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Advanced Nuclear Energy – An Overview

Prepared for:
Associated Governments of Northwest Colorado

Idaho National Laboratory

Objectives

- Very Brief overview of Idaho National Laboratory
- Context for Assessing Deployment Advantage and Risk
  - Nuclear Energy: Yesterday, today and tomorrow – Perspective on fundamental differences in deployment environments and markets
    - Size
    - Costs
    - Timelines and drivers
    - Benefits – known and hypothetical
    - What we know. What we Don’t know.
    - Hyperbole and reality

- Why the different technologies now? What's new, and what's not.
- The role of the national laboratories v. industry
- Economic potential in low-emission manufacturing
- Questions that might be considered

National Laboratories – Unique Capabilities and Innovation in the National Interest

Idaho National Laboratory
Idaho falls, Idaho

Pacific Northwest National Laboratory
Richland, Washington

National Renewable Energy Laboratory
Golden, Colorado

Argonne National Laboratory
Argonne, Illinois

Ames Laboratory
Ames, Iowa

Fermi National Accelerator Laboratory
Batavia, Illinois

National Energy Technology Laboratory
Morgantown, West Virginia
Pittsburgh, Pennsylvania

Brookhaven National Laboratory
Upton, New York

SLAC National Accelerator Laboratory
Menlo Park, California

Lawrence Berkeley National Laboratory
Berkeley, California

Lawrence Livermore National Laboratory
Livermore, California

Princeton Plasma Physics Laboratory
Princeton, New Jersey

Thomas Jefferson National Accelerator Facility
Newport News, Virginia

Savannah River National Laboratory
Aiken, South Carolina

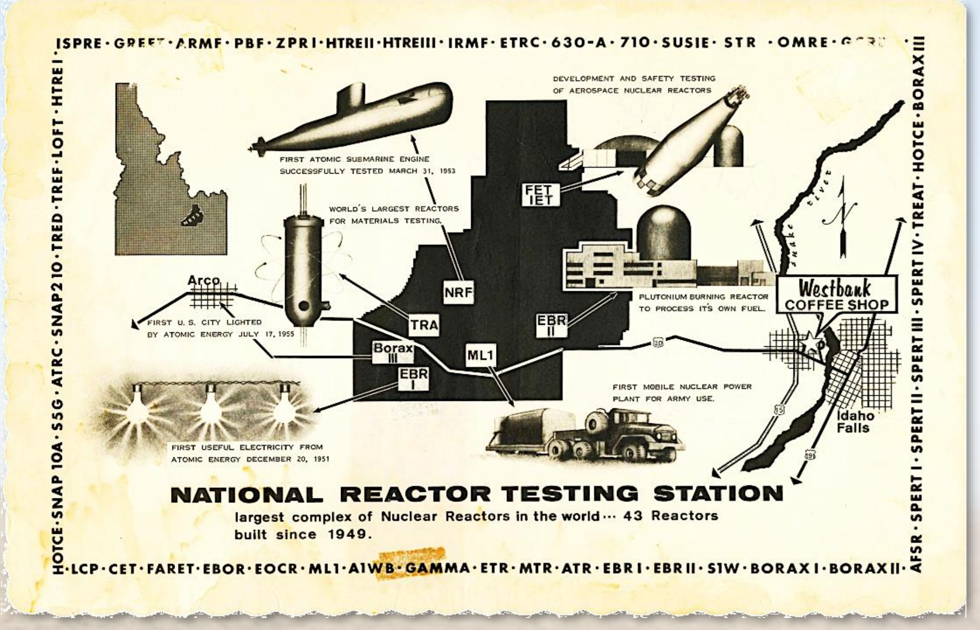
Sandia National Laboratory
Livermore, California
Albuquerque, New Mexico

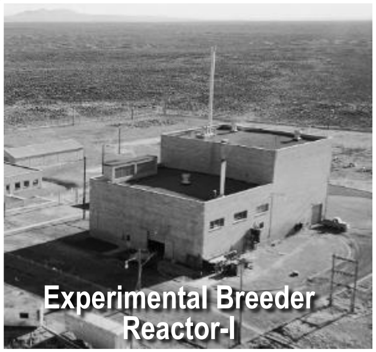
Los Alamos National Laboratory
Los Alamos, New Mexico

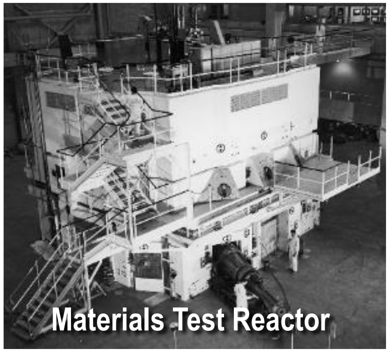
Oak Ridge National Laboratory
Oak Ridge, Tennessee

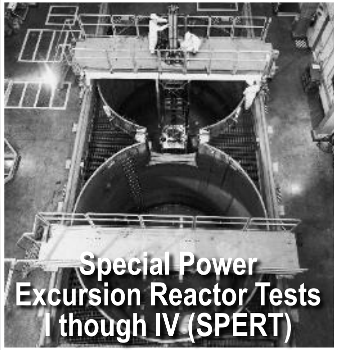
INL - Our Roots: The National Nuclear Reactor Testing Station

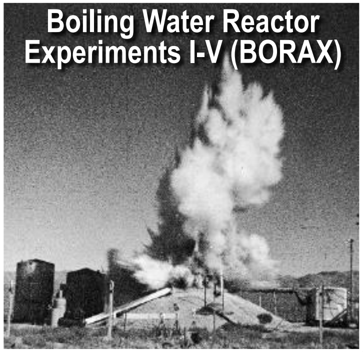
- First nuclear power plant
- First U.S. city to be powered by nuclear energy
- First submarine reactor tested; training of nearly 40,000 reactor operators until mid-90s
- First mobile nuclear power plant for the army
- Demonstration of self-sustaining fuel cycle
- Basis for LWR reactor safety
- Aircraft and aerospace reactor testing
- Materials testing reactors




Experimental Breeder Reactor-I


Materials Test Reactor

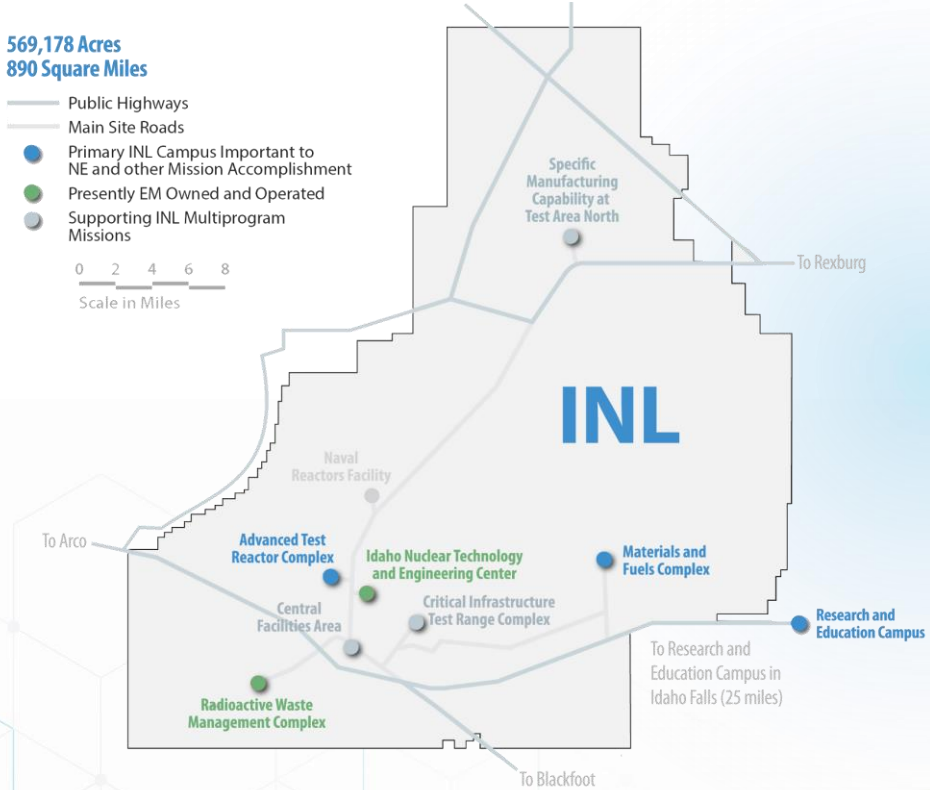

Special Power Excursion Reactor Tests I though IV (SPERT)


Boiling Water Reactor Experiments I-V (BORAX)


S1W (aka Submarine Thermal Reactor (STR)


Loss Of Fluid Test Facility (LOFT)

An Energy and Security Engineering Research Laboratory



305 DOE owned & operating buildings & trailers

35 Contractor leased operating buildings & trailers

4 Operating reactors

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

50 Radiological facilities/activities

5,496 full-time equivalent employees

$3.4B Replacement plant value*

3.7M Gross square feet*

3 Fire Stations
1 Landfill
1 Museum

** All INL buildings and trailers*

40 Miles primary roads / 125 total

17.5 Miles railroad for shipping nuclear fuel

40.2 Acres – REC Campus

7 Substations with interfaces to 2 power providers

112 Miles high-voltage transmission lines

Advanced Nuclear Energy: Past, Present and Future

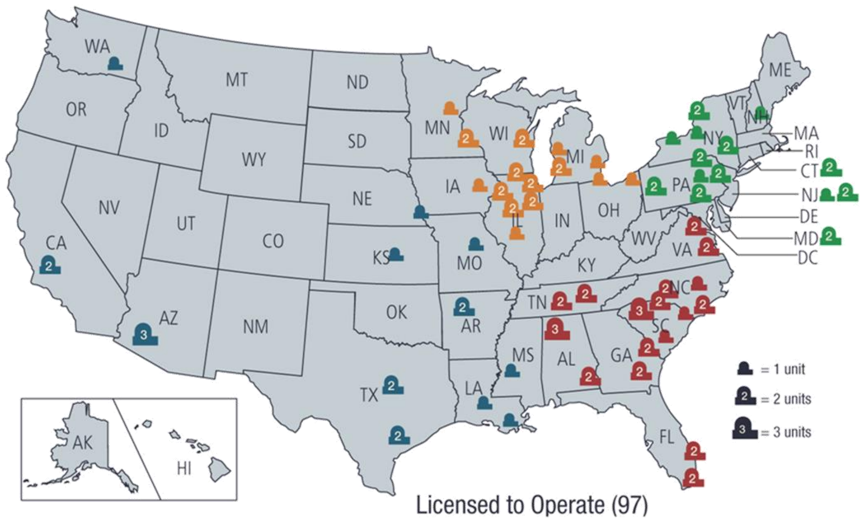
At the beginning of the age of commercial nuclear energy 65 years ago	Today	Our future. 2040 and beyond
Global population 2.8 B	Global population 7.8 B	Global population exceeding 9 B
Nuclear technology is new and novel; First commercial power plant at Shippingport, PA comes on-line	444 reactors, 31 countries, 388 Gwe, 11% of global generations, $2.6 T / 2-decade global market	Asymmetric global growth in baseload commercial nuclear energy; markets expand as nuclear powers more industry and non-baseload operations
130 quads global primary energy consumption; angst about American energy supply security	540 quads global primary energy consumption, angst about climate security and energy distribution	800 quads global primary energy consumption
U.S. per capita GDP $3 K (current USD)	U.S. per capita GDP $58 K (current USD)	U.S. per capita GDP > $90 K (current USD)

From a New Invention to a Mature Global Market – The Evolution of Civilian Nuclear Energy

Nuclear Energy Provides 20% of US’s electricity

- Currently 55 operating nuclear power plants with 93 light water reactors
- These plants are producing electricity > 90% of the time.
- Two reactors under construction in Georgia to start up in 2022 and 2023
- Reactor operations being extended to 80 years in many plants
- Other plants are shutting down due to financial pressures – States taking actions to keep plants operating

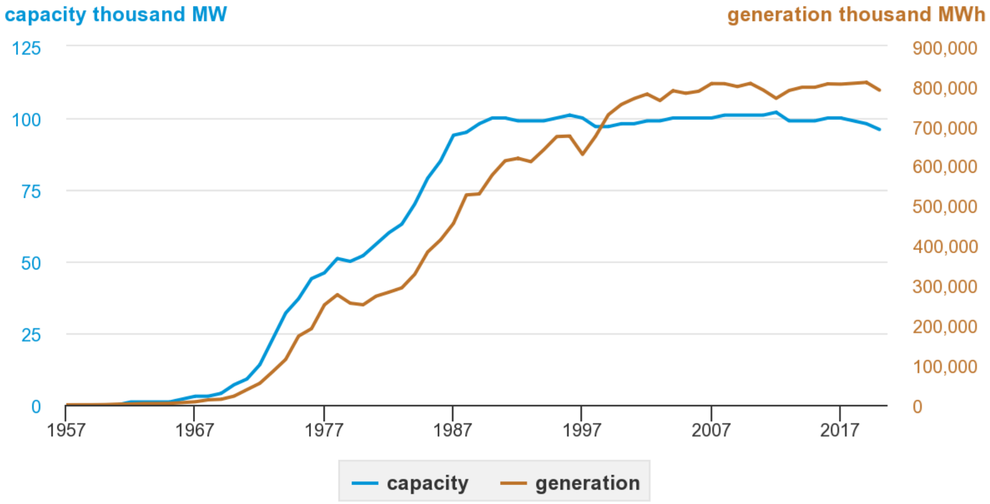
U.S. Operating Commercial Nuclear Power Reactors



U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

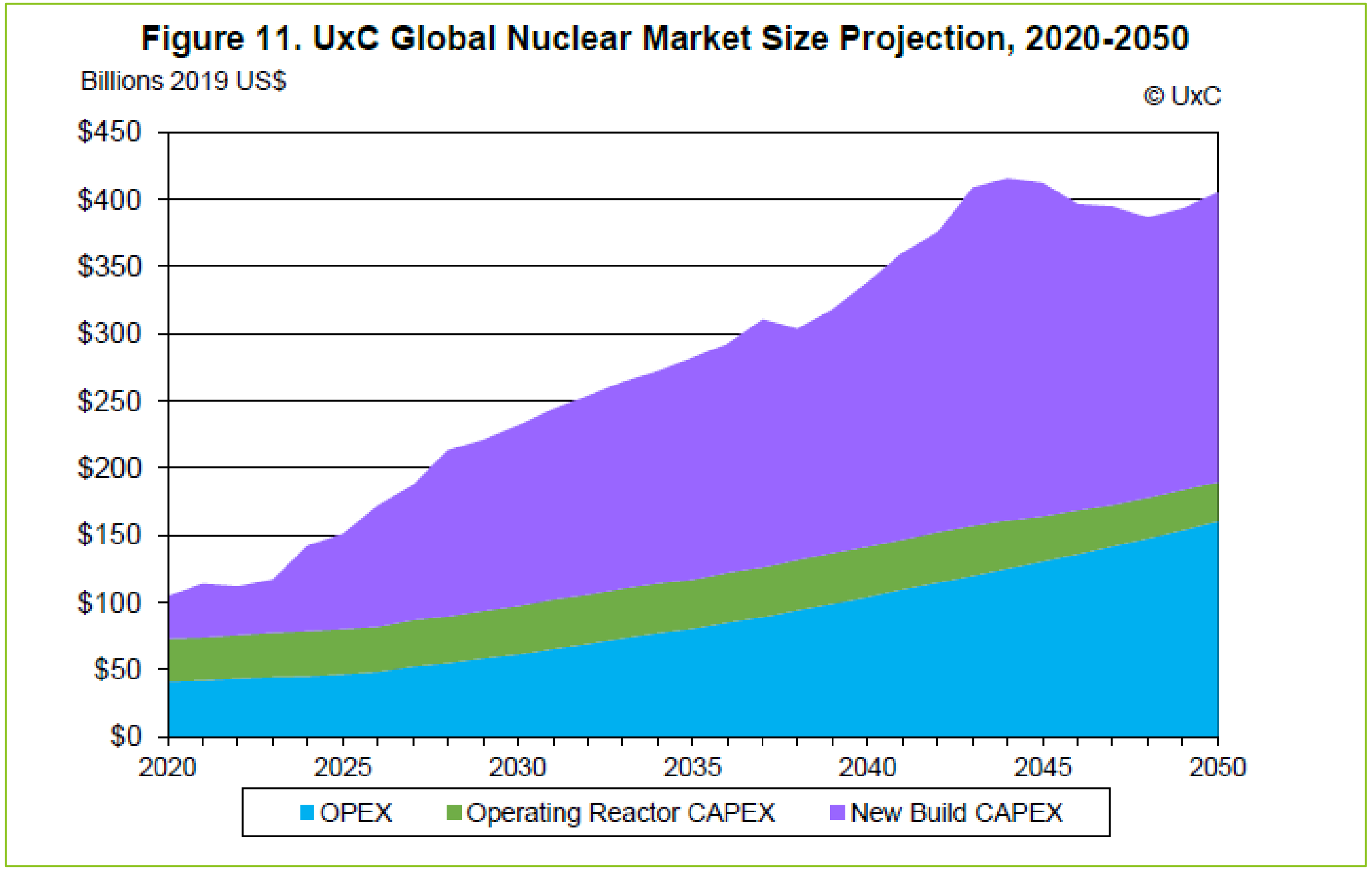
As of August 2019

U.S. nuclear electricity generation capacity and generation, 1957-2020



Note: Capacity is net summer; MW is megawatts; MWh is megawatthours.
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 8.1, March 2021, preliminary data for 2020

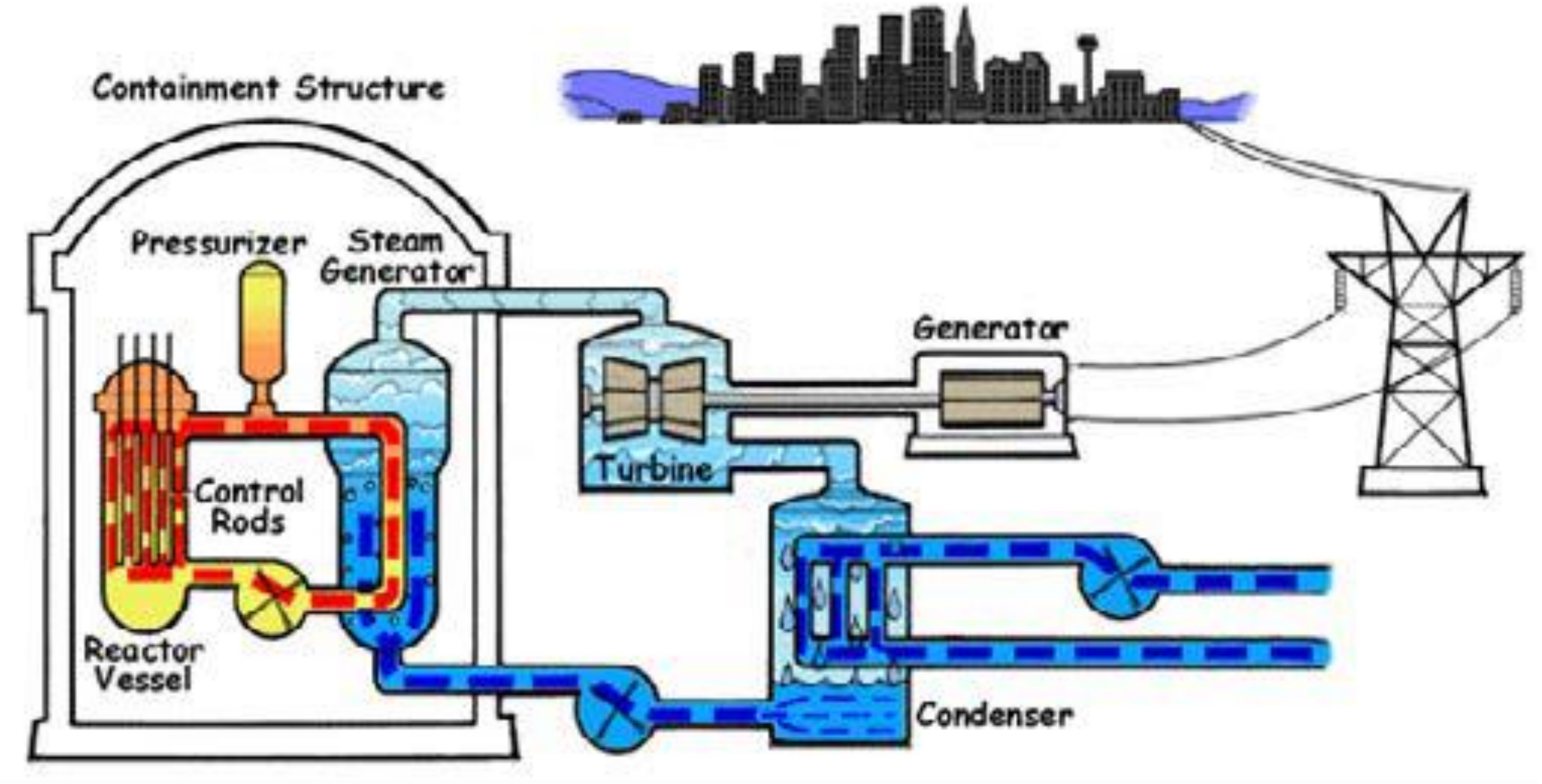
THE U.S. CAN CAPTURE GROWING GLOBAL MARKET FOR NEW NUCLEAR ENERGY SYSTEMS



ESTIMATED $8T+ GLOBAL NUCLEAR ENERGY MARKET THRU 2050

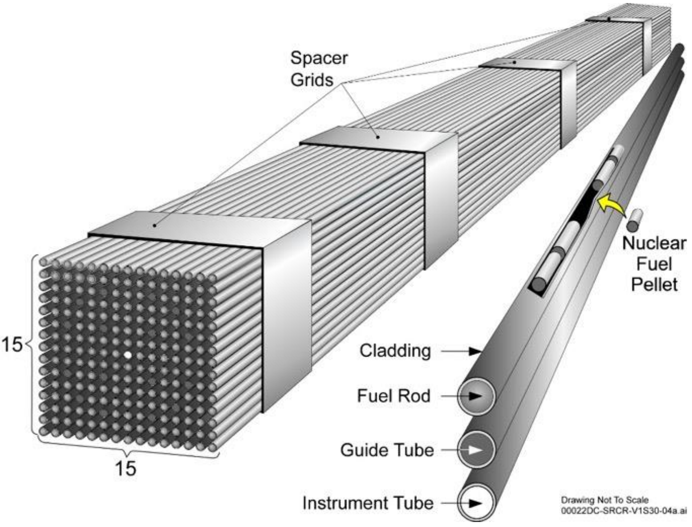
Source: https://www.nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/UxC-NEI-(IPCC-2050-Nuclear-Market-Analysis-PUBLIC)-2020-07-01.pdf. Slide Courtesy of John Kotek, NEI

Nuclear Energy Basics – Boil Water or Heat Gas ……

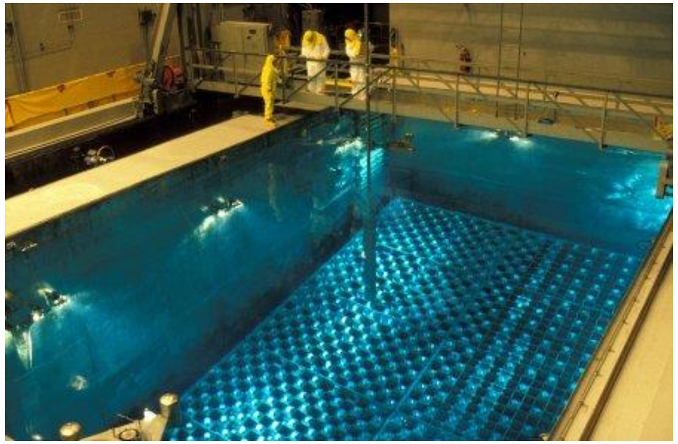


Graphic Courtesy Nuclear Innovation Alliance

Nuclear Energy Basics – Fuel



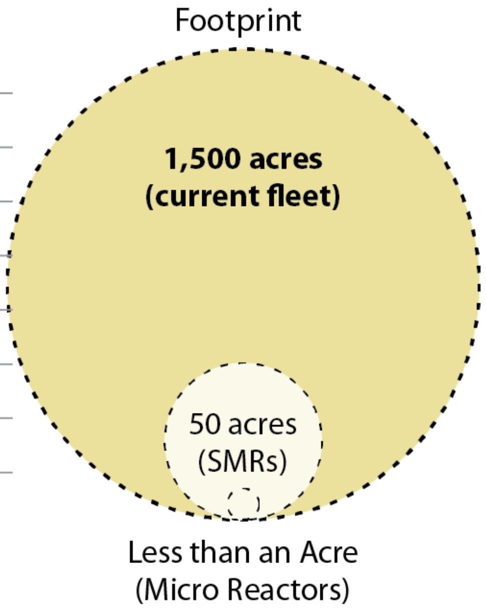
- All current commercial reactors are light water reactors (LWRs)
  - LWRs are fueled by enriched uranium (UO_2) fuel (assemblies) wit zirconium cladding
  - Assemblies are made of ~225 UO_2 rods
- LWR fuel is normally used for three 18 or 24 month cycles
- After ~5 years, it is declared spent nuclear fuel (SNF)
  - No longer useful in the current LWR
- The spent fuel is then moved into spent fuel pools (“wet storage”)
  - Pool storage provides cooling and shielding of radiation



Slide Courtesy of Josh Jarrell

Existing (large) nuclear reactors

Number in operation:	**95 in U.S.**
Timeframe:	**Built in the 1950s-1980s**
Products:	**Electricity**
Megawatts:	**1,000+ megawatts**
Customers:	**Large utilities**
Emergency zone:	**10 miles**
Construction:	**Custom built on site**
Scalability:	**Difficult due to size and cost**



Applications:
Baseload electricity; 24/7

Coming soon: Hydrogen production

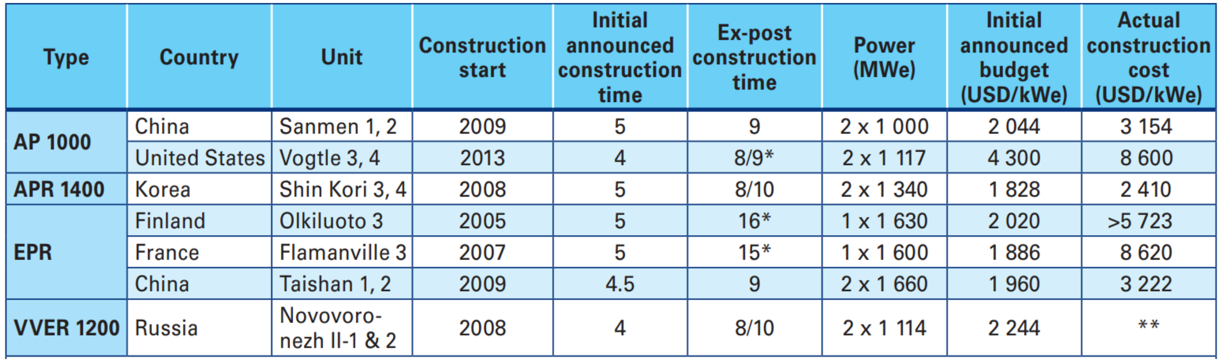
Did you know? In November 2018, the Union of Concerned Scientist recommended that federal and state governments adopt policies to preserve the low-carbon electricity the current fleet of nuclear reactors provides.

Slide courtesy of Kortny Rolston-Duce

“Big Nuclear”

- Large reactor projects (often Mega Projects >$10B) are subject to cost and schedule escalation.
- Stakeholder and public confidence in the capability of the nuclear industry to deliver new build projects has been eroded.
- This situation raises the level of perceived investment risk, challenging investors, and further reducing the chances of attracting financing for future projects.
- EIA (2020) estimates a new U.S. nuclear plant capital costs at $6,041/kWe (overnight cost) and LucidCatalyst (2018) estimates $6,870/kWe.
- Energy production price ~$80 / MWh

Construction Costs of Gen III/III+ Projects

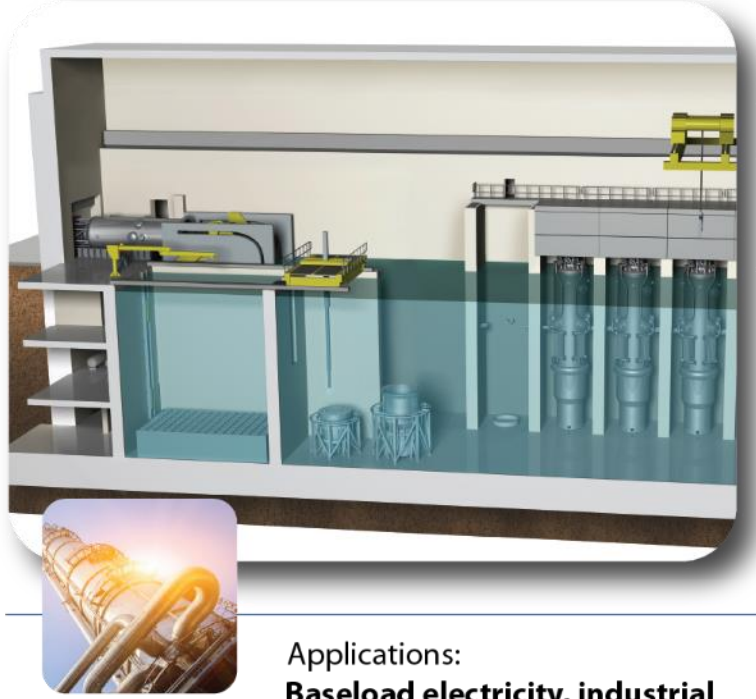


Type	Country	Unit	Construction start	Initial announced construction time	Ex-post construction time	Power (MWe)	Initial announced budget (USD/kWe)	Actual construction cost (USD/kWe)
AP 1000	China	Sanmen 1, 2	2009	5	9	2 x 1 000	2 044	3 154
	United States	Vogtle 3, 4	2013	4	8/9*	2 x 1 117	4 300	8 600
APR 1400	Korea	Shin Kori 3, 4	2008	5	8/10	2 x 1 340	1 828	2 410
EPR	Finland	Olkiluoto 3	2005	5	16*	1 x 1 630	2 020	>5 723
	France	Flamanville 3	2007	5	15*	1 x 1 600	1 886	8 620
	China	Taishan 1, 2	2009	4.5	9	2 x 1 660	1 960	3 222
VVER 1200	Russia	Novovoro-nezh II-1 & 2	2008	4	8/10	2 x 1 114	2 244	**

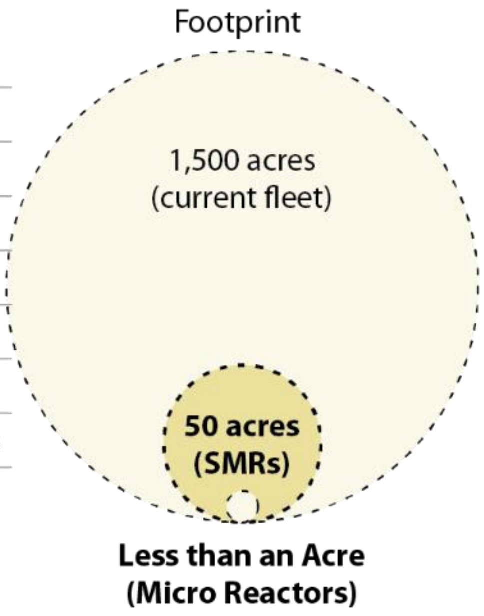
Credit: OECD IEA/NEA, Costs of Generating Electricity, 2020 Edition.

- Western OECD countries experience with large reactor costs is spotty at best.
- China and Korea have successfully executed projects in less than six years.

Small modular reactors



Number in operation:	**None***
Timeframe:	**First reactors expected by 2029**
Products:	**Electricity, heat, and steam**
Megawatts:	**60-300 megawatts per module**
Customers:	**Large utilities; municipalities; industry**
Emergency zone:	**.19 miles**
Construction:	**Factory built; assembled on site**
Scalability:	**Reactor modules added as demand increases**



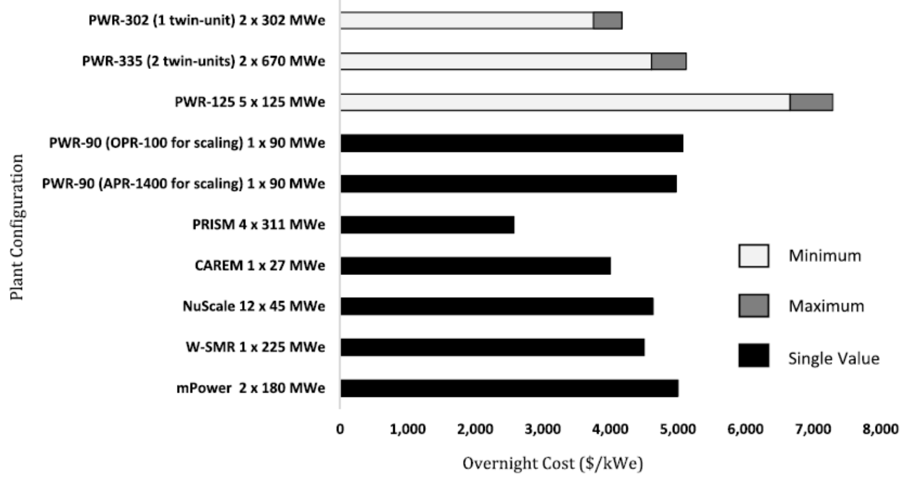
Applications:
Baseload electricity, industrial heat, industrial processes such as hydrogen production

**NuScale SMR has completed NRC design approval with plan to start operation on INL site in 2029*

Slide courtesy of Kortny Rolston-Duce

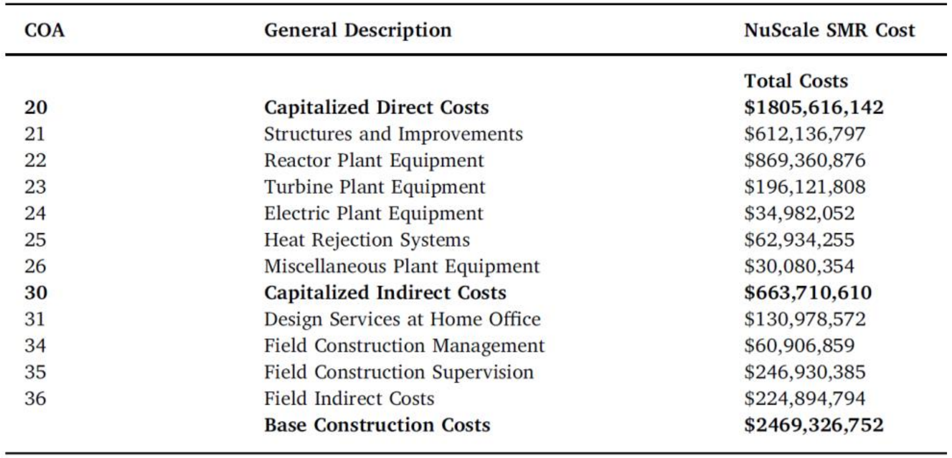
Small Modular Reactors (SMRs)

- Single or multiple modules (<300 MWe).
- Design features: modularity, simplicity, enhanced safety contribute to lower levelized unit electricity costs (LUEC).
- Smaller scale yields lower capital costs and risk than large reactors.



Credit: Mignacca and Locatelli, Economics and finance of Small Modular Reactors: A systematic review and research agenda, Renewable and Sustainable Energy Reviews, 118 (2020) 109519.

- Cogeneration opportunities (industrial steam, heating, desalinization, etc.).
- Smaller and localized better match, avoid long transmission lines, fits grids with limited capacity.
- Estimated SMR Direct and Indirect Overnight Costs: ~$2.5B for NuScale (12 x 60 MWe modules).

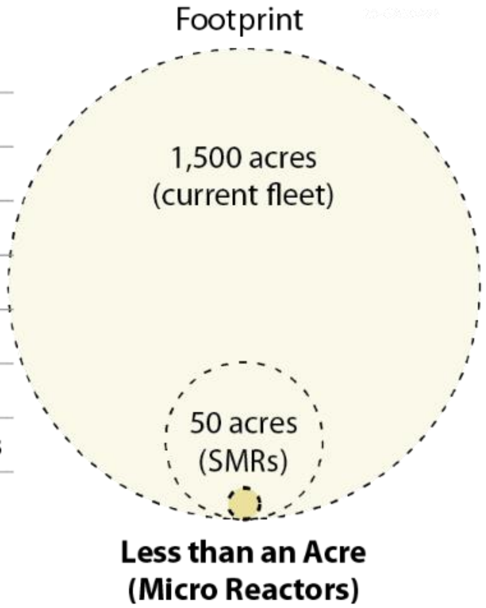


COA	General Description	NuScale SMR Cost
		Total Costs
20	**Capitalized Direct Costs**	**$1805,616,142**
21	Structures and Improvements	$612,136,797
22	Reactor Plant Equipment	$869,360,876
23	Turbine Plant Equipment	$196,121,808
24	Electric Plant Equipment	$34,982,052
25	Heat Rejection Systems	$62,934,255
26	Miscellaneous Plant Equipment	$30,080,354
30	**Capitalized Indirect Costs**	**$663,710,610**
31	Design Services at Home Office	$130,978,572
34	Field Construction Management	$60,906,859
35	Field Construction Supervision	$246,930,385
36	Field Indirect Costs	$224,894,794
	Base Construction Costs	**$2469,326,752**

Credit: Black et al, Economic viability of light water small modular nuclear reactors: General methodology and vendor data, Renewable and Sustainable Energy Reviews 103 (2019) 248–258 “Grid-Appropriate”.

Microreactors

Number in operation:	**None**
Timeframe:	**First reactors expected by 2025**
Products:	**Electricity, heat, and steam**
Megawatts:	**20 megawatts or less**
Customers:	**Military; municipalities; industry**
Emergency zone:	**Less than 1 acre**
Construction:	**Factory built; assembled on site**
Scalability:	**Reactor modules added as demand increases**



Applications:
Power for remote locations, maritime shipping, military installations, mining, space missions, desalination, disaster relief

Sen. Lisa Murkowski, R-Alaska, April 4, 2019 Op-Ed in the Anchorage Daily News.

Improvements in nuclear technology "are enabling the emergence of so-called "microreactors" that could be a perfect fit throughout our state. As the name suggests, these smaller reactors can be right-sized for dozens of Alaska communities and will have off-grid capability that could solve the challenge of providing clean, affordable energy in our remote areas."

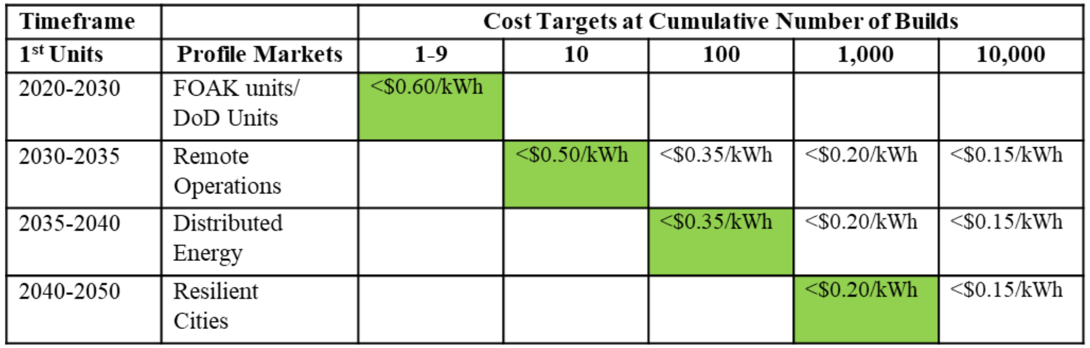
Slide courtesy of Kortny Rolston-Duce

Microreactors (MRs)

- MRs are a new subset of SMRs, sizes ranging from about 1MWe - 20MWe (50 MWe max.).
- Design features: factory production, minimal site preparation, enhanced inherent safety, transportable, remote and semi-autonomous operations.
- Competition initially in isolated and niche markets (e.g., remote mining).
- Preliminary INL capital cost estimates for MRs range from about \$6K/kWe - \$30K/kWe.
- Costs are uncertain, and achievement of cost targets critical for competitiveness in markets.
- MRs value proposition includes energy resilience and carbon reduction.

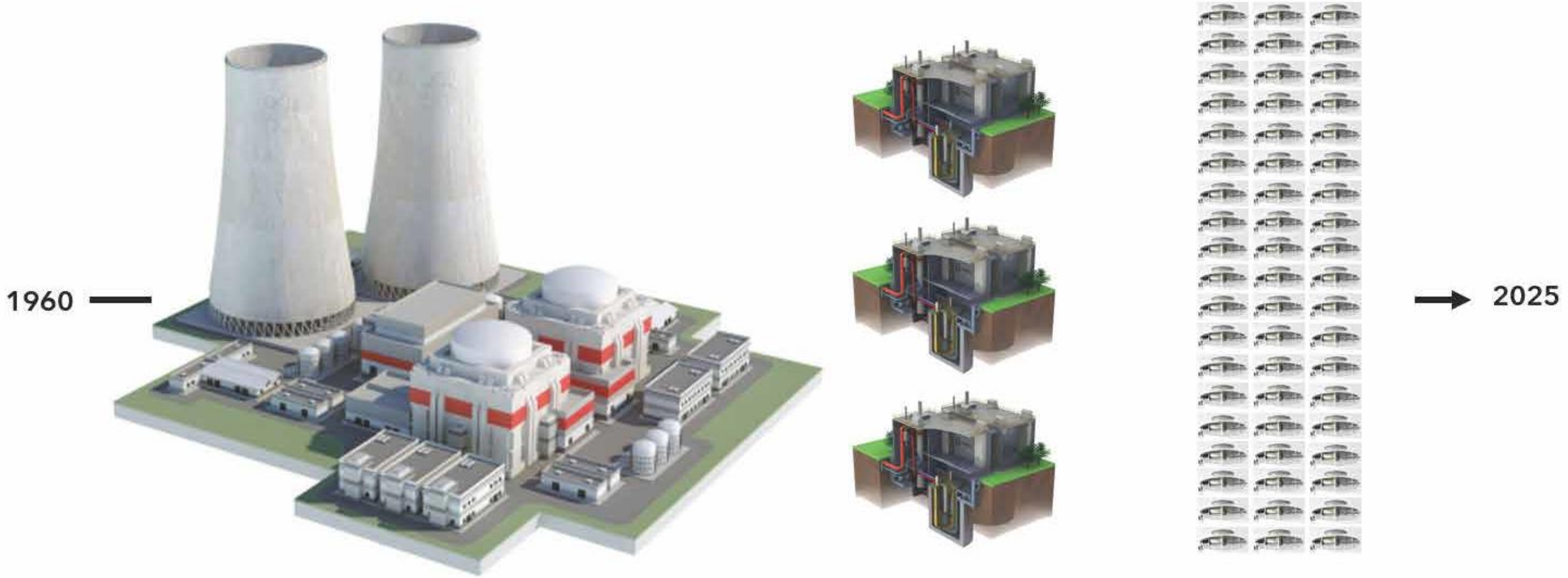
- MIT Study Findings:
  - Adding CHP (Combined heat and power) is key for MRs competing against diesel and natural gas.
  - Modest carbon emissions caps raise the capital cost ceiling and make MRs viable beyond isolated markets.

Credit: MIT Advanced Nuclear Power Program, Macdonald and Parsons, The Value of Nuclear Microreactors in Providing Heat and Electricity to Alaskan Communities, MIT-ANP-TR-192, October 2021.



Timeframe		Cost Targets at Cumulative Number of Builds				
1st Units	Profile Markets	1-9	10	100	1,000	10,000
2020-2030	FOAK units/ DoD Units	<\$0.60/kWh				
2030-2035	Remote Operations		<\$0.50/kWh	<\$0.35/kWh	<\$0.20/kWh	<\$0.15/kWh
2035-2040	Distributed Energy			<\$0.35/kWh	<\$0.20/kWh	<\$0.15/kWh
2040-2050	Resilient Cities				<\$0.20/kWh	<\$0.15/kWh

Credit: DOE Microreactor Program, Shropshire, Black, and Araujo; 2021, Global Market Analysis of Microreactors, INL/EXT-21-63214.



Light water reactors
(Electricity Project)

Small Modular Reactors
(Electricity Projects)

Nuclear Batteries
(CHP Inventory)

Image Courtesy of Rob Freda, MIT / ANPEG

Why Size Matters, and Why This Evolution?

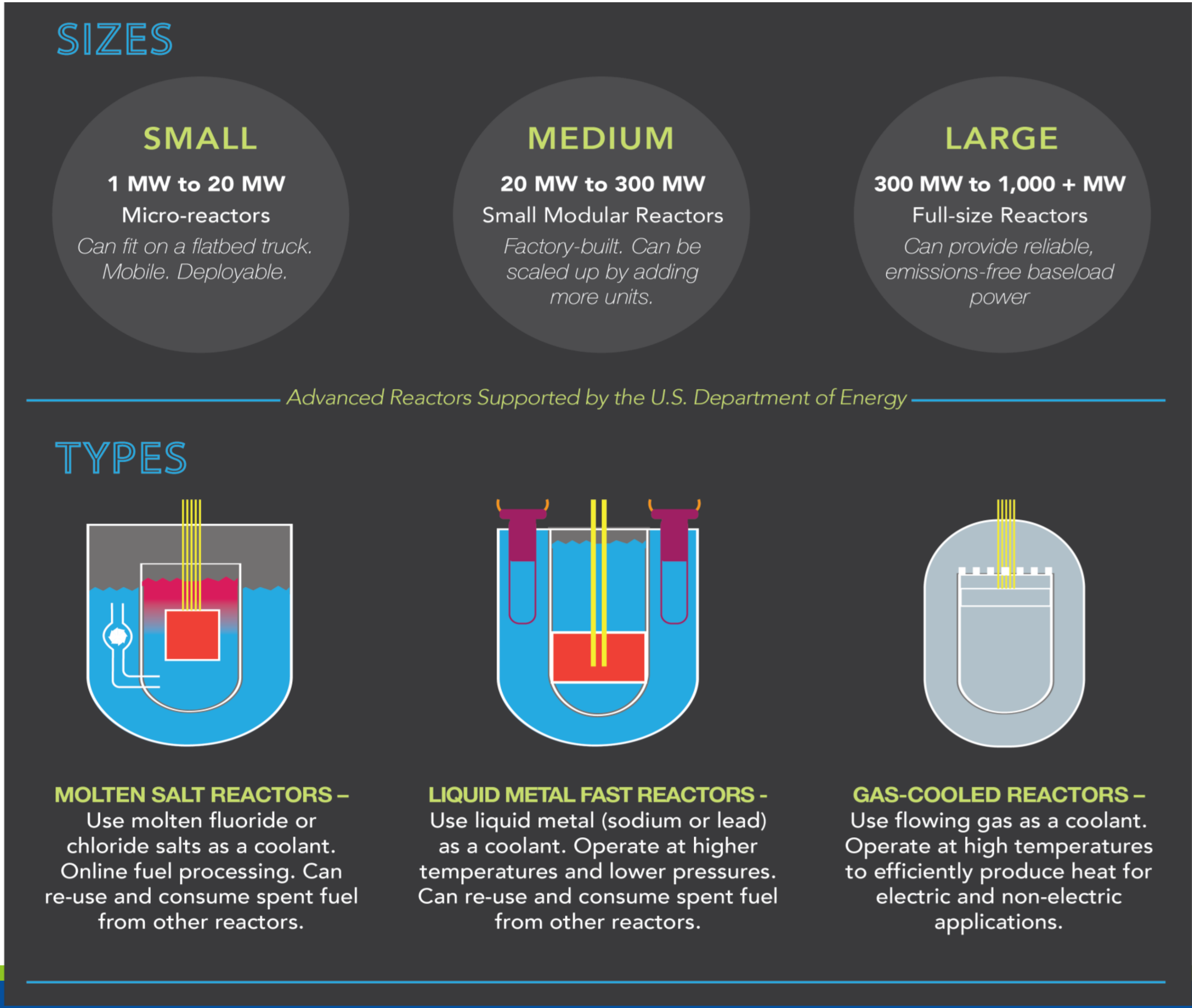
- Large size pursued principally for efficiencies of scale and to match rapidly growing electric markets
  - Larger the better

- Implications:
  - Significant for safety systems: System pressure, decay heat removal, reactor control mechanisms
  - NOT modular – generally each a unique massive construction project
  - Construction complexity (capital at risk, financing costs, etc)
  - Mis-match in market (load) and generation size as economies mature (growth rate) = underutilized capital

- Size (power) increase as industry matured –
  - Learning
  - Chasing efficiencies of scale
  - Application space

Advanced Reactors Are Trending Smaller, Integrated, and Modular – Why?

- Versatile applications due to range of sizes and ability to integrate with future energy needs
- Reduced cost by enabling factory fabrication
- Ability to modularize creates intriguing economics
  - Not all small reactors are modular, but no big reactor is ……
  - Capital / cash flow timing
  - Match generation to load
- Based on decades of research and development at DOE national laboratories



SIZES

SMALL
1 MW to 20 MW
Micro-reactors
Can fit on a flatbed truck. Mobile. Deployable.

MEDIUM
20 MW to 300 MW
Small Modular Reactors
Factory-built. Can be scaled up by adding more units.

LARGE
300 MW to 1,000 + MW
Full-size Reactors
Can provide reliable, emissions-free baseload power

Advanced Reactors Supported by the U.S. Department of Energy

TYPES

MOLTEN SALT REACTORS – Use molten fluoride or chloride salts as a coolant. Online fuel processing. Can re-use and consume spent fuel from other reactors.

LIQUID METAL FAST REACTORS - Use liquid metal (sodium or lead) as a coolant. Operate at higher temperatures and lower pressures. Can re-use and consume spent fuel from other reactors.

GAS-COOLED REACTORS – Use flowing gas as a coolant. Operate at high temperatures to efficiently produce heat for electric and non-electric applications.

Advanced Reactors and Passive Safety – The Important Role of Demonstrations

- Many decades of experience in demonstrating advanced technologies
  - Similar to approaches in other industries Develop, demonstrate, improve

- Experimental Breeder Reactor – 2
  - Sodium cooled fast reactor
  - Operated very successfully for 30 years
  - Demonstrated power production, plant operations, and ”inherent safety” of this class of technology
    - Most aggressive accident scenarios tested: Loss of coolant flow and loss of heat sink

- Lean on this knowledge base

EBR-II, a sodium cooled fast reactor, demonstrated inherent safety in 1986 and operated successfully and effectively for 30 years

1) Demonstrated natural circulation
2) Loss of flow without shutdown
3) Loss of heat sink without shutdown
4) Demonstrated industrial operations
5) Demonstrated decommissioning

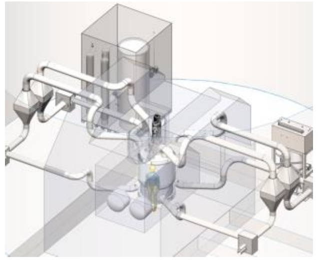
Accelerating advanced reactor demonstration and deployment

MARVEL
DOE
2023

DOME Test Bed
NRIC
2023-2024

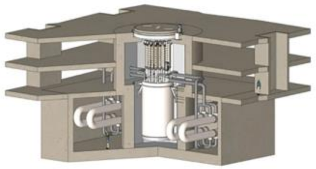
Project Pele Microreactor
DoD
2023-2024

LOTUS Test Bed
NRIC
2024



MCRE
Southern Co. & TerraPower
2025

TerraPower
Southern Company

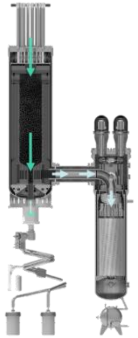


Hermes
Kairos
2026

Kairos Power

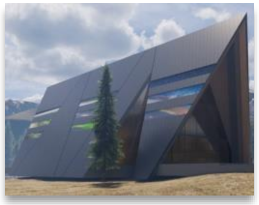
Xe-100
X-energy
2027

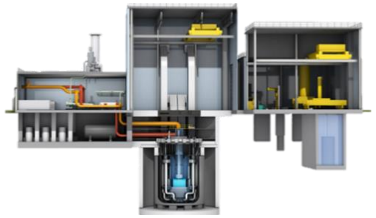
energy



Aurora
Oklo Inc.
TBD

OKLO





Natrium Reactor
TerraPower & General Electric
2028

TerraPower
HITACHI

SMR
UAMPS &
NuScale
2029

UAMPS
NUSCALE Power for all humankind

2030

NRIC National Reactor Innovation Center

Meeting the Needs of a World of 9 B People: The Broader Potential for Economic Value and Climate Impact

- In the model of the past, nuclear energy touches a very small share of global energy
  - Projections that electricity accounts for ~25% of 800 quad energy demand in 2040
  - Nuclear accounts for 10%-15% of electricity in the 2040 scenario
  - Baseload electricity is ~40% of electricity market (U.S.)

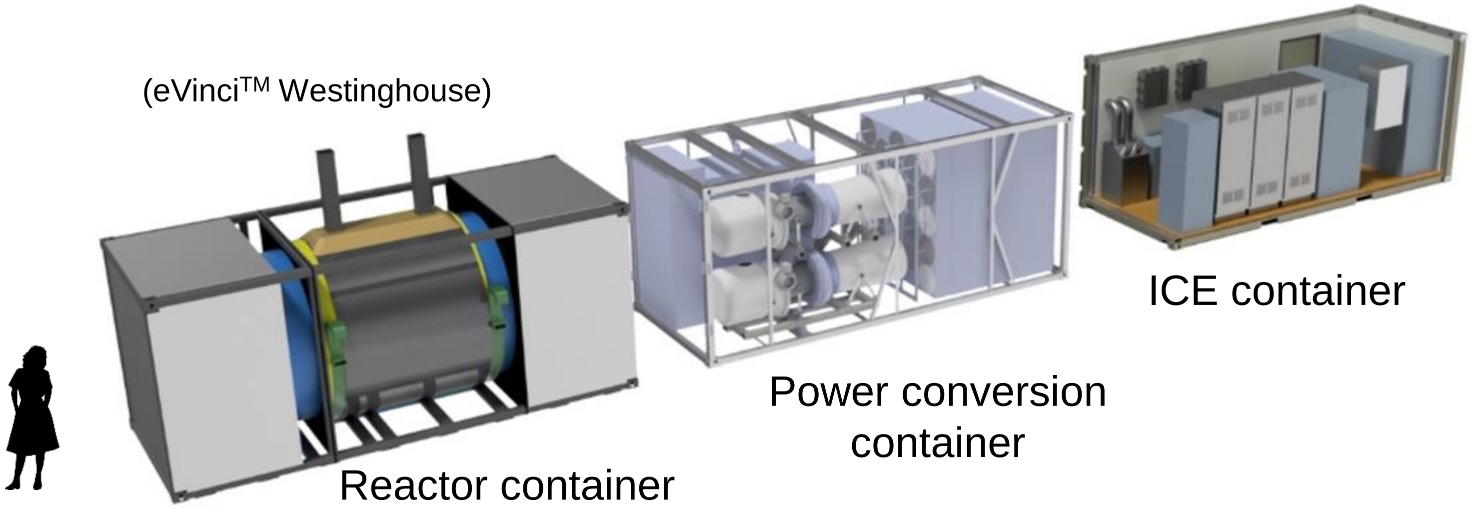
- What if?
  - Innovation allowed lower cost, easier to operate plants *(advanced SMR, microreactors, etc.)*?
  - Innovation allowed integration into broader energy economy– decarbonize hard to address industry
  - Innovation introduced game-changing embedded nuclear-industrial process designs and "smart reactors"?
  - Smaller scale, niche markets, affordable – key tool to achieve net-zero economy

Conceptual Functional Layout for Quantum Battery - MIT

Value chain (what one produces with the energy) is likely much larger than supply chain (stuff that goes into a plant)

WHAT IS A NUCLEAR BATTERY

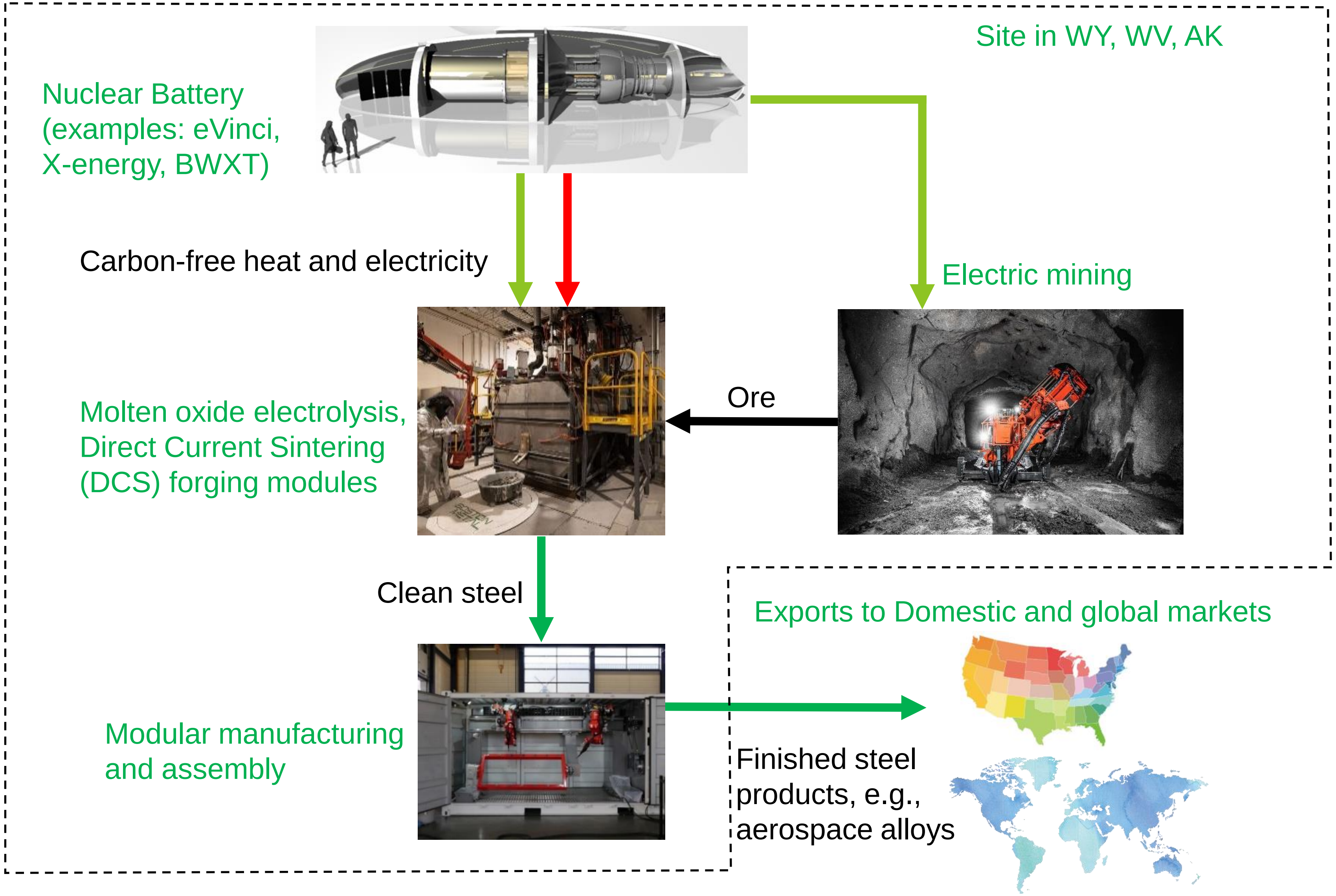
(eVinci^{TM} Westinghouse)



Slide Courtesy of Jacopo Buongiorno, MIT

- A nuclear microreactor producing 1-20 MW of heat and/or electricity
- Carbon free
- Dry cooling (no water needed)
- Standardized reactor design
- Mass produced in factories
- Transportable in ISO containers
- Plug-and-play connections
- Semi-autonomous operation
- Offsite refuelling every 5-10 years
- No onsite storage of radioactive material
- Very small footprint
- US suppliers are in the lead (Westinghouse, BWXT, X-energy)

NUCLEAR BATTERY + ADVANCED INDUSTRIAL PRODUCTION = GAME CHANGER


Site in WY, WV, AK

Nuclear Battery (examples: eVinci, X-energy, BWXT)

Carbon-free heat and electricity

Electric mining

Molten oxide electrolysis, Direct Current Sintering (DCS) forging modules

Ore

Clean steel

Exports to Domestic and global markets

Modular manufacturing and assembly

Finished steel products, e.g., aerospace alloys

Slide Courtesy of Jacopo Buongiorno, MIT

Systems features

(1) No grids or pipelines needed; (2) Shortened markup chains;
(3) Allows for incremental provisioning; (4) Carbon-free products

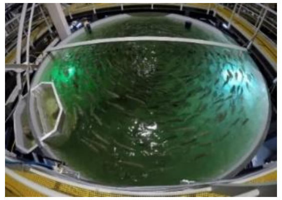
THIS APPROACH APPLIES ACROSS EVERY SECTOR OF THE ECONOMY


military bases


microgrids (remote communities, islands)


mining sites


indoor farming


indoor aquaculture


high-end metals, ceramics and glass


data centers


desalination


portable pharma

time

Slide Courtesy of Jacopo Buongiorno, MIT

Question, Plan, Engage-

- Rely on and engage with your university, your energy authority and regulators
- Regulatory oversight: Air, water, land, cultural, utilities
- Operations excellence
- Jobs, supply chain, value chain – what's the reality?
- Broader value ala engaging global markets
- Build partnerships for talent development, process learning, manufacturing, etc
- Fuel cycle – short / long term plan
- Consider facts – esp demonstrations past and future: What can be learned? What can be leveraged?

Other Slides of Possible Interest

The 40 used fuel casks hold all the fuel from 29 years of Connecticut Yankee operations

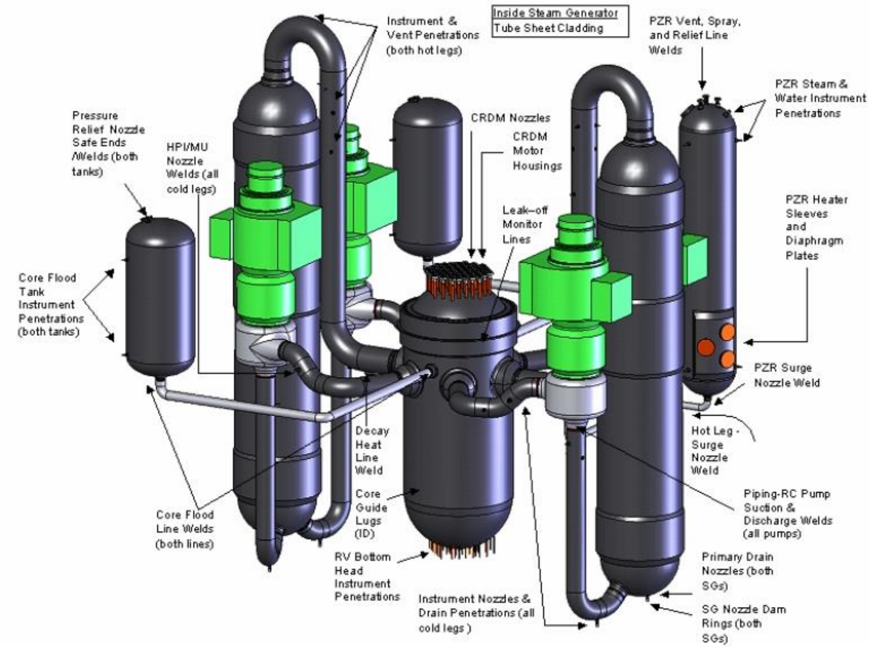
If the electricity produced by this fuel instead came from natural gas, the emitted CO2 would fill the Superdome. More than 3,000 times.

(source: http://www.connyankee.com/html/fuel_storage.html).   Slide Courtesy of John Kotek, NEI

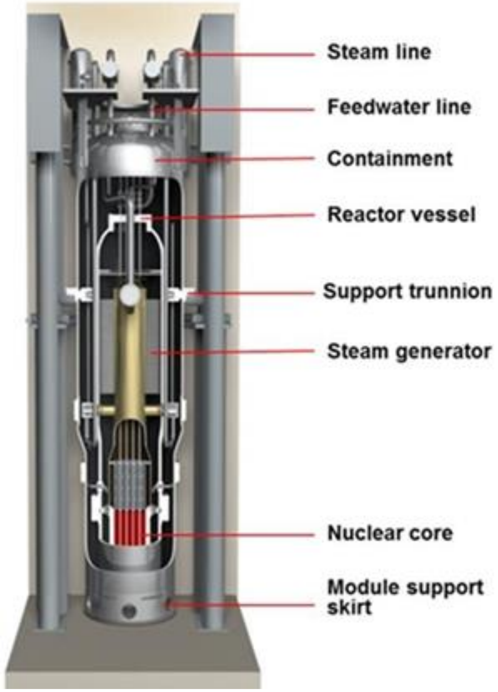
Integrated Small Reactor

SMR reactor and full primary system in one vessel

Simplified systems
Fewer Failure Modes



Typical PWR Reactor

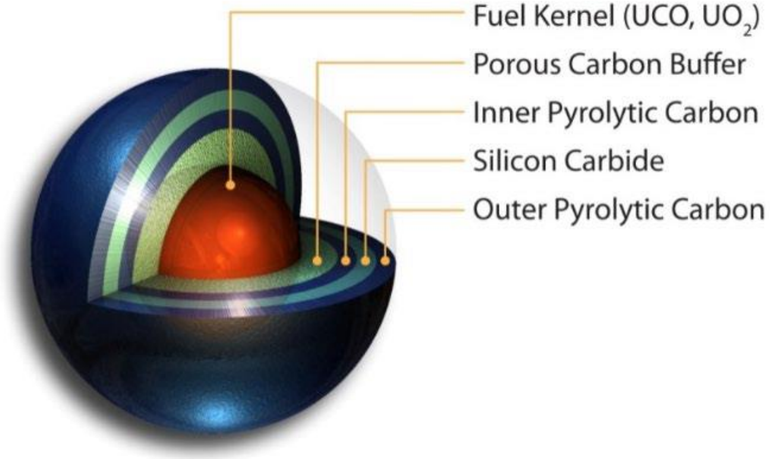


IPWR Reactors

Slide courtesy of George Griffith, INL

Key Enablers

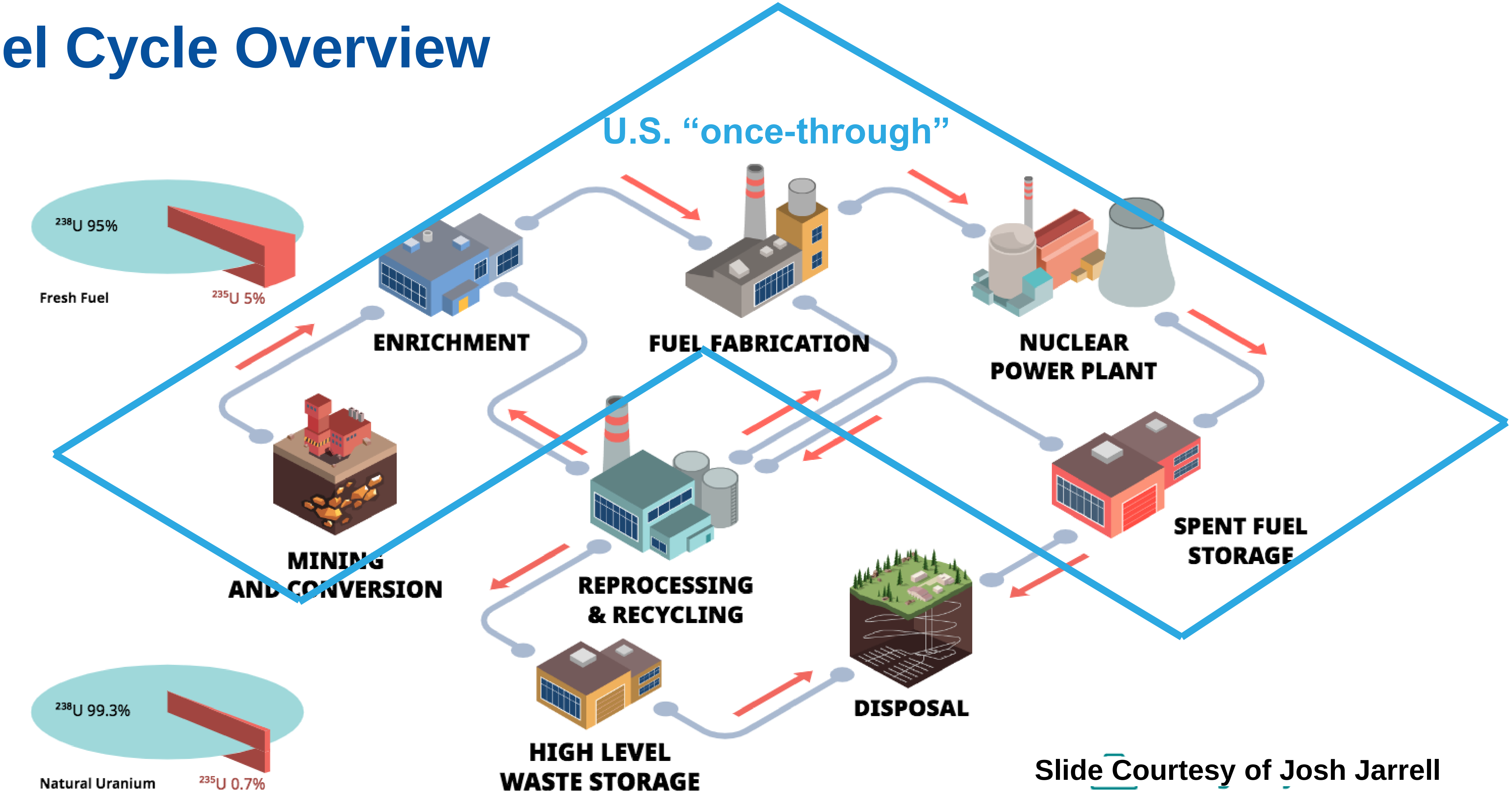
- New materials
  - High-assay, low-enriched (HALEU) nuclear fuel central to most all advanced reactors
  - Today's commercial fuels contain less than 5% uranium-235
  - HALEU slightly less than 20%
  - Longer core life, smaller size, advanced performance
  - TRISO fuel form



TRISO Fuel Particle

- New digital techniques
  - Remote monitoring, security, performance
  - Entirely new business models for deployment ?

Fuel Cycle Overview

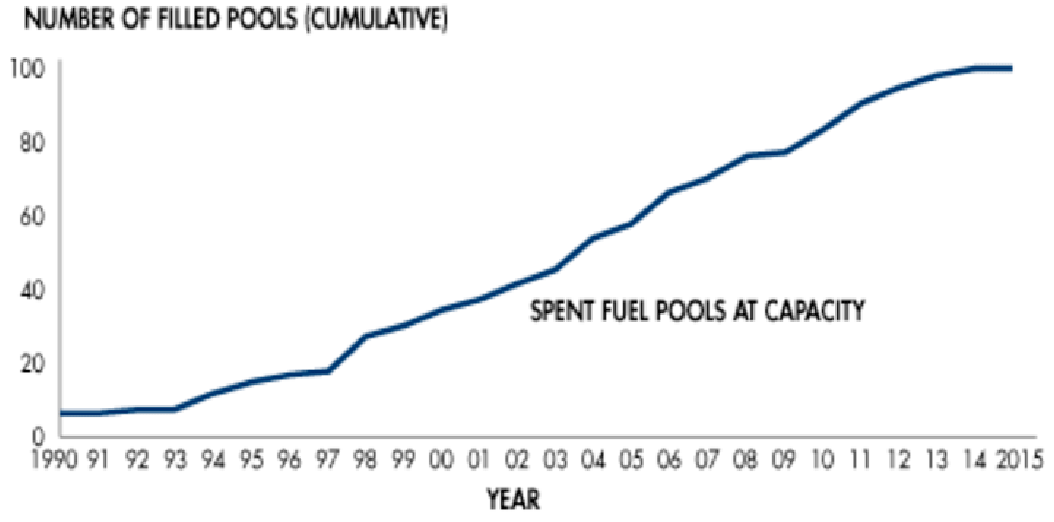


Slide Courtesy of Josh Jarrell

Source: International Atomic Energy Agency, Spent Fuel and Radioactive Waste Management, Decommissioning and Environmental Remediation e-learning curriculum, Module SFM1: Policy and Strategy for Spent Fuel Management (elearning.iaea.org – requires free IAEA Nucleus account)

Current Spent Fuel Management Practices (2)

- Due to lack of Federal Government progress with ”accepting” spent nuclear fuel due to repository delays, US spent fuel pools have reached capacity limits
- To allow continued operations, utilities have implemented dry storage
  - Each site generally loads a few storage casks every other year

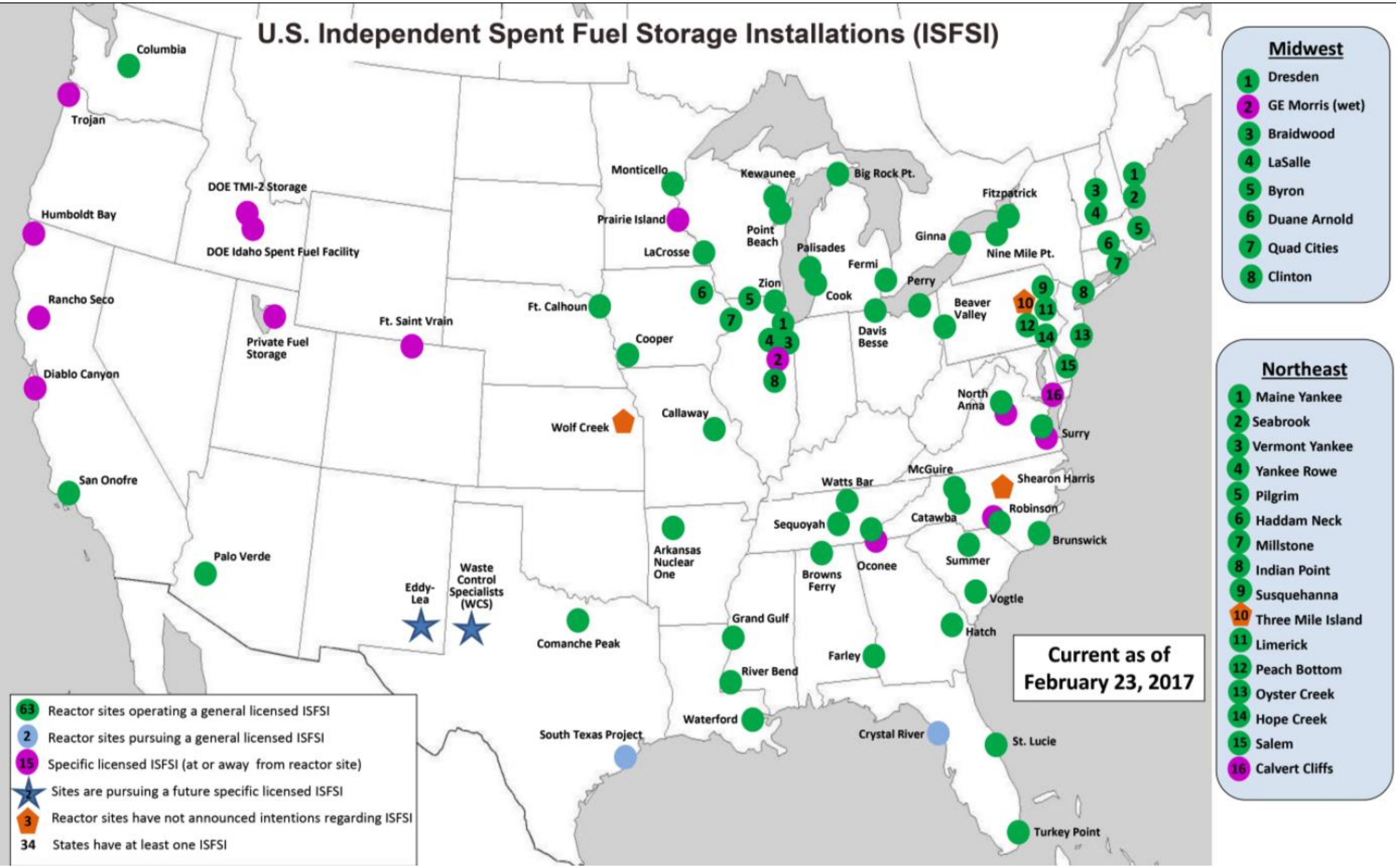


Note: All operating nuclear power reactors are storing used fuel under NRC license in spent fuel pools. Some operating nuclear reactors are using dry cask storage. Information is based on loss of full-core reserve in the spent fuel pools.

Source: Energy Resources International and DOE/RW-0431 – Revision 1

Slide Courtesy of Josh Jarrell

There are thousands of dry storage canisters across the US (1)

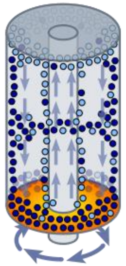


https://www.nrc.gov/reading-rm/doc-collections/maps/isfsi.html

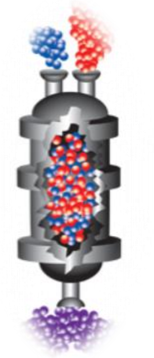
Slide Courtesy of Josh Jarrell

Sources of HALEU?

- **New** Enrichment



- Downblend
  - **Existing** HEU stocks
  - **Recovered** HEU stocks



Enriched Uranium

Natural Uranium (NU)

- 99.28% U-238
- **0.71% U-235**
- 0.005% U-234

Low Enriched Uranium (LEU)

- 95.46% U-238
- **4.5% U-235**
- 0.04% U-234

High Assay Low Enriched Uranium (HALEU)

- 80.09% U-238
- **19.75% U-235**
- 0.16% U-234

Slide Courtesy of Monica Regalbuto, INL

NRC Licenses

Fuel Cycle Facilities

⊖	Depleted Uranium Deconversion Facility	⊕	Uranium Enrichment – Gas Centrifuge Facility
◉	Fuel Fabrication Facility	◆	Uranium Enrichment – Laser Separation Facility
■	Uranium Conversion Facility		

Licensee/Facility	Location	Docket Number
Uranium Conversion		
Honeywell	Metropolis, IL	40-3392 (04003392)
Uranium Enrichment – Gas Centrifuge		
Eagle Rock	Idaho Falls, ID	70-7015 (07007015)
Louisiana Energy Services (LES)	Eunice, NM	70-3103 (07003103)
American Centrifuge Plant (ACP)	Piketon, OH	70-7004 (07007004)
Uranium Enrichment – Laser Separation		
Global Laser Enrichment (GLE)	Wilmington, NC	70-7016 (07007016)
TOP		
Fuel Fabrication – Category 1		
BWXT	Lynchburg, VA	70-27 (07000027)
NFS	Erwin, TN	70-143 (07000143)
Fuel Fabrication – Category 3		
Framatome	Richland, WA	70-1257 (07001257)
GNF-A	Wilmington, NC	70-1113 (07001113)
Westinghouse	Columbia, SC	70-1151 (07001151)
Fuel Fabrication – Mixed Oxide		
MOX	Aiken, SC	70-3098 (0700398)
TOP		
Depleted Uranium Deconversion		
International Isotopes	Lea County, NM	40-9086 (04009086)

Slide Courtesy of Monica Regalbuto, INL

The Nuclear Regulatory Commission Licenses Commercial Power Reactors

- All commercial power reactors operate under NRC licenses
  - Originally issues for 40 years
  - Subsequent licenses extended to 60 and 80
- Two current licensing approaches
  - 10 CFR 50 – Construction licenses followed by Operating License
  - 10 CFR 52 – Design approval/Combined Construction and Operating License
  - 10 CFR 53 – Technology inclusive regulatory framework under development
- Recent/current experience
  - NuScale SMR – 10 CFR 52 – 42 months for design approval
  - Oklo Aurora Microreactor – 10 CFR 52 - 36 month planned review period; recently NRC denies license application