Nuclear Energy: State of Micro Reactors

Alaska Energy Security Task Force

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NEI NUCLEAR ENERGY INSTITUTE

Micro Reactor Technology

Designed to replace Diesel Generators

Oklo Aurora
1.5 MWe

Ultra Safe Nuclear Corporation
5 MWe

Westinghouse eVinci
5 MWe

BWXT BANR
17 MWe

- Very small size
  - Site as small as 0.1 acres, building ~size of a house
  - Reactor is road shippable, minimal site work
- Resilience – withstand, mitigate or quickly recover from
  - Extreme natural events
  - Man-made physical and cyber threats
- Operations
  - Automatic operations, island mode and black-start
  - Flexible – hybrid energy and renewables integration

Other Designs (not all inclusive)

- General Atomics
- HolosGen
- Hydromine
- NuGen
- NuScale
- Radiant
- X-energy

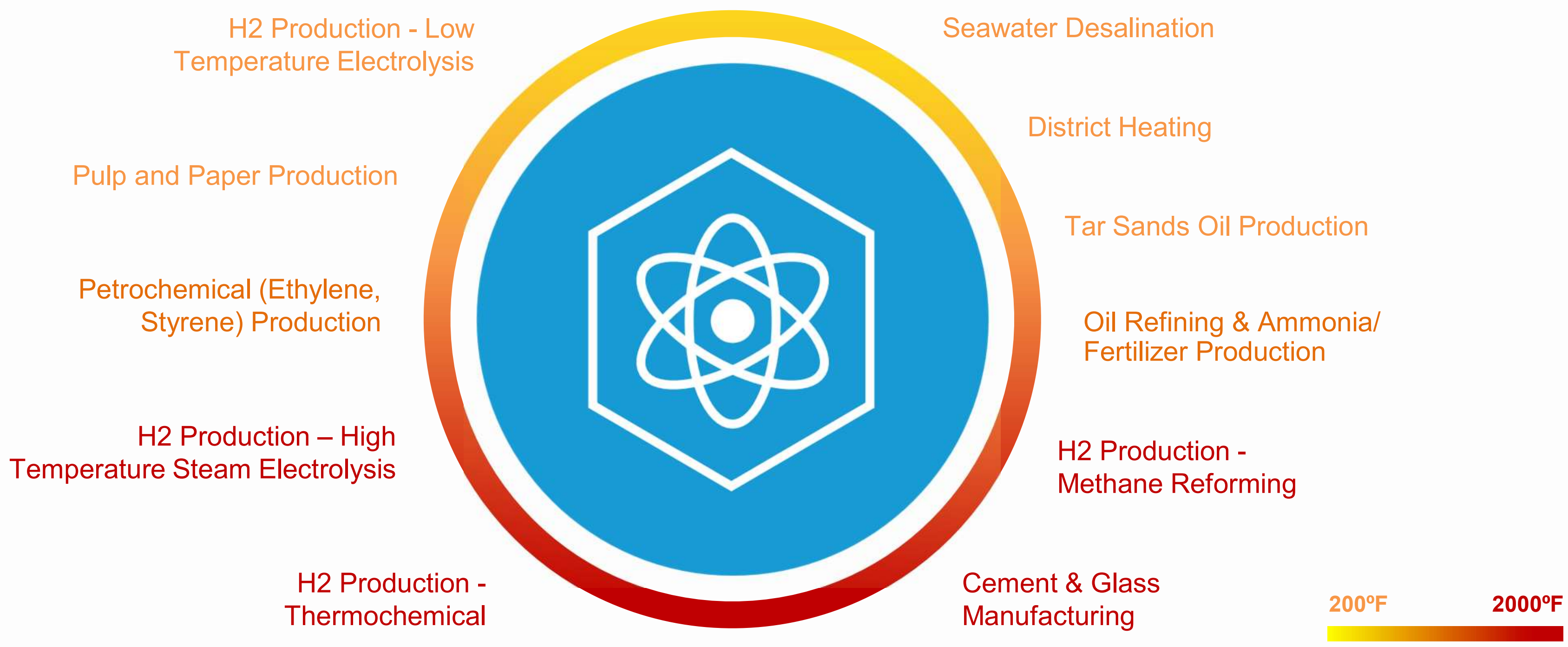
System Benefits of Advanced Reactors

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*

Gateway to Heat Markets

Process Heat Temperature Needs

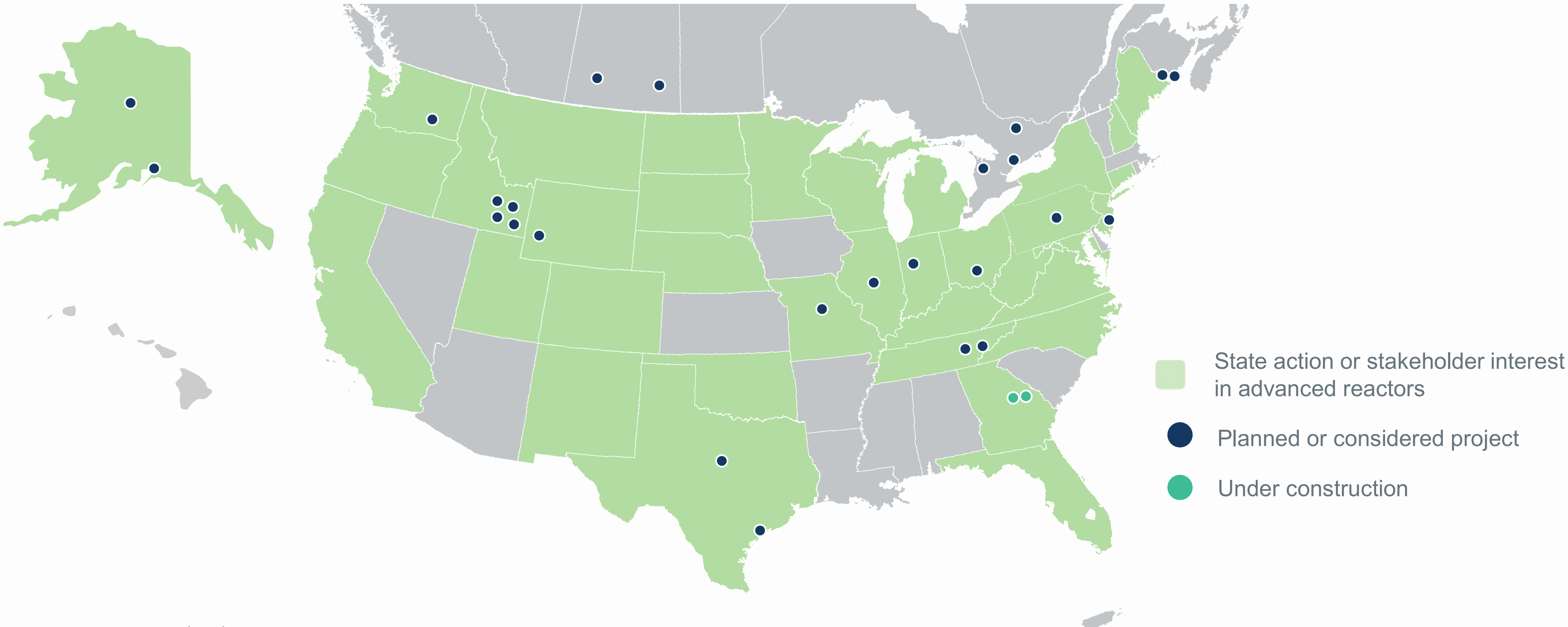


Source: Nuclear Cogeneration, civil nuclear energy in a low-carbon future, The Royal Society, October 2020

Market Opportunities

Advanced Nuclear Deployment Plans

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



Updated 5/25/2023

Advanced Reactor Deployment Plans

Micro-reactors and low scale test reactors

Updated 5/25/2023

Developer	Utility / User	Location	Size	Target Online
Oklo	Oklo	Idaho, USA	15 MWe	2026
	Oklo	Ohio, USA	2 @ 15 MWe	2028
	Compass Mining	TBD	TBD (150 MWe total)	TBD
Ultra Safe Nuclear	Global First / OPG	CRL, Canada	5 MWe	2025
	University of Illinois	Illinois, USA	5 MWe	2027
	Copper Valley (CVEA)	Alaska, USA	5 MWe	TBD
Westinghouse	Sask Research Council	West Canada	5 MWe	2027
	Bruce Power	ON, Canada	5 MWe	2027
	Penn State University	USA	5 MWe	2027
Radiant	TBA	Idaho, USA	1.2 MWe	2026
TBD	Eielson AFB	Alaska, USA	1 – 10 MWe	2027
BWXT	DoD SCO	Idaho, USA	1.5 MWe	2024
Kairos Power	Kairos	TN, USA	35 MWth	2026
Natura	Abilene Christian University	TX, USA	1 MWth	2025
TBD	Univ. of Missouri	MO, USA	TBD	TBD

Advanced Reactor Licensing Progress

Approved	Under Review	Pre-Application
1. NuScale Power	1. Abiline Christian University 2. Kairos Power 3. NuScale (power uprate)	1. GEH BWR X-300 2. General Atomics 3. Holtec SMR-160 4. Kairos Power 5. Oklo 6. TerraPower Natrium 7. TerraPower MCFR 8. Terrestrial 9. Univ. of Illinois U-C 10. X-energy 11. Westinghouse

Micro-Reactor

Resource Planning

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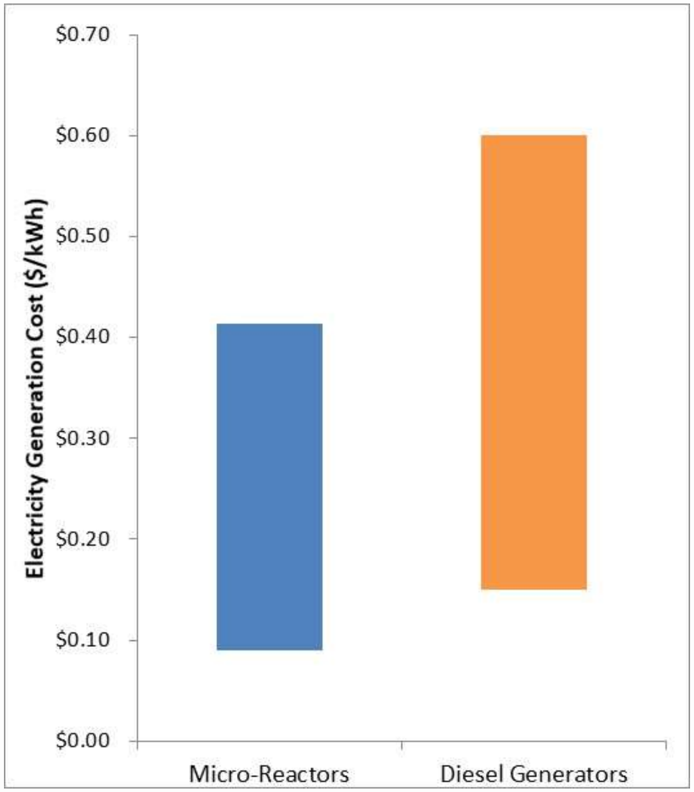
Benefits	Considerations	Planning Options
• Fuel diversity • Carbon-free • Flexible/dispatchable • Resilience/reliability • Renewables integration • Repower retired fossil sites	• Schedule • Cost • Risks • Environmental • Economic benefits	• Monitoring • Planning • Evaluating sites • Licensing • Project initiation

http://smrstart.org/wp-content/uploads/2020/02/SMR-Start-Public-SMRs-in-IRPs-APPROVED-2020-02-28.pdf

Cost Comparison

Full cost of micro-reactor vs only diesel fuel cost

- Diesel generator costs
  - Primarily fuel costs
  - Fuel from $2.86/gallon to $4.89/gallon
- Micro-reactor costs
  - Include used fuel disposal and decommissioning
  - 10 year fuel life
  - 40 year plant life
  - 95% capacity factor



NEI: *Cost Competitiveness of Micro-Reactors for Remote Markets*, April 2019

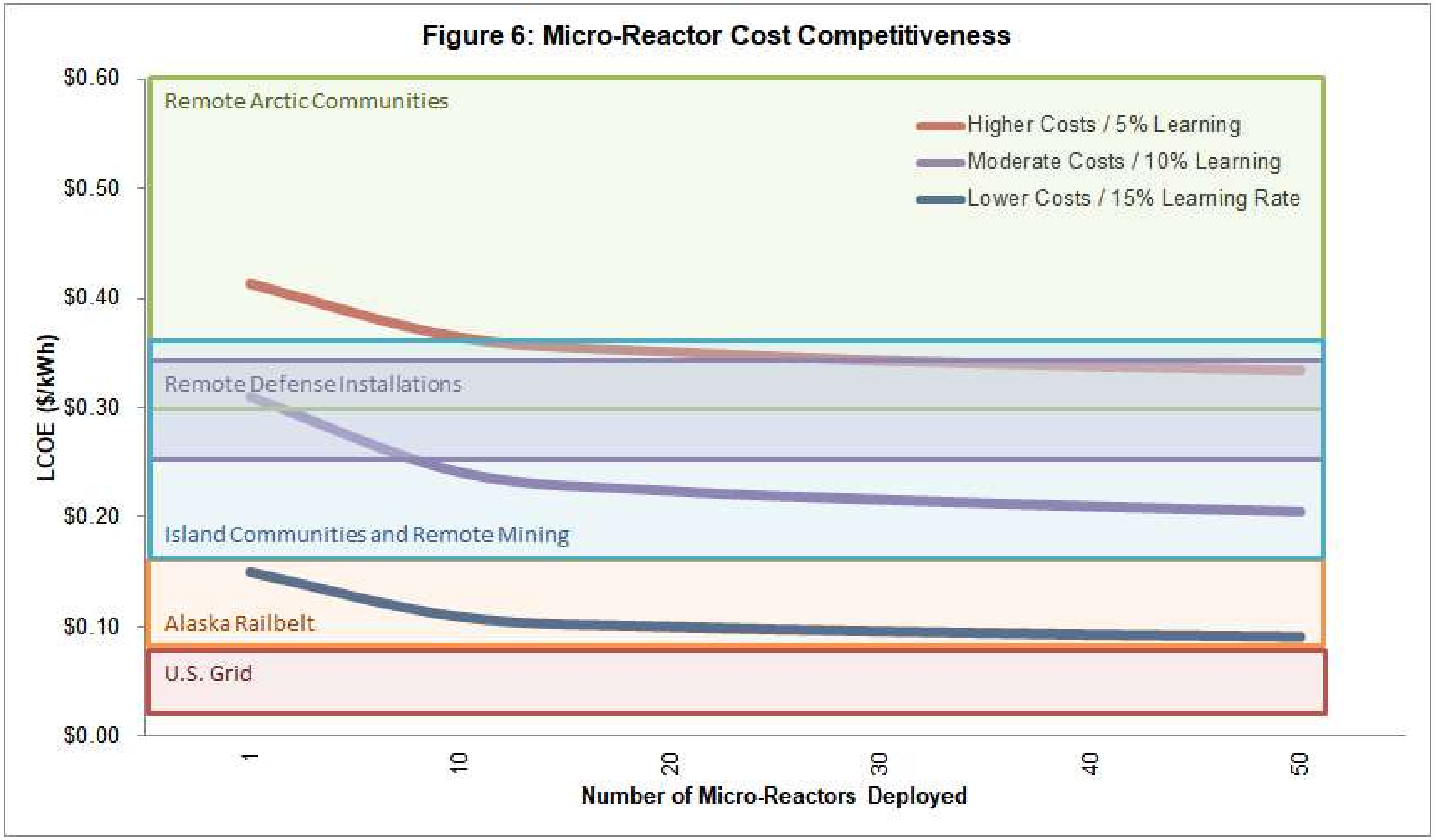


Figure 6: Micro-Reactor Cost Competitiveness
$0.60
$0.50
$0.40
$0.30
$0.20
$0.10
$0.00
LCOE ($/kWh)
Remote Arctic Communities
Higher Costs / 5% Learning
Moderate Costs / 10% Learning
Lower Costs / 15% Learning Rate
Remote Defense Installations
Island Communities and Remote Mining
Alaska Railbelt
U.S. Grid
1
10
20
30
40
50
Number of Micro-Reactors Deployed

Figure 1: Estimated Levelized Cost of Electricity Generation for the First Micro-Reactor

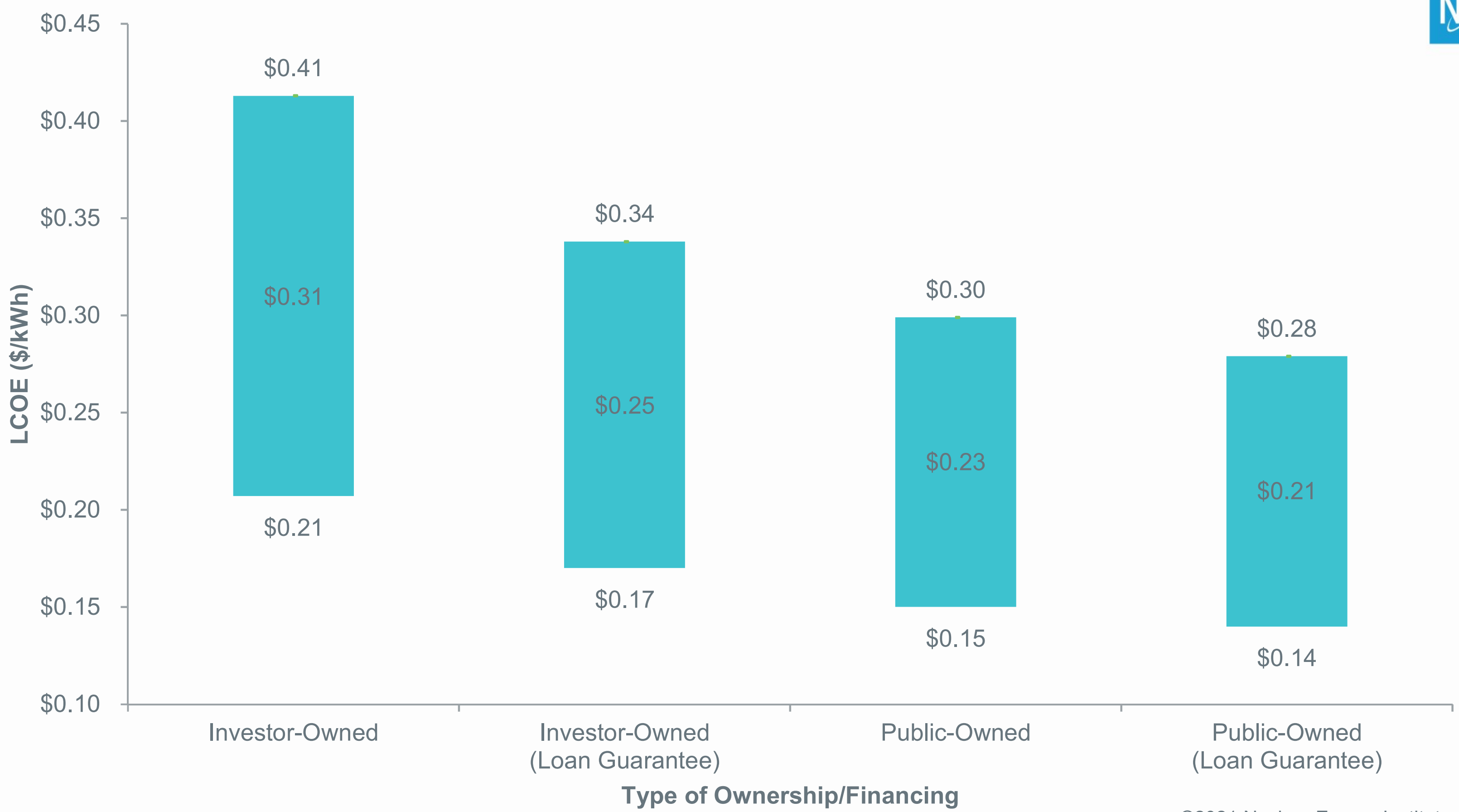
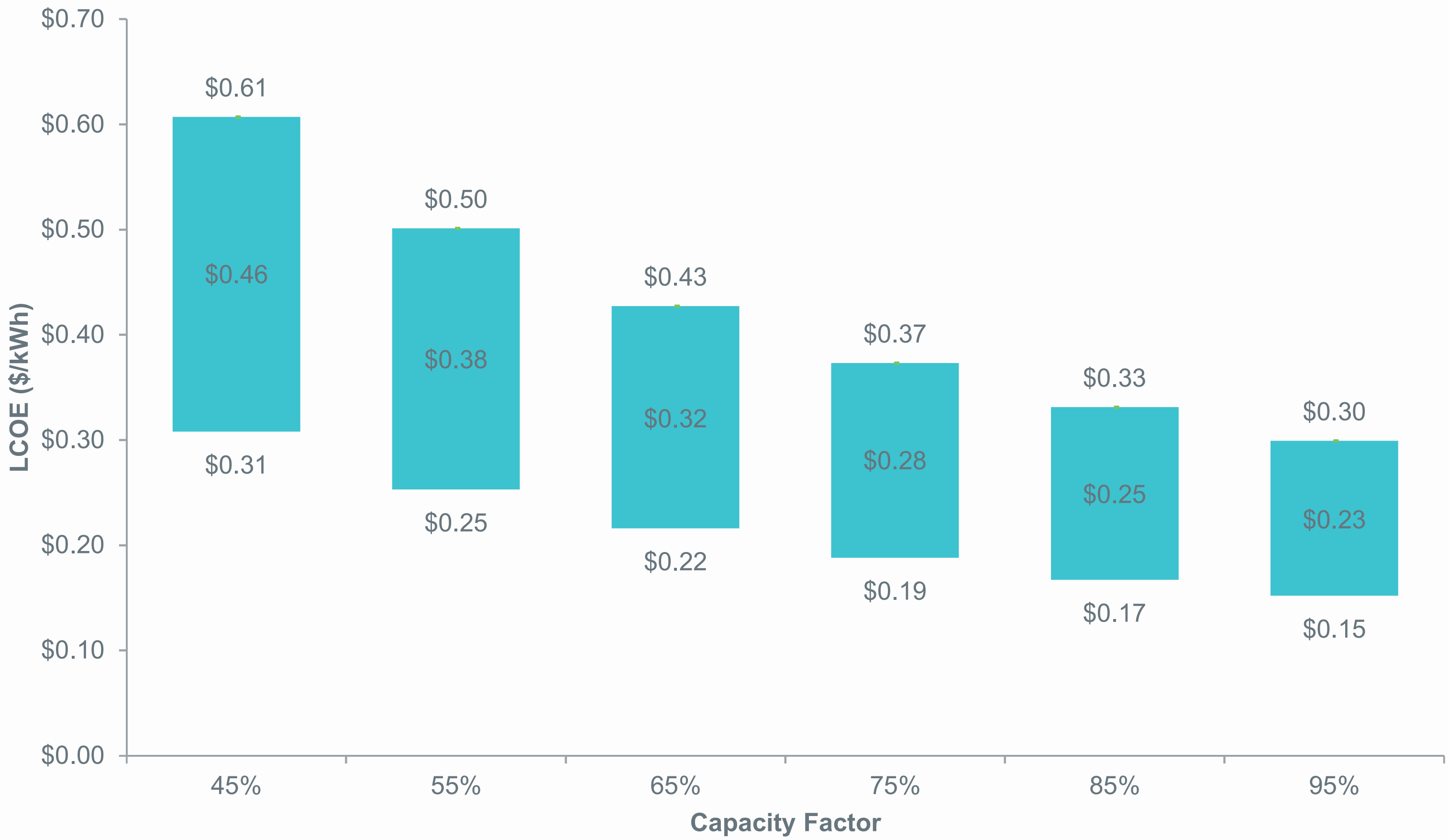


Figure 4: Sensitivity of Micro-Reactor LCOE on Capacity Factor



Financing Micro-Reactors

Capital Costs of 5 MWe plant = $50M to $100M*

- Conventional business model
  - Local utility finances capital costs
  - Financing typically by debt at low rates, amortized

- New business models
  - Developer owns and operates plant, uses a Power Purchase Agreement
  - Local utility does not finance capital costs, only pays for power

- Similarities and differences
  - In both: customers only pay as levelized cost of capital
  - New business model: developer bears bulk of financial risk of project

*Derived from NEI *Cost Competitiveness of Micro-Reactors for Remote Markets*, April 2019
https://nei.org/resources/reports-briefs/cost-competitiveness-micro-reactors-remote-markets

Micro-Reactor Workforce

Target <10 employees to power rural areas

Technology enablers	NRC considering for micro-reactors
Safety and simplicity in design	Minimal worker training and qualifications
Automatic operations	Operators allowed additional duties (e.g., maintenance, administrative)
Remote operations	No operator needed on site
Security by design	No armed security guards needed

- Hub areas: population sizes that can supply workers
  - Direct use of electricity and heat with existing grid and district heating
- Spoke areas: population sizes that cannot supply workers
  - Electric transmission from hub region (if close by); OR
  - Use hydrogen or ammonia from hub region (low-cost due to economics of micro-reactors and short transport distances)

Lowest System Cost Achieved by Enabling Large Scale New Nuclear Deployment

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Lowest Cost System	Energy System with Nuclear Constrained
Nuclear is 43% of generation (>300 GW of new nuclear)	Wind and Solar are 77% of generation
Wind and solar are 50%	Nuclear is 13% (>60 GW of new nuclear)
	Increased cost to customers of $449 Billion

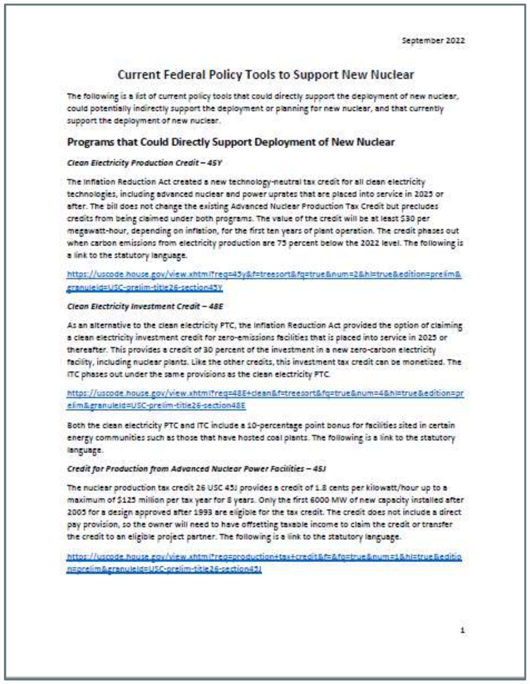
Both scenarios are successful in reducing electricity grid GHG emissions by over 95% by 2050 and reducing the economy-wide GHG emissions by over 60%

VCE VIBRANT CLEAN ENERGY

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

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=&fq=true&num=1&hl=true&edition=prelim&granuleId=USC-prelim-title26-section45J

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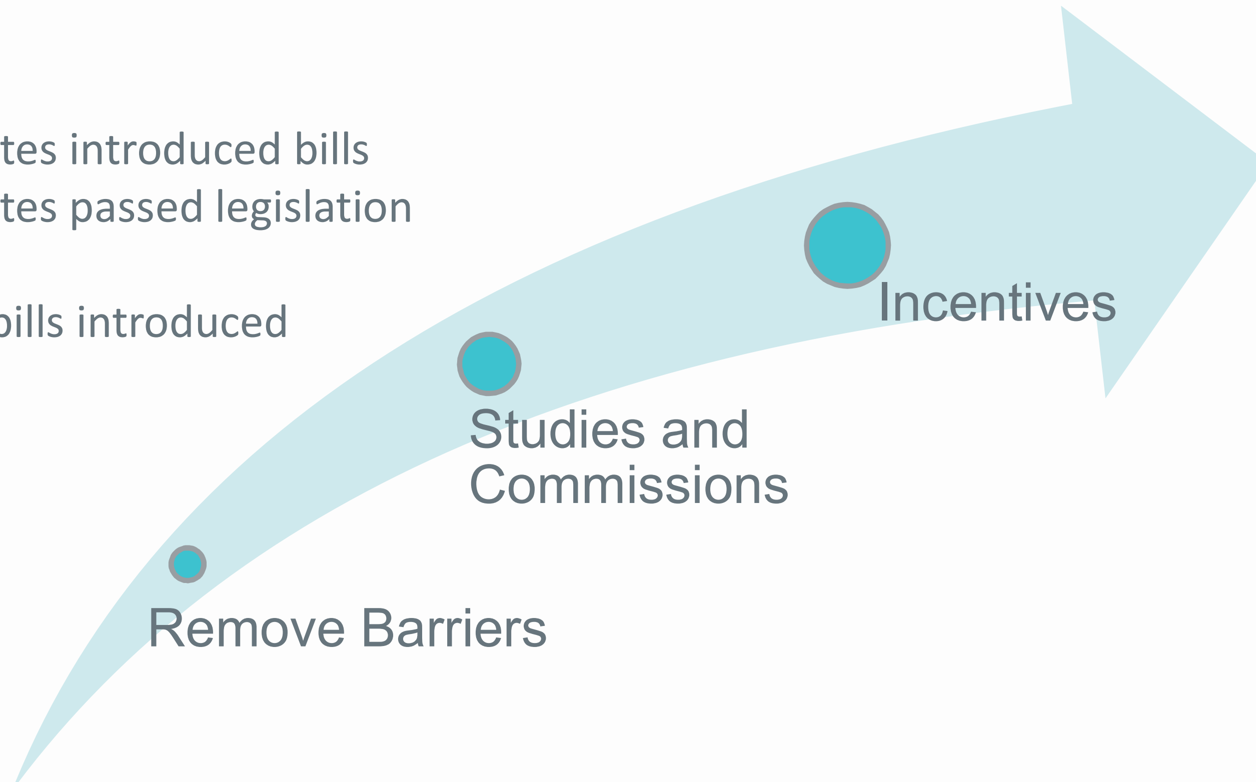
Current Federal Policies: https://www.nei.org/CorporateSite/media/filefolder/advantages/Current-Policy-Tools-to-Support-New-Nuclear.pdf

State Action for Advance Reactors

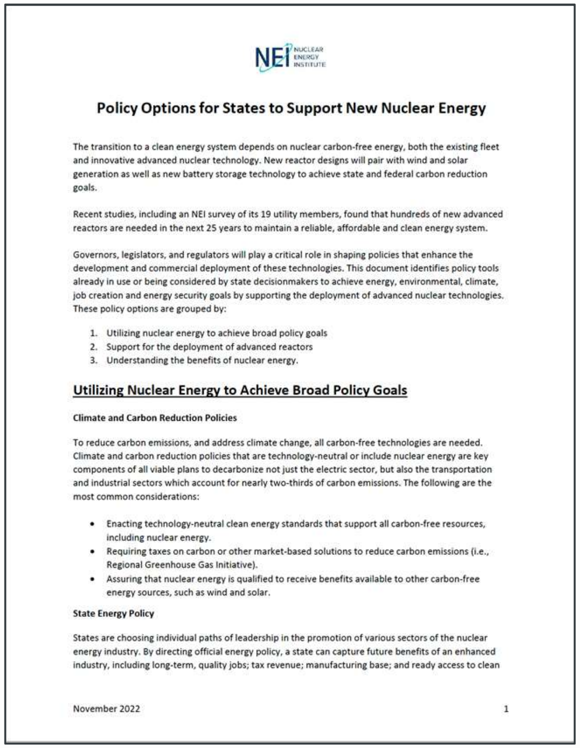
2022
- 19 States introduced bills
- 11 States passed legislation

2023
- 100+ bills introduced



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


QUESTIONS?
By Third Way, GENSLER