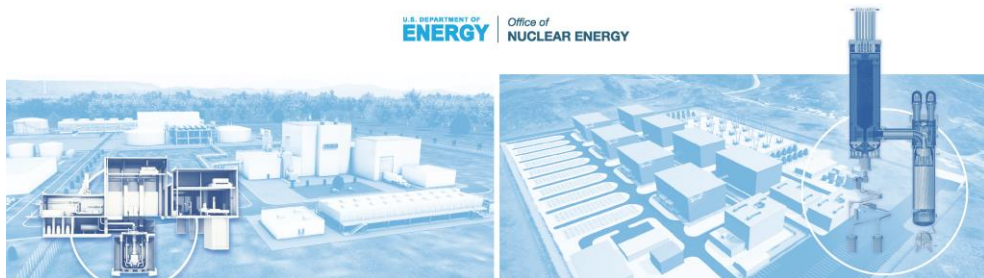
of **all emissions-free electricity** in the U.S.

- R&D programs enhance performance, extend lifetime, reduce operating costs, and develop advanced fuels.
- Integrated energy systems research and hydrogen production demonstrations expand applications and markets for nuclear energy.

Enable deployment of advanced nuclear reactors



ADVANCED NUCLEAR TECHNOLOGY



- Essential to tackling climate crisis, supplying clean energy, and decarbonizing the economy
- Demonstrating reactors with advances in sustainability, safety and reliability, resource utilization, and economics
- Developing small modular reactors to offer siting flexibility, scalability, and energy uses beyond electricity
- Developing microreactors for off-grid communities, remote industrial locations, and disaster relief missions

Coal to Nuclear Transition

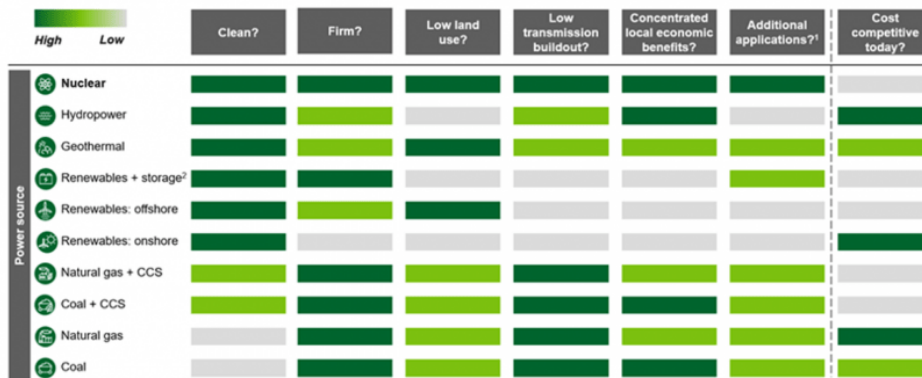
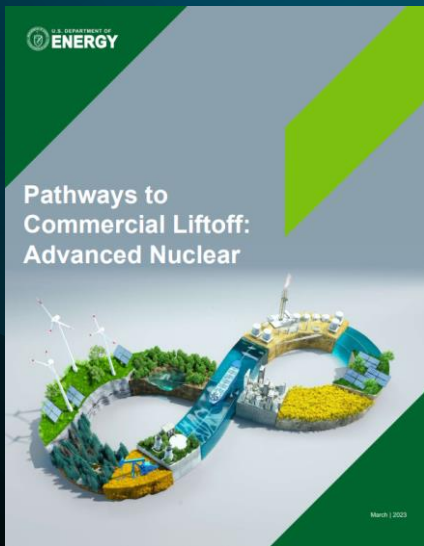


A recent [@ENERGY](#) report finds 80% of coal power plant sites could be converted to nuclear power plants—more than doubling U.S. nuclear capacity to more than 250 gigawatts.



- Nuclear reactors are especially suited to leverage grid, workforce, and other assets at retiring or retired coal plant sites.
- Repurposing unabated fossil plants could deliver place-based solutions and ensure equitable energy transition.
- DOE analysis finds hundreds of coal power plant sites across the country could be converted to nuclear power plant sites.
- Study shows energy communities could benefit from adding 650 permanent jobs, additional economic activity of \$275 million, and 86% reduction in greenhouse gas emissions.
- Leveraging existing infrastructure and highly skilled workforce can reduce system costs.

Pathways to Commercial Liftoff



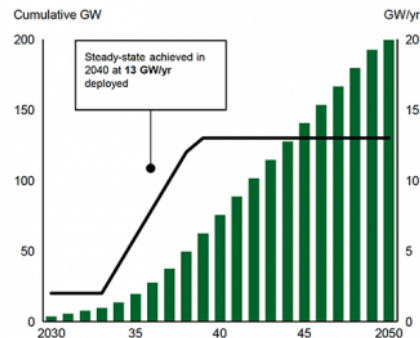
1. Additional applications include clean hydrogen generation, industrial process heat, desalination of water, district heating, off-grid power, and craft propulsion and power
2. Renewables + storage includes renewables coupled with long duration energy storage or renewables coupled with hydrogen storage

Figure: Select elements of nuclear energy's value proposition as compared to other power sources.

Figure: New nuclear build-out scenarios and implications for industrial base capacity requirements.

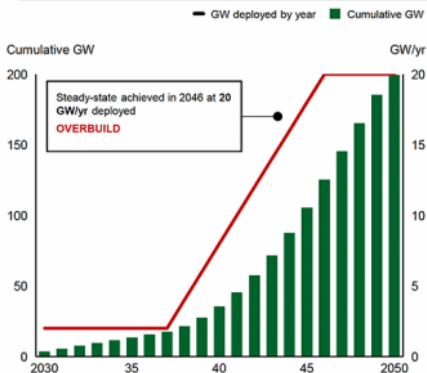
New nuclear deployment starting in 2030

Annual deployment (GW/yr) built and Cumulative GW online

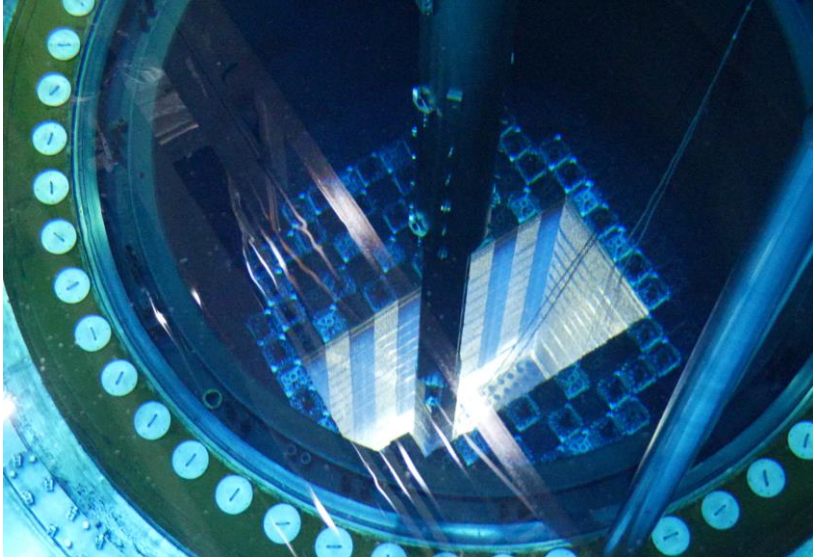


New nuclear deployment starting in 2035

Annual deployment (GW/yr) built and Cumulative GW online



Secure and sustain the global nuclear fuel cycle



- Addressing gaps in the domestic nuclear fuel supply chain for existing and advanced nuclear reactors
- Encouraging expansion of domestic commercial capacity in conversion and enrichment services to assure the supply of low enriched uranium (LEU) and high-assay low-enriched uranium (HALEU)
- Developing strategy for the integrated waste management of spent nuclear fuel
- Developing a consent-based approach to siting interim storage facilities

Consent-Based Siting

While spent nuclear fuel is stored safely at over 70 U.S. sites, those communities never agreed to host that material in the long term.

DOE is committed to a consent-based process for siting one or more consolidated interim spent nuclear fuel storage facilities.

- Prioritizes people and communities
- Seeks willing and informed consent
- Flexible, adaptive, and collaborative process
- Responsive to community concerns
- Centers equity and environmental justice
- Informed by public feedback



energy.gov/consentbasedsiting

Expand International Nuclear Energy Cooperation



- Support Front-End Engineering Design studies for U.S. nuclear builds in foreign markets.
- Support nuclear safety in Armenia and Ukraine, including emergency support.
- Deploy Clean Energy Training Centers to inform small and emerging nuclear states of U.S. nuclear technology within clean energy systems.
- Increase U.S. technical presence through bilateral nuclear energy cooperation particularly in Central and Eastern Europe, the Baltic States, Southeast Asia, and the Americas including workforce capacity building, academic and professional training, joint studies, and regional technical events.
- Leverage U.S. sponsorship of subject matter experts in international organizations to advance U.S. nuclear equities.



Thank You!

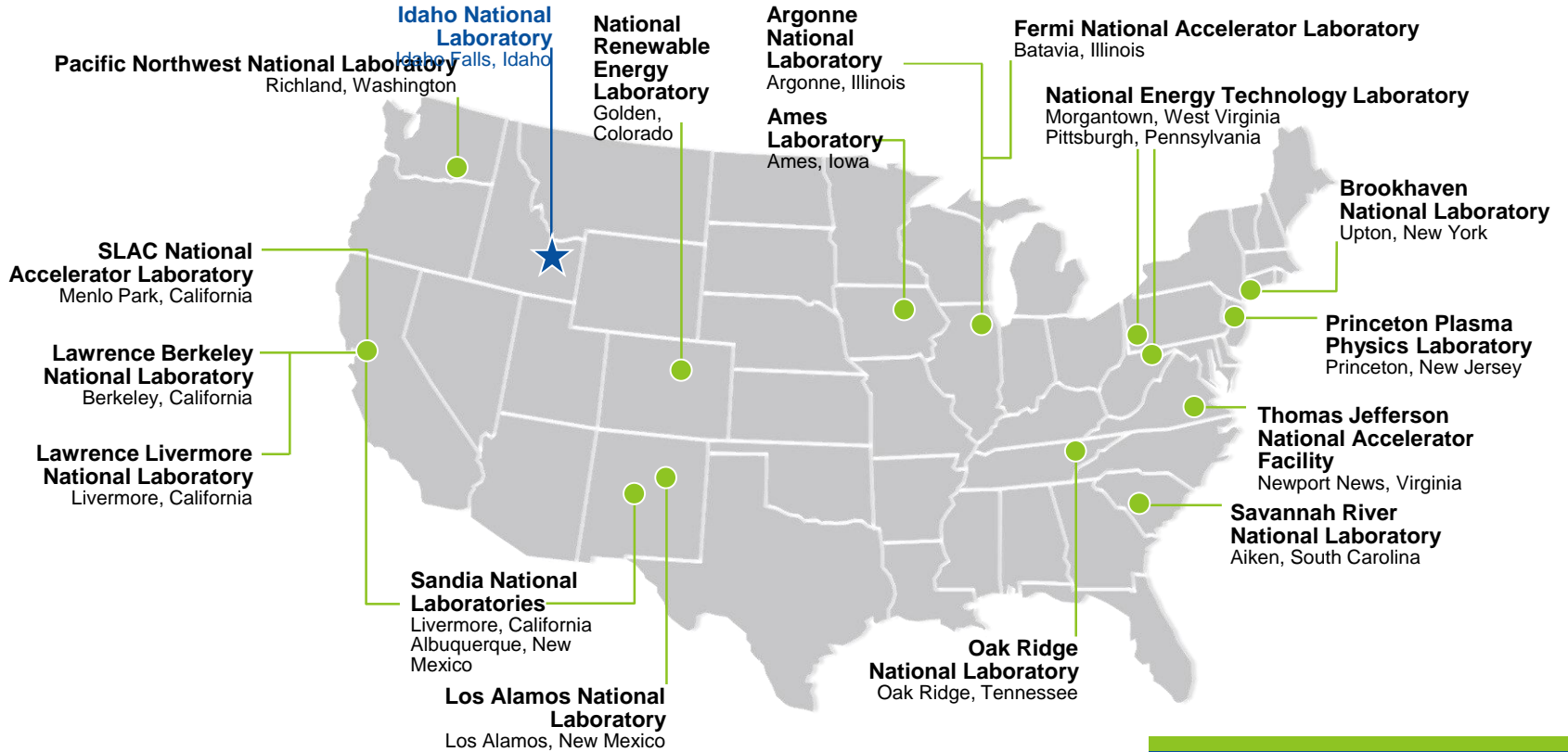
U.S. DEPARTMENT OF
ENERGY

Office of
NUCLEAR ENERGY

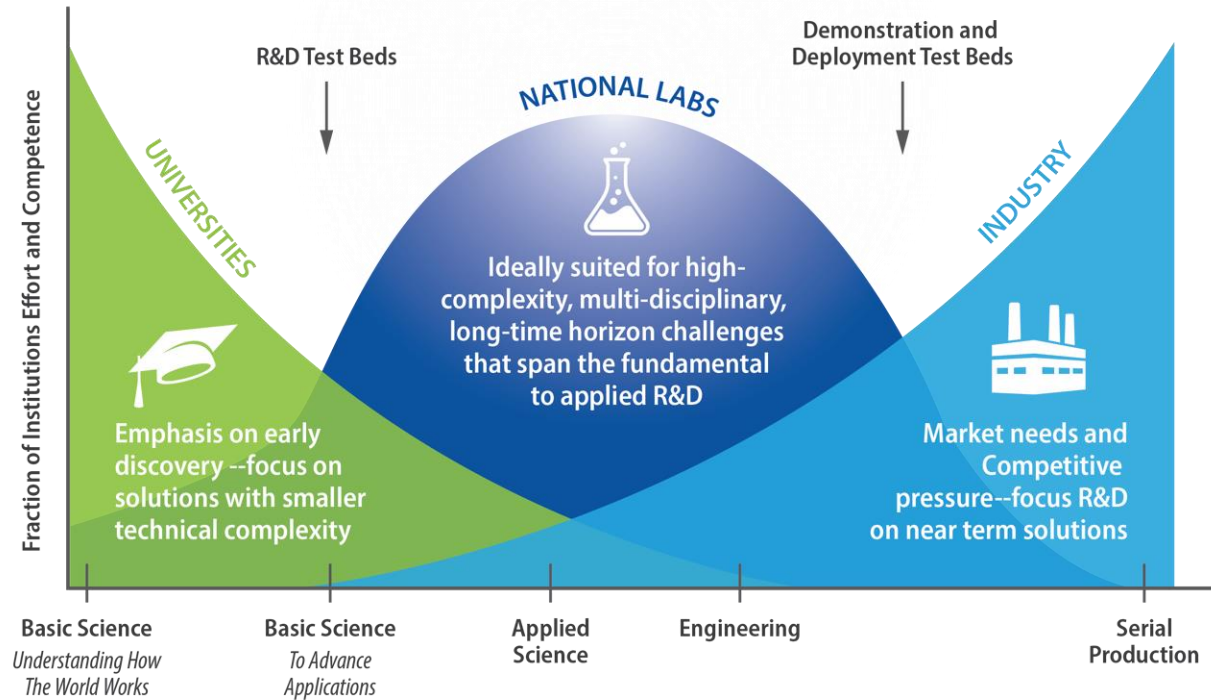
Jhansi Kandasamy
Executive Director
INL Net-Zero Program

Idaho National Laboratory: The Role of Nuclear in Reaching Net-Zero Emissions

DOE National Laboratories

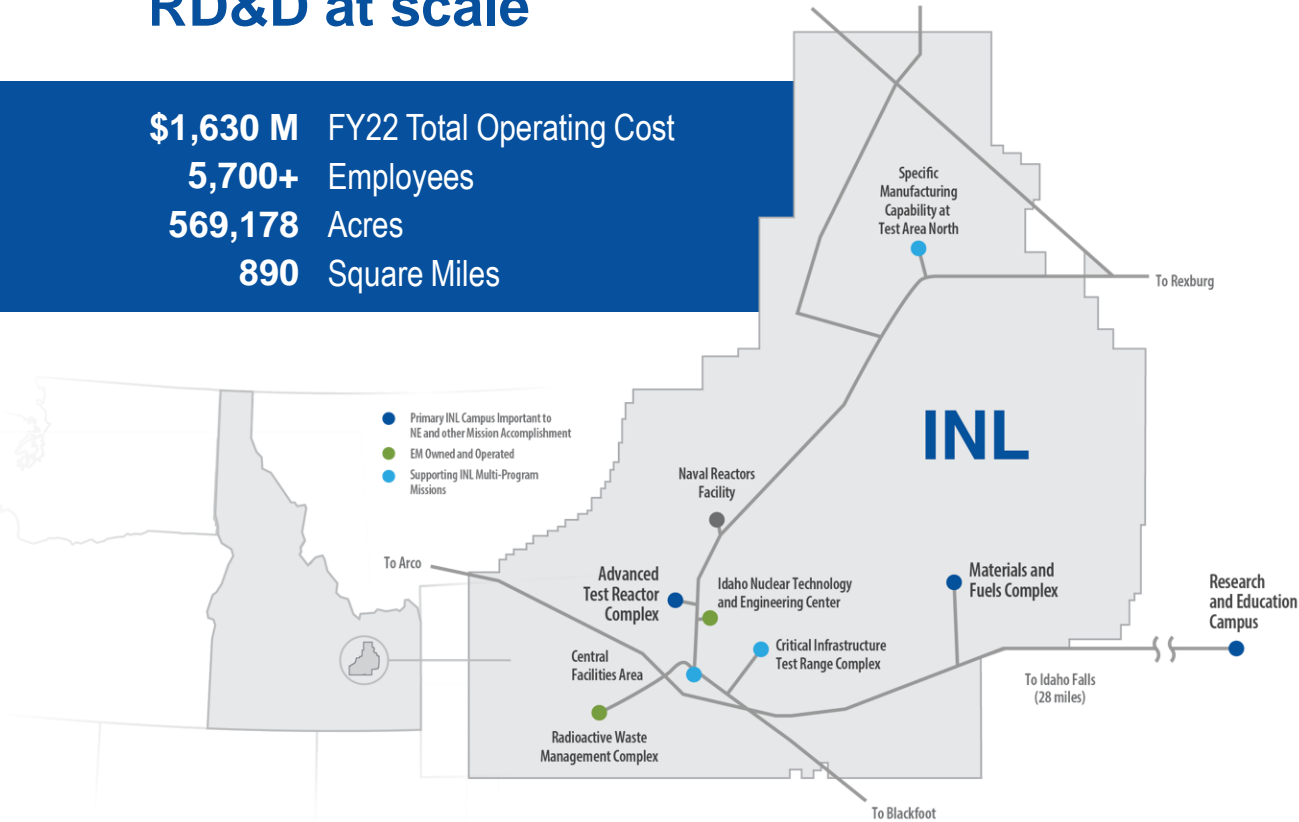


DOE labs support the entire technology lifecycle



Unique INL site, infrastructure, and facilities enable energy and security RD&D at scale

\$1,630 M FY22 Total Operating Cost
5,700+ Employees
569,178 Acres
890 Square Miles



4 Operating reactors

22 Hazard Category II & III non-reactor facilities/ activities

49 Radiological facilities/activities

17. Miles railroad for shipping nuclear fuel

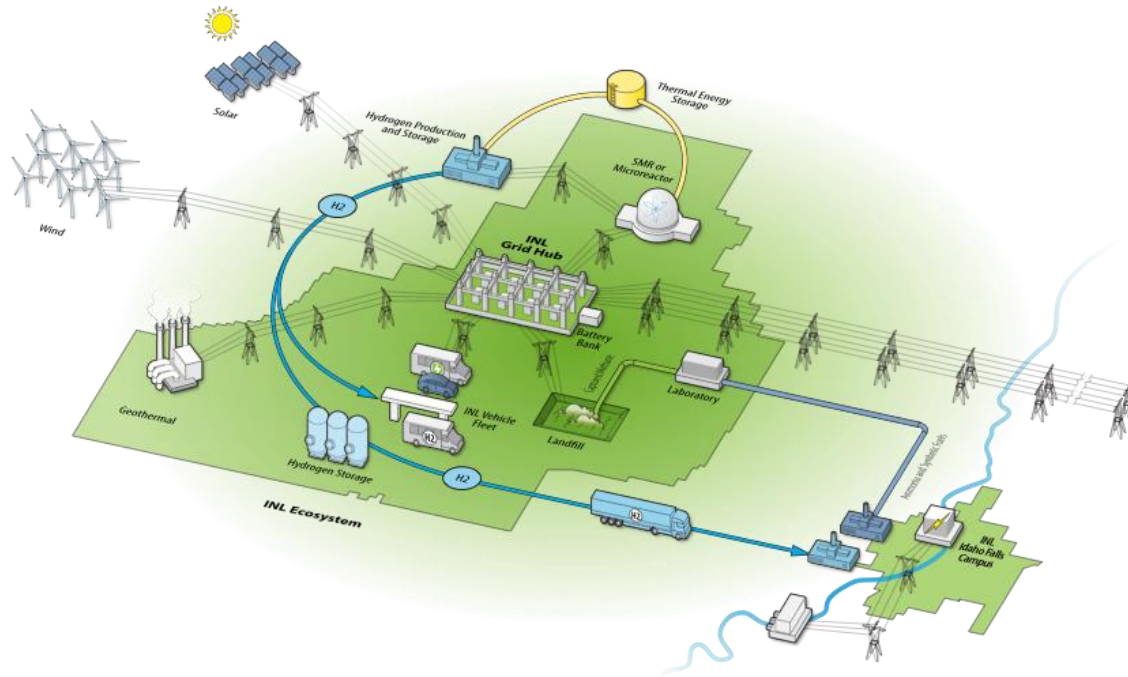
4⁵ Miles primary roads (125 miles total)

9 Substations with interfaces to two power providers

128 Miles high-voltage transmission & distribution lines

3 Fire Stations

Net-Zero City



INL's Roadmap to Net-Zero through Nuclear

Time to Market and Operability Case Study for On-Site Microreactor Deployment

Infrastructure & Siting

Developing infrastructure and siting resources necessary for onsite deployment

Licensing & Regulation

Determine efficient, timely and economical process

Fuel Cycle

Entire cycle from fuel identification to waste management

Financial & Contracting

Identify financial structure and funding methodology

Public Engagement: Communication, Outreach, and Education

NRIC/NRC Collaboration

- Congress recognized the importance of agency coordination in the Nuclear Energy Innovation Capabilities Act
- DOE/NRC MOU to “coordinate DOE and NRC technical readiness and sharing of technical expertise and knowledge on advanced nuclear reactor technologies and nuclear energy innovation, including reactor concepts demonstrations, through the [NRIC].”
 - NRIC Rotations



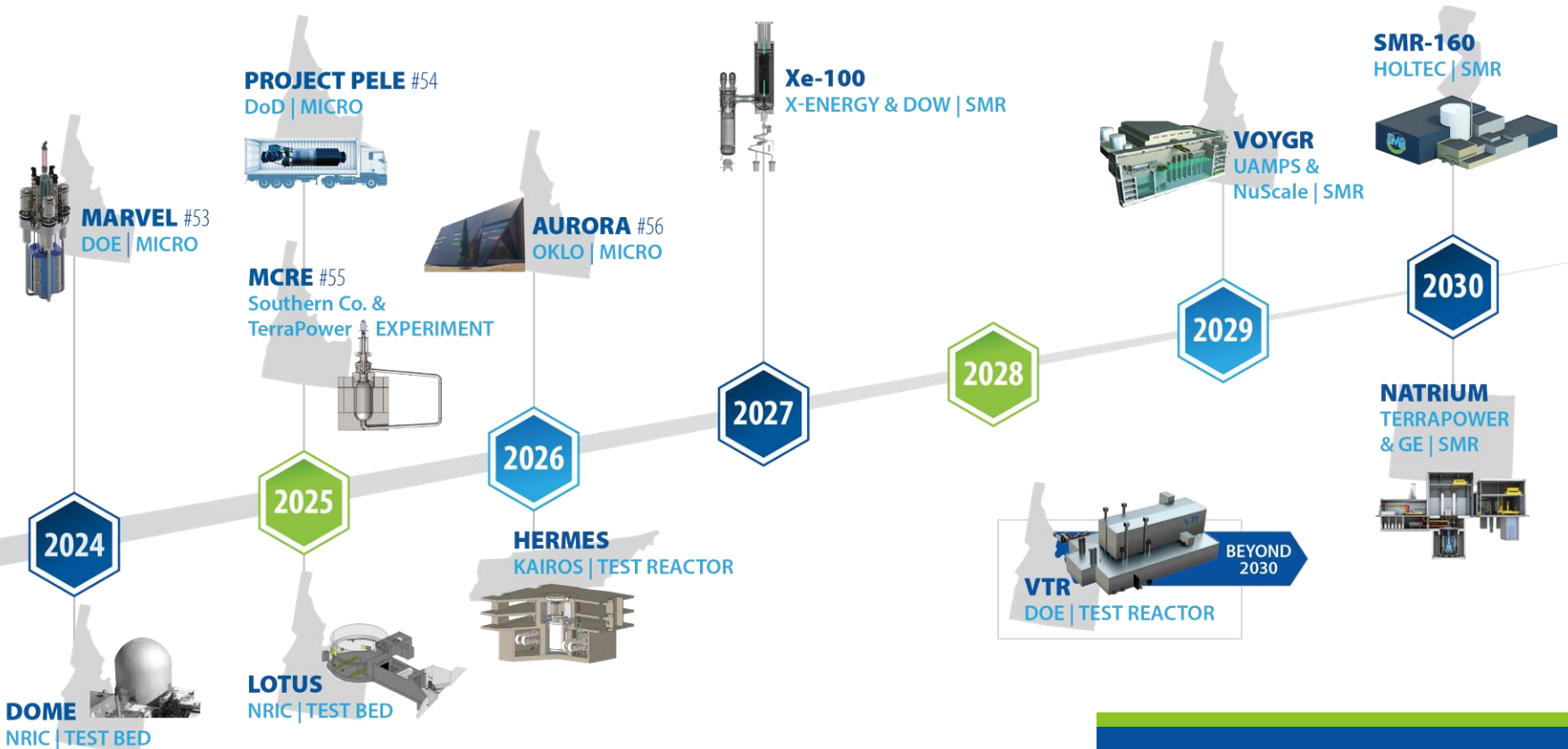
*Fred Sock
Office of
Nuclear
Regulatory
Research*



*Allen Fetter
Office of
Nuclear Reactor
Regulation*

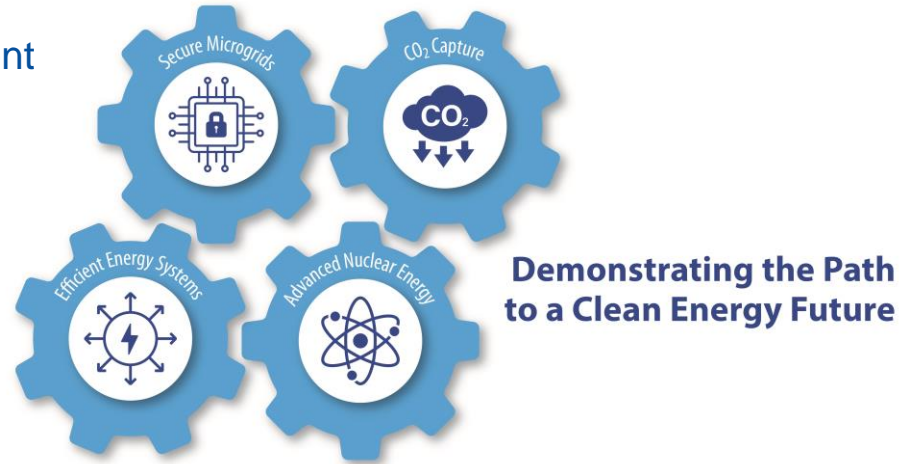
- Monthly Coordination Calls – DOE/NRC/NRIC

Accelerating advanced reactor demonstration & deployment

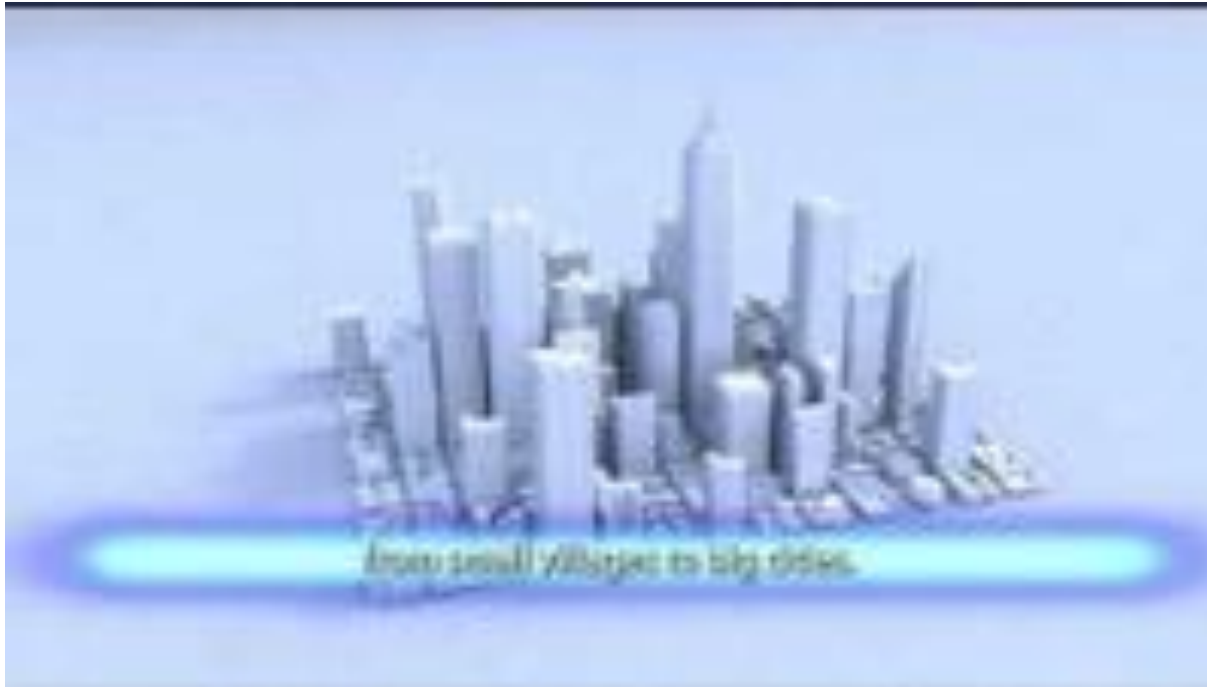


Collaborations

- National Labs
 - Partnering on key Net-Zero initiatives with all 17 national labs
- State of Idaho
 - EV infrastructure & workforce development
- Universities
 - Innovations, research, and workforce development
- Tribal Nations
- Net-Zero World
 - Ukraine
 - Indonesia
 - ASEAN



Transforming the world to a net-zero future



Contact Information



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INL Net-Zero Program
Jhansi.Kandasamy@inl.gov
(o) 208-526-5390

Visit our website at inl.gov/net-zero/





Backup slides

Research, Development, & Demonstration at Idaho National Laboratory

- INL's site characteristics and operations make it a highly relevant demonstration site
- Representative of a city or county.
- INL will lead by example; lessons learned can inform best-practices



U.S. nuclear industry recognizes the demand for new nuclear power projects

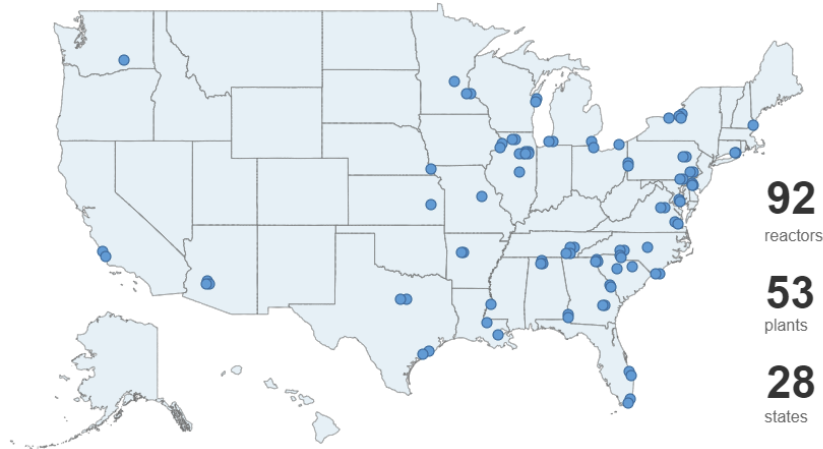
Utilities recently identify the need to add 100 gigawatts of nuclear power by 2050, more than doubling current capacity.



NUCLEAR ENERGY
FACT SHEET 2022

United States

NUCLEAR POWER ACROSS THE U.S.



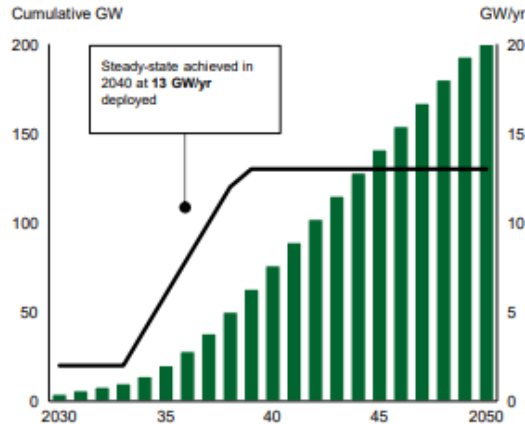
Today, 92 reactors provide nearly 20% of the electricity produced for our power grid and more than half of our carbon-free electricity – more than solar, wind, hydro, and geothermal combined.

- Utilities are prepared to invest in nuclear energy because it is a proven non-carbon-emitting solution
- New reactor designs are simpler, more versatile, and more economical at scale
- Utilities are evaluating reusing retired coal plant sites to leverage existing infrastructure and workforce
- Emissions avoided by adding 100 gigawatts of nuclear power is equivalent to taking more than 100 million cars off the road.

U.S. domestic nuclear capacity has the potential to scale from ~100 GW in 2023 to ~300 GW by 2050

New nuclear deployment starting in 2030

Annual deployment (GW/yr) built and Cumulative GW online



New nuclear deployment starting in 2035

Annual deployment (GW/yr) built and Cumulative GW online

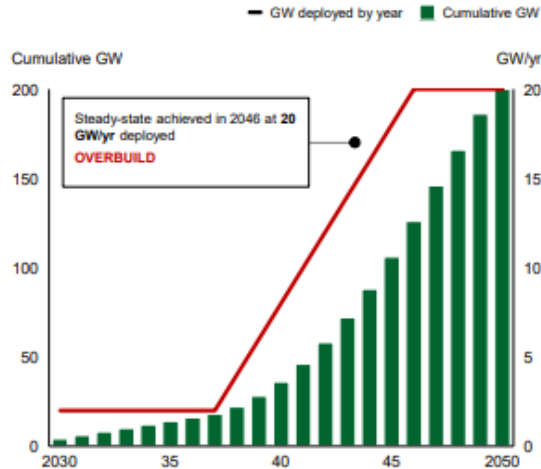
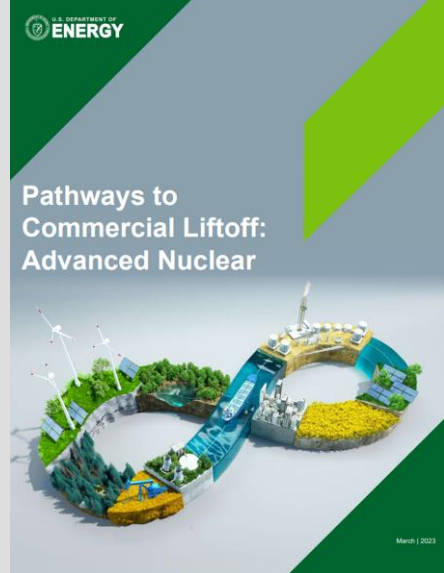


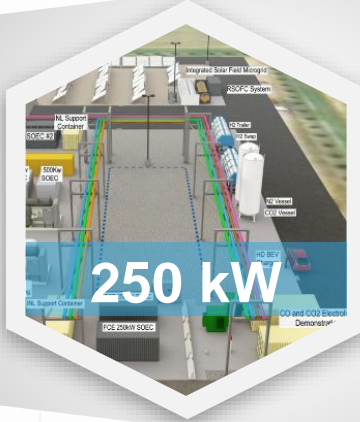
Figure 1: New nuclear build-out scenarios and implications for industrial base capacity requirements



“Power system decarbonization modeling, regardless of level of renewables deployment, suggests that the U.S. will need ~550–770 GW of additional clean, firm capacity to reach net-zero.”

Next level integrated energy systems – *Demonstrating the pathway to commercial use*

Scaling up
high temp
electrolysis for
hydrogen
production



Nuclear Waste: Leading Environmental and Waste Technologies

Haruko Wainwright, MIT

NSE

Nuclear Science & Engineering at MIT

science : systems : society



Nuclear Waste: Key Facts

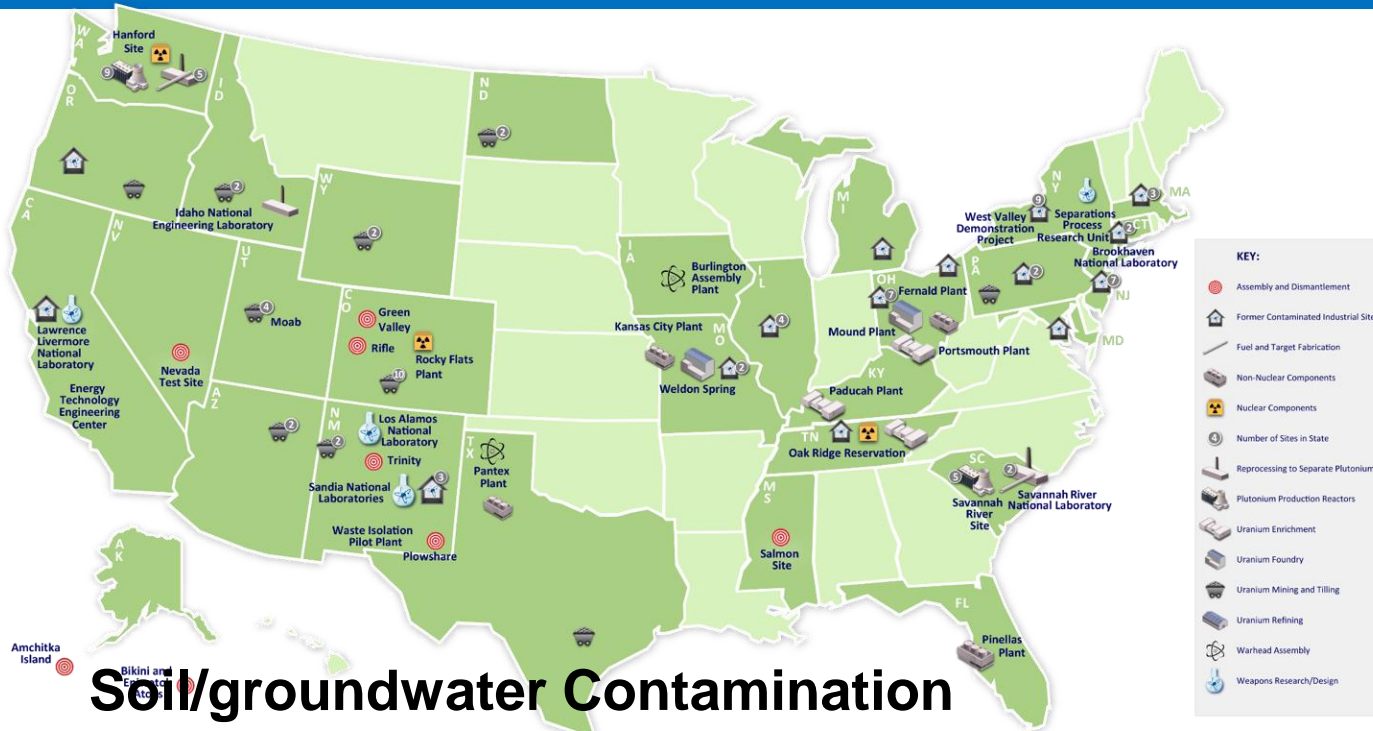
Small/well accounted waste footprint across the life cycle

Best managed/isolated waste

Environmental monitoring for providing assurance

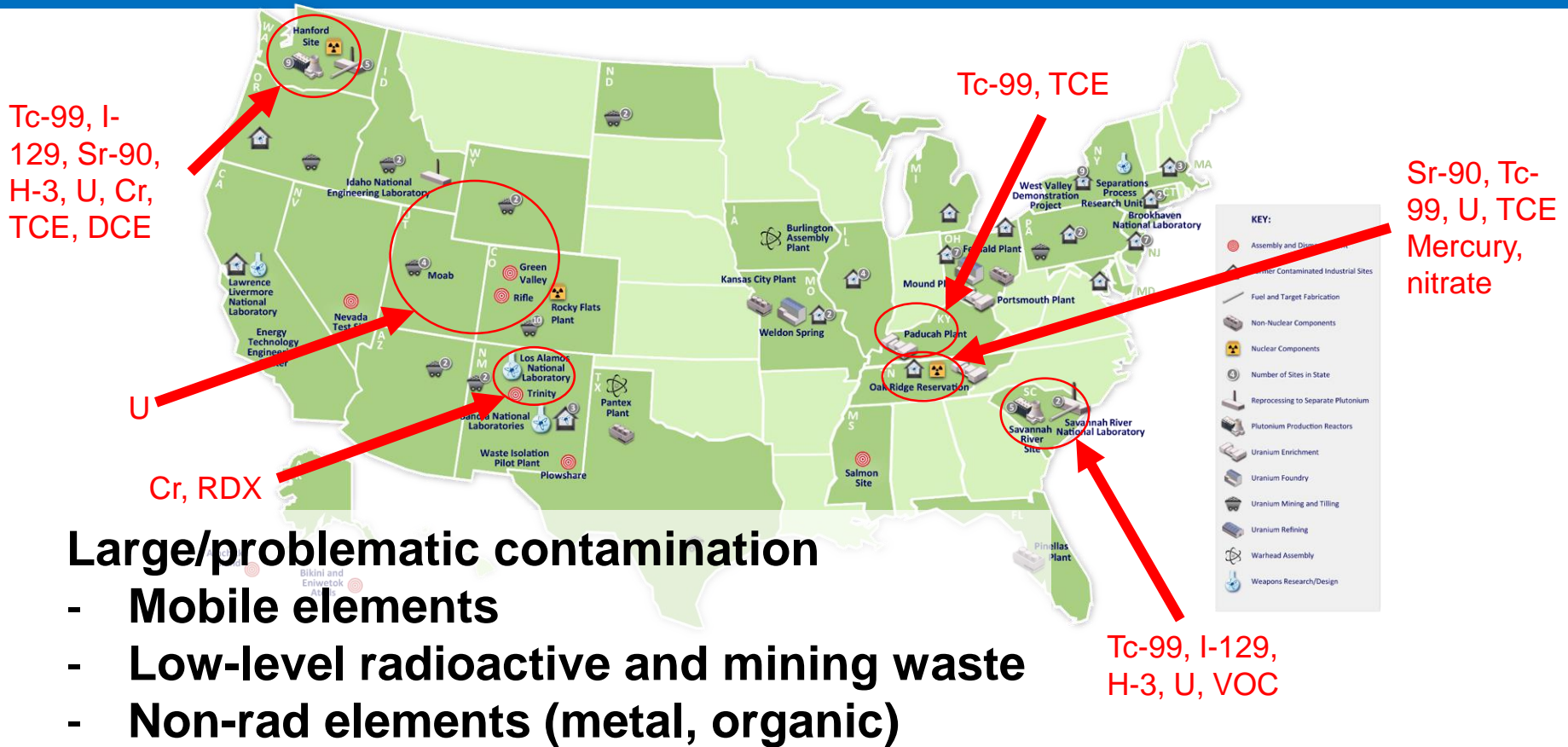
Advancing interdisciplinary research and education

Lessons Learned from DOE's Legacy Sites



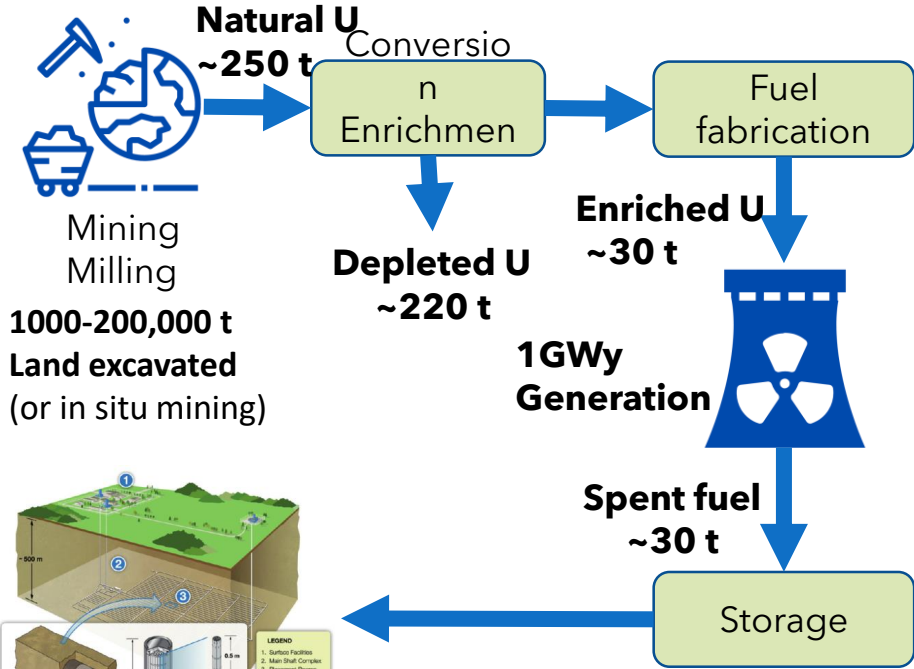
Soil/groundwater Contamination
Radionuclides, Metal, Organic contaminants
→ 30+ years of remediation

Lessons Learned from DOE's Legacy Sites



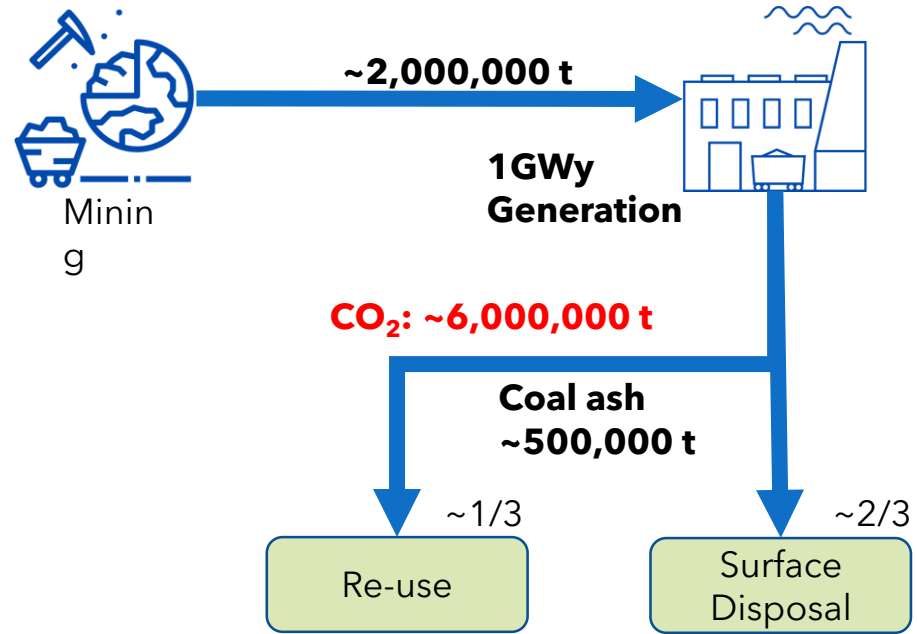
Waste Across Energy Life Cycle: Nuclear/Coal

Nuclear Energy



Construction: ~9,000 t of concrete/metal

Coal Energy



Coal ash contains Hg, Cd, As, U etc

Construction: ~11,700 t of concrete

Waste Across Energy Life Cycle: Renewable?



Mining

Manufacturing

1GWy
Generation



Waste
~3,000 t/year

- Cap. factor = 0.3
- 30 year life

(IEA-PVPS 2016)



Chemical Engineering Journal 431 (2022) 133825



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej



Metal leaching from Lithium-ion and Nickel-metal hydride batteries and photovoltaic modules in simulated landfill leachates and municipal solid waste materials

M. Kayla Kilgo^a, Annick Anctil^b, Marian S. Kennedy^c, Brian A. Powell^{a,*}

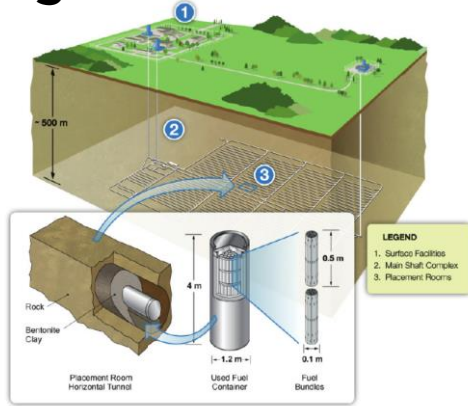
^a Department of Environmental Engineering and Earth Sciences, Clemson University, Clemson, SC 29634, United States

^b Department of Civil and Environmental Engineering, Michigan State University, East Lansing, MI 48824, United States

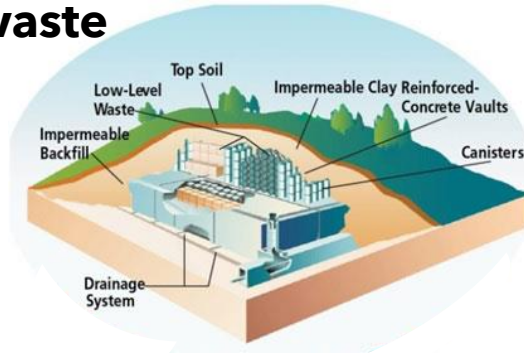
^c Department of Materials Science and Engineering, Clemson University, Clemson, SC 29634, United States

Disposal: Waste Isolation Systems

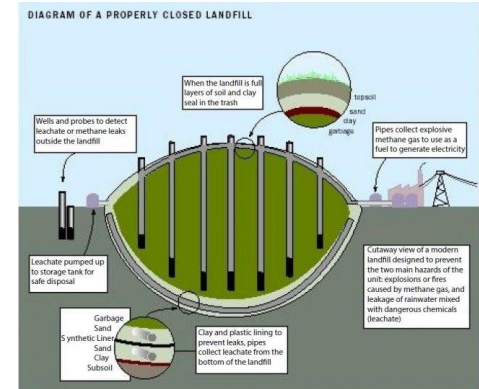
High-level rad. waste



Low-level (U mining) waste

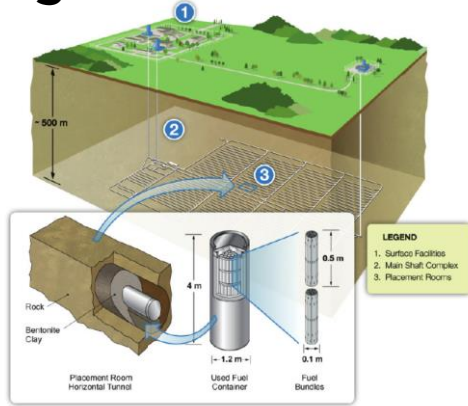


Hazardous waste

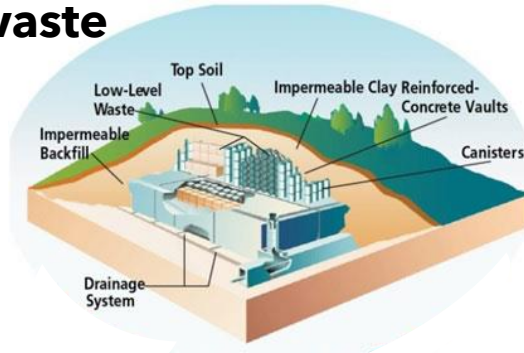


Disposal: Waste Isolation Systems

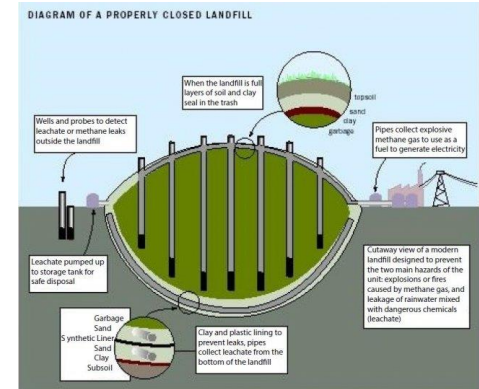
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Hazardous waste



Barrier systems

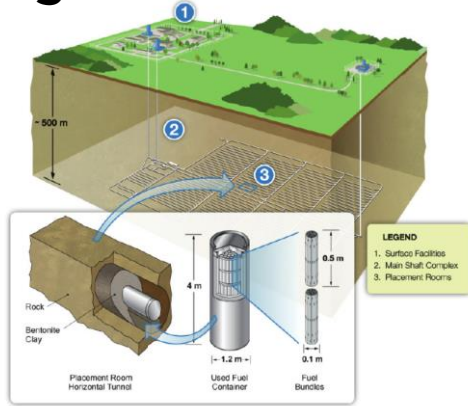
- Waste form/canister/clay
- Deep geology

- Clay cover/geomembrane

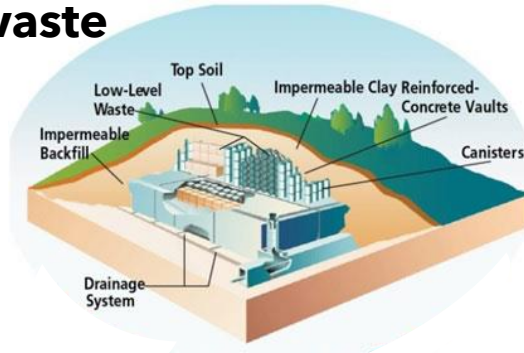
- Clay cover/geomembrane

Disposal: Waste Isolation Systems

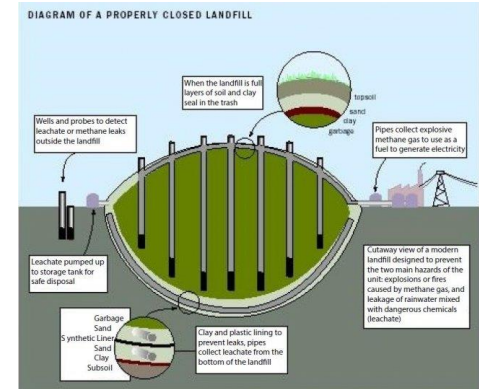
High-level rad. waste



Low-level (U mining) waste



Hazardous waste



Barrier systems

- **Waste form/canister/clay**
- **Deep geology**

- **Clay cover/geomembrane**

- **Clay cover/geomembrane**

Compliance

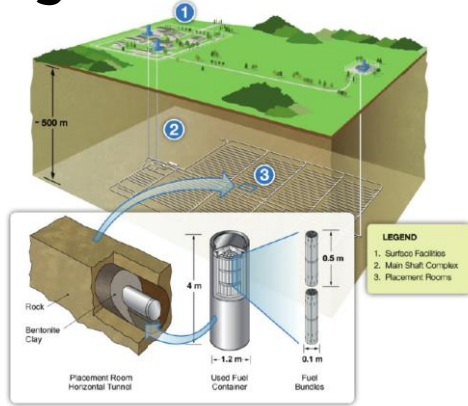
- **10,000 - 1,000,000 years**
- Probabilistic risk assessment

- **500 - 100,000 years**
- Probabilistic risk assessment

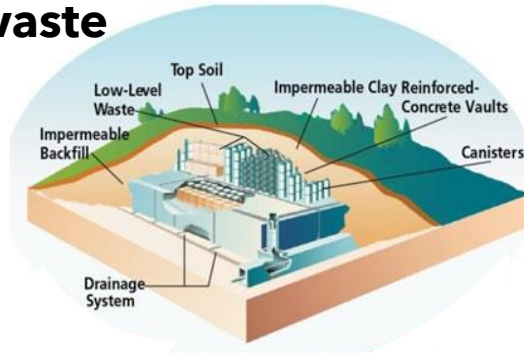
- **30 years + extension**
- No risk assessment required

Disposal: Waste Isolation Systems

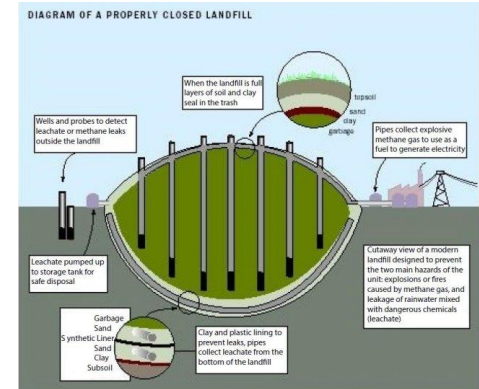
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Hazardous waste



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Compliance

- **10,000 - 1,000,000 years**
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- **500 - 100,000 years**
- Probabilistic risk assessment

- **30 years + extension**
- No risk assessment required

Radioactive toxicity

Decays over time/Long-lived nuclides are internal exposure

Toxicity:

Some never decay: metals etc

Waste Management History

General Hazardous Waste



Times Beach



Cuyahoga River

Solid Waste Disposal Act, 1965

Clean Air Act, 1970

Clean Water Act, 1972

Resource Conservation and Recovery Act,
1976

Comprehensive Environmental Response
Compensation and Liability Act, 1980

Coal ash rule, 2015

Nuclear Waste

1955 Nuclear power to generate electricity

1957 National Academy recommend
geologic disposal of high-level waste

1970 U.S. begins search for sites

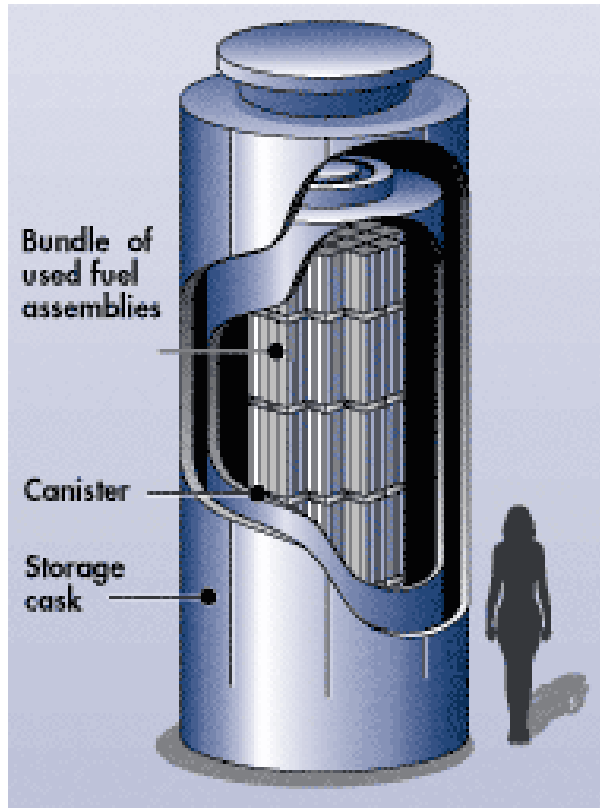
1980 Nuclear Waste Policy Act (NWPA)

1985 Low-level Radioactive Waste Policy
Amendments Act

1987 NWPA to focus on Yucca Mountain

2015 Consent-based siting

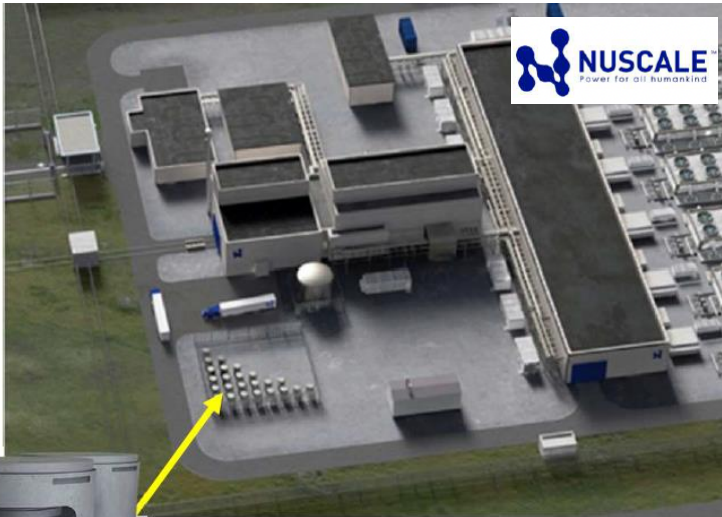
Dry Cask Storage for Spent Fuel



- Annual spent fuel: 2-3 casks per year
- Passive safety: no active cooling
- Probabilistic risk assessment for earthquakes, floods, high winds, lightning strikes, accidental aircraft crashes, and pipeline explosions
- No accident/leak since 1986

Advanced Reactors

Advanced reactor companies have waste management plans



**Independent spent fuel storage:
0.8 acre pad for 60-yr operation**

Different types of waste

- Different fuel: TRISO fuel
- Structural material: Graphite
- Coolant: Molten salt, sodium

→ Many research activities on managing/disposing these wastes

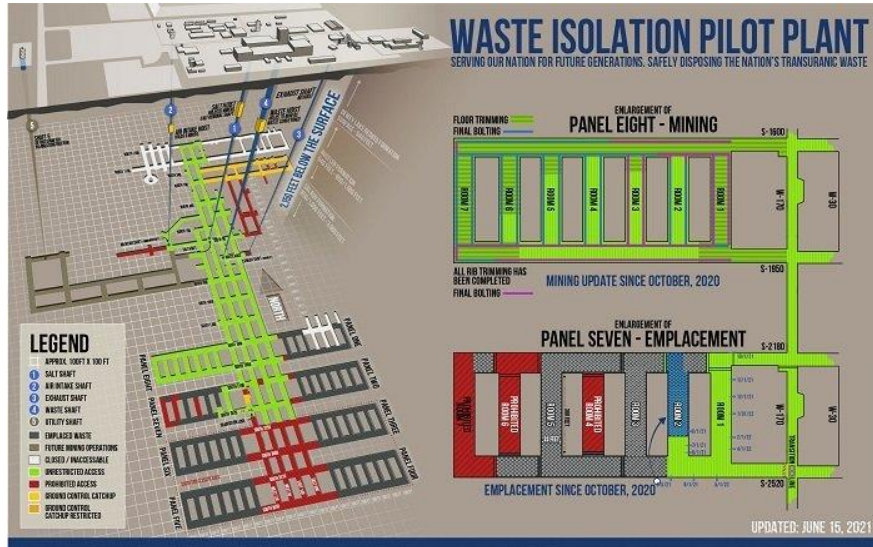
Is it really safe?

Environmental Monitoring



- **Data/evidence provides assurance to local communities**
- **Detection of anomalies if they happen**
- **Critical ways to keep operators accountable/responsible**

Monitoring for Consent-based Siting



Waste Isolation Pilot Plant

- First deep geological disposal in the world for transuranic waste
- Successful consent-based siting

Carlsbad Environmental Monitoring and Research Center (CEMRC)

- Independent/state-funded center
- Characterized background radiation and its fluctuation
- Outreach and surveys to understand people's concerns
- Detected the 2014 accident first, and provided assurance

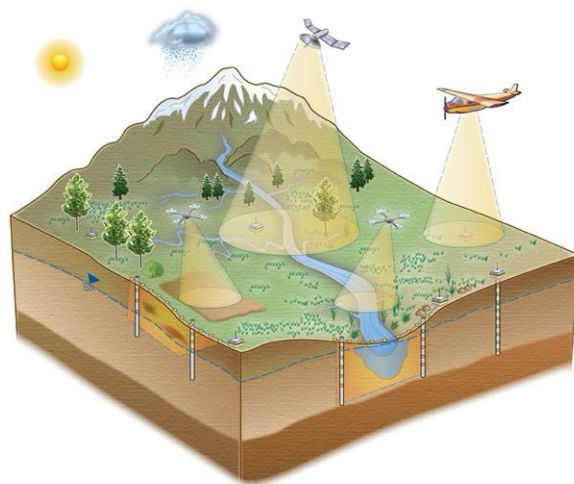
Advanced Long-term Environmental Monitoring Systems



ML/AI



Sensing

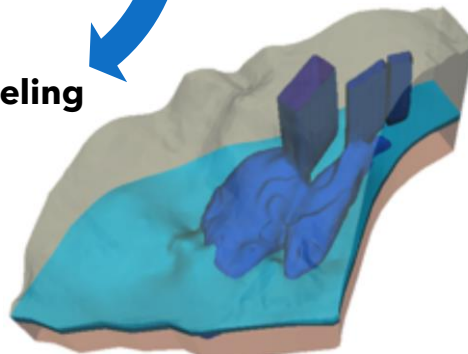


ALTEMIS

altemis.lbl.gov



Modeling



*New paradigm for
long-term environmental
monitoring*

POWER & OPERATIONS

Importance of environmental monitoring for consent-based siting of nuclear facilities

Sat, Nov 19, 2022, 6:04AM | Nuclear News | Haruko Wainwright and Carol Eddy-Dilek



Transforming Education

NWE Network

[Home](#) [Workshops](#) [Resources](#) [🔍](#)

Nuclear Waste Educators' Network

Graphics from Lawrence Berkeley National Laboratory, Nuclear Waste Program

Share resources and ideas

for interdisciplinary nuclear waste education and research

Changing Mindsets

- Develop a diverse and inclusive community.
Antagonistic views are important for protecting the environment and improving safety
- ~~○ Send waste to the middle of nowhere~~
→ Engineers should design waste isolation in a way that they can have it in their “backyard”
- Engineers should design reactors and technologies from the “waste up”

Nuclear Waste: Key Facts

Small/well accounted waste footprint across the life cycle

Best managed/isolated waste

Environmental monitoring for providing assurance

Advancing interdisciplinary research and education

Commercializing Advanced Nuclear Energy

4/19/2023

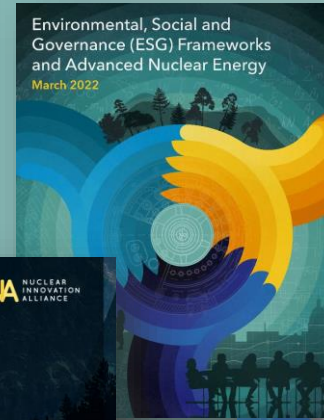
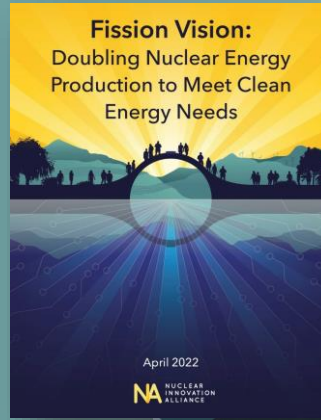
EESI Briefing: *The State of Play for Nuclear Energy in the United States*

Dr. Patrick White (pwhite@nuclearinnovationalliance.org)



Who is Nuclear Innovation Alliance (NIA)?

- NIA is a “think-and-do” tank working to ensure advanced nuclear energy can be a key part of the climate solution.
- NIA identifies barriers, performs analysis, engages with stakeholders and policy makers, and nurtures entrepreneurship through its Nuclear Innovation Bootcamp.



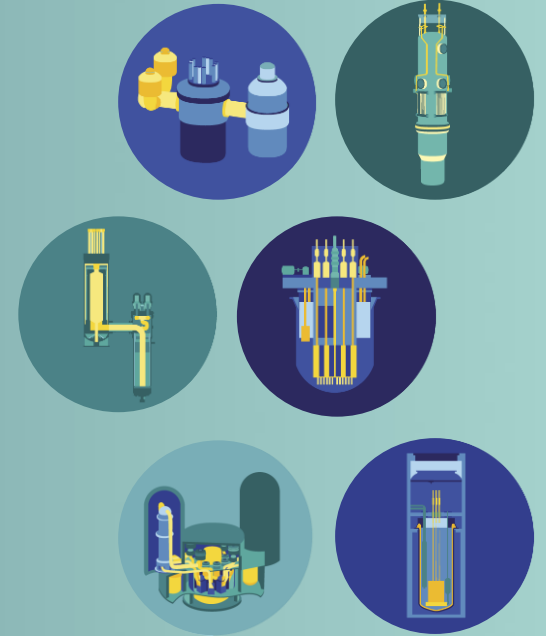
Takeaways on Commercializing Advanced Nuclear Energy

Nuclear energy can play a major role in creating a clean energy economy

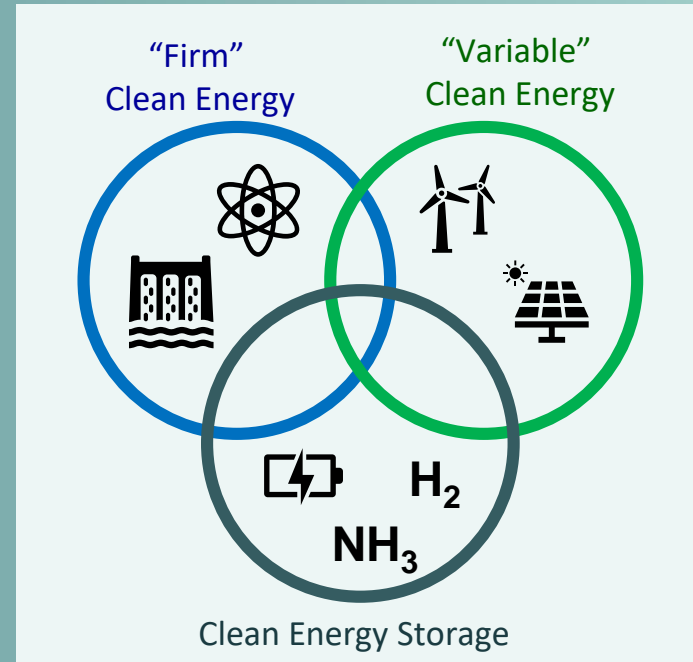
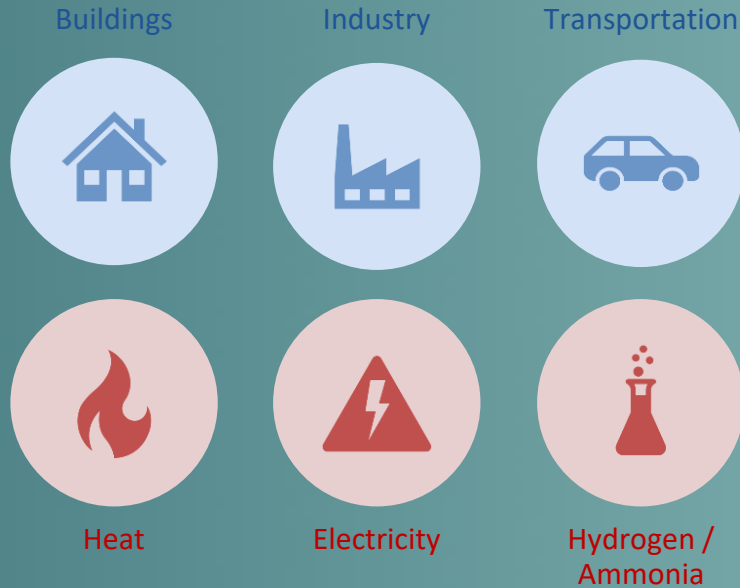
Advanced reactors have a wide array of different commercial use cases

Developers are leveraging DOE support to accelerate reactor deployment

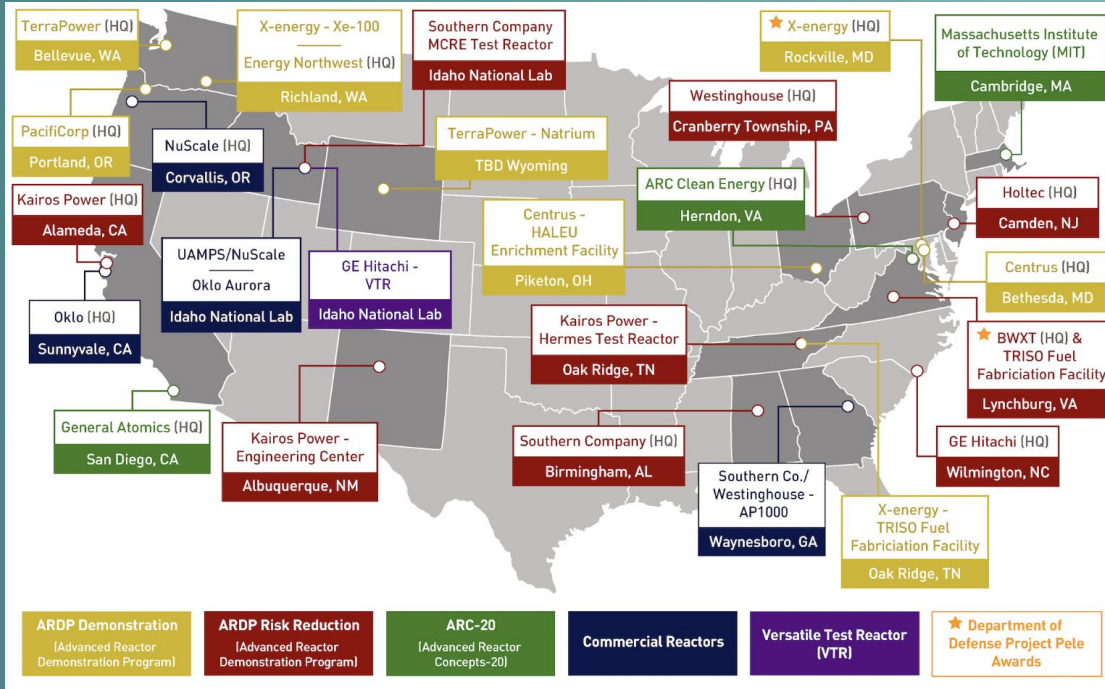
Continued federal support and incentives can catalyze private investments



Advanced nuclear energy is an important complementary clean energy source to help fully decarbonize U.S. energy production



Large (and growing) group of private companies are developing advanced nuclear energy to meet clean energy needs



HITACHI



Kairos Power



NUSCALE
Power for all humankind



energy

Utility partners and industrial energy users have expressed interest in deploying advanced nuclear energy



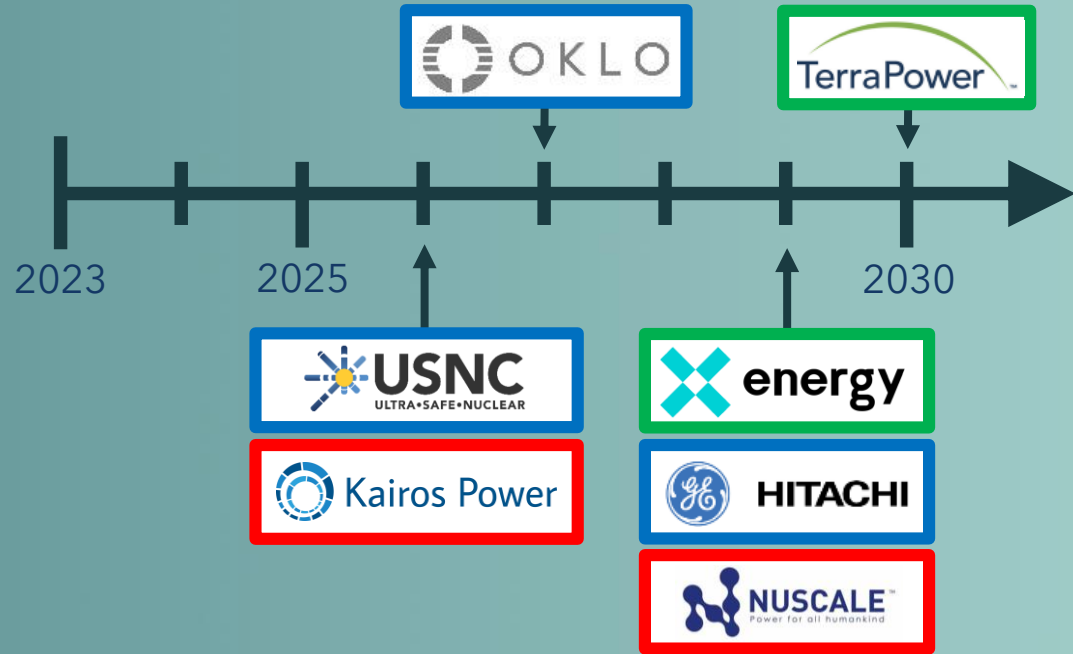
Public-private partnerships are accelerating the demonstration and deployment of first-of-a-kind advanced reactors

Federal Partnerships with Private Companies

Advanced reactor demonstration award

Advanced reactor development award

Enabling technology development award



Developers are preparing to submit a large number of formal license applications for review to the NRC in FY23

Site-Specific Applications

- Kairos: Hermes (*in progress*)
- ACU: NEXT MSR (*in progress*)
- X-energy: Xe-100
- TerraPower: Natrium
- GEH: BWRX-300
- Oklo: NCSFR-1
- Oklo: NCSFR-2

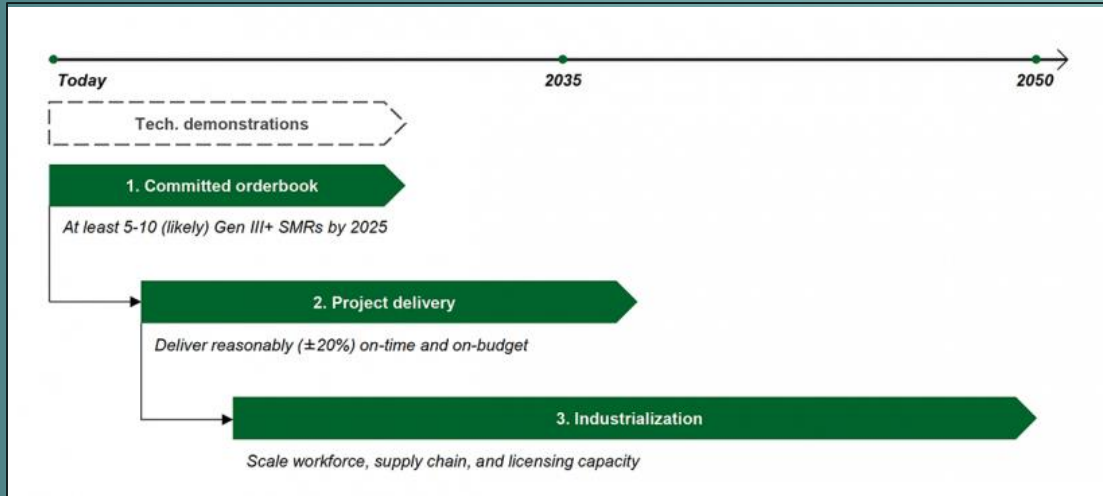
Design-Specific Applications

- NuScale: VOYGR (*complete*)
- NuScale: NPM-20 (*in progress*)
- Terrestrial Energy: IMSR
- Westinghouse: eVinci

Pre-Application Interactions

- NuScale: UAMPS (COL)
- Holtec: SMR-160 (CP)
- GA: EM2 (CP)
- BWXT: BANR
- FLiBe: LFTR (ESP)
- ARC: ARC-100
- Radiant Energy: Kaleidos
- USNC: UIUC MMR (CP)
- TerraPower: MCFR
- GA: FMR (CP)

Pathway from first-of-a-kind to widescale deployment requires an orderbook, on-time and on-budget delivery, and supply chains



Example: *BWRX-300*

The logos for the BWRX-300 partnership are displayed: GE (General Electric), HITACHI, ONTARIO POWER GENERATION, and TVA.

[Link: BWRX-300 Partnership Announcement](#)

Figure from 2023 DOE Report *Pathways to Commercial Liftoff - Advanced Nuclear*

Successful commercialization could dramatically increase demand for advanced nuclear energy for a wide variety of applications

New nuclear deployment starting in 2030

Annual deployment (GW/yr) built and Cumulative GW online

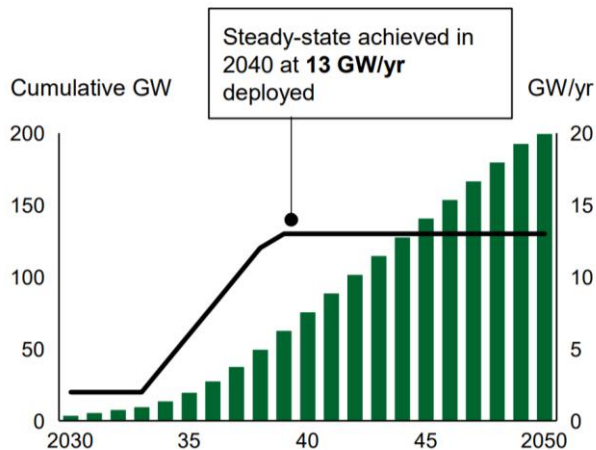


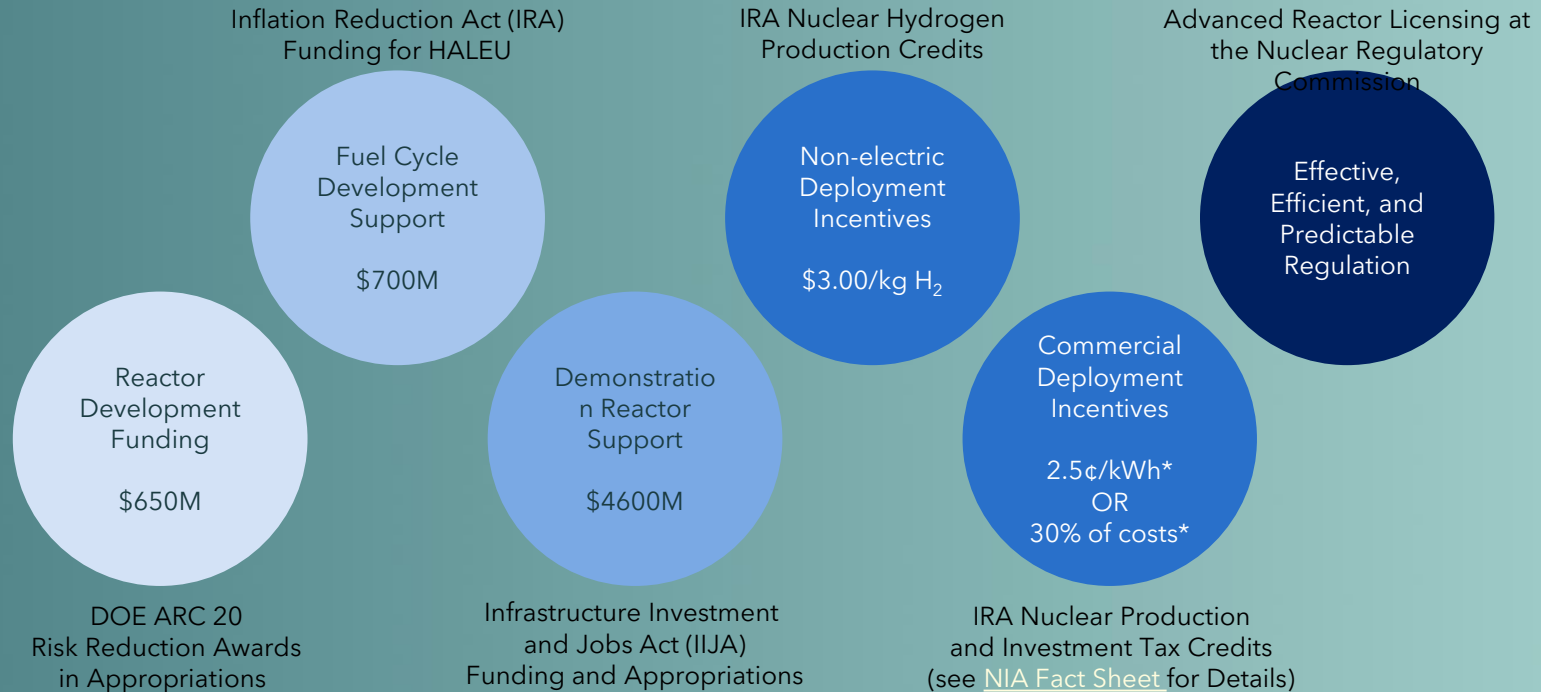
Figure from 2023 DOE Report *Pathways to Commercial Liftoff - Advanced Nuclear*



2022 Nuclear Energy Institute survey of 19 member utilities:

- More than **300 new SMRs** deployed for electricity generation by 2050
- More than **90 GW of new nuclear generation** by existing owners alone
- Evaluations of sites that currently host **operating or retired coal plants** for new nuclear reactors

Continued federal support and incentives can catalyze private investments in advanced nuclear energy



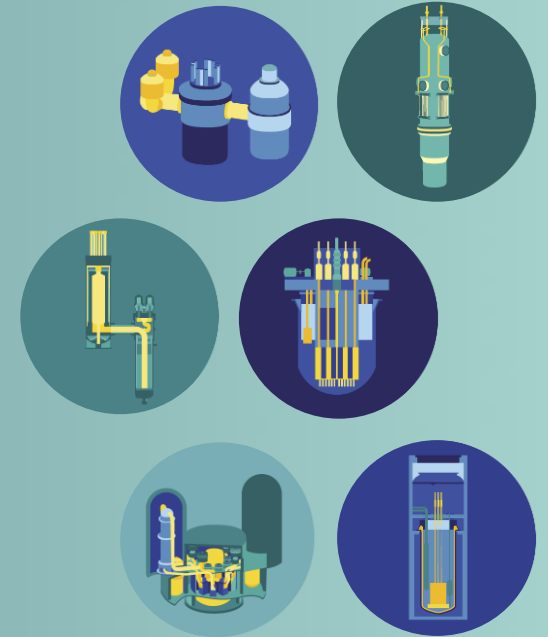
Takeaways on Commercializing Advanced Nuclear Energy

Nuclear energy can play a major role in creating a clean energy economy

Advanced reactors have a wide array of different commercial use cases

Developers are leveraging DOE support to accelerate reactor deployment

Continued federal support and incentives can catalyze private investments



Back-up Slides

Advanced nuclear energy adds flexibility and versatility in comparison to conventional nuclear through innovative design

Conventional Nuclear Energy

Predominantly Large:
More than 1000 MW_e

Predominantly
Light-Water Reactors

Primarily Baseload
Generation

Designed with Active
Safety Systems

Reactor Size

Reactor Technology

Generation Type

Safety Approach

Advanced Nuclear Energy

Versatile:
1.5 MW_e to 300+ MW_e

Wide Variety of
Reactor Technologies

Flexible and
Dispatchable Generation

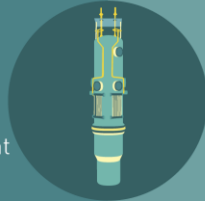
Designed with Inherent
Safety Systems

Definition of advanced nuclear energy includes a variety of nuclear technologies with different advantages

Thermal Fission

Advanced Light-Water Reactors

Evolutionary design from existing reactors with inherent safety features



High-temperature reactors (HTRs)

High temperatures drive high efficiency, well-suited for process heat or hydrogen production. Uses TRISO fuel



Thermal or Fast Fission

Molten Salt-Fueled Reactors (MSRs)

Using molten salt for coolant and a fuel form, MSRs can bring significant safety benefits



Fast Fission

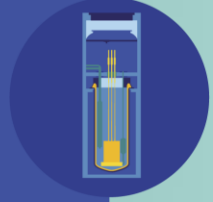
Gas-cooled fast reactor (GFR)

An evolution of HTRs, GFRs operate at very high temperatures while using a more sustainable fuel cycle



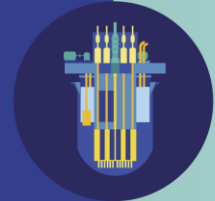
Sodium-cooled fast reactor (SFR)

With many existing experimental reactors, SFRs offer increased fuel efficiency, reduced waste, and passive safety features

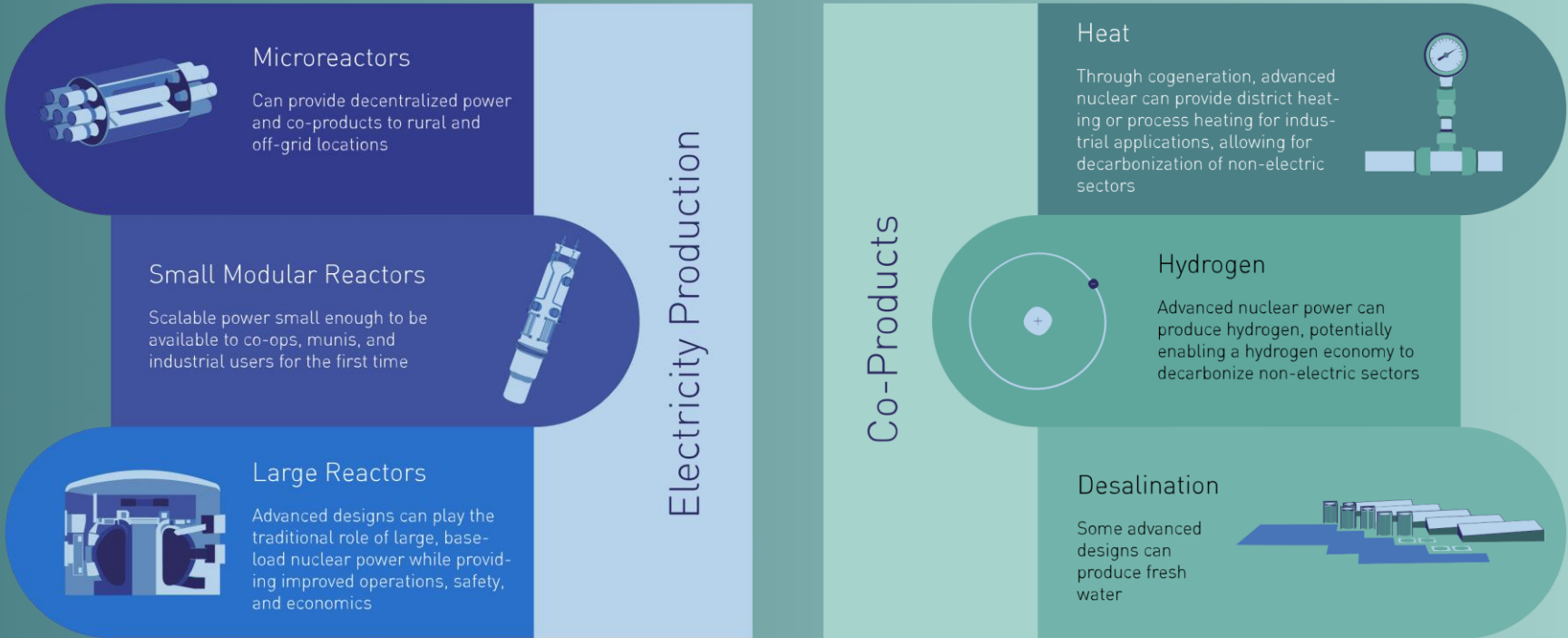


Lead-cooled Fast Reactor (LFR)

Similar in design to SFRs, LFRs are advantageous as lead is operationally safer than sodium



Variety of reactor sizes and low-carbon products enable integration of advanced nuclear into future energy systems



Both NRC and companies play a role in improving licensing under current rules and creating a new regulatory framework

Optional Licensing Tools

- Preapplication Interactions
- Topical Reports
- Early Site Permits
- Standard Design Approvals
- Standard Design Certifications

Construction Permit

Operating License

Licensing Path 1
("Part 50")

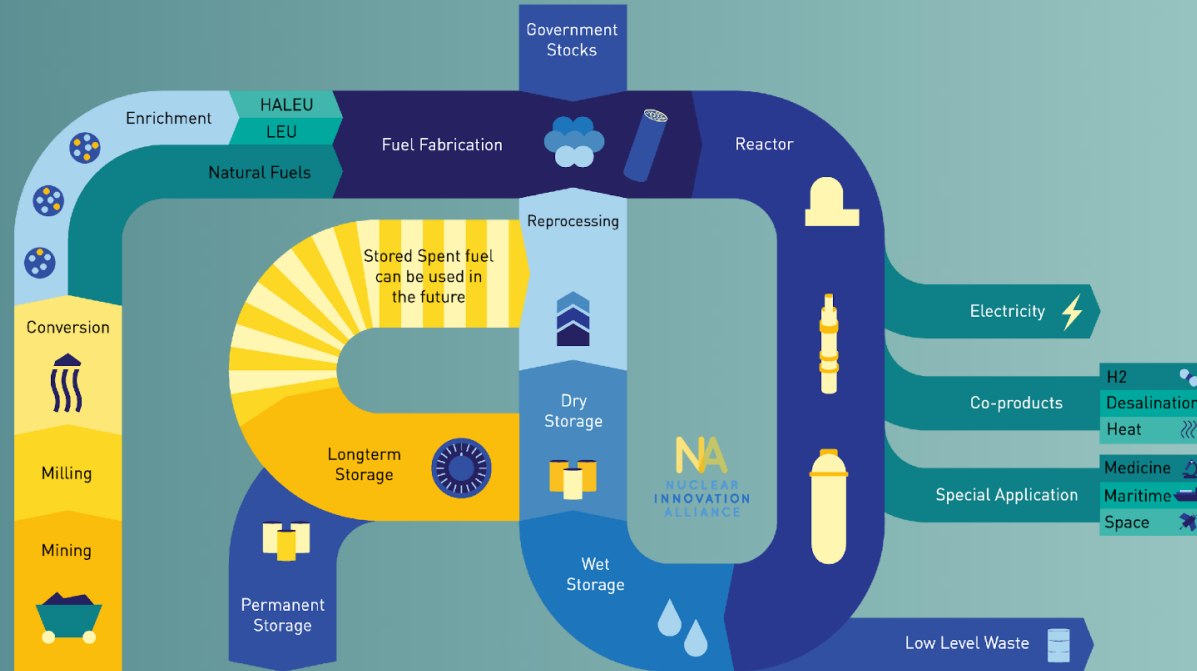
Combined Operating License

Licensing Path 2
("Part 52")

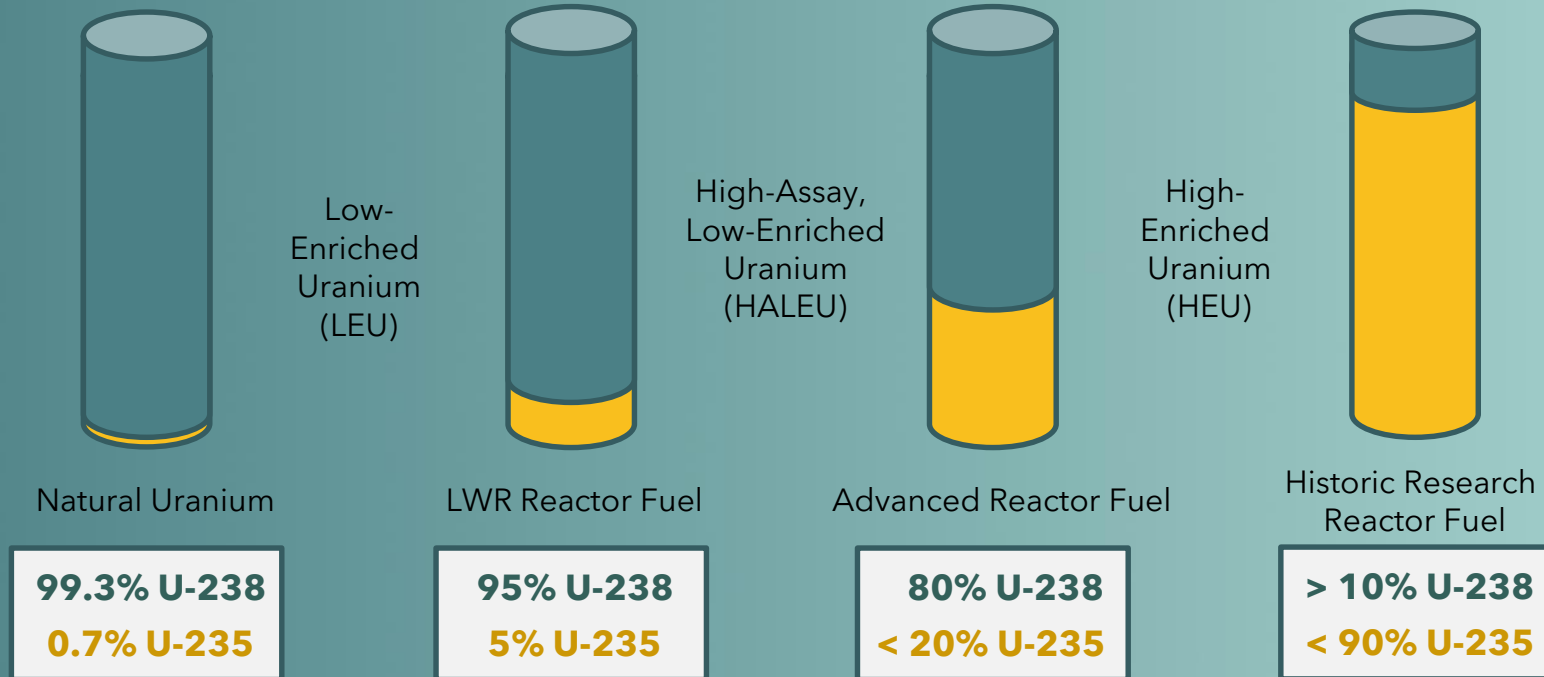
New Regulatory Framework

Licensing Path 3
("Part 53")

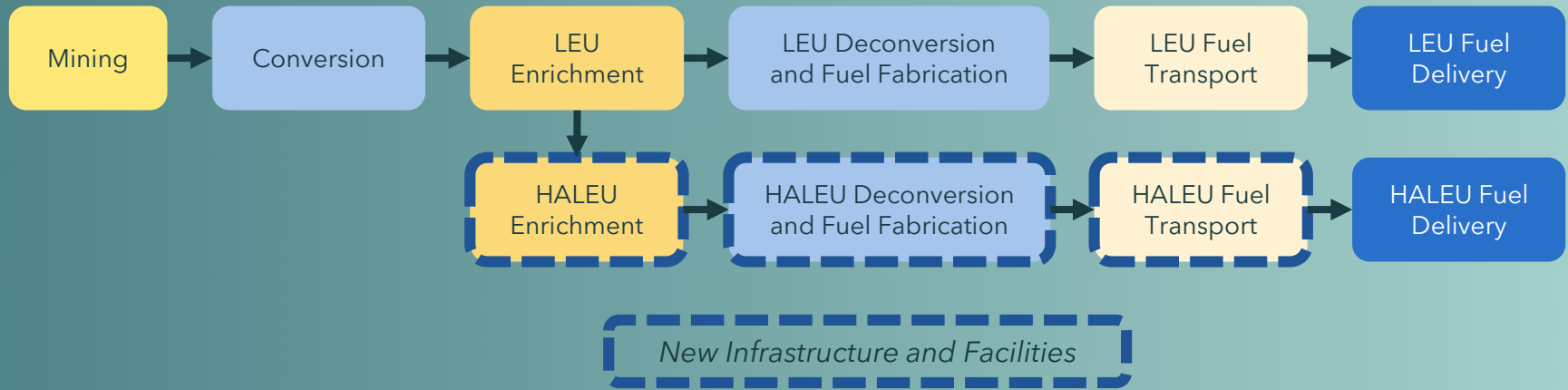
Advanced reactor commercialization requires coordination and planning across all stages of a sustainable fuel cycle



Some advanced reactor technologies will require nuclear fuel cycles with higher uranium enrichment levels



Advanced reactors that require HALEU or recycled fuels will need new fuel cycle infrastructure and facilities



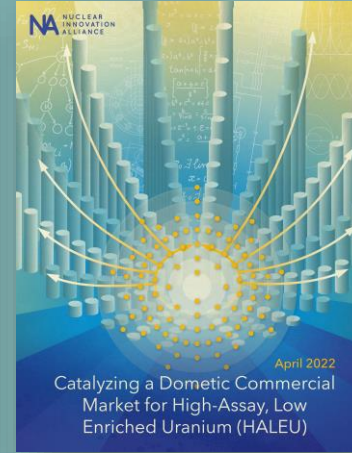
Stakeholders can get up to speed on advanced nuclear energy and engage with policymakers on clean energy deployment



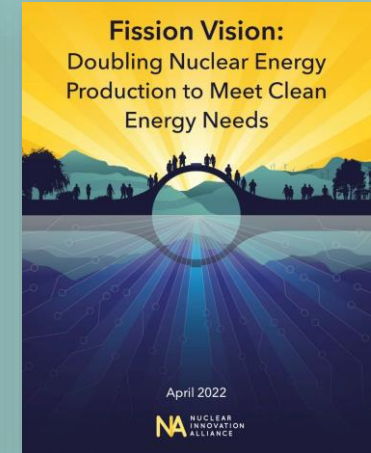
Advanced Nuclear Primer
March 2023 Update
[Download](#)



Advanced Nuclear Compendium
July 2022
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HALEU Fuel Availability
April 2022
[Download](#)



Fission Vision
April 2022
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Briefing Series: Farm Bill in Focus



EESI
Environmental and
Energy Study Institute

Every Other Wednesday Starting April 26

The Process and Path Forward for Passing a Bipartisan Farm Bill | April 26, 2:00-3:30 PM

Climate, Energy, and Economic Win-Wins in the Farm Bill | May 10, 1:30-3:00 PM EDT

Unlocking Rural Economies: Farm Bill Investments in Rural America | May 24, 2:00-3:30 PM EDT

The Future of Forestry in the Farm Bill | June 07, 2:00-3:30 PM EDT

Conservation Practices from Farms to Forests and Wetlands | June 21, 2:00-3:30 PM EDT



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Wednesday, April 19, 2023