Nuclear Energy: State of Advanced Reactors

North Dakota Association of Rural Electric Cooperatives

Annual Meeting

February 8, 2023

Marc Nichol
Senior Director, New Reactors

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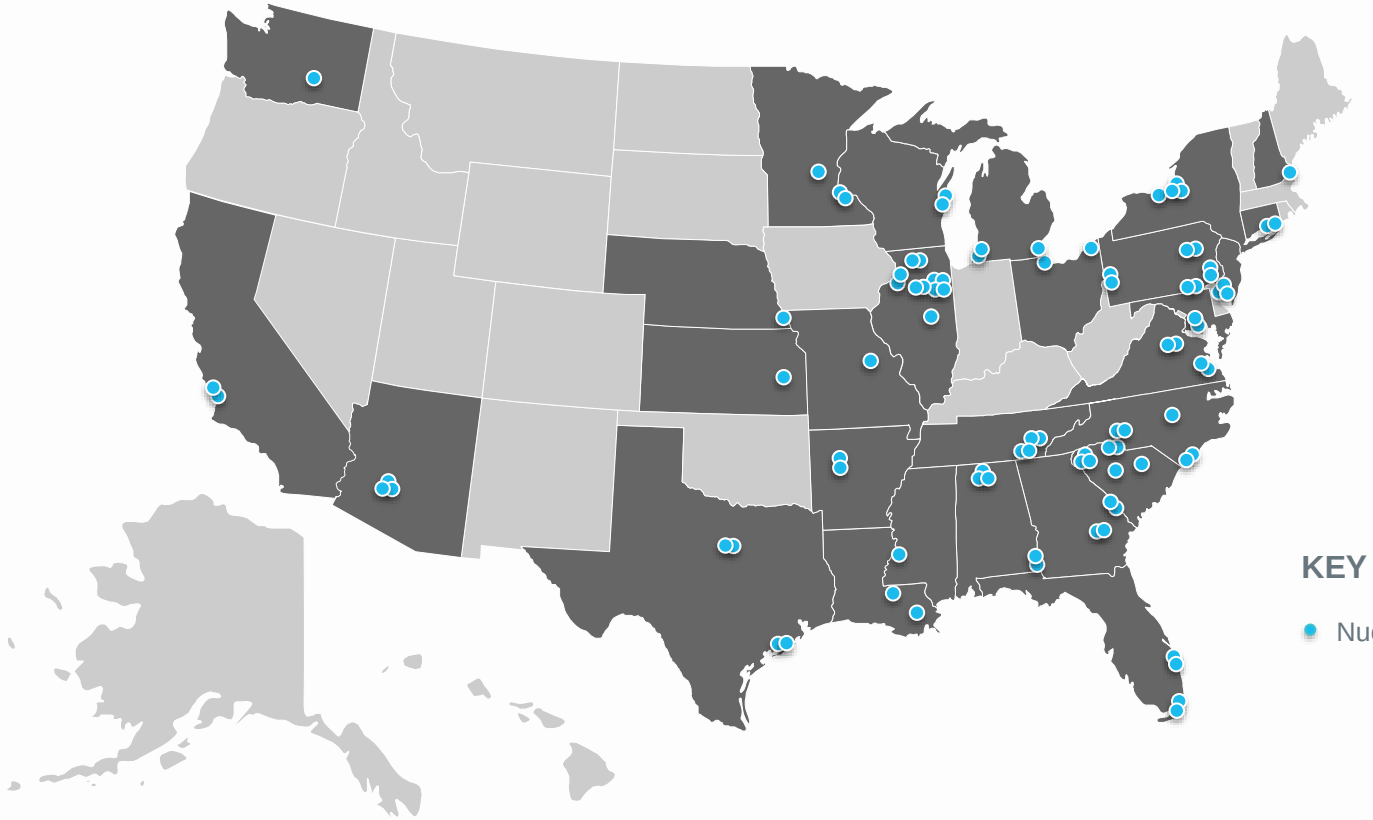
Nuclear Provided Over 50% of Emissions-Free Electricity



Nuclear generated 19% of electricity in the U.S.

From 92 reactors at 53 plant sites across the country

KEY

- Nuclear power reactor

Updated: May 2022 for the Year 2021

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Advanced Reactor Developer Members

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Expanding Versatility through Advanced Technology

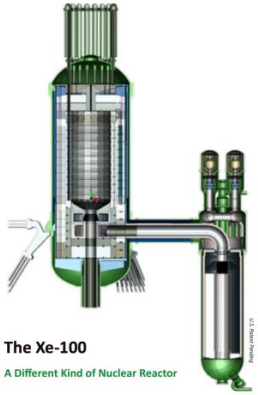
Micro Reactors (< 20MW)

Oklo (shown)
Approximately a dozen in development

LWR SMRs <300MW

NuScale (shown)
GEH X-300
Holtec SMR-160

High Temp Gas Reactors

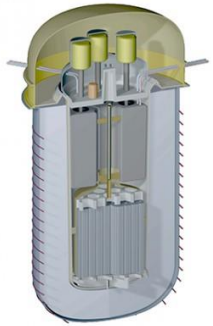


X-energy (shown)
Several in development

Liquid Metal Reactors

TerraPower Natrium (shown)
Several in development

Molten Salt Reactors



Terrestrial (shown)
Several in development

Non-Water Cooled
Most <300MW, some as large as 1,000 MW

NIA Technology Primer: https://nuclearinnovationalliance.org/sites/default/files/2022-07/ANRT-APrimer-July2022.pdf

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Expanded Versatility Meets a Diverse Set of Market Needs

Spectrum of Sizes and Options

Micro (Few MW)

Mini (10s of MW)

Small (100s of MW)

Large (1,000+ MW)

Variety of Outputs

Electricity

H_2 Hydrogen

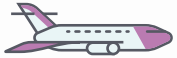
Process Heat

Multitude of Uses

Homes

Vehicles

Businesses



Aviation

Rail

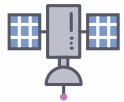
Shipping

Concrete

Steel

Factories

Water



Space

Watch the video: https://www.youtube.com/watch?v=7zN_YLg-roo

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Micro-Reactor Market Opportunities

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System Benefits of Advanced Reactors

Long term price stability	• Low fuel and operating costs
Reliable dispatchable generation	• 24/7, 365 days per year, years between refueling (Capacity factors >92%)
Integration with renewables and storage	• Paired with heat storage and able to quickly change power
Efficient use of transmission	• Land utilization <0.1 acre/TWh (Wind =1,125 acre/TWh; Solar 144 acre/TWh)
Environmentally friendly	• Zero-carbon emissions, one of lowest total carbon footprints • Many SMRs are being designed with ability for dry air cooling
Black-start and operate independent from the grid	• Resilience for mission critical activities • Protect against natural phenomena, cyber threats and EMP

Source: SMR Start, *SMRs in Integrated Resource Planning*

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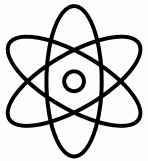
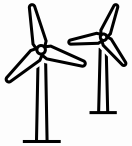
Lowest System Cost Achieved by Enabling Large Scale New Nuclear Deployment

Lowest Cost System

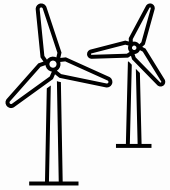


Nuclear is 43% of generation (>300 GW of new nuclear)

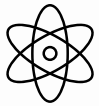


Wind and solar are 50%

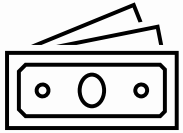
Energy System with Nuclear Constrained



Wind and Solar are 77% of generation



Nuclear is 13% (>60 GW of new nuclear)



Increased cost to customers of $449 Billion

Both scenarios are successful in reducing electricity grid GHG emissions by over 95% by 2050 and reducing the economy-wide GHG emissions by over 60%

Source: Vibrant Clean Energy: https://www.vibrantcleanenergy.com/media/reports/

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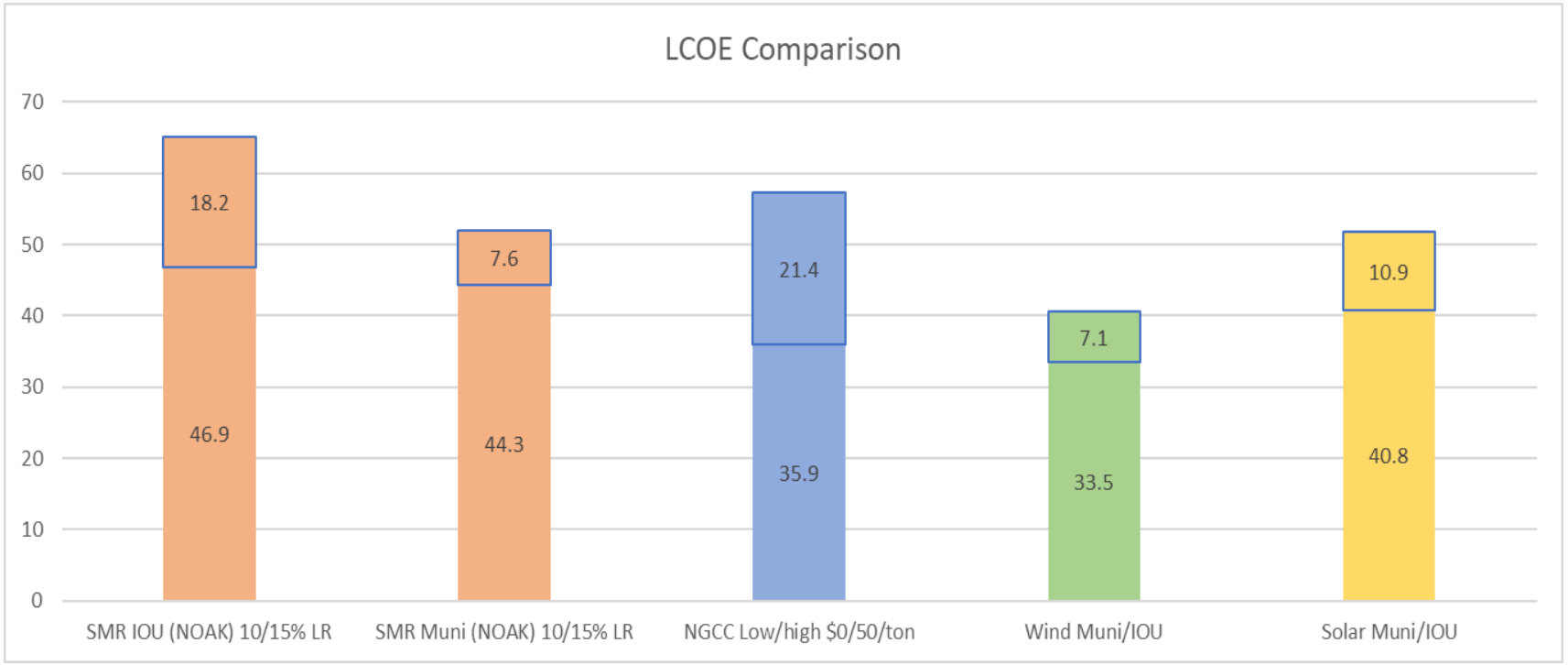
Advanced Reactors Expected to be Cost Competitive



SMR Start Report: http://smrstart.org/wp-content/uploads/2021/03/SMR-Start-Economic-Analysis-2021-APPROVED-2021-03-22.pdf

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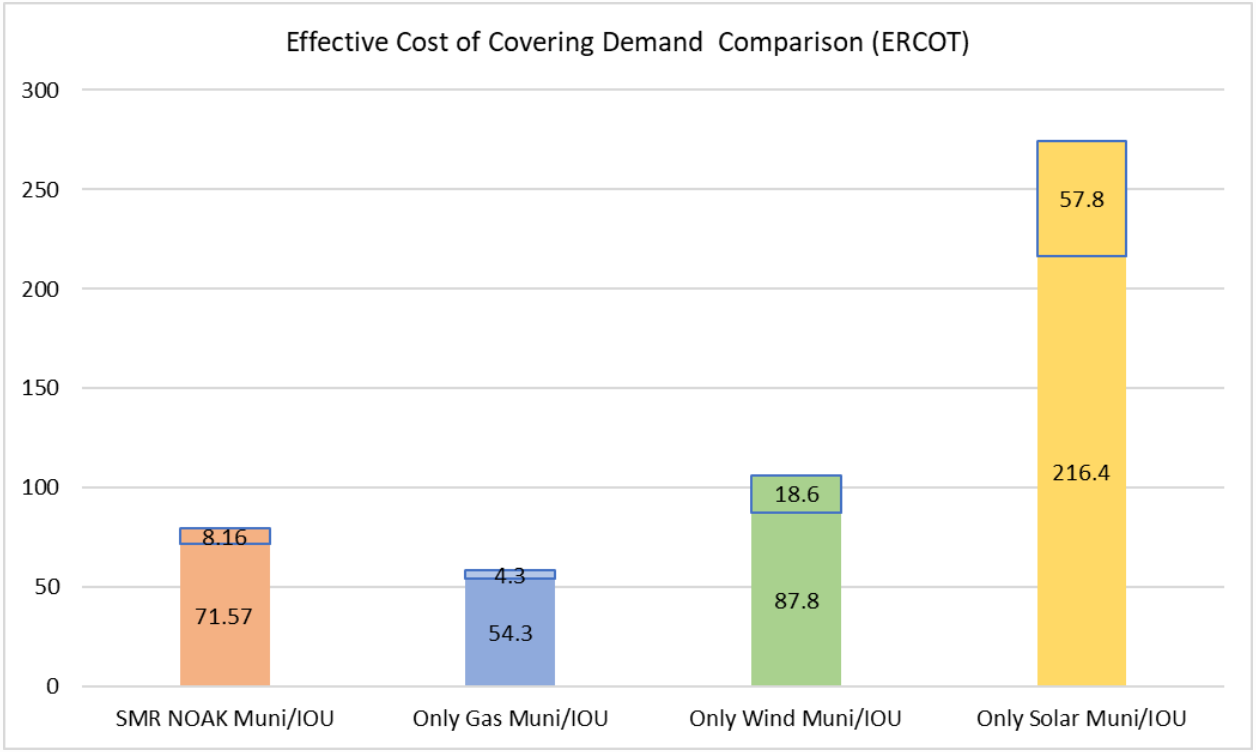
Nuclear Affordability is Clear when Considering Reliability



SMR Start Report: http://smrstart.org/wp-content/uploads/2021/03/SMR-Start-Economic-Analysis-2021-APPROVED-2021-03-22.pdf

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Advanced Reactor Safety

Building upon a strong safety record

- Operating fleet: one of the safest industrial working environments
  - Strong-Independent Regulator, Built tough, Operational Performance
- Enhancing safety for advanced reactors*
  - Safety profile fundamentally differ from other power reactors

Inherent Safety Features	Reduce Risks	Emergency Response

• Robust hardened structures
• Rely on physics
  • Natural circulation
  • Gravity
• Fail-safe, shuts itself off
• Operational simplicity: very few instruments and controls
	• Much smaller radionuclide inventory
	• Minimize potential for accidents
	• Mitigate consequences
	• Proliferation resistant fuel and enrichments below 20% U-235
		• No credible event that could result in unacceptable off-site doses
		• Maintain safety without the need for
		  • Power
		  • Additional coolant
		  • Human actions
		• Emergency planning

*Features vary by design

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Addressing Waste

All Energy Sources Have Waste, and All Must Do Three Things to Address it

- Must be able to manage it safely
  - Used fuel is solid, compact and there is proven technology to store it safely
  - Over 1,300 used fuel shipments safely completed in U.S.
- Must be able to pay for it
  - U.S. law requires nuclear plants to fund used fuel management and decommissioning activities
  - Over $40 billion in Nuclear Waste Fund
- Must have a place to put it
  - Department of Energy required dispose of used fuel
  - Most micro-reactor companies will take back used fuel soon after refueling

Nuclear Fuel

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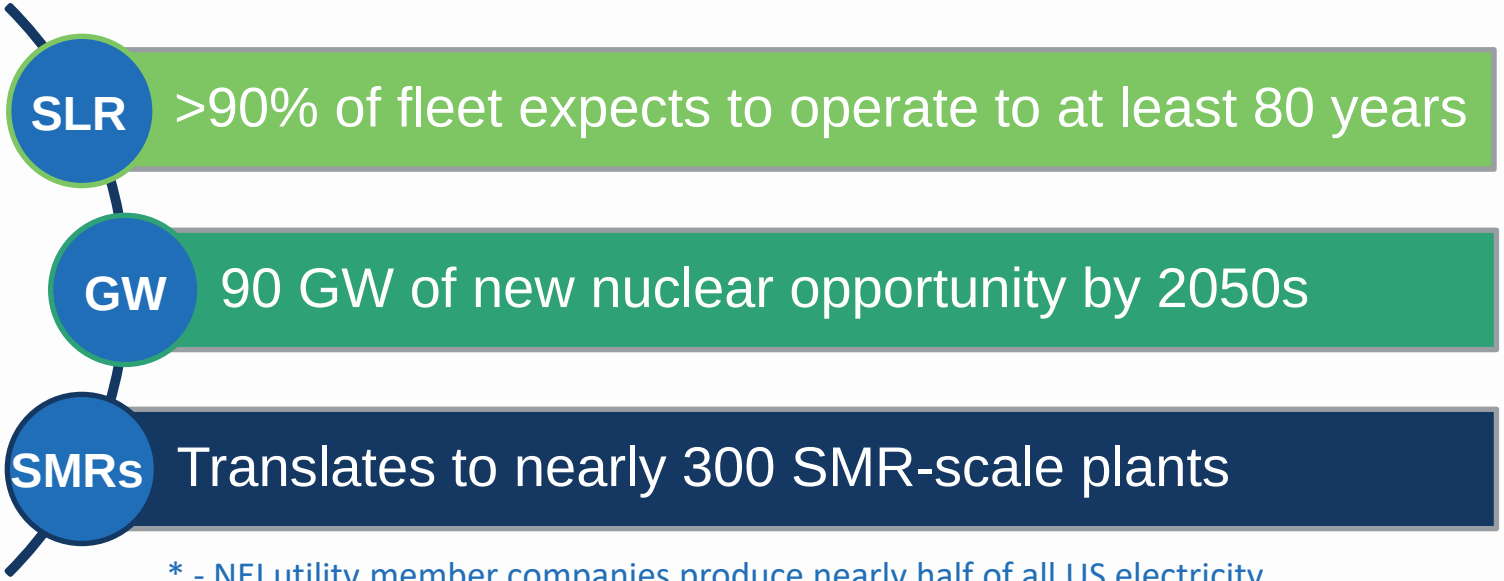
Electric Utilities are Planning for New Nuclear

Nuclear power's potential role in meeting their company's decarbonization goals:



* - NEI utility member companies produce nearly half of all US electricity

NEI Overview of Demand::https://www.nei.org/CorporateSite/media/filefolder/advantages/The-Path-to-Decarbonization-Overview-of-the-Demand-for-New-Nuclear.pdf

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Coal to Nuclear Transition

- Coal power plant shutdowns can be devastating to local communities
- Transition to a small modular reactor (SMR) can provide carbon-free replacement power while:
  - Capitalizing on existing infrastructure,
  - Saving jobs, and
  - Supporting communities
- Pursuing policy actions to encourage coal to nuclear

Scott Madden Coal to Nuclear Paper:
https://www.scottmadden.com/content/uploads/2021/10/ScottMadden_Gone_With_The_Steam_WhitePaper_final4.pdf

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Small Modular Reactors/Advanced Reactors Offer Significant Well-Paying, Long-Term Jobs

Generation Type	Permanent Jobs on Site	Industry Wage Median	Carbon-free Energy?	Role on Grid-firm Energy?	Benefits Concentrated in Local Community?
Nuclear	237*	$41.32	**Yes**	**Yes**	**Yes**
Coal	107	$33.64	No	**Yes**	**Yes**
Natural Gas	30	$34.02	No	**Yes**	**Yes**
Wind	80	$25.95	**Yes**	No	No
Solar	36	$24.48	**Yes**	No	No

* - Based on NuScale 12-pack design

Note: Comparison of alternatives producing annual electricity output equivalent to a typical 1,000 Mwe coal plant

Source: ScottMadden, *Gone with the Steam*, October 2021 – https://www.scottmadden.com/content/uploads/2021/10/ScottMadden_Gone_With_The_Steam_WhitePaper_final4.pdf

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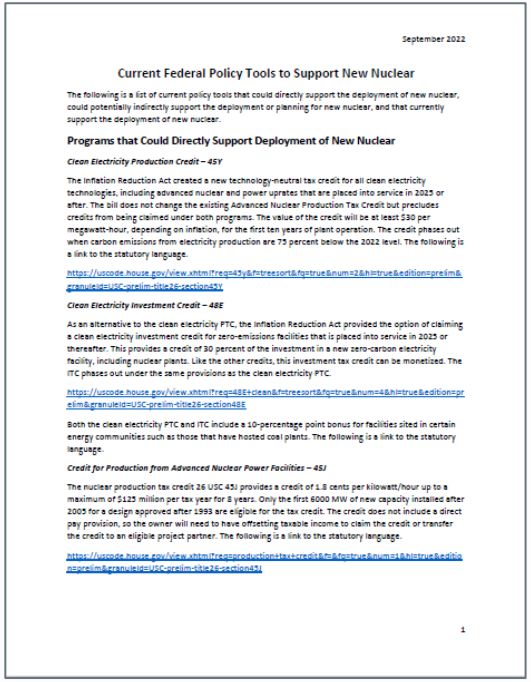
Strong Federal Support for Advanced Reactors

- DOE funding 12 different designs, >$5B over 7 years
- Infrastructure Bill
  - $2.5B funding for two demonstration projects
- Inflation Reduction Act
  - PTC: At least $30/MWh for 10 years
  - ITC: 30% of investment
  - Both can be monetized, include 10% bonus for siting in certain energy communities
  - Loan Guarantees – up to $40B in expanded authority
  - HALEU Fuel - $700M
- CHIPS Act
  - Financial assistance to States, Tribes, local governments and Universities



September 2022

Current Federal Policy Tools to Support New Nuclear

The following is a list of current policy tools that could directly support the deployment of new nuclear, could potentially indirectly support the deployment or planning for new nuclear, and that currently support the deployment of new nuclear.

Programs that Could Directly Support Deployment of New Nuclear

Clean Electricity Production Credit – 45Y

The Inflation Reduction Act created a new technology-neutral tax credit for all clean electricity technologies, including advanced nuclear and power uprates that are placed into service in 2025 or after. The bill does not change the existing Advanced Nuclear Production Tax Credit but precludes credits from being claimed under both programs. The value of the credit will be at least $30 per megawatt-hour, depending on inflation, for the first ten years of plant operation. The credit phases out when carbon emissions from electricity production are 75 percent below the 2022 level. The following is a link to the statutory language.

https://uscode.house.gov/view.xhtml?req=45y&f=treesort&fq=true&num=2&hl=true&edition=prelim&granuleId=USC-prelim-title26-section45Y

Clean Electricity Investment Credit – 48E

As an alternative to the clean electricity PTC, the Inflation Reduction Act provided the option of claiming a clean electricity investment credit for zero-emissions facilities that is placed into service in 2025 or thereafter. This provides a credit of 30 percent of the investment in a new zero-carbon electricity facility, including nuclear plants. Like the other credits, this investment tax credit can be monetized. The ITC phases out under the same provisions as the clean electricity PTC.

https://uscode.house.gov/view.xhtml?req=48E+clean&f=treesort&fq=true&num=4&hl=true&edition=prelim&granuleId=USC-prelim-title26-section48E

Both the clean electricity PTC and ITC include a 10-percentage point bonus for facilities sited in certain energy communities such as those that have hosted coal plants. The following is a link to the statutory language.

Credit for Production from Advanced Nuclear Power Facilities – 45J

The nuclear production tax credit 26 USC 45J provides a credit of 1.8 cents per kilowatt/hour up to a maximum of $125 million per tax year for 8 years. Only the first 6000 MW of new capacity installed after 2005 for a design approved after 1993 are eligible for the tax credit. The credit does not include a direct pay provision, so the owner will need to have offsetting taxable income to claim the credit or transfer the credit to an eligible project partner. The following is a link to the statutory language.

https://uscode.house.gov/view.xhtml?req=production+tax+credit&f=treesort&fq=true&num=1&hl=true&edition=prelim&granuleId=USC-prelim-title26-section45J

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Current Federal Policies: https://www.nei.org/CorporateSite/media/filefolder/advantages/Current-Policy-Tools-to-Support-New-Nuclear.pdf

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Recent State Legislative Actions

State	Legislative Action	State	Legislative Action
Alaska	Passed bill to repeal Legislature approval to site micro-reactors	Nebraska	Passed bill on SMR tax incentives and SMR study funding approved
Colorado	Considered bill to study SMRs	New Hampshire	Passed bill to create a nuclear commission and study SMRs
Connecticut	Passed bill to partially repeal the moratorium for new nuclear, and allow consideration at Millstone	New Jersey	Considered bills to create SMR task force and incentivize construction of advanced nuclear
Idaho	Tax incentives passed	North Carolina	Passed decarbonization plan bill
Indiana	Nuclear Certificate of Necessity program enabled	Ohio	Considered bill to create an SMR task force
Kentucky	Considered bill to study SMRs	Oklahoma	Considered bill to study SMRs
Michigan	Passed bill to study SMRs	Pennsylvania	Considered bill to study SMRs
Maryland	Considered including SMRs in Climate Solutions legislation	Virginia	Nuclear Energy Strategic Plan and SMR Task Force created
Minnesota	Considered bill to study SMRs and either fully or partially repeal its nuclear moratorium	Washington	Clean energy standard including nuclear
Missouri	Considered a bill to repeal a CWIP moratorium	West Virginia	Repealed nuclear moratorium
Montana	Passed bill to study coal to SMR Repealed voter approval to site	Wyoming	Passed bill calling for coal retirements to be replaced with SMRs

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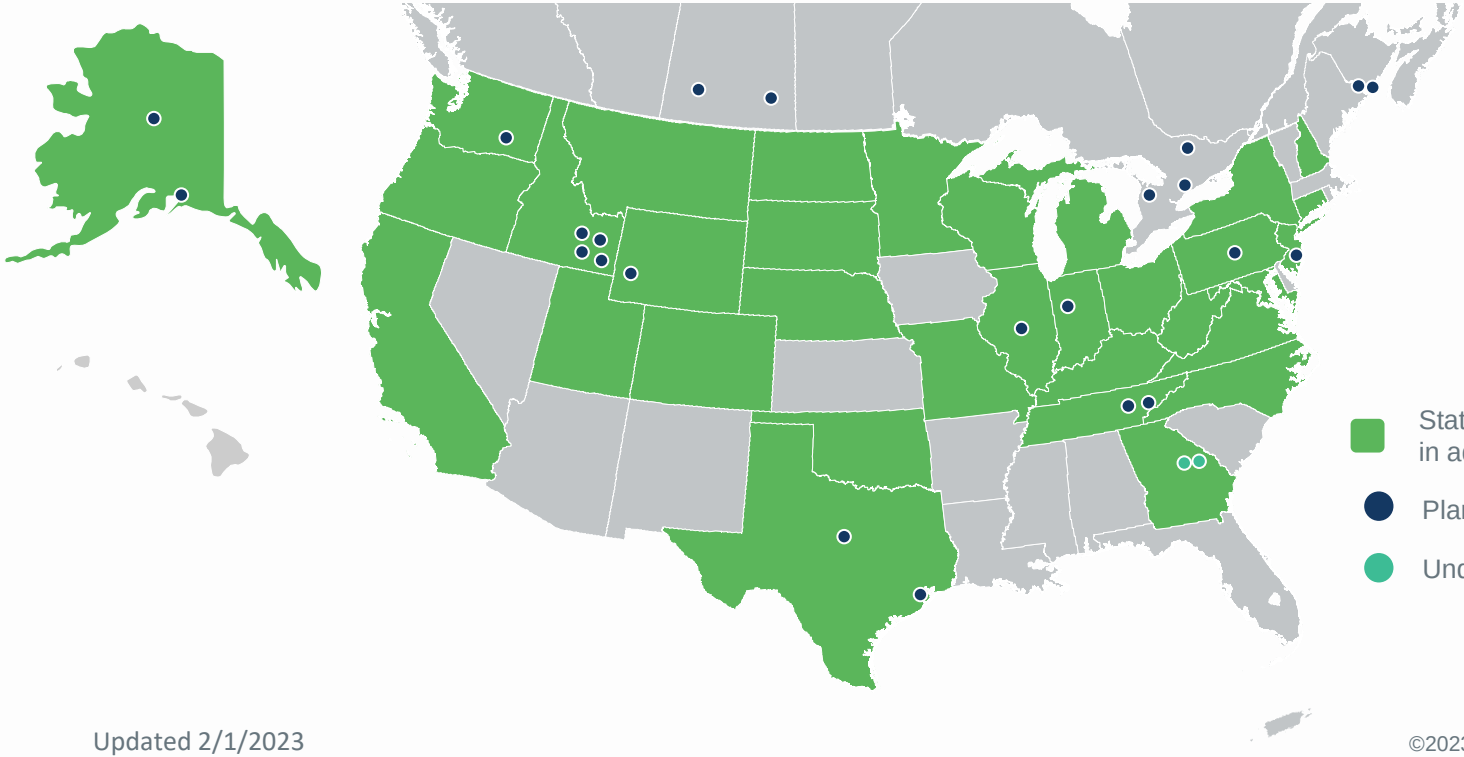
Advanced Nuclear Deployment Plans

Projects in planning or under consideration in U.S. and Canada >20; Globally >30



Updated 2/1/2023

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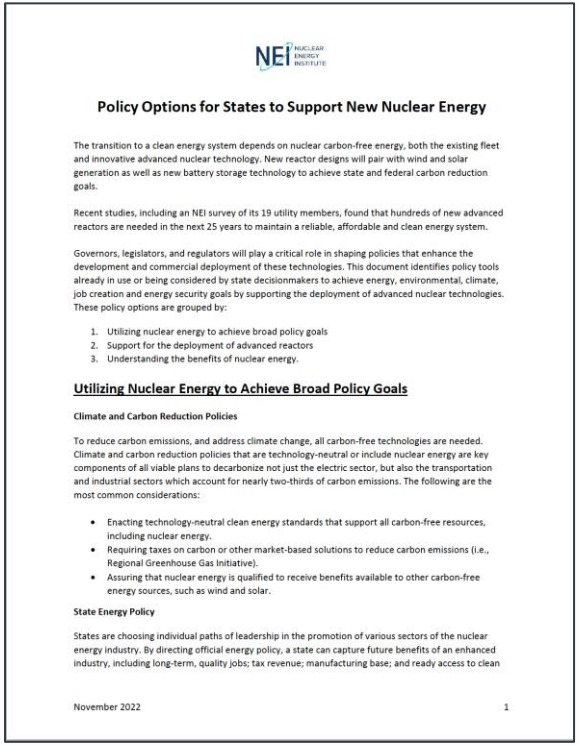
State Options to Support Advanced Reactors

- Feasibility Studies
- Reducing Barriers
- Tax incentives (e.g., property)
- Advanced cost recovery
- Workforce and infrastructure



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Policy Options for States to Support New Nuclear Energy

The transition to a clean energy system depends on nuclear carbon-free energy, both the existing fleet and innovative advanced nuclear technology. New reactor designs will pair with wind and solar generation as well as new battery storage technology to achieve state and federal carbon reduction goals.

Recent studies, including an NEI survey of its 19 utility members, found that hundreds of new advanced reactors are needed in the next 25 years to maintain a reliable, affordable and clean energy system.

Governors, legislators, and regulators will play a critical role in shaping policies that enhance the development and commercial deployment of these technologies. This document identifies policy tools already in use or being considered by state decisionmakers to achieve energy, environmental, climate, job creation and energy security goals by supporting the deployment of advanced nuclear technologies. These policy options are grouped by:

1. Utilizing nuclear energy to achieve broad policy goals
2. Support for the deployment of advanced reactors
3. Understanding the benefits of nuclear energy.

Utilizing Nuclear Energy to Achieve Broad Policy Goals

Climate and Carbon Reduction Policies

To reduce carbon emissions, and address climate change, all carbon-free technologies are needed. Climate and carbon reduction policies that are technology-neutral or include nuclear energy are key components of all viable plans to decarbonize not just the electric sector, but also the transportation and industrial sectors which account for nearly two-thirds of carbon emissions. The following are the most common considerations:

- Enacting technology-neutral clean energy standards that support all carbon-free resources, including nuclear energy.
- Requiring taxes on carbon or other market-based solutions to reduce carbon emissions (i.e., Regional Greenhouse Gas Initiative).
- Assuring that nuclear energy is qualified to receive benefits available to other carbon-free energy sources, such as wind and solar.

State Energy Policy

States are choosing individual paths of leadership in the promotion of various sectors of the nuclear energy industry. By directing official energy policy, a state can capture future benefits of an enhanced industry, including long-term, quality jobs; tax revenue; manufacturing base; and ready access to clean

November 2022 1

State Policy Options: https://www.nei.org/resources/reports-briefs/policy-options-for-states-to-support-new-nuclear

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QUESTIONS?

By Third Way, GENSLER