

The Role of Nuclear Energy in our Future Energy System

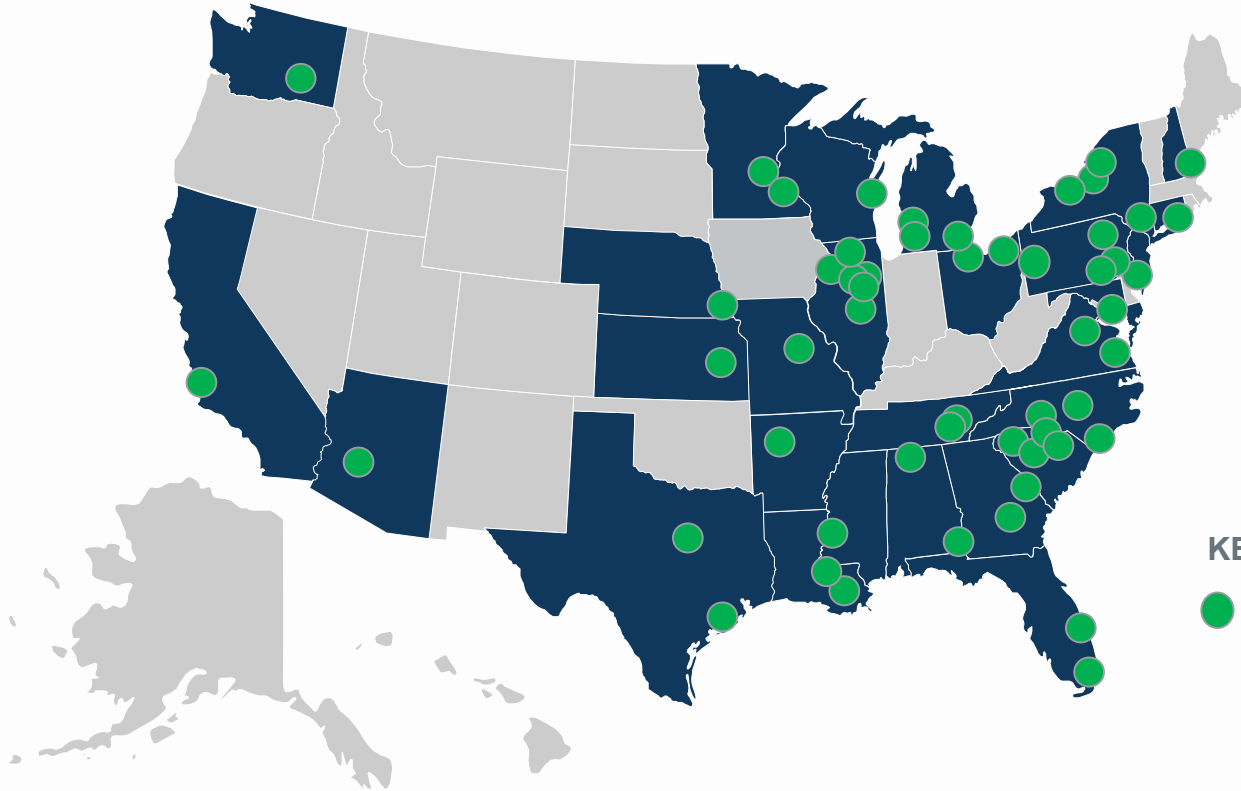
February 2021



©2020 Nuclear Energy Institute



U.S. Commercial Power Reactors



94 reactors at 55 sites in 28 states

Reactors can operate for 80 years (at least)

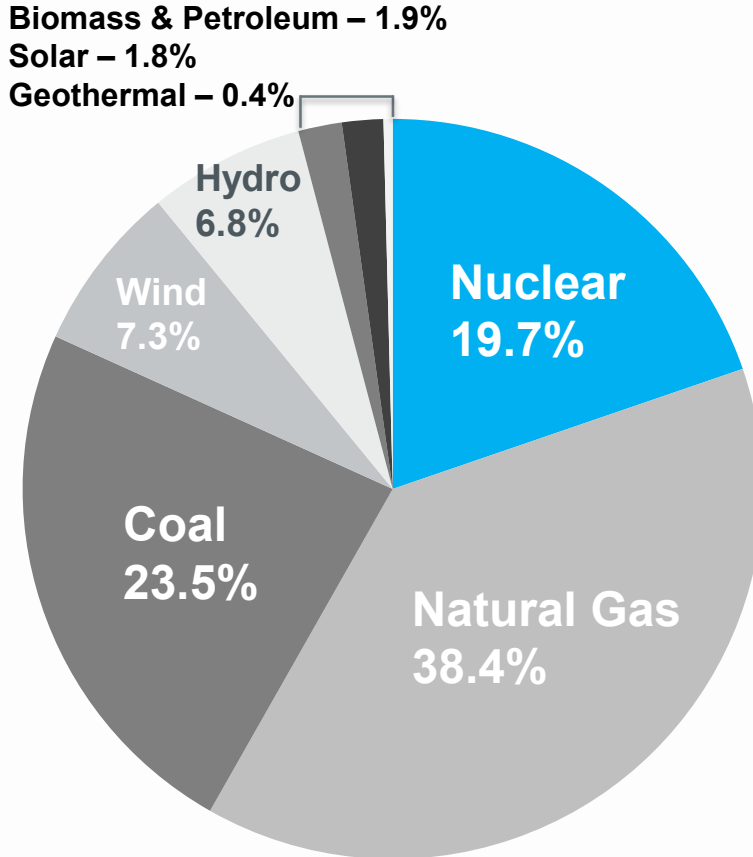
About 500 direct jobs per reactor

Wages about 1/3 higher than average jobs in local area

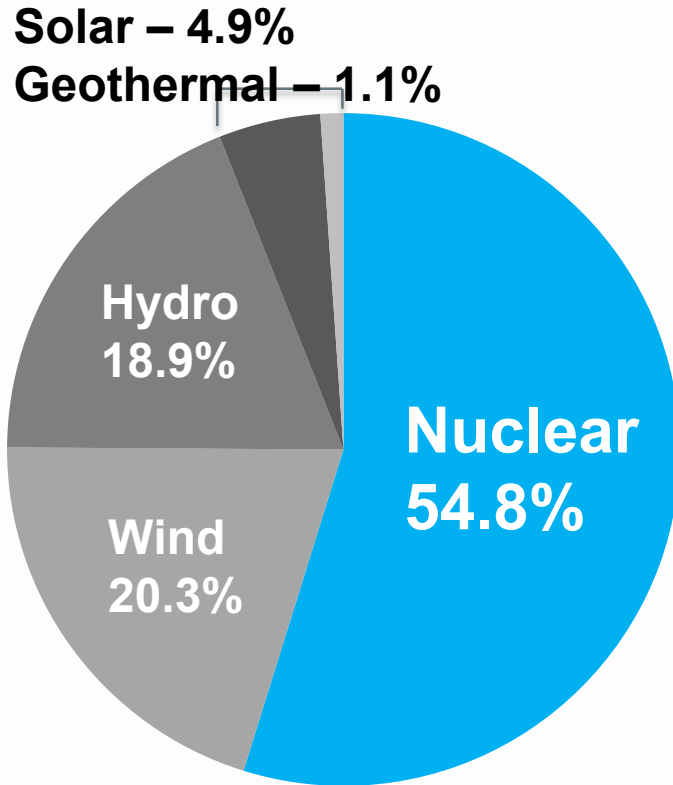
KEY

 Nuclear power plant site

Nuclear generates nearly 20% of U.S. electricity



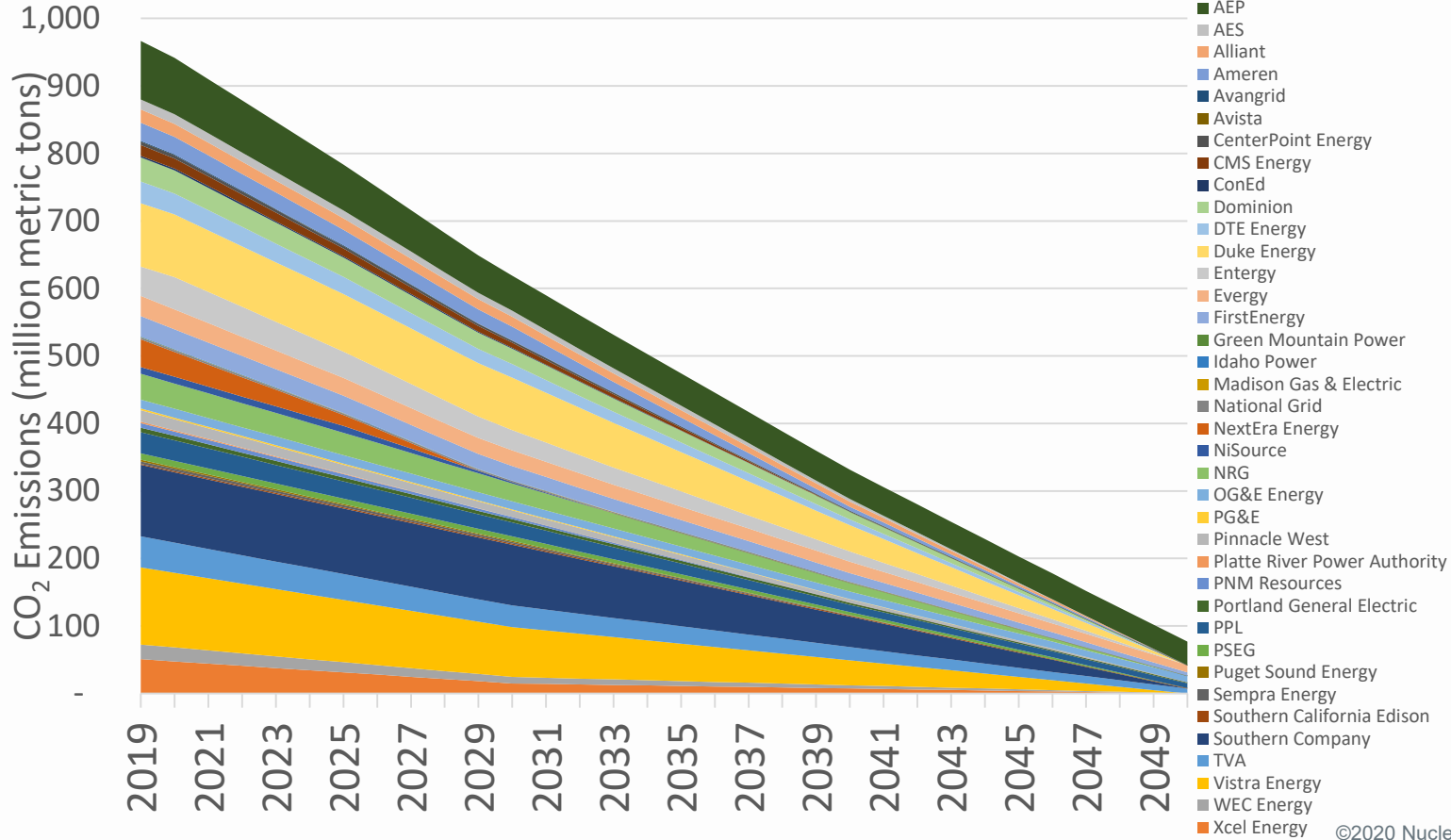
Nuclear supplied more than half of U.S. carbon-free electricity in 2019



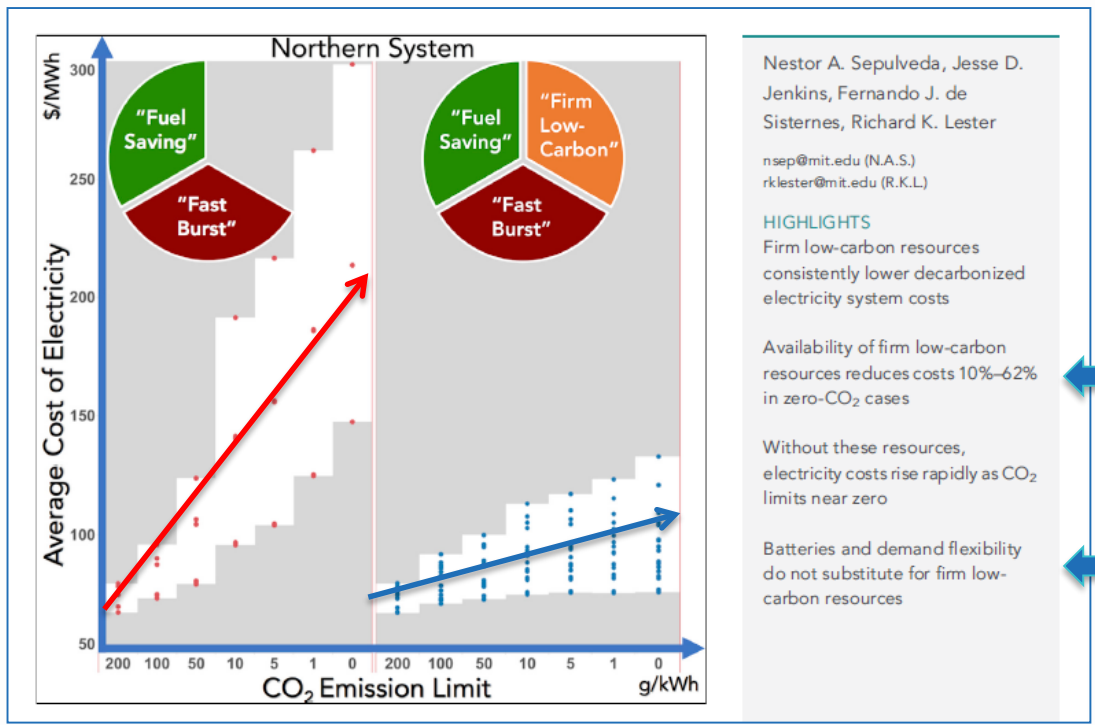
Carbon-free resources generated about 37% of U.S. electricity in 2019

Carbon-free generation in U.S. increased by net 18.7 million MWh in 2019

Utility carbon emission projections based on pledges



Firm, Low-carbon Generation (like nuclear) Enables Affordable Decarbonization

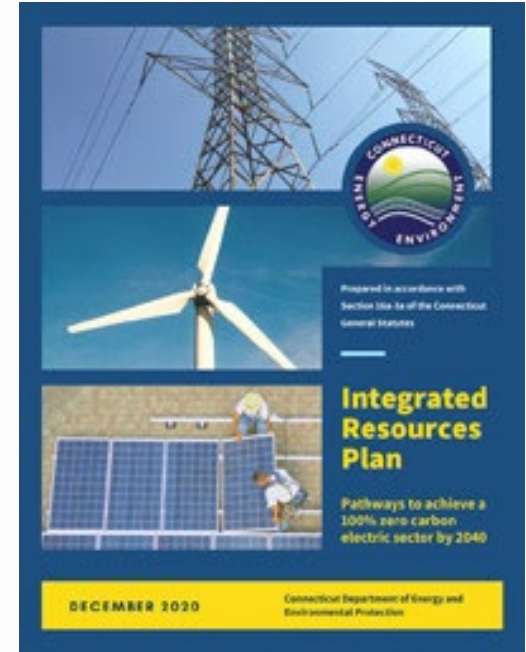


Recognizing the Carbon-Free Attribute

STATE IRPS

Connecticut

- “By preventing the Millstone retirement Connecticut saved the region from significant negative impacts on the region’s electric grid with respect to fuel diversity, energy security, and grid reliability; **avoided an estimated \$1.8 billion (2017\$) in replacement costs** that would have been borne by Connecticut ratepayers; and prevented regional carbon emissions from increasing by 20 percent.”
- the Millstone Extension scenario shows **\$5 billion in ratepayer savings** compared to the other zero-carbon pathways – mainly because it reduces the need to procure new (more expensive) carbon-free resources to meet the state’s 100% zero-carbon electric sector goal. In addition, the Millstone Extension scenario enables more than 8,000 MW of fossil fuel retirements across the region by 2040.



STATE DECARB PLANS RELY ON PRESERVATION OF NUCLEAR

More than 10,150 direct jobs saved via state actions

Plant / Site	State	Summer Capacity (MWe)	Initially Announced Closure Year	Electricity Generated (billion kWh in 2019)	CO ₂ Emissions Avoided (Million metric tons per in 2019)
Beaver Valley 1 & 2	Pennsylvania	1,808	2021	15.5	9.9
Clinton	Illinois	1,065	2017	8.4	8.4
Davis-Besse	Ohio	894	2020	7.8	5.0
Fitzpatrick	New York	848	2017	7.4	3.5
Ginna	New York	582	2017	5.0	2.4
Hope Creek & Salem 1 & 2	New Jersey	3,500	~2020-2021	26.6	17.0
Millstone 2 & 3	Connecticut	2,073	~2020	16.7	7.6
Nine Mile Point 1 & 2	New York	1,917	2017-2018	15.8	7.5
Perry	Ohio	1,240	2020	9.2	5.9
Quad Cities 1 & 2	Illinois	1,819	2018	15.5	9.9
TOTAL		15,746		127.9	76.9

This is nearly **twice** the electricity generation by all solar in the U.S. in 2019.

Recognizing the Carbon-Free Attribute

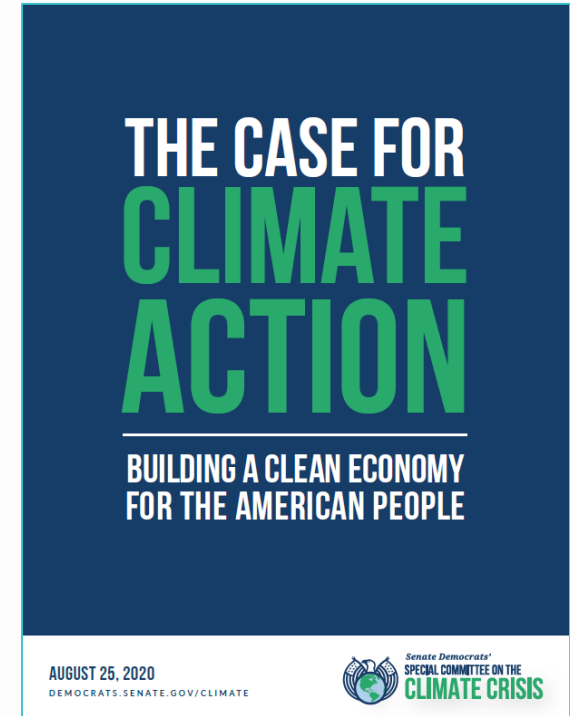
CONGRESSIONAL REPORTS

Senate Democrats – Special Committee on the Climate Crisis:

- “Nuclear energy currently plays an important role in providing reliable zero-carbon power to the grid.”
- “Research priorities include advanced nuclear R&D...”

House Select Cmte on the Climate Crisis (D staff):

- “Congress should establish a national clean energy standard to achieve net-zero emissions in the electricity sector by no later than 2040...It should cover zero-emission technologies, including wind, solar, energy storage, nuclear...”



CONGRESSIONAL DEMOCRATS INCREASINGLY EMBRACING NUCLEAR

Recognizing the Carbon-Free Attribute

BIDEN CAMPAIGN

Biden Plan for Climate Change and Environmental Justice:

- “This initiative will target affordable, game-changing technologies to help America achieve our 100% clean energy target, with a specific focus on the following, as recommended by the founding director of ARPA-E:
 - grid-scale storage at one-tenth the cost of lithium-ion batteries;
 - small modular nuclear reactors at half the construction cost of today’s reactors;...”

Biden-Sanders Unity Task Force Recommendations:

- “We will advance innovative technologies that create cost-effective pathways for industries to decarbonize, including...advanced nuclear that eliminates risks associated with conventional nuclear technology...”

BIDEN INCLUDES NUCLEAR IN DECARBONIZATION PLANS

Recognizing the Carbon-Free Attribute

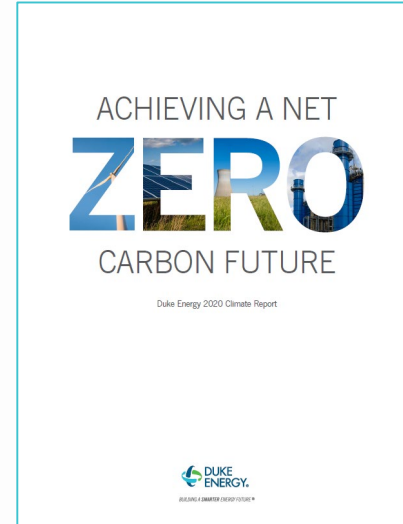
UTILITY PLANS

Duke Energy

- SLR planned for all 11 reactors
- SMRs, Advanced Reactors an option in IRP

Dominion Energy

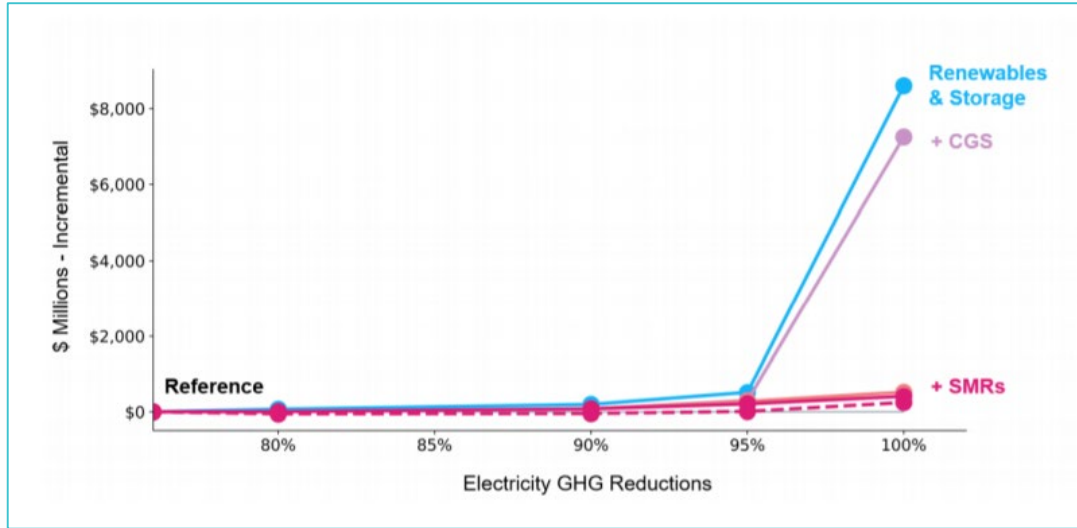
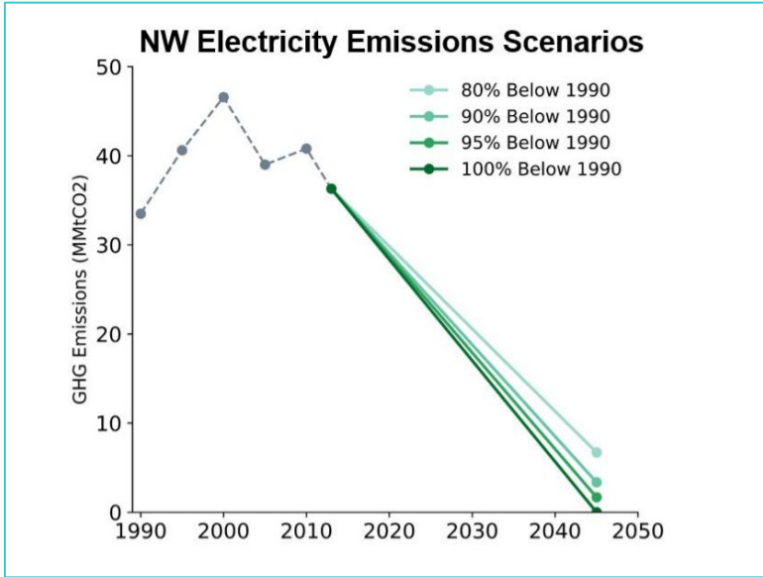
- SLR applications under review for all 4 reactors
- SMRs, Advanced Reactors an option in IRP



Multiple generating companies reportedly teaming with developers for Advanced Reactor Demonstration Program awards

UTILITY DECARB PLANS INCLUDE SLR, ROLE FOR NEW NUCLEAR

Existing + New Nuclear is a Solution Pathway to Achieving Emissions Goals



Source: Energy + Environmental Economics (E3), see <https://www.energy-northwest.com/Documents/E3%20Study%20Executive%20Summary%20final.pdf>.

Status of SLR Applications

Approved

Turkey Point Units 3 & 4 (FL)
 Renewed License Issued
 December 2019



Peach Bottom Units 2 & 3 (PA)
 Renewed License Issued
 March 2020



Pending

Surry Units 1 & 2 (VA)
 Current expiration 2032 & 2033
 Under review; SER issued
 (Pending Coastal Zone Management
 Act Certification from VA)



Under Review

North Anna Units 1 & 2 (VA)
 Current Expiration: 2038 & 2040
 Application Dated August 2020

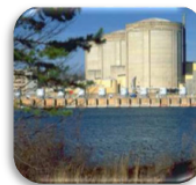


Point Beach Units 1 & 2 (WI)
 Current Expiration: 2033, 2033, & 2034
 Application Dated November 2020



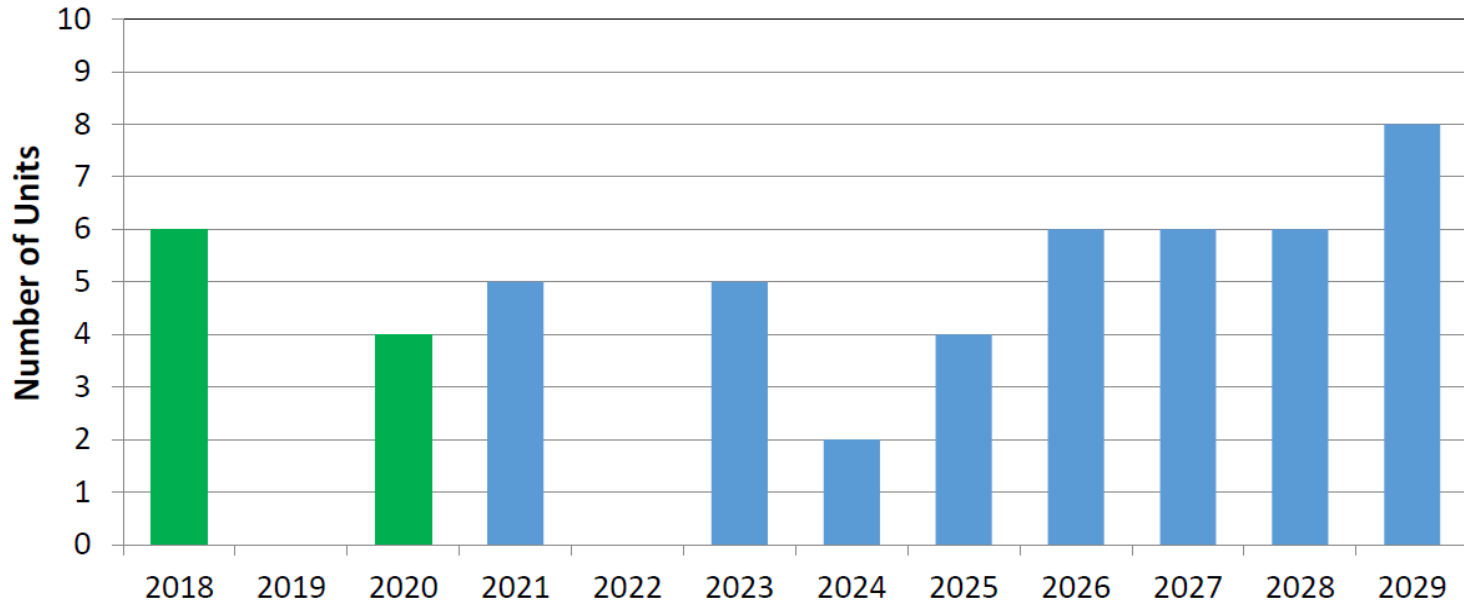
Expected in FY21*

Oconee Units 1, 2, and 3
 Expected by the end of the Year



*Letter of Intent Received

Subsequent License Renewal Applications by Unit



Increasing Utility Interest in SMRs



“The grid can’t be 100 percent renewable...that last 20 percent [from 80 percent to 100 percent] has to be carbon-free, and it has to be dispatchable.”

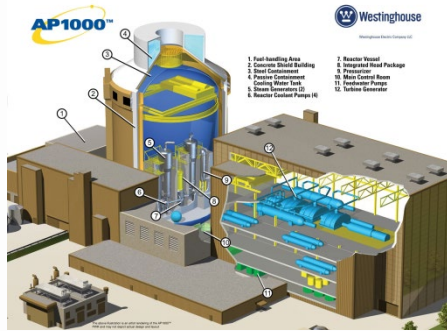
“I think nuclear plays a role in our carbon-free future...I think there's another generation out there that is smaller, less a capital bet for somebody like me sitting in a boardroom...and is safer, and has passive safety controls.” – Ben Fowke, CEO, Xcel

The price for storage has come down but is still not low enough to provide the backup needed for intermittent power sources like wind and solar. So Idaho Power will consider buying into a proposed modular nuclear reactor at the Idaho National Laboratory in East Idaho, [CEO Darrel] Anderson said. Idaho Power uses no nuclear power now, but it considers nuclear to be clean, carbon-free energy. – *Idaho Statesman*, March 26, 2019

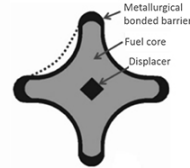


"We believe that nuclear power has a vital role in ensuring a clean, reliable, and cost-effective supply of electricity to meet the needs of a growing economy," – Dan Stoddard, Chief Nuclear Officer, Dominion Energy

Continuum of Innovation



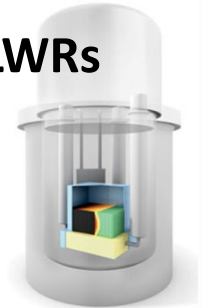
Evolutionary LWR Fuels



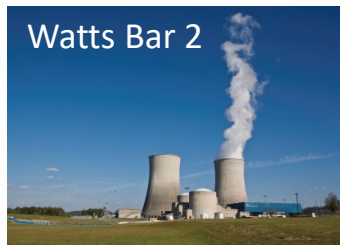
Lightbridge's four-lobe metallic fuel rod cross section

Advanced Non-LWRs

- Hi-temp gas
- Liquid metal
- Molten salt
- Micro-reactors



2016



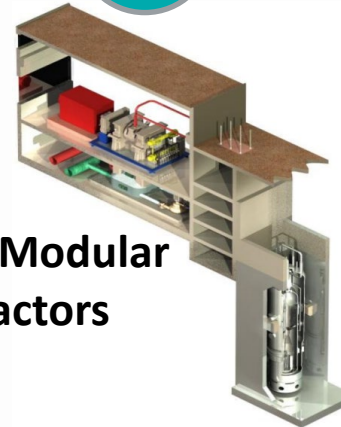
2020

Large LWRs



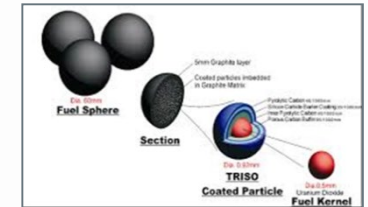
2025

NuScale Power Module

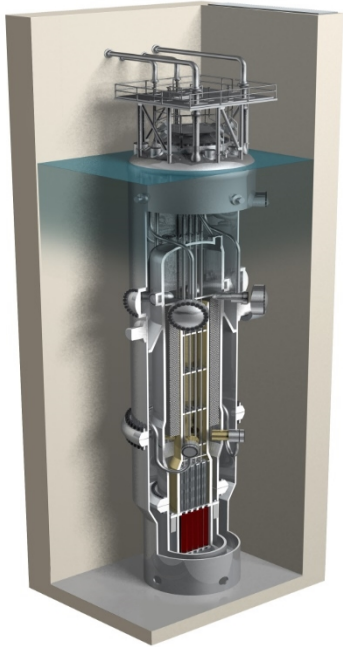


Small Modular Reactors

2030



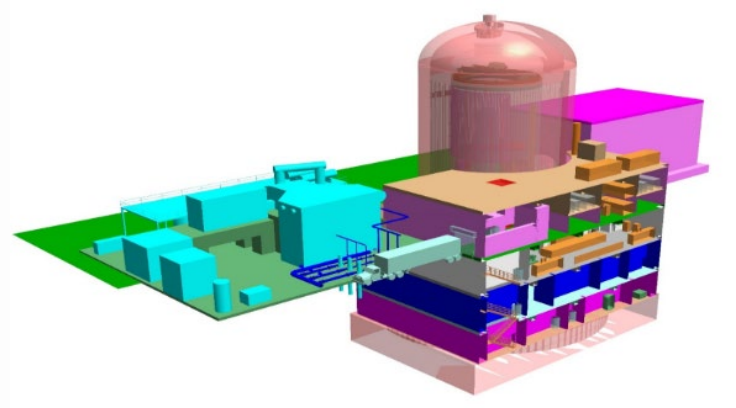
Small Modular LWRs



NuScale Power Module



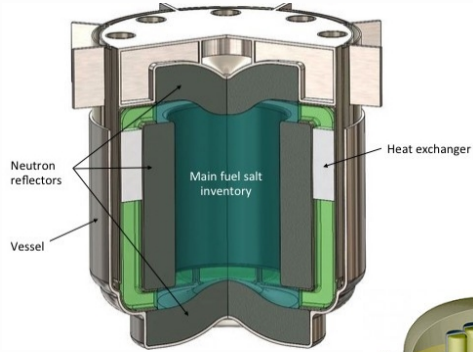
GEH BWRX-300



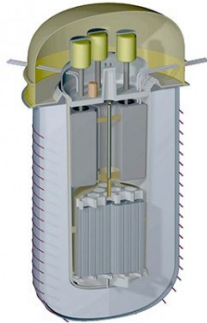
Holtec SMR-160

Non-Water Cooled Reactors

Molten Salt Reactors

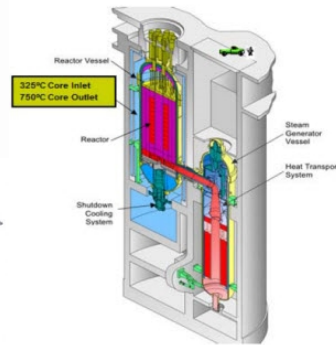


TerraPower

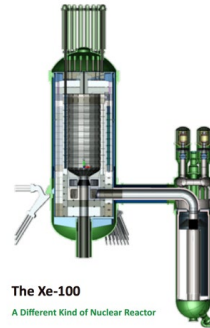


Terrestrial Energy

High Temperature Gas Reactors



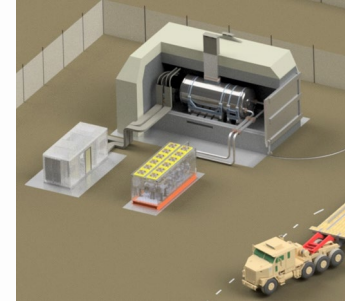
Framatome



The Xe-100
A Different Kind of Nuclear Reactor

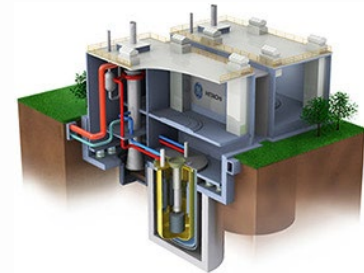
X-energy

Micro Reactors



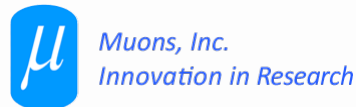
Westinghouse eVinci

Liquid Metal Reactors



GE PRISM

Advanced Reactor Developers



MOVING BEYOND ELECTRICITY

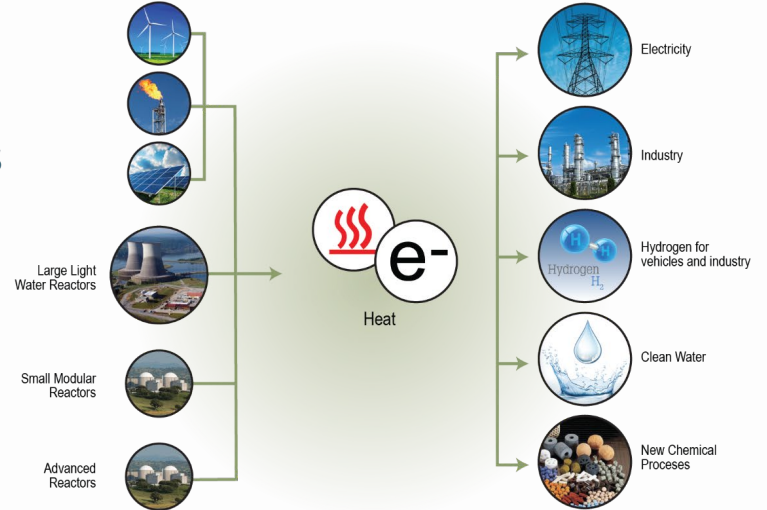
TODAY

Electricity focused



FUTURE

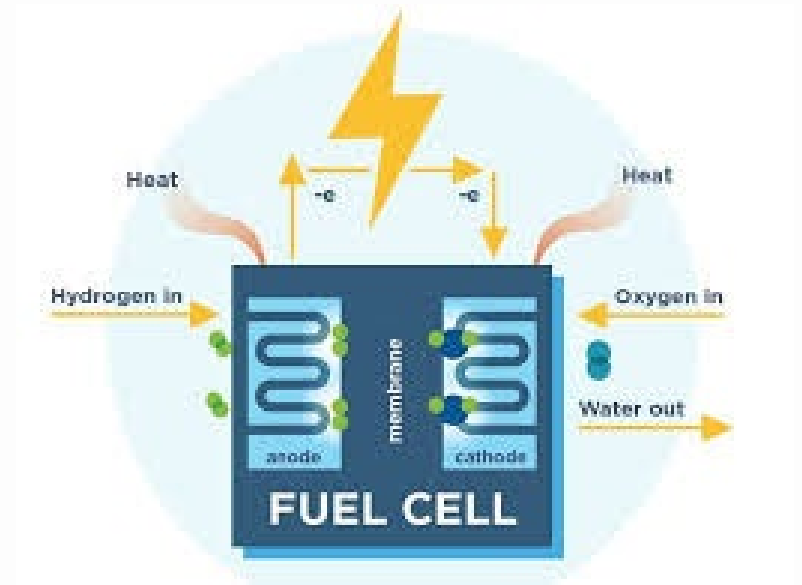
Integrated grid system that leverages contributions from nuclear fission **beyond** electricity sector



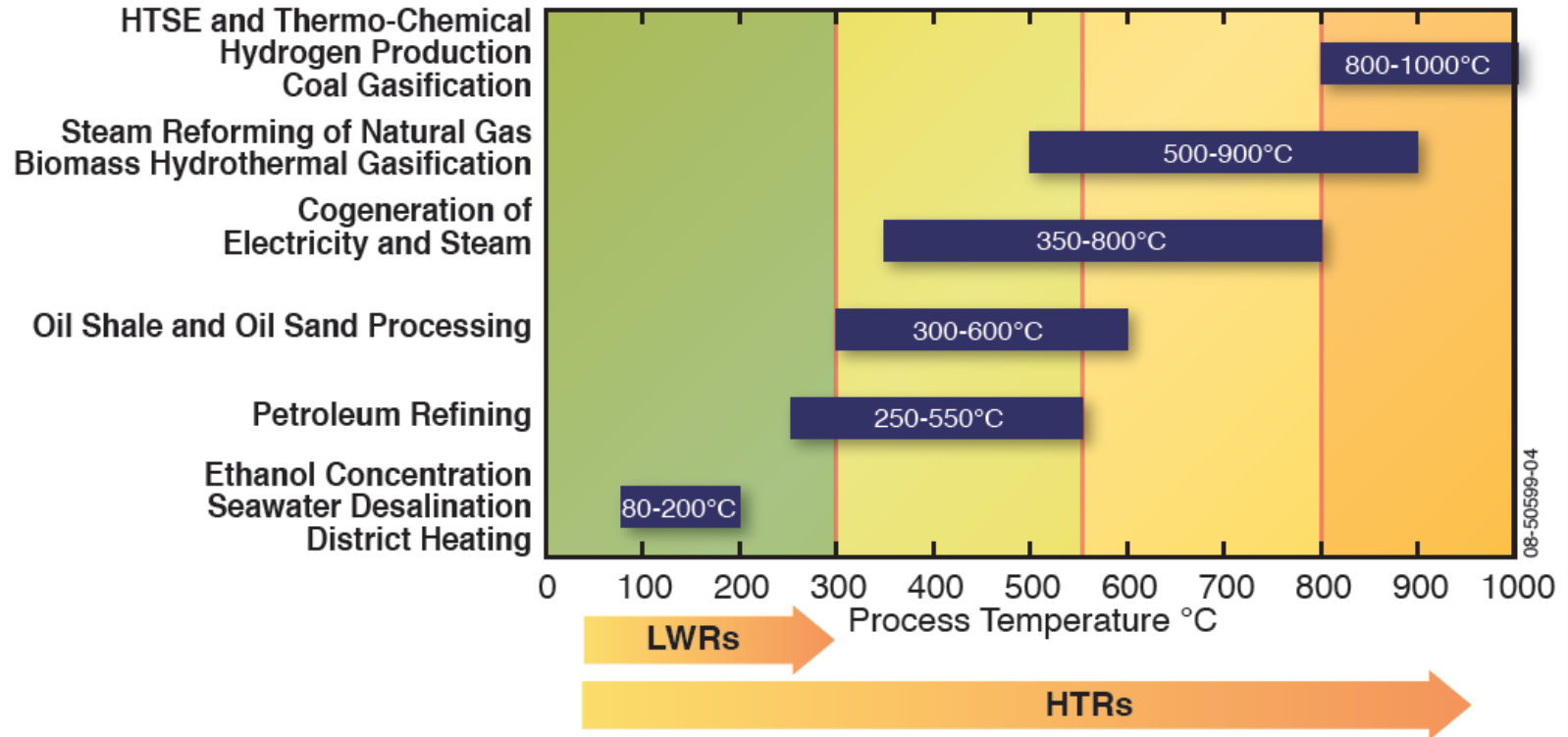
Tomorrow's nuclear will produce more than electricity

HYDROGEN GENERATION USING EXISTING REACTOR FLEET

- Exelon, First Energy, Xcel Energy, and Arizona Public Service have received DOE awards
- Will demonstrate hydrogen production from large light water reactors starting in 2020 and 2021
- Hydrogen could be used transportation, industrial processes, storage medium for electricity production



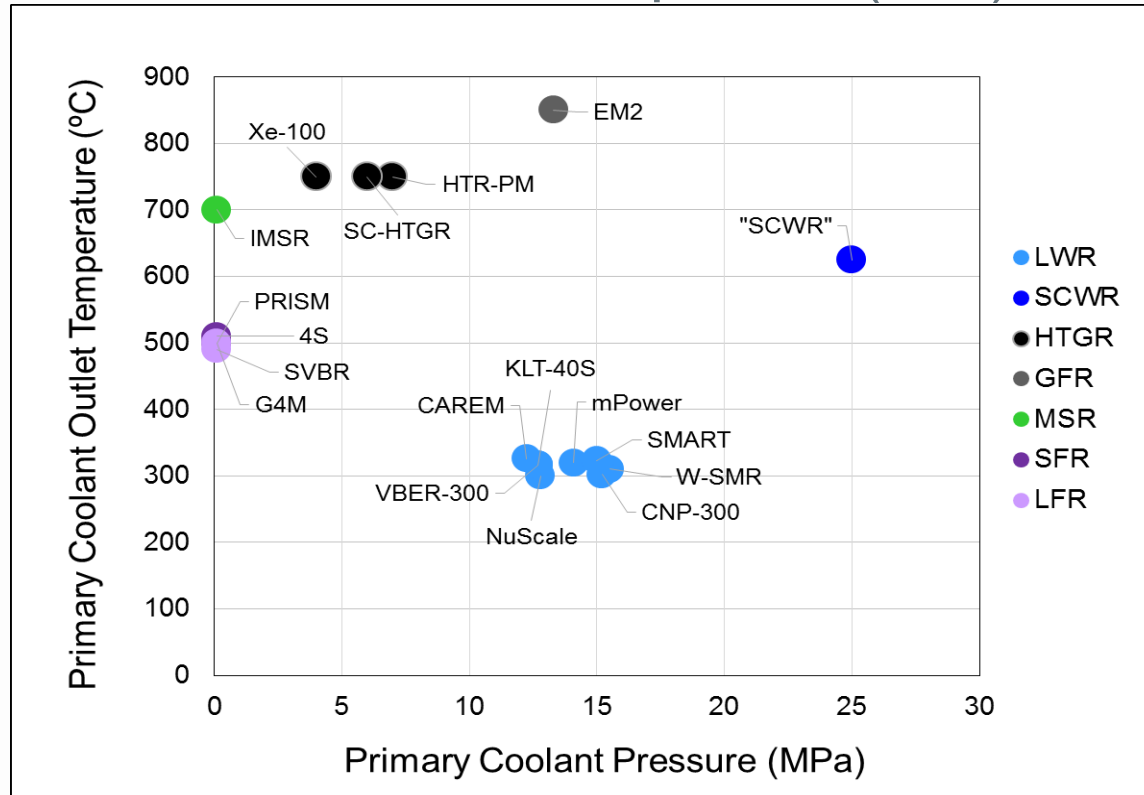
High Operating Temperatures – Gateway to Heat Markets



Source: NGNP Alliance <http://www.ngnpalliance.org/images/general_files/HTGR%20page%20individual%20040611.pdf>

Source: Electric Power Research Institute

Importance of Coolant Choice: Economics, Flexibility Tied to Fundamental Properties (P, T)



Source: Electric Power Research Institute

Department of Energy Advanced Reactor Demonstration Program

Advanced Reactor Demonstrations

- Technical feasibility that the demonstration can be operational in five to seven years
- 50/50 cost share – awards for 7 years with possible 3 year extension
- DOE share \$3.2 billion (combined)
- TerraPower and X-energy
- Reactors and fuel fabrication facilities

Department of Energy Advanced Reactor Demonstration Program

Risk Reduction for Future Demonstrations

- Commercial horizon approximately 5 years later than the Demos
- Up to 80/20 cost share – awards for 7 years
- DOE share \$600 million (combined)
- Kairos, Westinghouse, BWXT, Holtec, and Southern Company

Advanced Reactor Concepts 20

- Lowest design maturity – commercial horizon in the mid- 2030's
- Up to 80/20 cost share – awards for 3 to 3.5 years
- DOE share \$56.2 million (combined)
- Advanced Reactor Concepts, General Atomics, Massachusetts Institute of Technology

ARDP Demonstration Awards

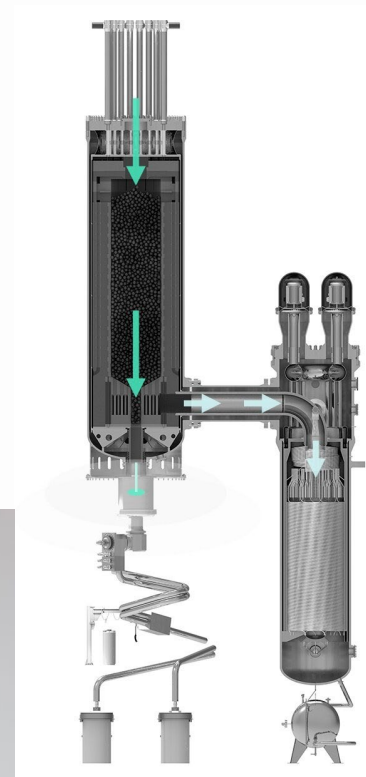
-  **TerraPower™**
Natrium Reactor
 - Liquid sodium fast reactor - 345 MWe
 - Metallic fuel
 - Molten salt thermal storage for peaking to 500 MWe



ARDP Demonstration Awards

- **energy**[®] Xe-100
 - Pebble bed Helium cooled gas reactor – 80 MWe
 - Four reactors
 - TRISO fuel

TRISO Fuel Pebble Cutaway



Summary of New Commercial Reactor Projects in U.S. With Target Dates Before 2030

- Vogtle 3 and 4
- Oklo Aurora
- UAMPS with NuScale
- TerraPower Sodium
- X-energy Xe-100
- Kairos Power Test Reactor
- Southern Company Molten Chloride Reactor Experiment

Key Takeaways

- Consumers and policymakers (U.S. and abroad) increasingly demanding low-carbon electricity
- States and utilities responding with deep decarbonization goals
- Maintaining existing nuclear is the least expensive way to avoid carbon emissions
- New nuclear is extremely valuable to deep decarbonization
 - Least-cost, most reliable low-carbon systems include nuclear energy
 - State and federal policy actions needed to overcome FOAK cost barriers
 - Nuclear can help decarbonize non-electric energy uses

QUESTIONS?

