NARUC
National Association of Regulatory Utility Commissioners

Nuclear Energy as a Keystone Clean Energy Resource

August 26, 2022, 1-2 PM ET

Moderator: Hon. Anthony O'Donnell, Maryland Public Service Commission

Panelists:

Phillip Graeter, Manager, Energy Ventures Analysis

Deeksha Anand, Senior Integrated Energy Analyst, Energy Ventures Analysis

Opening Remarks

Hon. Anthony O’Donnell,
Maryland

Panelists

- Phillip Graeter, Manager, Energy Ventures Analysis
- Deeksha Anand, Senior Integrated Energy Analyst, Energy Ventures Analysis

NUCLEAR ENERGY AS A KEYSTONE CLEAN ENERGY RESOURCE

NARUC-DOE Nuclear Energy Partnership

August 26, 2022

Presenters: **Phillip Graeter** graeter@evainc.com
Deeksha Anand Deeksha.anand@evainc.com

ENERGY VENTURES ANALYSIS
8045 Leesburg Pike, Suite 200
Vienna, VA 22182
(703) 276 8900
www.evainc.com

ABOUT ENERGY VENTURES ANALYSIS

Energy Ventures Analysis is an energy consulting firm located in the DC Metro area. Since 1981, EVA has been publishing supply, demand, and price forecasts as part of its FUELCAST subscription service for the electric power, coal, natural gas, petroleum, renewable, and environmental sectors.

EVA's cutting-edge expertise in energy market, economic, financial, and operation management matters has led our firm to international recognition. For over three decades, our innovative insights have helped our clients make confident, informed investment and operational decisions to maximize value and spur financial growth.

Our clients include:

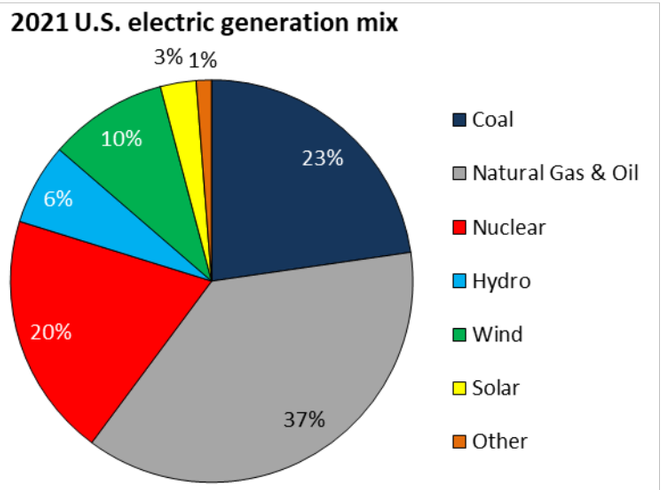
- power & natural gas utilities
- fuel producers
- fuel transporters
- commodity traders
- regulators
- financial institutions

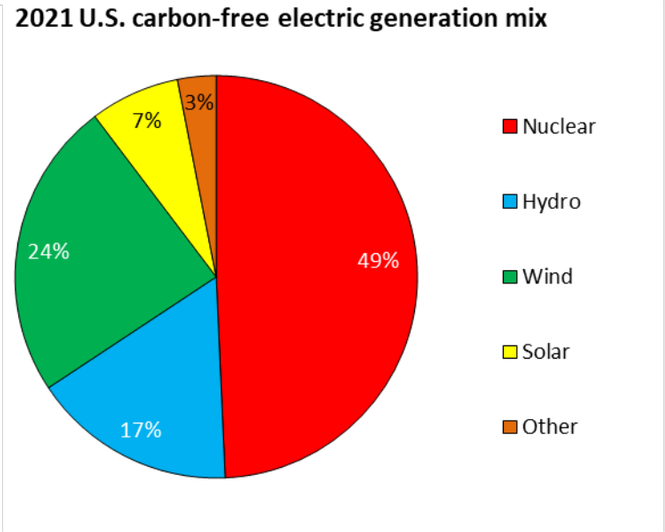
OUTLINE

1. Overview of the Current U.S. Nuclear Fleet & its Unique Role & Opportunities
2. Brief Background on Current & Future Nuclear Technology
3. Current Treatment & Support of Nuclear Energy on Federal and State Level
4. Potential States for Retaining or Expanding their Nuclear Fleet
5. Role of PUCs in Ensuring Nuclear as a Keystone Clean Energy Resource in the Future

NUCLEAR ENERGY IS A KEYSTONE IN TODAY'S EVER-CHANGING U.S. ELECTRIC GRID

- Over the last decade, the U.S. electric grid has gone through some significant changes that saw the rise of natural gas and renewables such as wind and solar and the fall of coal
- Through it all, nuclear energy has maintained its position as one of the keystone electric generating resources in the U.S., overcoming some unique challenges in the process
- In 2021, electricity generated by nuclear power plants accounted for approximately one-fifth of the total electricity generated
- Additionally, nuclear energy accounts for almost half of all the carbon-free electricity generated last year
- To date, 14 states have passed legislation or regulations requiring their electric power sector to be carbon-free by mid-century
- Nuclear energy will likely continue to play a key role in helping states and the U.S. as a whole to advance on the path of decarbonization over the next few decades

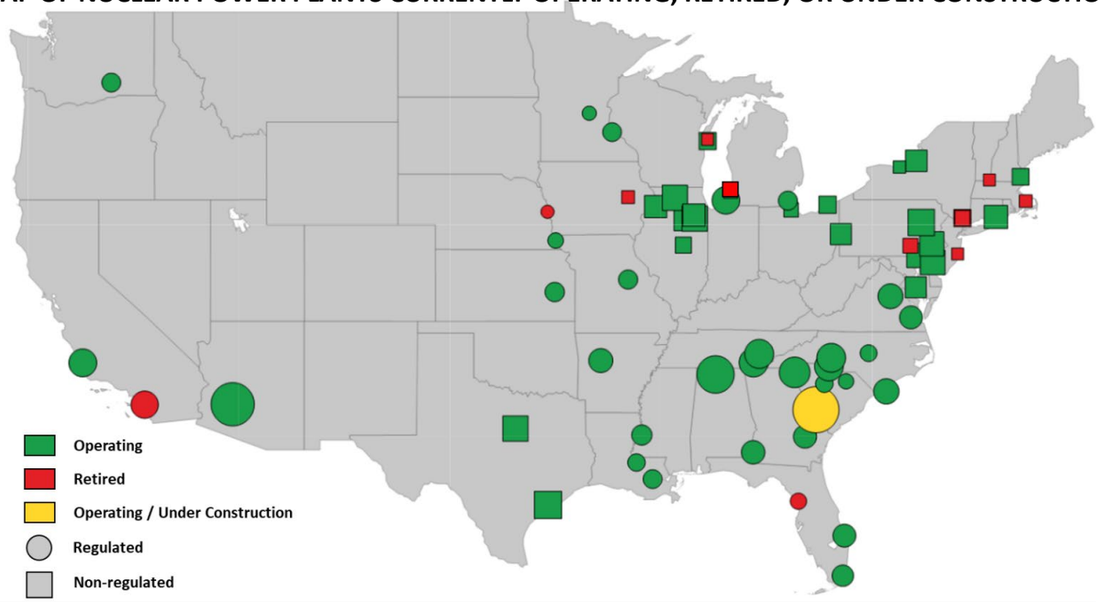




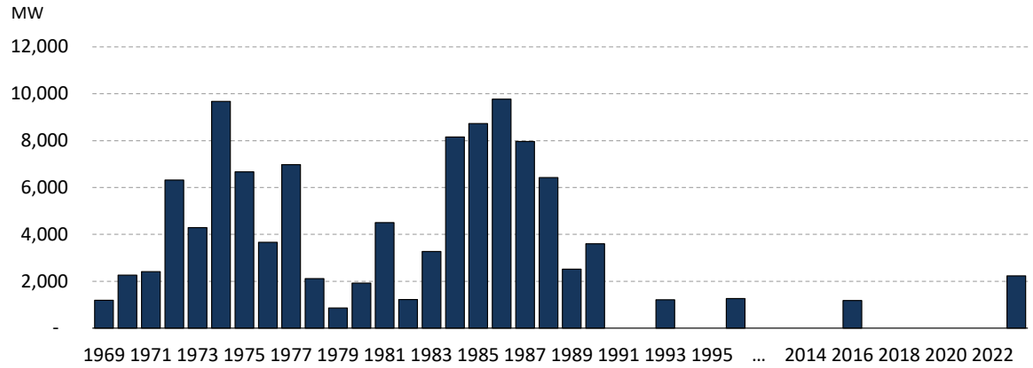
OVERVIEW OF THE CURRENT U.S. NUCLEAR FLEET

- **Currently, there are 92 commercial nuclear reactors actively operating in the United States, totaling over 97,400 MW of nameplate capacity, across 28 different states**
- **Constellation Energy is the owner of almost one-quarter of all operating nuclear reactors in the U.S., with Duke Energy, the Tennessee Valley Authority (TVA), Southern Company, and Dominion Energy rounding out the top 5**
  - Overall, 22 different majority owners own and operate while the top 10 largest companies account for almost 80% of the total capacity
- **The vast majority of nuclear power plants were built in the 1970s and 1980s during a time of rapid electricity demand growth and a favorable regulatory environment**
- **Since 1996, only 1 nuclear power reactor has come online (TVA's Watts Bar 2), while two more are currently under construction (Georgia Power's Vogtle 3 & 4)**

MAP OF NUCLEAR POWER PLANTS CURRENTLY OPERATING, RETIRED, OR UNDER CONSTRUCTION



NUCLEAR GENERATING CAPACITY BY ONLINE YEAR

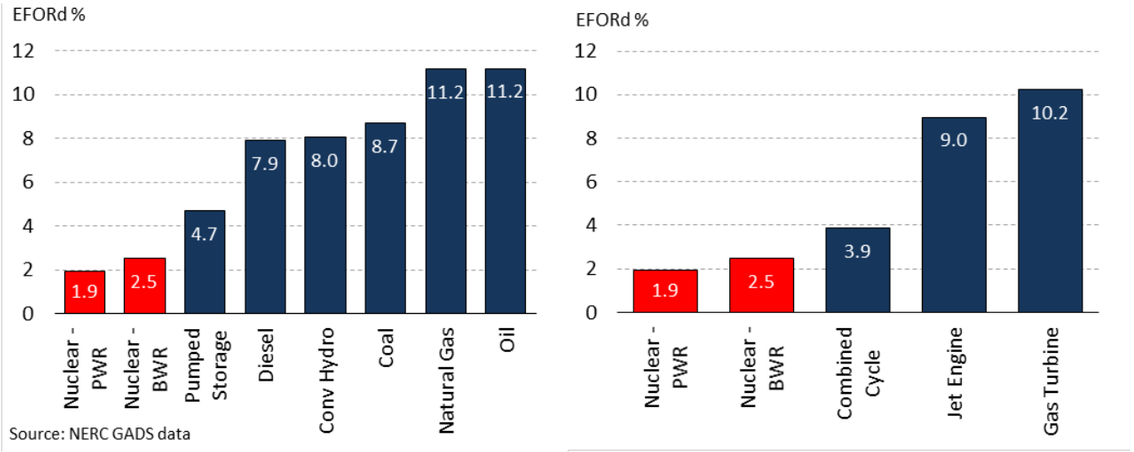


Source: EVA's Power Plant Tracking System

NUCLEAR ENERGY'S UNIQUE CHARACTERISTICS MAKE IT AN INVALUABLE ASSET IN THE U.S. ELECTRIC GRID

- **Nuclear power plants are the most reliable type of electric generating resource currently operating in the U.S., with a forced outage rate (EFORd) of 2.5% or less**
- **Virtually all nuclear power plants operate in so-called baseload mode, where electricity is provided at a steady rate around the clock due to their low variable cost compared to other non-renewable generating resources**
- **Nuclear power plants are some of the largest local and state taxpayers and employers in the energy communities these plants are located in**
- **Nuclear power plants require the smallest amount of land on an acre per MW basis compared to other non-carbon emitting resources such as wind and solar**

2016-2020 AVERAGE FORCED OUTAGE RATE BY FUEL & TECHNOLOGY TYPE



Source: NERC GADS data

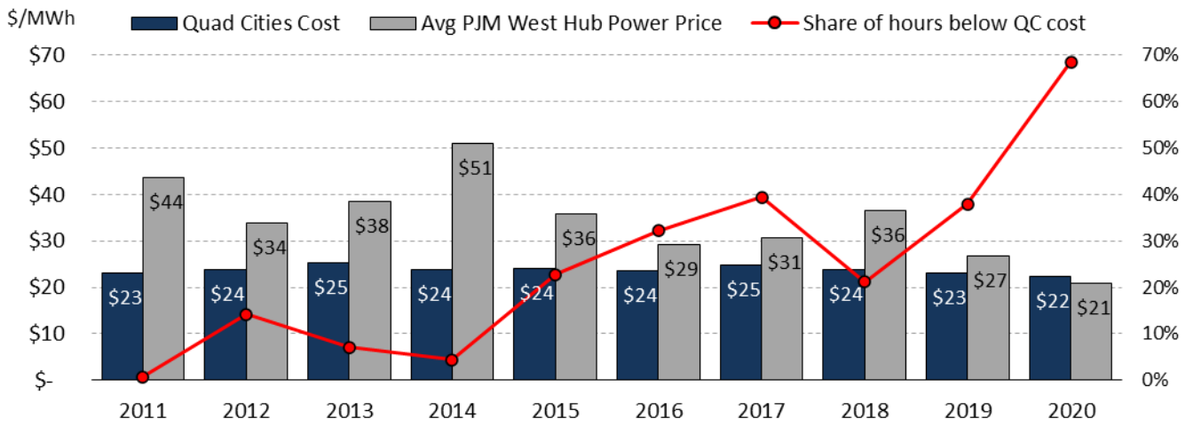
LAND REQUIREMENT BY TECHNOLOGY TO REPLACE 1,000-MW COAL PLANT

		Coal	Nuclear	Solar	Wind
Capacity	*MW*	1,000	556	2,000	1,250
Capacity Factor	*%*	50%	90%	25%	40%
Generation	*GWh*	4,380	4,380	4,380	4,380
Land Use	*acre/MW*	n/a	0.8	8.0	85.3
Land Use	***total acres***	**n/a**	**462**	**16,000**	**106,564**

RECENT CHANGES IN U.S. POWER MARKETS HAVE MADE SOME NUCLEAR PLANTS UNPROFITABLE

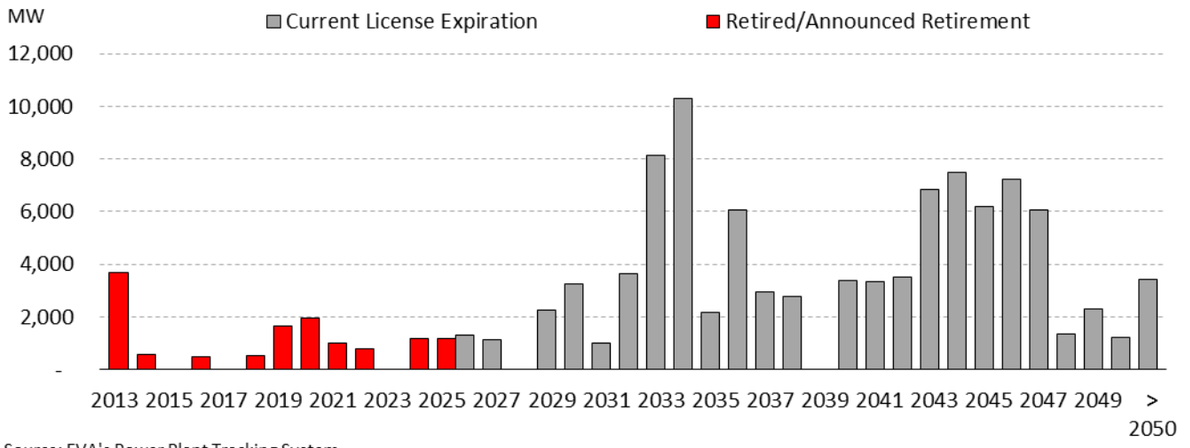
- With the rise in wind generation, especially in Central U.S. states, power prices during off-peak hours (usually late night/early morning hours) have dropped significantly, while power prices during on-peak hours (late morning through late evening) have dropped due to lower natural gas prices
- Since U.S. nuclear plants operate essentially at 100% utilization around the clock, they are "price-takers", which substantially eroded energy revenues of nuclear power plants over the last decade
- Since 2013, almost 11,000 MW of nuclear generating capacity has retired, with more recent plant closures due to increased economic pressures as states only recently began to value the carbon-free electricity generated by nuclear power plants

AVERAGE QUAD CITIES PRODUCTION COST VS. PJM ATC WEST HUB POWER PRICE



Source: FERC Form 1 & PJM power price data

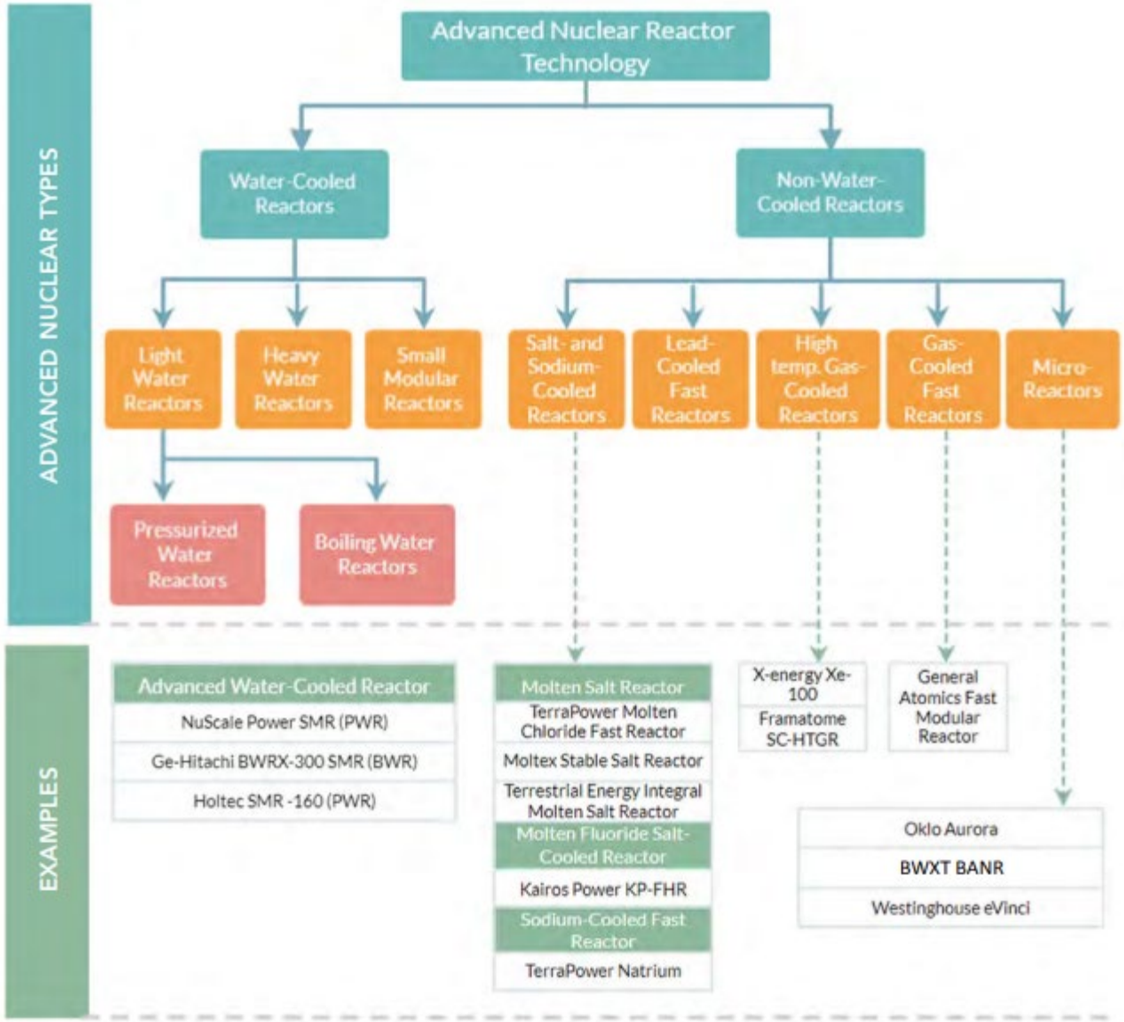
RETIREMENT OR CURRENT OPERATING LICENSE EXPIRATION



Source: EVA's Power Plant Tracking System

ADVANCED NUCLEAR REACTOR TECHNOLOGY DESIGNS TARGET IMPROVED SAFETY, COSTS, AND EFFICIENCY

- **All 92 operating nuclear reactors in the U.S. use light water reactor technology for power generation**
  - Of the 92 reactors, 2/3rd are pressurized-water reactors (PWRs) and the rest boiling-water reactors (BWRs)
- **Advanced reactor designs use new and existing technologies and materials to make improvements in safety, financing, versatility, and waste management**
  - Size (micro, small modular reactors, full-size)
  - Coolant (water, molten salt, liquid metal)
- **Some advanced nuclear reactor projects in the development pipeline in the U.S. include NuScale's small modular PWR, TerraPower's Natrium sodium fast reactor with molten salt storage, and X-energy's Xe-100 high-temperature gas-cooled reactor**
  - Currently, NuScale's SMR design is the only one with NRC approval



INTEGRATED NUCLEAR ENERGY SYSTEMS CAN ADD VALUE AND HELP MEET NET-ZERO CARBON GOALS

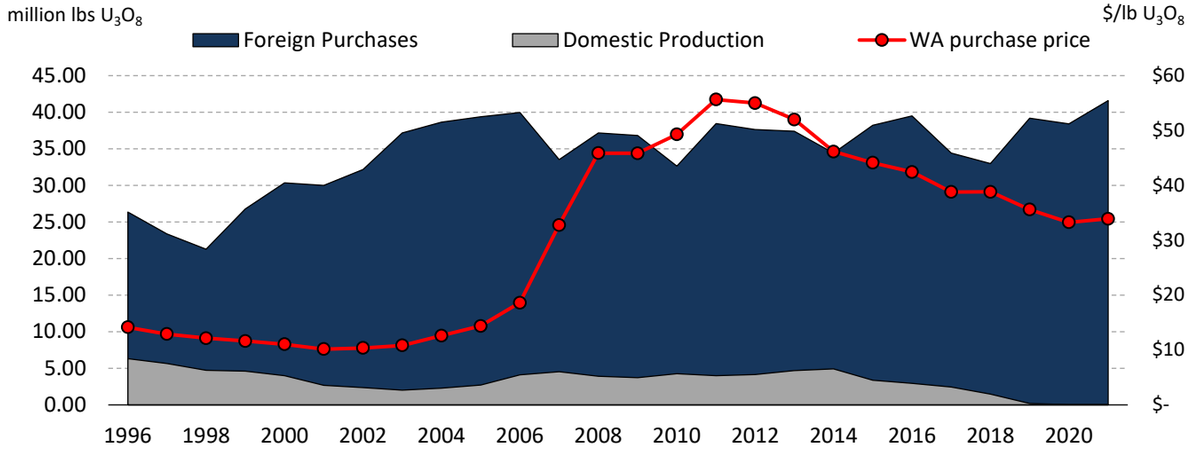
- **To enhance nuclear energy's value proposition and maximize generator profitability, reactor developers are increasingly pairing nuclear energy with non-grid operations (ex: hydrogen production, desalination, industrial heating) through integrated energy systems**
- **Integrated nuclear energy systems may achieve synergies with and complement variable renewable technologies**
- **DOE awarded cost-shared funding to demonstrate integrated nuclear energy systems that can produce electricity and non-electric products**
  - Exelon-Nel Hydrogen partnership to demonstrate H2 production, storage, and usage at Nine Mile nuclear station
  - Energy Harbor to demonstrate hybrid H2 production at Davis-Besse nuclear station
- **Advanced reactor developers are considering brownfield sites of retired or decommissioned nuclear and coal power plants to take advantage of existing transmission rights, cooling water delivery systems, and the workforce**
- **Most current projects are targeting late-2020s for commercial deployment**

Reactor Developer	Name	Utility/Customer	State	Reactor Site	No. of units	Total Cap. (MW)	Technology	Deployment Timeline
X-Energy	Xe-100	Grant PUD, Energy Northwest	WA	Columbia (nuclear)	4	320	HTGR	2027-28
TerraPower	Natrium	Pacificorp	WY	Naughton (coal)	1	345	SFR	2028
NuScale	VOYGR	Utah Associated Municipal Power Systems	ID	Idaho national lab	6	462	PWR - SMR	2029-30
Holtec	SMR-160		NJ	Oyster creek (nuclear)	1	160	PWR - SMR	2030
GE Hitachi	BWRX-300	Tennessee Valley Authority	TN	Clinch river (nuclear)	1	300	BWR - SMR	2032
Kairos Power	Hermes	Tennessee Valley Authority	TN	Oak ridge	1	50	MSR	2026
Westinghouse	Vogtle 3	Southern Co.	GA	Burke county	1	1,117	PWR	Q1 2023
Westinghouse	Vogtle 4	Southern Co.	GA	Burke county	1	1,117.0	PWR	Q4 2023
Oklo Power	Aurora		ID	Idaho national lab	1	2	Micro	2025
		U.S. Air Force	AK	Eielson air force base		1-5	Micro	2027
USNC	MMR		IL	Urbana-Champaign	1	15.0	Micro	
TerraPower	MCRE	Southern Co.	ID	Idaho national lab	1	0.5	MCFR - Micro	

SOURCE OF FUEL AND SPENT NUCLEAR FUEL DISPOSAL

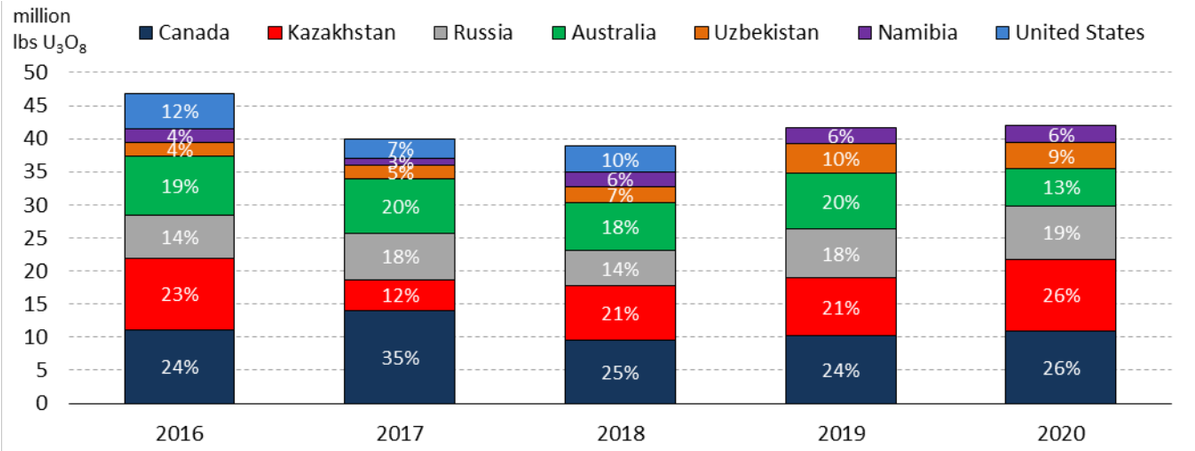
- **U.S. power plant operators rely mostly on imports and inventories to cover their fuel requirements**
- **Over the last few decades, foreign uranium purchases have increased substantially while domestic production has dropped to an insignificant amount**
  - As of 2020, Canada, Kazakhstan, Russia, Australia, and Uzbekistan were the top 5 countries of origin for uranium purchases
- **Geopolitical tensions underscore the need to swiftly re-develop and expand the domestic uranium supply chain**
- **Next wave of advanced reactors require high-assay low-enriched uranium (HALEU)**
  - Centrus Energy and Urenco are exploring HALEU production capabilities
- **After use, utilities are currently storing the spent nuclear fuel at power plant sites. U.S. is yet to develop a consolidated interim storage facility or permanent disposal repository**

U.S. DOMESTIC URANIUM PRODUCTION VS. IMPORTS



Source: EIA Uranium Marketing Report and EVA Analysis

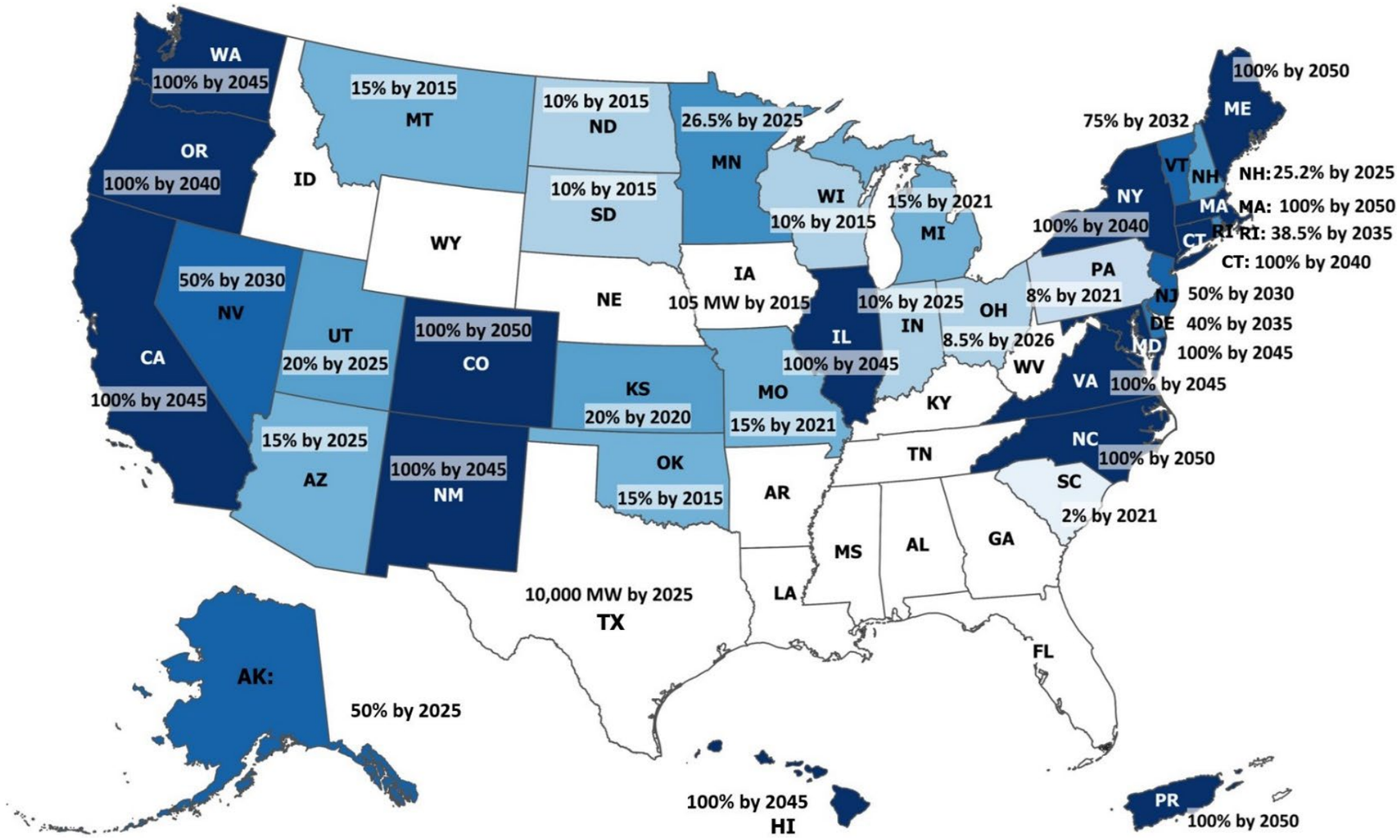
URANIUM PURCHASES FOR U.S. NUCLEAR REACTORS BY COUNTRY OF ORIGIN



Source: EIA Uranium Marketing Report and EVA Analysis

CURRENT RPS & CES TARGETS – BY STATE

- State renewable portfolio standards (RPS) and clean energy standards (CES) are vehicles that drive clean energy adoption
- RPS/CES require state utilities to source a minimum % of their electricity from renewable or clean energy sources by a certain date
- Currently, 30 states, Washington D.C. and Puerto Rico have binding RPS or CES standards



STATE SUPPORT

- **While some states have specific policies in place such as zero-emissions credits (ZECs) to target and support existing nuclear generation, others include zero-emitting technologies like nuclear in the CES-eligible technology umbrella**
- **14 states have binding clean energy standards (CES) that outline carbon-free or low-carbon mandates**
  - California, Colorado, Connecticut, Hawaii, Illinois, Maine, Maryland, Massachusetts, New Mexico, New York, North Carolina, Oregon, Virginia, Washington, Washington D.C., and Puerto Rico have established goals for 100% of their retail electricity sales to originate from eligible clean energy resources before 2050
- **New York, Illinois, and New Jersey awarded zero-emissions credits to existing nuclear power plants at risk of closure**
  - ZECs are state-created subsidy instruments that reflect the zero-carbon emission attributes of nuclear generation, valued at $/MWh of electricity produced by a qualified nuclear power plant
- **Some states (Kansas, Nebraska) passed laws allowing tax exemptions or tax incentives for any nuclear-associated property or investments**
- **States like Idaho, Virginia, and Washington established task forces and commissions to explore viable pathways to maintain existing nuclear reactors as well as support advanced reactor developments**

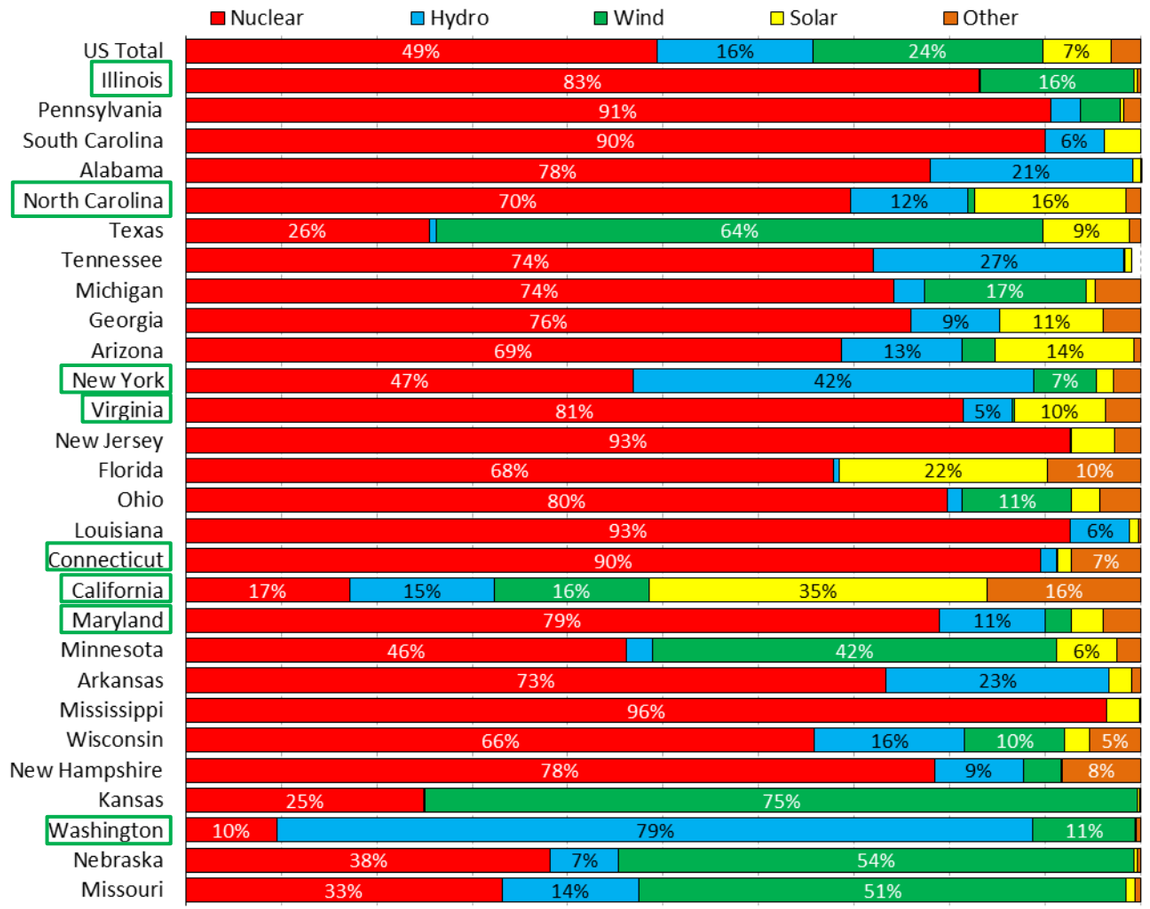
FEDERAL POLICIES AND INCENTIVES HELP SUPPORT EXISTING NUCLEAR REACTORS AND ADVANCED REACTOR BUILDS

- **The Inflation Reduction Act signed into law on August 16th, 2022, includes provisions that boost nuclear energy**
  - Production Tax Credit (PTC) of $15/MWh for existing nuclear plants
  - Technology-inclusive PTC for clean electricity technologies from 2025, including advanced nuclear and power uprates
  - Technology-inclusive investment tax credit (ITC) for zero-emission facilities placed into service in 2025 or after
  - $700 million for research, development, and production of domestic HALEU fuel
  - Additional incentives, including incentive to utilize domestic content and incentive to locate a facility in an energy community (retired coal or decommissioned nuclear plant site), may be utilized by advanced reactor developers
- **The Bipartisan Infrastructure Law passed in 2021 established the $6 billion Civil Nuclear Credit (CNC) program to prevent premature closure of existing U.S. nuclear reactors due to economic circumstances**
  - CNC credits will be allocated to qualifying reactors at risk of ceasing operations due to economic factors
- **DOE launched the Advanced Reactor Demonstration Program (ARDP) in 2020 to leverage Congress-appropriated funding and establish public-private partnerships to accelerate the deployment of advanced nuclear reactors in the U.S**
- **2005 Energy Policy Act established an Advanced Nuclear PTC (S. 45J) of $18/MWh that can be availed on a first-come-first-serve basis by the first 6,000 MW of advanced nuclear energy generating capacity deployed**

NUCLEAR ENERGY SHOULD BE AN INTEGRAL PART IN STATES' PLANNING FOR A DECARBONIZED ELECTRIC GRID

- **Nuclear power plants provide at least two-thirds of carbon-free electricity in 20 of the 28 states in which they operate**
  - 8 of the 28 states with nuclear power plants also have passed legislation or state regulation establishing a 100% CES by or before 2050
  - States with 100% CES and no existing nuclear generation include Colorado, Hawaii, Maine, Massachusetts, New Mexico and Oregon
- **Currently, 12 states either outright ban new nuclear construction or require legislative or other major state-level approvals, including states with existing nuclear power plants or 100% CES targets in place**
- **Additionally, retiring coal plants provide a capable workforce and infrastructure that can be repurposed to integrate new nuclear plants in the U.S. electric grid**

2021 SHARE OF CARBON-FREE GENERATION BY FUEL TYPE - BY STATE



Source: EVA analysis of EIA 923 data

Marks states with 100% CES by 2050

RECOMMENDATIONS FOR PUCS AND OTHER STAKEHOLDERS IN RETAINING OR EXPANDING NUCLEAR ENERGY

- **The role of state public utility commissions in facilitating the retention and advancement of nuclear energy depends on whether utility generation within the state is regulated**
  - Today, PUCs have direct jurisdiction over only 56% of operating nuclear plants
- **In deregulated states, the role of PUCs and other state agencies is mostly limited to administering the implementation of state legislation passed to support in-state merchant generators, such as zero-emission credit programs**
- **To encourage the development of new nuclear projects with the state, deregulated states could potentially allow cost recovery in support of state CES requirements, while weighing costs and risks to ratepayers as part of decision**
- **In regulated states, state PUCs have considerably more influence on existing and new resource decisions**
- **A few recommendations for PUCs in regulated states include:**
  1. Ensure regulated utilities properly examine the value of applying for all available ILRs/SLRs for existing nuclear plants to maximize the lifespan of existing nuclear plants
  2. Require new nuclear power plants appropriate to each service territory to be given adequate consideration as future resource options and ensure that all applicable federal and state incentives are included (PTC/ITC/CEC)
  3. Require that the IRP define under what circumstances new nuclear power plants could become a desirable resource (e.g., the value of ZECs needed, CO2 allowance price level, RPS/CES level)

Q&A

PRESENTATION BY:

Phillip Graeter, Manager & Primary Author graeter@evainc.com

Deeksha Anand, Lead Analyst & Co-Author deeksha.anand@evainc.com

ENERGY VENTURES ANALYSIS
Leesburg Pike, Suite 200
Vienna, VA 22182
(703) 276 8900
www.evainc.com

- **Sept. 16**, 2:00 – 3:00 pm ET: NEP webinar on Nuclear Provisions in the Inflation Reduction Act
- **Aug. 26**: deadline to submit an abstract for NARUC's Nov. 2022 Annual Meeting & Education Conference and Feb. 2023 Winter Policy Summit
- Check www.naruc.org/cpi for information on upcoming activities

Thank you!

Visit www.naruc.org/cpi to download the paper

Contact Kiera Zitelman (kzitelman@naruc.org) and Kathryn Kline (kkline@naruc.org) with questions