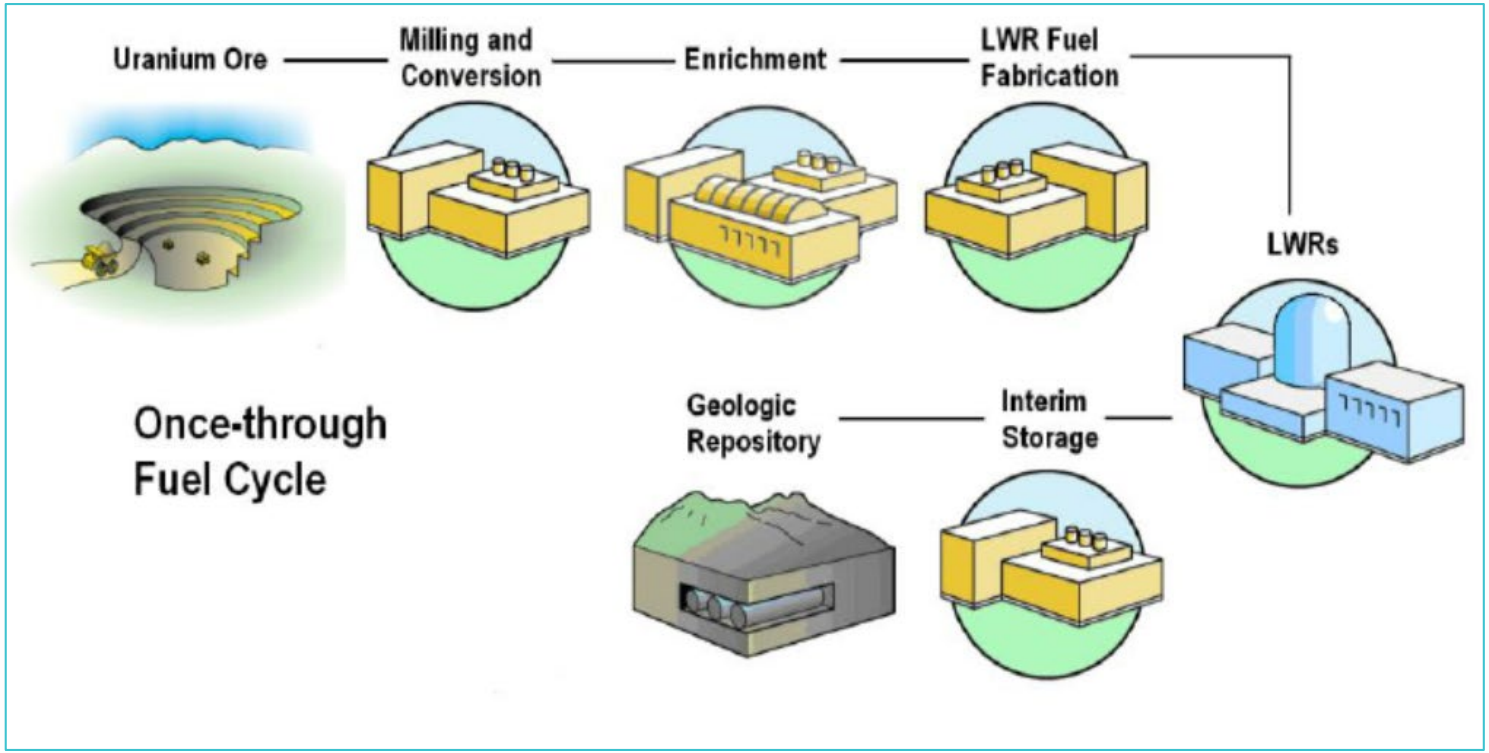
U.S. Nuclear Energy Overview

West Virginia Public Energy Authority

John Kotek
Senior VP, Policy & Public Affairs
May 25, 2022

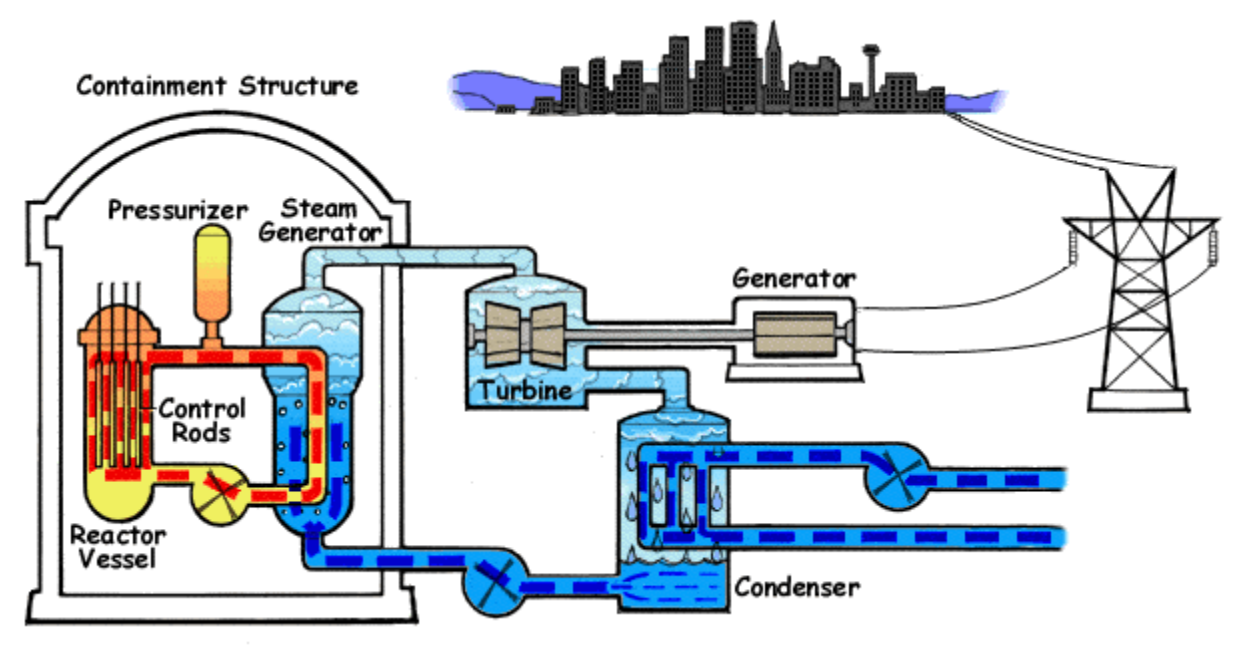
NUCLEAR ENERGY INSTITUTE

The Nuclear Fuel Cycle



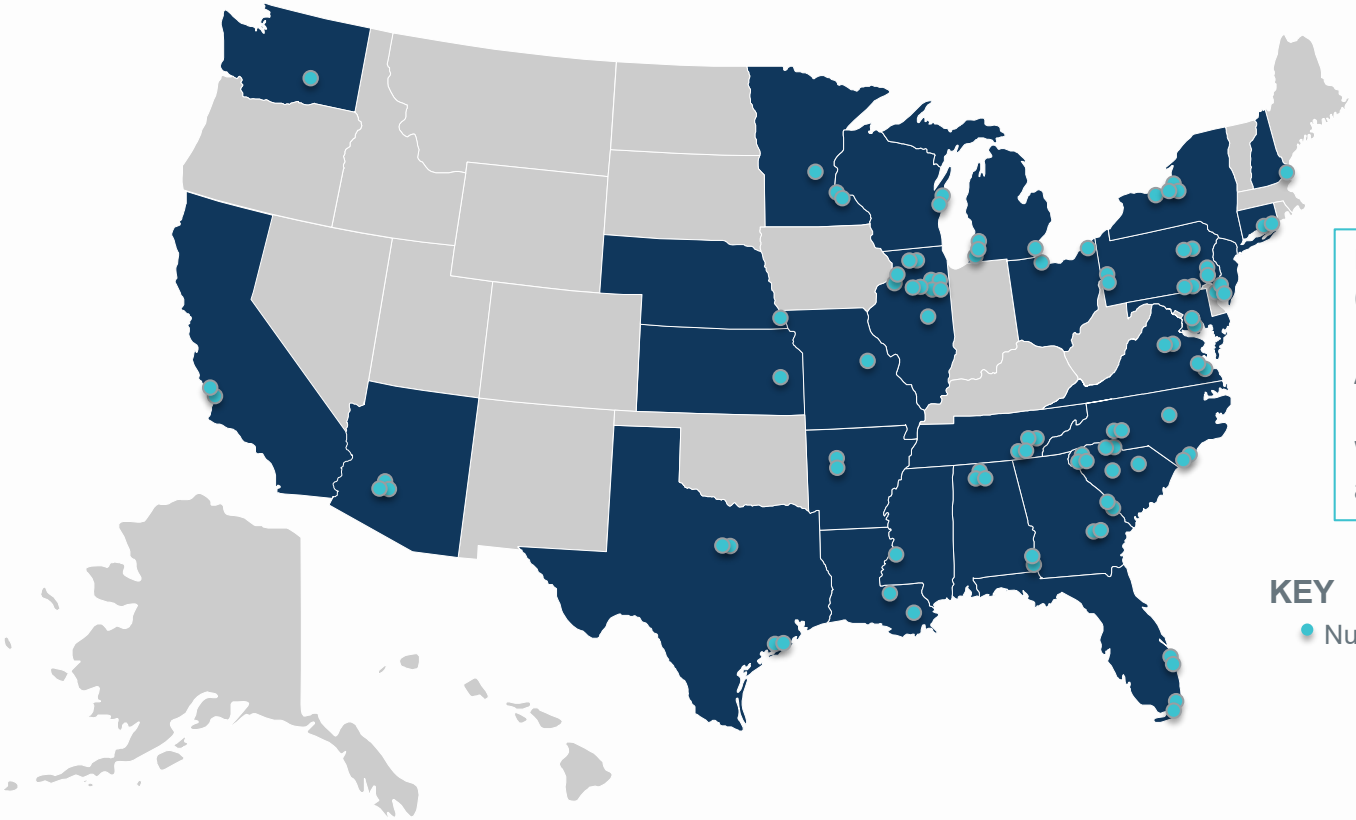
Source: Wigeland, R & Dixon, Brent. (2020). Identification, Description, and Characterization of Existing and Alternative Nuclear Energy Systems.

How a Pressurized Water Reactor works…



Source: https://www.nrc.gov/reading-rm/basic-ref/students/animated-pwr.html

93 REACTORS AT 54 PLANT SITES ACROSS THE COUNTRY



Reactors can operate for 80 years (at least)

About 500 direct jobs per reactor

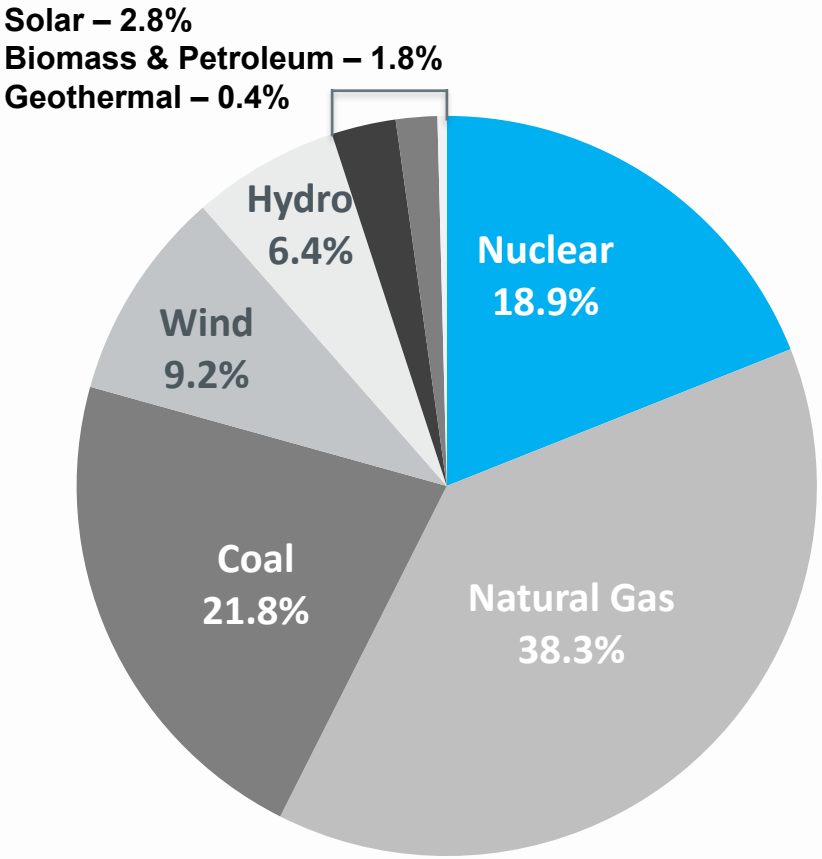
Wages about 1/3 higher than average jobs in local area

KEY

- Nuclear power reactor

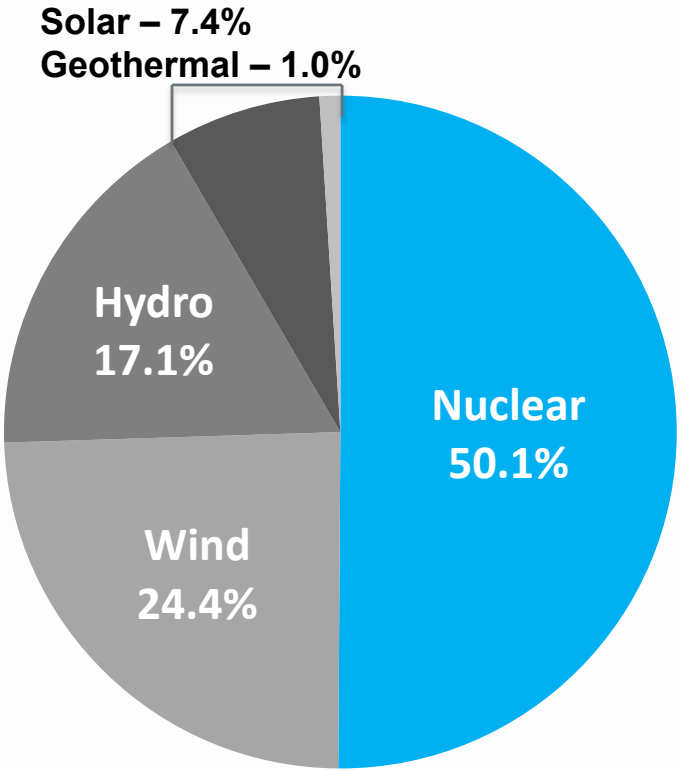
Updated: May 2021

Nuclear generated 19% of U.S. electricity in 2021



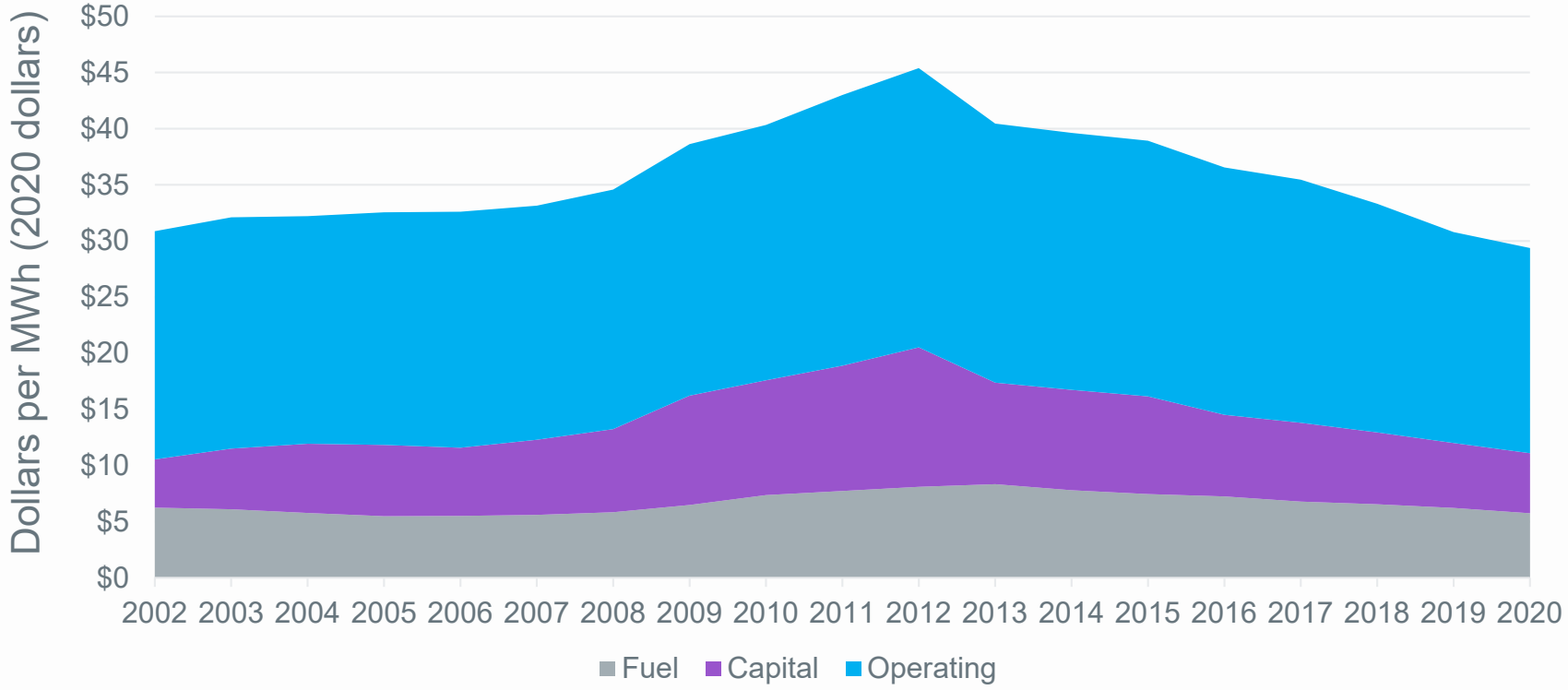
Source: U.S. Energy Information Administration
Updated: March 2022

Nuclear power continued to provide **the majority of U.S. emissions-free electricity** in 2021



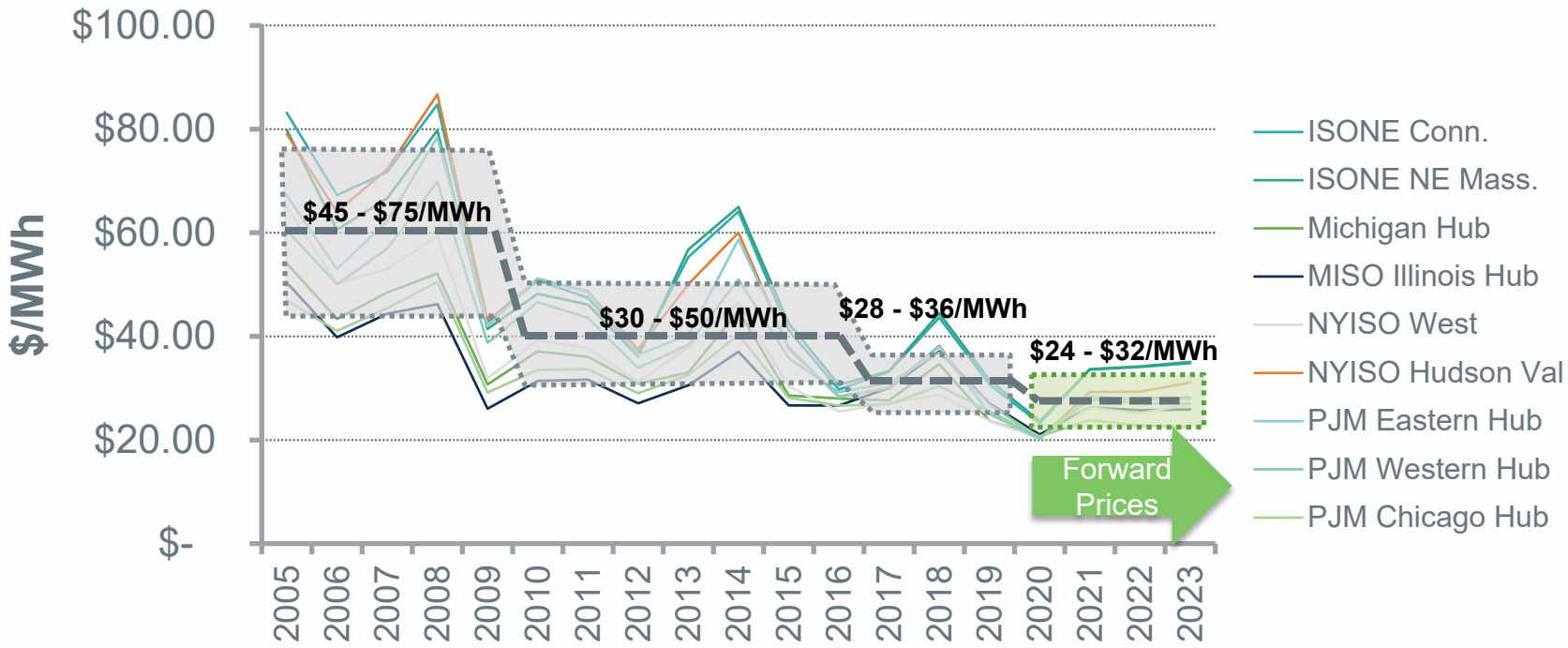
Source: U.S. Energy Information Administration
Updated: March 2022

Total Generating Costs 2002 – 2020



Source: Electric Utility Cost Group
Updated: September 2021

Declining U.S. Wholesale Electricity Prices



THE EMISSIONS REDUCTION IMPERATIVE

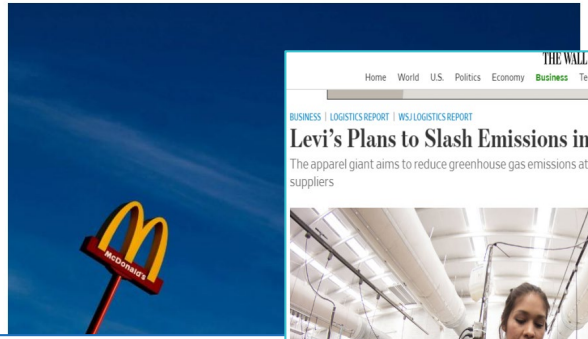
ENVIRONMENT MARCH 20, 2018 / 10:29 AM / A YEAR AGO

REUTERS

McDonald's sets greenhouse gas reduction targets

Lisa Baertlein 3 MIN READ

(Reuters) - McDonald's Corp on Tuesday announced an approved, science based target to cut greenhouse gas emissions and battle climate change, saying it is the first restaurant company to do so.



Supply chains + Add to myFT

Blue chips act to cut supply chain greenhouse gas emissions

Rolls-Royce, Nestlé and Panasonic among larger companies taking action

Michael Pooler JANUARY 29, 2018 2

The number of large companies taking serious action to tackle greenhouse gas emissions in their supply chains has doubled, according to research by an

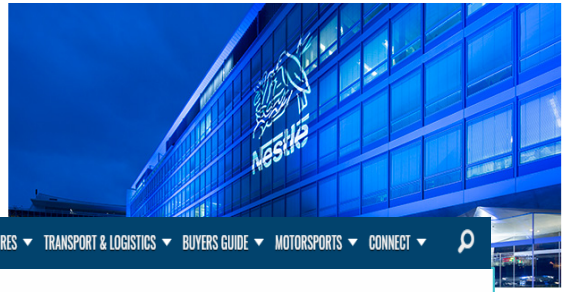
CLIMATE

Nestlé commits to net-zero target by 2050

E&E NEWS PM

Haley Weiss, E&E News reporter

Published: Monday, September 16, 2019



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Levi's Plans to Slash Emissions in Global Supply Chain by 2025

The apparel giant aims to reduce greenhouse gas emissions at a sprawling set of factories and mills in 39 countries, sta… suppliers

Levi's will start its effort to cut greenhouse gas emissions through energy-efficiency programs at factories run by vendors in the first tier of its supply chain, such as this supplier facility in Mexico. PHOTO: PHOTO COURTESY OF LEVI STRAUSS & CO.

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Toyota wants zero carbon emissions in all factories by 2050

Marcus De Guzman

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Clean, zero emission Toyota factories may soon be a reality

Toyota

May 31, 2019 09:41

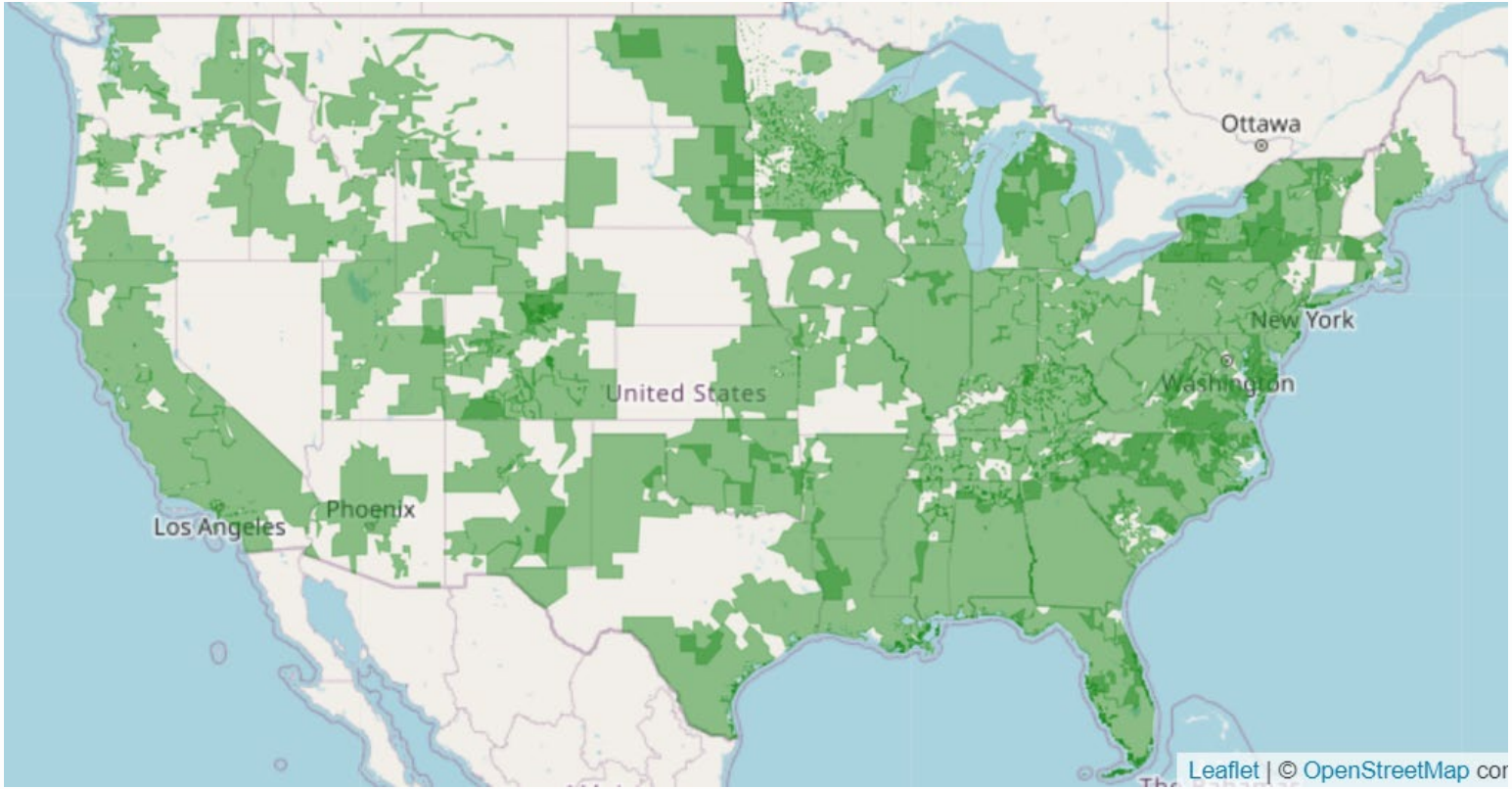
Let's face it, manufacturing cars is no easy feat. Aside from the fact that you have to build a whole fleet of them, you'll also need plenty of resources and energy to manufacture batches of them. But using energy means you're also producing CO_2 emissions, which is never good.

That's right, aside from automobiles, car factories also use plenty of energy that result in more CO_2 emissions that harm the environment and add more greenhouse gases that pollute the air. So how does Toyota plan to combat that? By setting a goal of achieving 35% reduced CO_2 emissions in global plants worldwide by 2030, and having zero Co_2 emissions in all manufacturing plants by 2050.

Part of the "Toyota Environmental Challenge 2050", the automaker is looking at not just reducing their carbon footprint from their cars, but also from their manufacturing facilities. To do this, Toyota has been finding ways of recycling and using alternative means of generating energy.

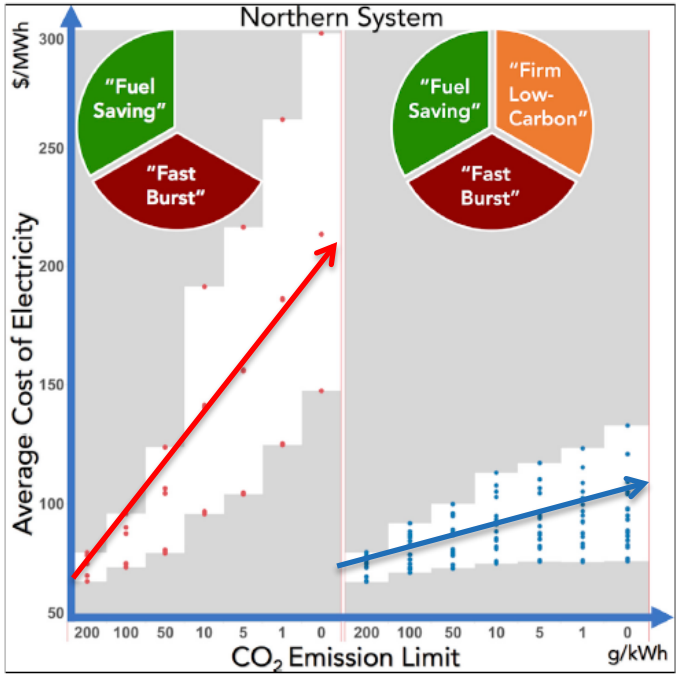
Advertisement

UTILITIES WITH EMISSIONS REDUCTION PLEDGES



Source: https://sepapower.org/utility-transformation-challenge/utility-carbon-reduction-tracker/

FIRM, LOW-CARBON GENERATION FROM NUCLEAR ENABLES AFFORDABLE DECARBONIZATION AND SYSTEM RESILIENCE



Nestor A. Sepulveda, Jesse D. Jenkins, Fernando J. de Sisternes, Richard K. Lester

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rklester@mit.edu (R.K.L.)

HIGHLIGHTS

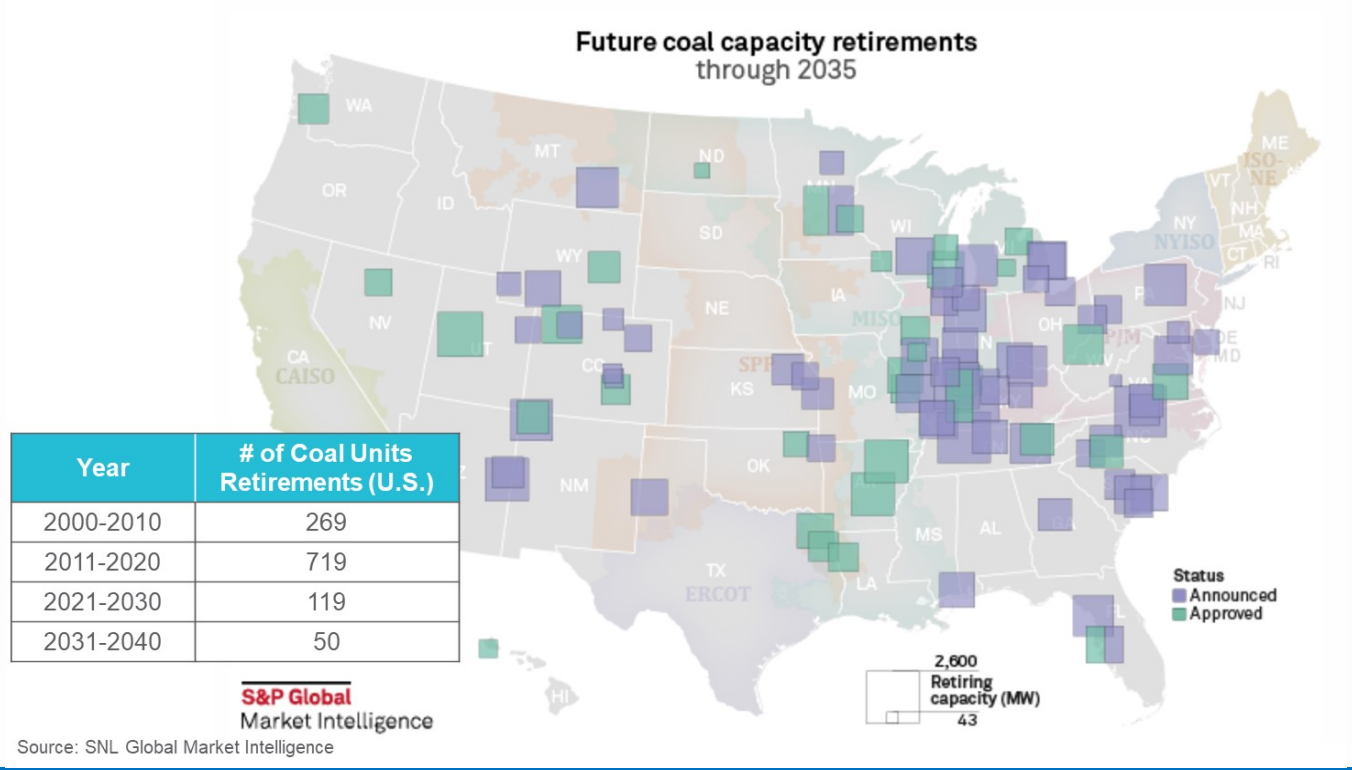
Firm low-carbon resources consistently lower decarbonized electricity system costs

Availability of firm low-carbon resources reduces costs 10%–62% in zero-CO_2 cases

Without these resources, electricity costs rise rapidly as CO_2 limits near zero

Batteries and demand flexibility do not substitute for firm low-carbon resources

DECARBONIZATION WILL DRIVE FURTHER COAL PLANT CLOSURES – INCREASING RISKS TO RELIABILITY



Year	# of Coal Units Retirements (U.S.)
2000-2010	269
2011-2020	719
2021-2030	119
2031-2040	50

S&P Global Market Intelligence

Source: SNL Global Market Intelligence

MANY OF THESE PLANTS ARE OF SIMILAR SIZE TO SMRs/ADVANCED REACTORS

NUCLEAR GENERATION CREATES LONG-TERM, WELL-PAYING JOBS

Coal Plant Position	# Dedicated Coal Positions	SMR Position	# Dedicated SMR Positions	Position Type	Degree of Retraining Required
Operations Supervisor	5	Senior Reactor Operator	5	Supervisor	High
Control Room Operator	10	Reactor Operator	15	Operator	High
Field Operator	15	Non-Licensed Operator	25	Operator	Low
Lab Operator/Chemistry/Scrubber	4	Chem Tech	14	Craft	Medium
Maintenance Supervisor	2	Maintenance Supervisor	3	Supervisor	Medium
Mechanical Craft	12	Mechanical Craft	21	Craft	Low
I&C Craft	9	I&C Craft	10	Craft	Medium
Electrician Craft	5	Electrician Craft	11	Craft	Low
Technician	11	Technician	13	Laborer	Low
Security Officer	20	Security Officer	48	Laborer	Low
Sub-Total	**93**		**165**		
All Other Positions	14		72	42 are O&M Support (Planners, Outage, etc.)	Medium
Total On-Site Positions	**107**		**237**		
Possible Centralized Positions			33		
Total Positions			**270**		

Sources: NuScale; ScottMadden analysis

NUCLEAR GENERATION IN U.S. PAYS HIGHEST AVERAGE WAGES

Sourcehttps://www.scottmadden.com/content/uploads/2021/10/ScottMadden_Gone_With_The_Steam_WhitePaper_final4.pdf

BIPARTISAN LEADERS EMBRACE NUCLEAR ENERGY

Biden American Jobs Plan:

- Recognizes important role of existing nuclear
- Pledges support for demonstration projects, manufacturing infrastructure investments

Bipartisan Infrastructure Bill:

- Operating nuclear plant credit program
- Advanced reactor demonstration funding
- Large-scale H2 demos

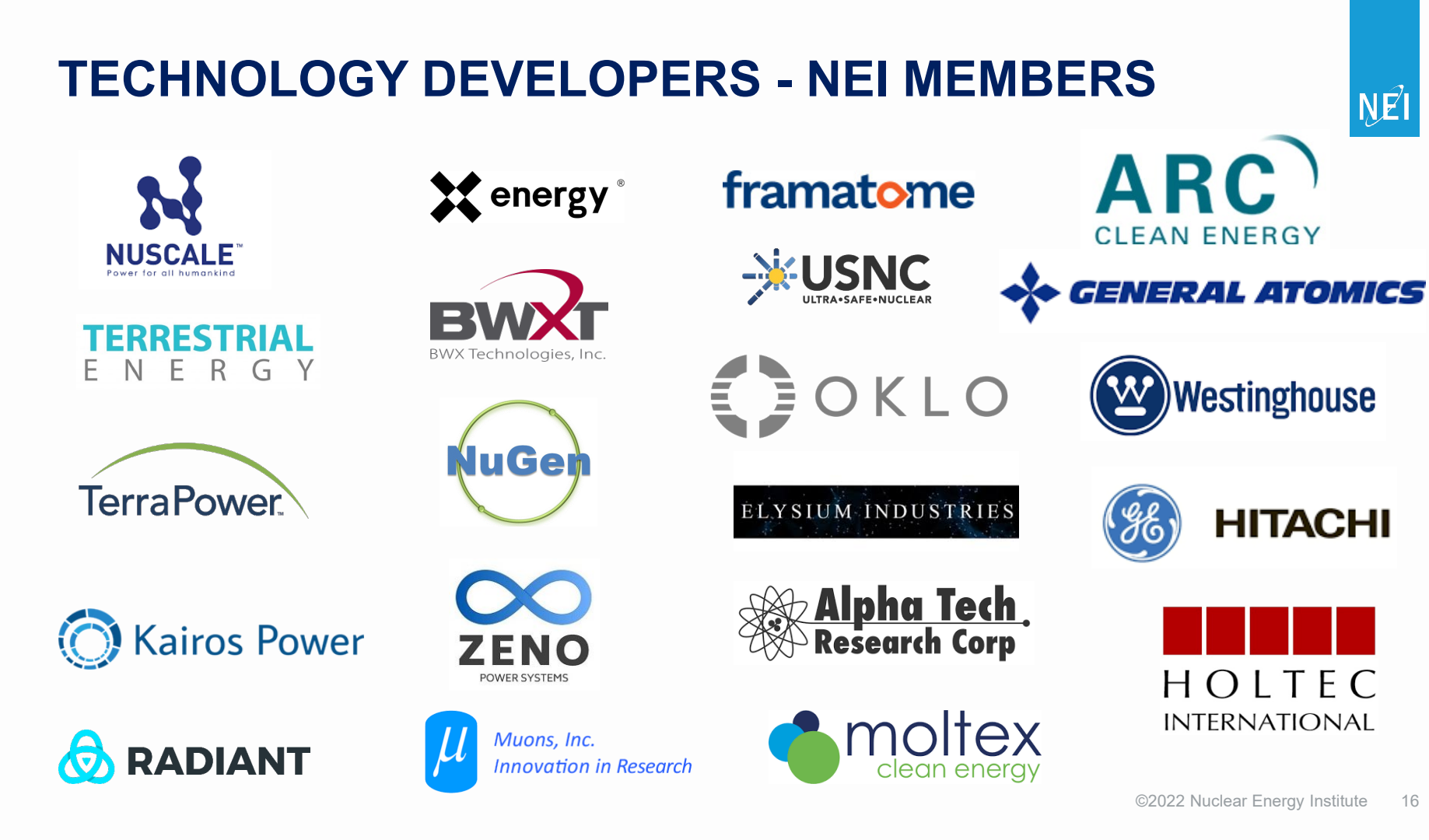
Build Back Better Bill:

- Tax credits for existing reactors
- Tax credits for all new clean generation
- Expanded federal loan guarantees

Utility and State Interest

State	Legislative Action	Utility Action
Alaska	Bills introduced to repeal Legislature approval to site	Eielson AFB site for first micro-reactor for DoD
Connecticut	Partially repealed nuclear moratorium (allows new nuclear at Millstone)	Dominion actively supported repeal
Idaho	Tax incentives passed	Host of UAMPS/NuScale SMR
Indiana	Nuclear Certificate of Necessity program enabled	Duke and AEP have SMRs in their IRPs
Montana	Passed bill to study coal to SMR Repealed voter approval to site	NorthWestern Energy exploring coal to nuclear
Nebraska	Passed bill on SMR tax incentives and SMR study funding approved	TBD – strong support for SMRs in state
North Carolina	Passed decarbonization plan bill	Duke Energy includes SMRs in IRP
Virginia	Nuclear Energy Strategic Plan and SMR Task Force created	Dominion includes SMRs in IRP
Washington	Clean energy standard including nuclear	Energy Northwest with X-energy demo Grant County PUD MOU with X-energy and NuScale
West Virginia	Repealed nuclear moratorium	Dominion Energy and AEP have SMRs in IRPs
Wyoming	Passed bill calling for coal retirements to be replaced with SMRs	Rocky Mt. Power siting for TerraPower demo

TECHNOLOGY DEVELOPERS - NEI MEMBERS



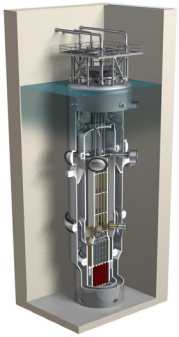
Types of Advanced Reactors

Range of sizes and features to meet diverse market needs

Micro Reactors (< 20MW)

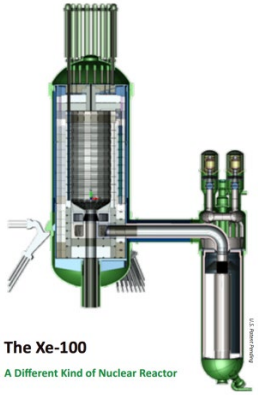
Oklo (shown)
Approximately a dozen in development

LWR SMRs <300MW



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

High Temp Gas Reactors

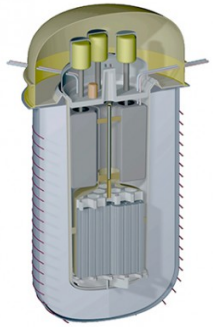


X-energy (shown)
Several in development

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

ARDP Demonstration Awards

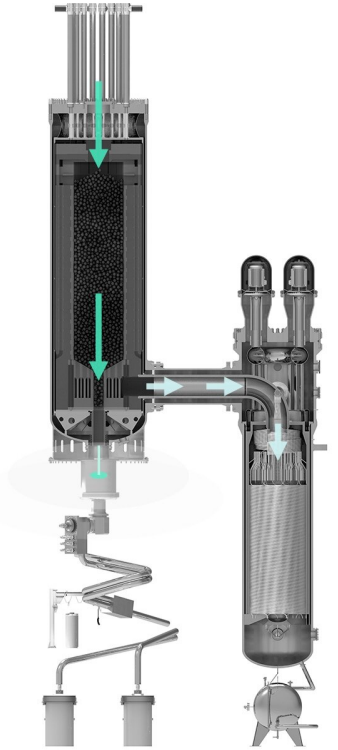
- TerraPower

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

ARDP Demonstration Awards

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

TRISO Fuel Pebble Cutaway



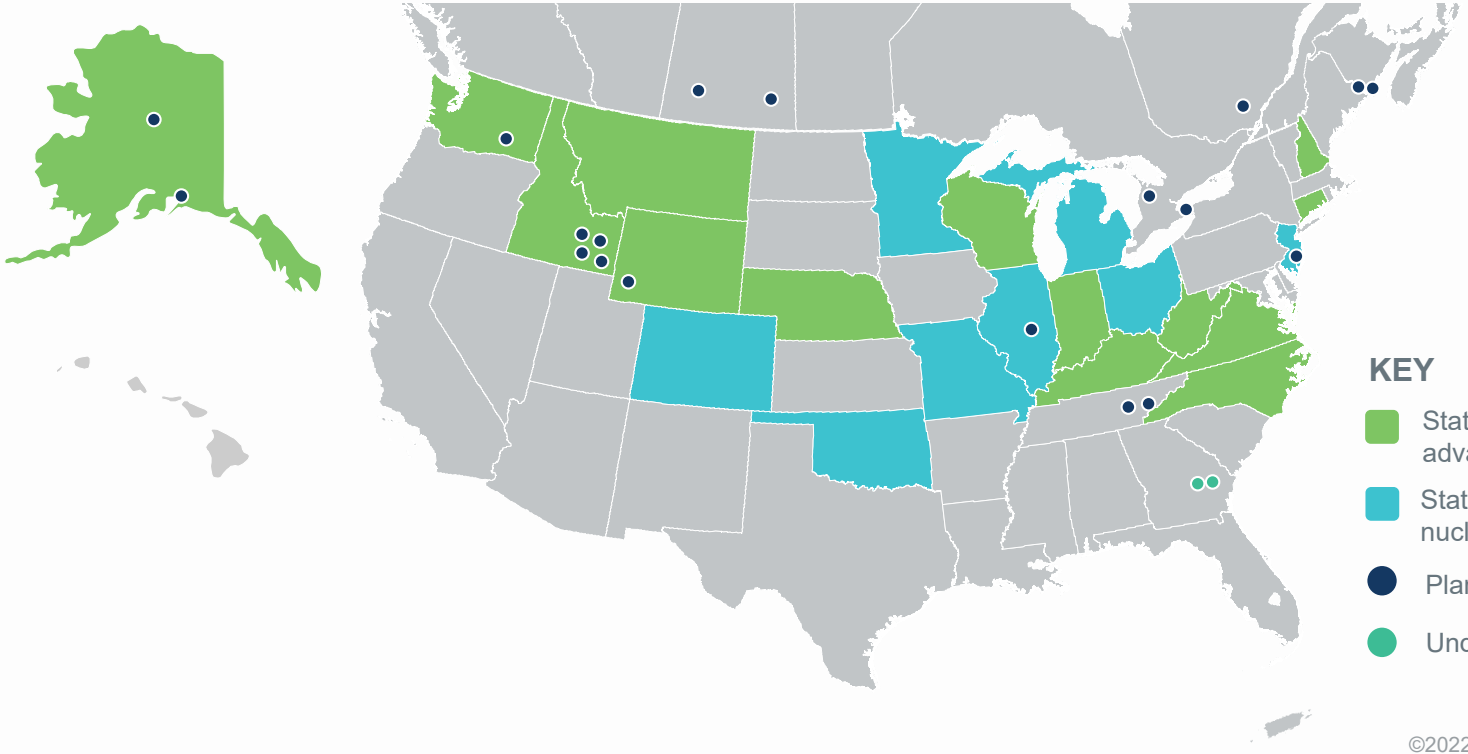
UAMPS

- Utah Associated Municipal Power Systems (UAMPS) plans to construct and operate a NuScale reactor at Idaho National Lab around 2029

- DOE approved $1.4 billion multi-year cost share in October 2020 for UAMPS

Advanced Nuclear Deployment Plans

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



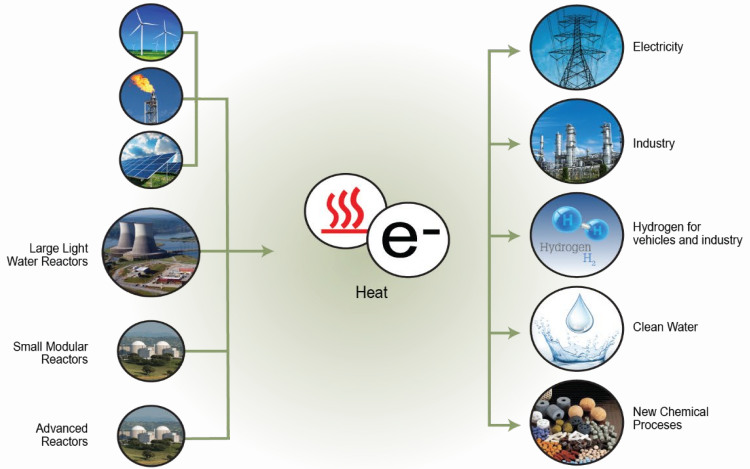
MOVING BEYOND ELECTRICITY

TODAY

Electricity focused

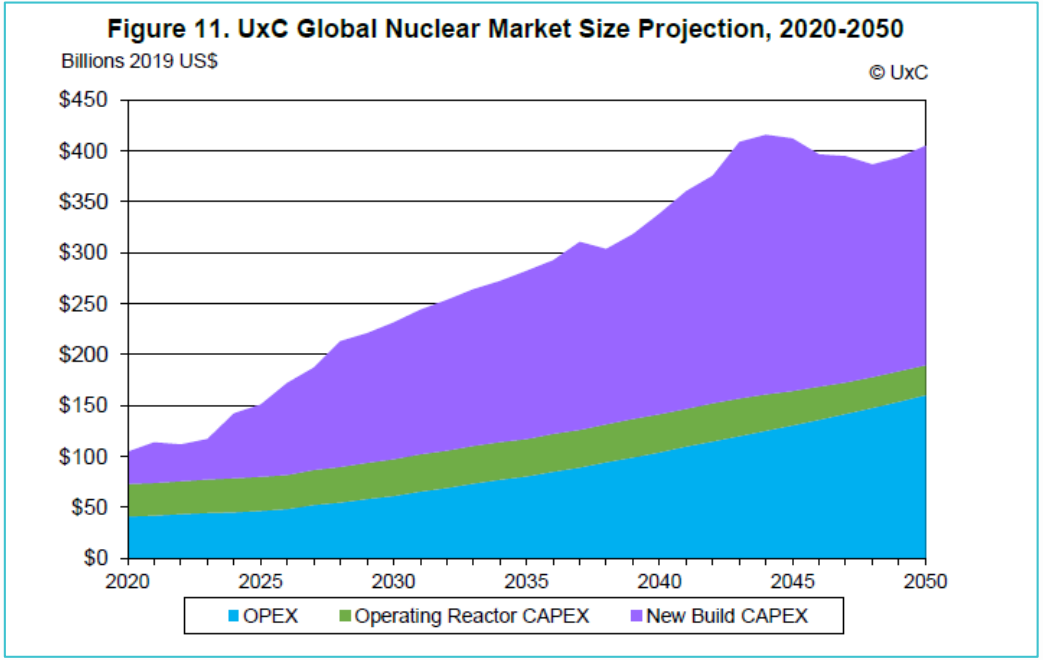
FUTURE

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



Tomorrow's nuclear will produce more than electricity

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

KEY TAKEAWAYS

- Consumers and policymakers (U.S. and abroad) increasingly demanding low-carbon electricity; states and utilities responding with ambitious goals

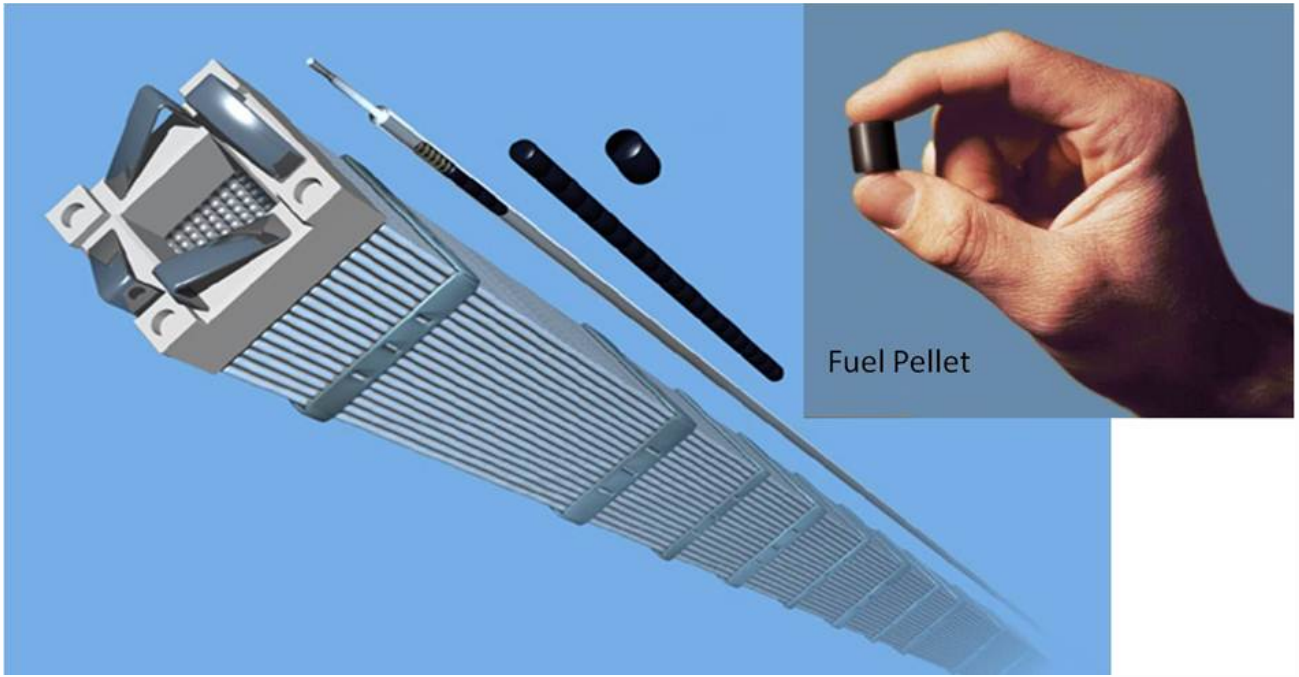
- Growing understanding that new nuclear is extremely valuable to a cleaner energy system
  - Least-cost, most reliable low-carbon systems include firm clean generation
  - State and federal policy actions needed to incentivize investment, drive down costs
  - Nuclear can help decarbonize non-electric energy uses

- Tremendous opportunities in domestic and global markets

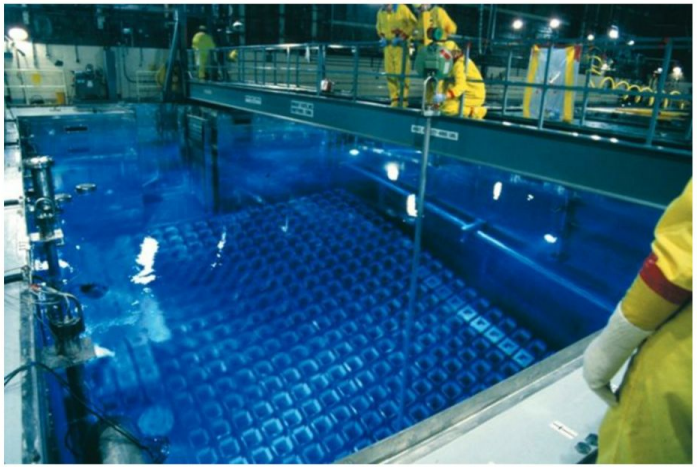
WIND + SOLAR + NUCLEAR + STORAGE IS THE BALANCED MIX THAT WILL GET US TO A CLEAN ENERGY FUTURE

QUESTIONS?

By Third Way, GENSLER



(source: https://nuclear.duke-energy.com/2014/02/11/do-we-have-enough-nuclear-fuel)



(source: https://nuclear.duke-energy.com/2016/10/05/the-facts-about-used-nuclear-fuel)

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)

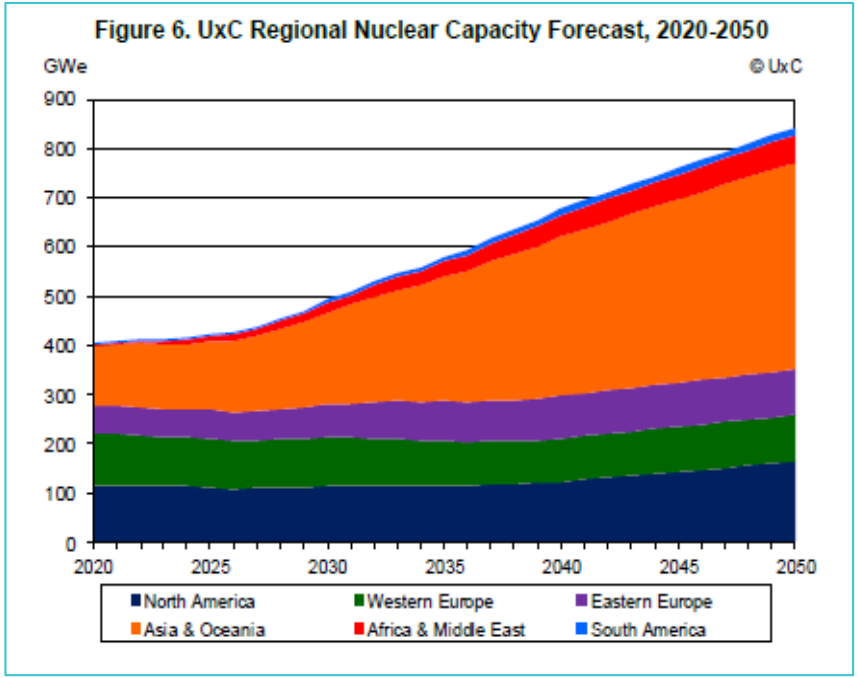
TOWARD A DURABLE, INTEGRATED SPENT FUEL MANAGEMENT PROGRAM

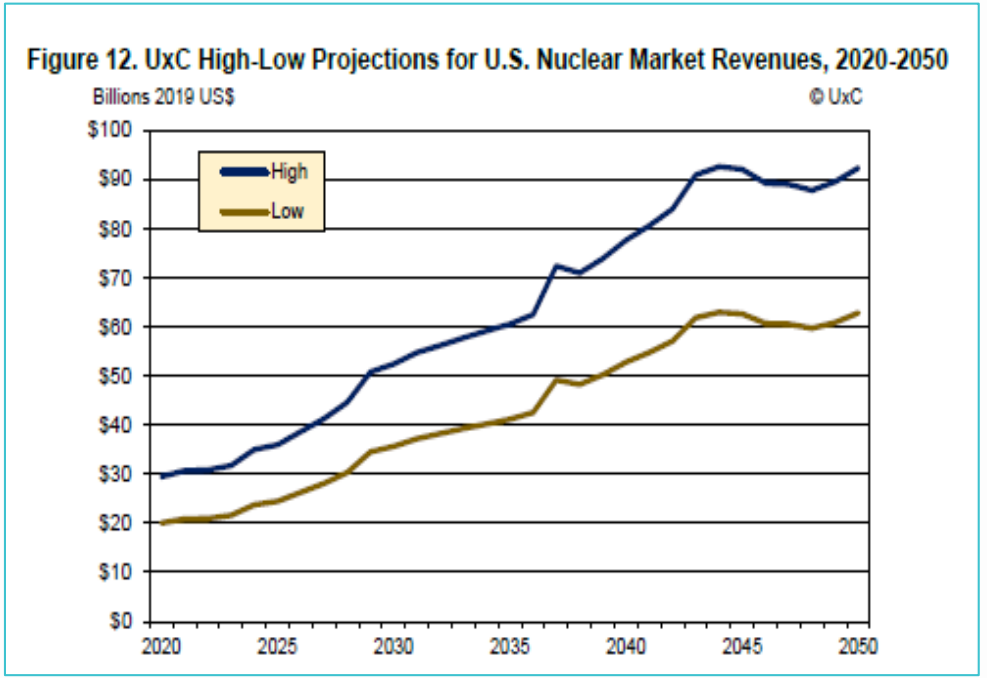
- Congress – consider the future of the NWPA

- Biden Administration:
  - Take steps to stand up an organization to resume management of the nuclear waste program
  - Seek Congressional authorization and funding to begin implementation of an integrated nuclear waste management system that allows for private consolidated interim spent fuel storage approaches

$>$40B AVAILABLE IN THE NUCLEAR WASTE FUND

USG ADVOCACY CAN HELP U.S. VENDORS CAPTURE GROWING GLOBAL MARKET FOR NEW NUCLEAR ENERGY SYSTEMS

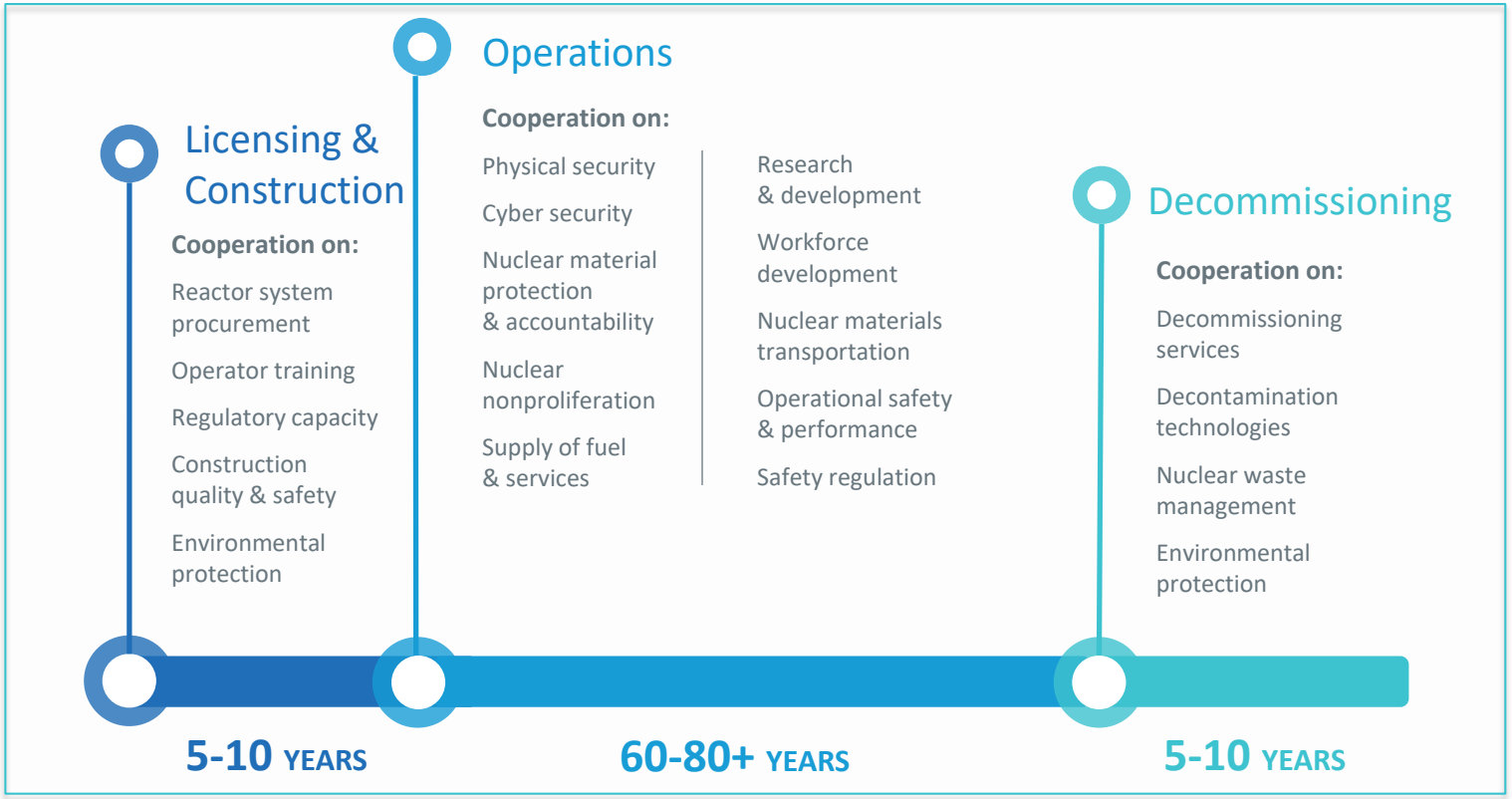




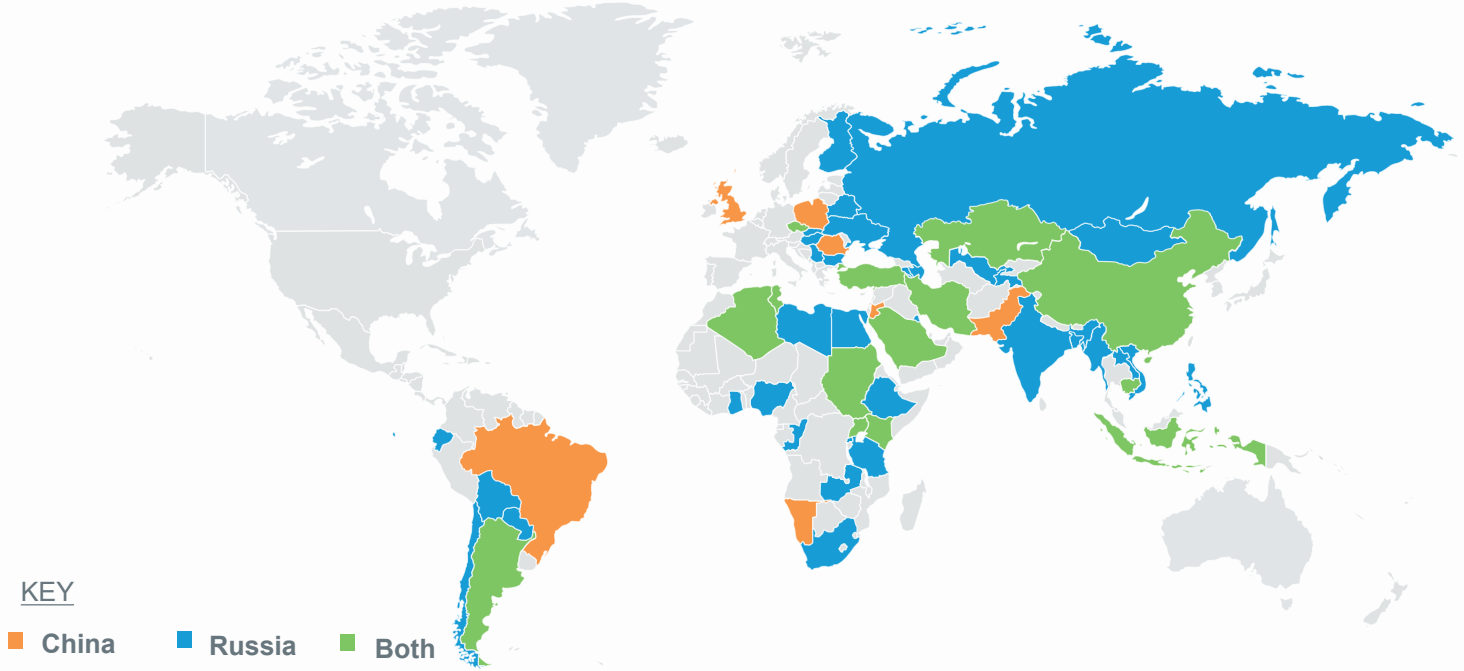
ESTIMATED $1.3-1.9T OPPORTUNITY FOR U.S. VENDORS THRU 2050

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

CIVIL NUCLEAR EXPORTS CREATE A CENTURY-LONG RELATIONSHIP



RUSSIA AND CHINA ARE SEEKING TO DOMINATE THE CIVIL NUCLEAR EXPORT MARKET



BOTH RUSSIA AND CHINA HAVE NUCLEAR ENERGY AGREEMENTS WITH MUCH OF AFRICA, ASIA AND SOUTH AMERICA

A USG STRATEGY TO COMPETE AND WIN IN THE CIVIL NUCLEAR MARKETPLACE

- Ensure high-level coordination across USG and re-establish a senior nuclear energy policy position in the EOP
- Elevate nuclear engagement and advocacy in bilateral dialogues and through intergovernmental agreements
- Continue to employ ExIm Bank, USDFC and USTDA and enhance their competitiveness
- Ensure that nuclear energy is included in international and multinational standards for clean energy development and financing
- Continue to improve the speed and predictability of DOE's export control licensing process

ACCORDING TO U.S. DOC, EVERY $1B IN CIVIL NUCLEAR EXPORTS CREATES 5,000 TO 10,000 U.S. JOBS

NUCLEAR GENERATION CREATES LONG-TERM, WELL-PAYING JOBS

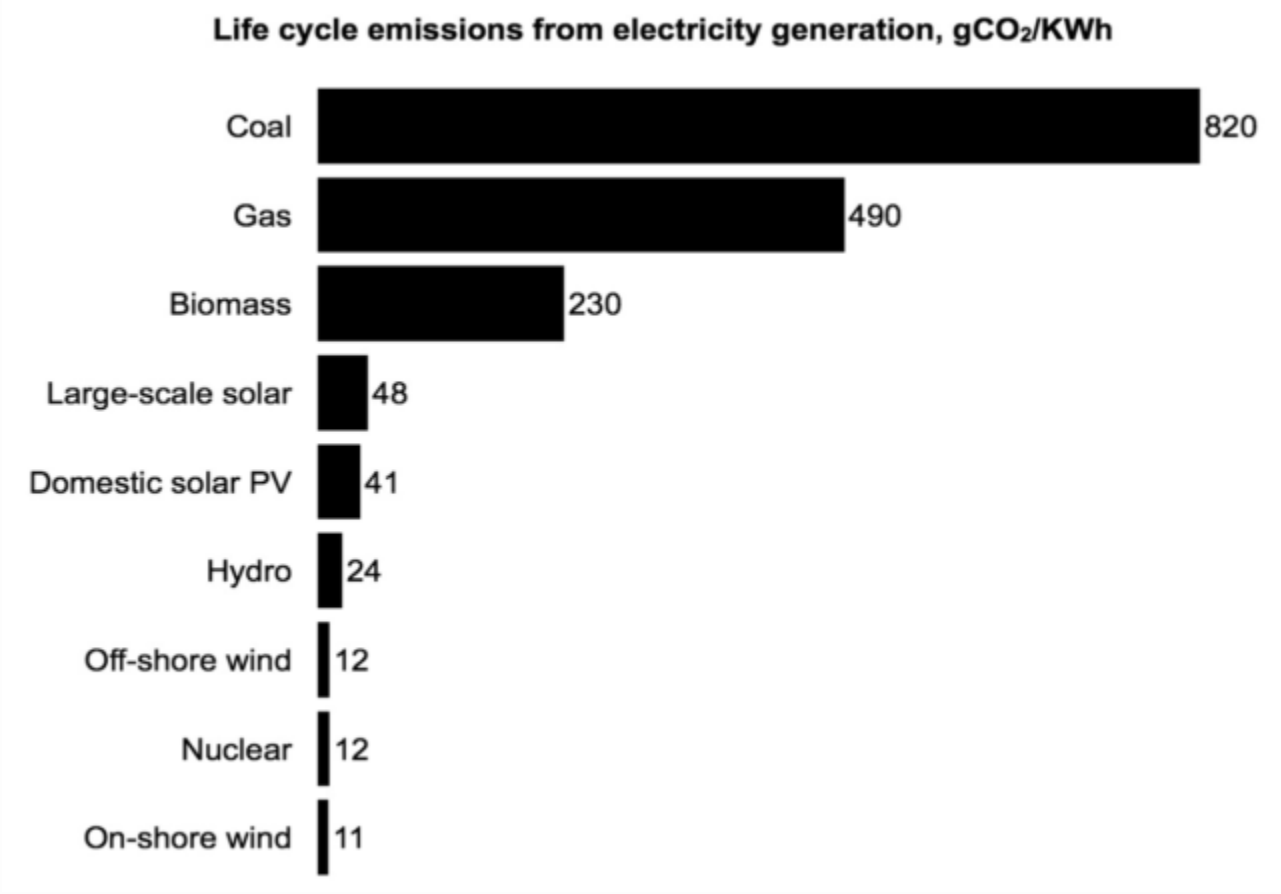
NEI

Overall Industry Crosscut Wages, 2019[15]

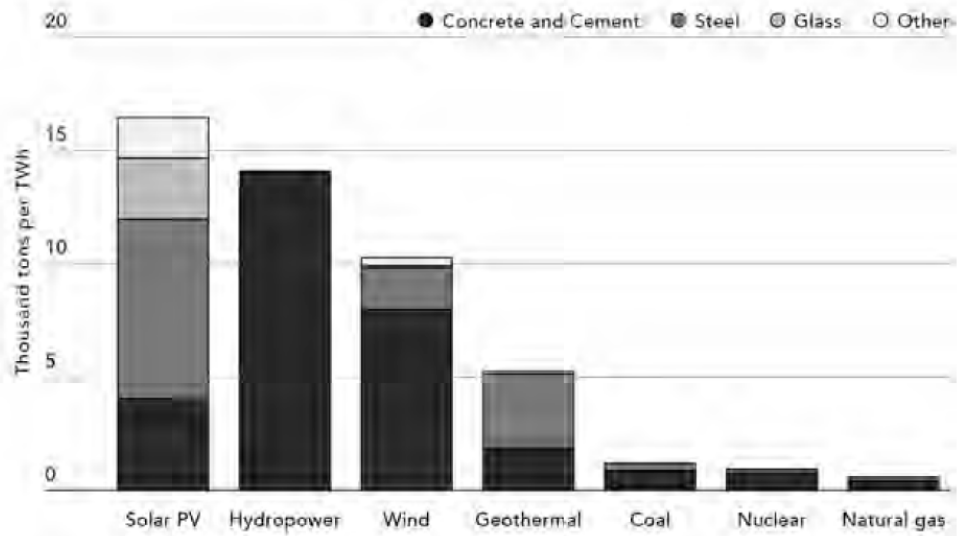
Industry Crosscut	Median Hourly Wage	Premium or Discount Compared to National Median	Total Employment, 2019	Percent of Total Energy Employment, 2019
Nuclear	$39.19	104.8%	70,323	0.8%
Electric Power Transmission & Distribution	$31.80	66.1%	830,291	9.9%
Natural Gas	$30.33	58.5%	636,043	7.6%
Coal	$28.69	49.9%	185,689	2.2%
Hydropower	$26.97	40.9%	67,772	0.8%
Oil	$26.59	38.9%	839,831	10.0%
Wind	$25.95	35.6%	114,774	1.4%
Solar	$24.48	27.9%	345,393	4.1%
Energy Efficiency	$24.44	27.7%	2,378,893	28.4%
Storage (excl. fossil fuels)	$24.36	27.3%	80,550	1.0%
National Median Wage	**$19.14**			

NUCLEAR GENERATION IS HIGHLY UNIONIZED AND DIVERSE, PAYS GREATEST AVERAGE WAGES

Source: https://www.usenergyjobs.org/wages



Raw Material Inputs per TWh

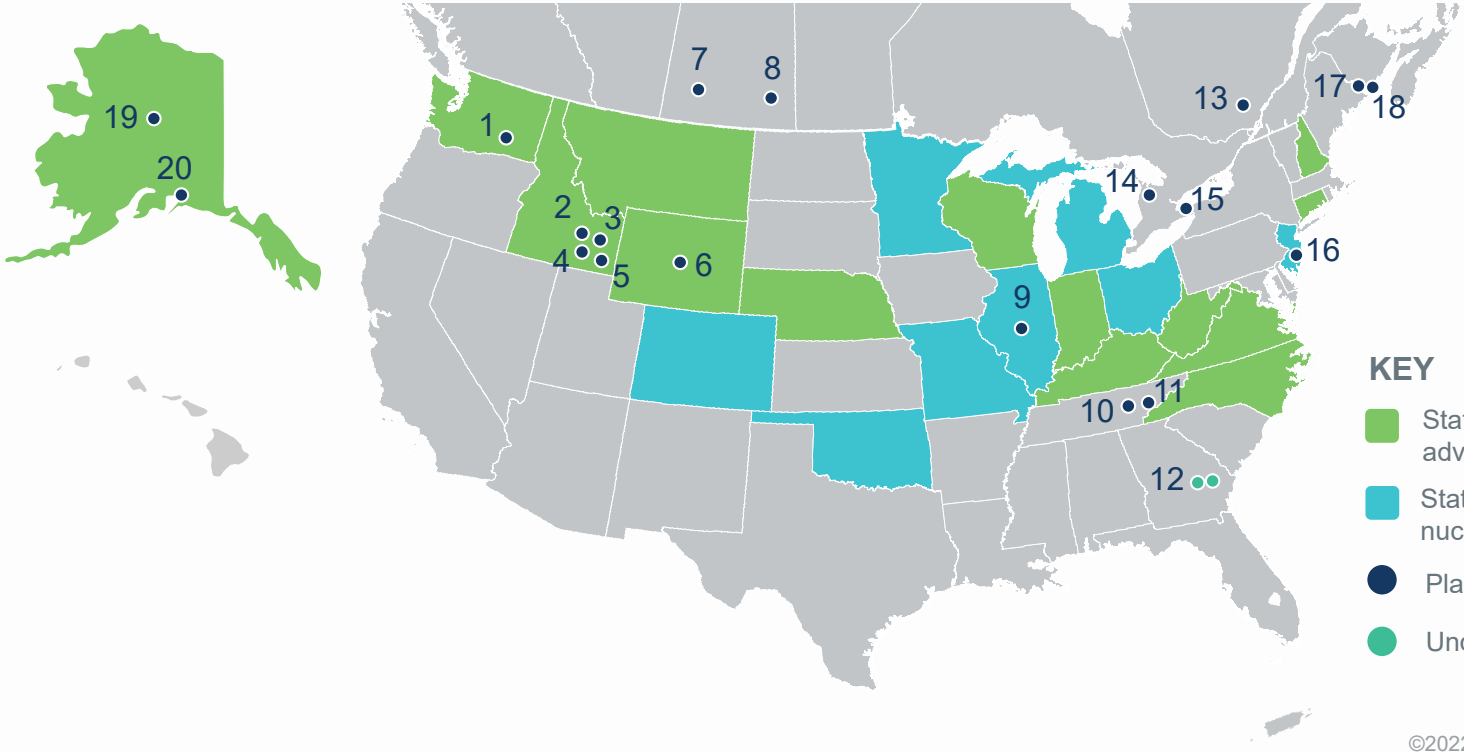


How much stuff does it take to build and run a power plant? That depends on the type of plant. Nuclear is the most efficient, using much less material per unit of electricity generated than other sources do. (U.S. Department of Energy)

Source: *How to Avoid a Climate Disaster*, Bill Gates, 2021

Advanced Nuclear Deployment Plans

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



Legend (customer; location; developer; design; type; size; online)

1. Grand County Public Utility District/Energy Northwest, Richland, Wash., X-energy Xe-100 (HTG SMR); four 80-MW units; Online 2027
2. UAMPS, Idaho Falls (INL); NuScale VOYGR (PWR SMR); six 77-MW units; Online 2029
3. Oklo, Idaho Falls (INL); Oklo Aurora (metal-cooled microreactor); 1.5 MW; Online 2025
4. Sponsor TBD, Idaho Falls (INL); Radiant Industries Kaleidos (helium/air-cooled microreactor); 1.2 MW; Online 2026
5. Department of Defense, Idaho Falls (INL); X-energy Xe-mobile (HTGR microreactor); 1.5 MW; Online 2025
6. Rocky Mountain Power, Kemmerer, Wyo.; TerraPower-GEH Natrium (liquid sodium fast reactor; SMR); 345-500 MW; Online 2028
7. SaskPower, Saskatchewan, Canada; developer TBD; four 300-MW units; Online 2032-2042
8. Sponsor TBD, Western Canada; Westinghouse eVinci (metal-cooled microreactor); 5 MW; Online 2027
9. University of Illinois, Urbana-Champaign, IL; Ultra Safe Nuclear MMR (HTGR microreactor; test and research); 5 MW; Online 2027
10. Tennessee Valley Authority, Clinch River,Tenn.; BWR X-300 (BWR SMR); 300-MW; Online 2032
11. TVA/Kairos, Oak Ridge, Tenn.; Kairos Power FHR (salt-cooled, HT SMR); 35 MW; Online 2026
12. Southern Company, Waynesboro, Ga.; Westinghouse AP1000 [Vogtle 3/4] (PWR); two 1,117-MW units; Online 2022-2023
13. Bruce Power; Westinghouse eVinci (metal-cooled microreactor); 5 MW; Online 2027
14. Ontario Power Generation/Global First; Chalk River Laboratory, Ontario, Canada; Ultra Safe Nuclear MMR (HTGR microreactor demonstration); 5 MW; Online 2025
15. Ontario Power Generation; Darlington; BWR X-300 (BWR SMR); 300 MW; Online 2028
16. Sponsor TBD, Oyster Creek, New Jersey; Holtec SMR-160 (PWR SMR); 160 MW; Online 2030
17. New Brunswick Power, New Brunswick, Canada: ARC Clean Energy ARC-100 (sodium-cooled fast SMR); 100 MW; Online 2030;
18. New Brunswick Power, New Brunswick, Canada:, Moltex Energy Stable Salt Reactor (SSR) (molten salt SMR); 300 MW; Online 2032
19. Eielson Air Force Base, Fairbanks, Alaska; X-energy Xe-mobile (HTGR microreactor); 1-10 MW; Online 2025
20. Copper Valley Electric Association, Glennallen, Alaska; Ultra Safe Nuclear MMR (HTGR microreactor); 10 MW; Online TBD