Nuclear Energy Overview & Update

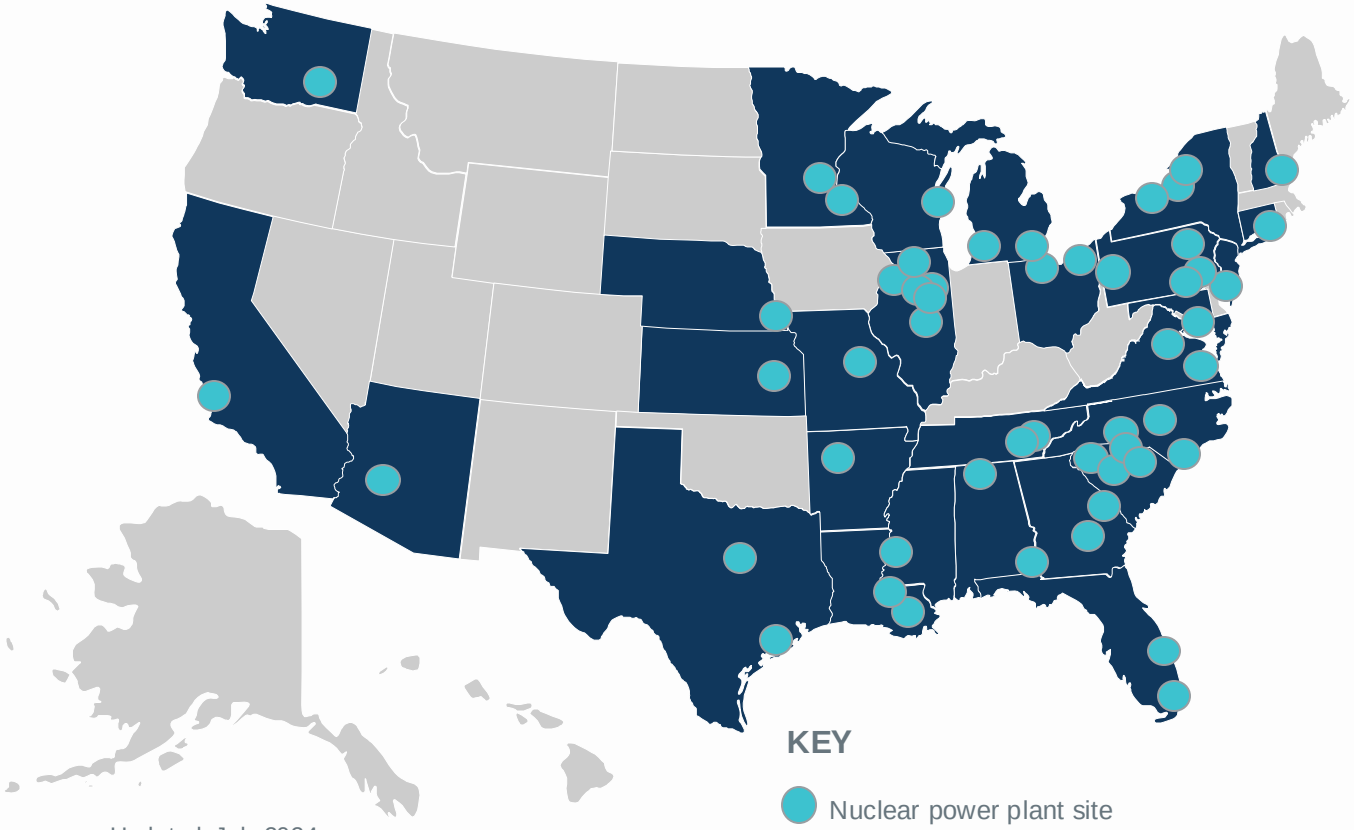
NASUCA Webinar

John Kotek & Kati Austgen

December 11, 2024

NUCLEAR ENERGY INSTITUTE

Nuclear Provides Majority of Emissions Free Electricity



Updated: July 2024

U.S. Clean Generation (2023)

47.8% NUCLEAR

26.2% WIND

14.8% HYDRO

10.2% SOLAR

1% GEOTHERMAL

The Emissions Reduction Imperative

REUTERS

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

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

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

AMERICAN BANKER

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BANKING POLICY PAYMENTS TECH CREDIT UNIONS WORKPLACE

Regional banks join forces to tackle climate change

By Allissa Kline March 23, 2022, 5:28 p.m. EDT 2 Min Read

Two months after forming a consortium of large, international banks to address the risks associated with climate change, the Risk Management Association has established a similar group for midsize banks.

rs, including
cticut, RMA
e regional
sk

THE WALL STREET JOURNAL.

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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.

Google Data Centers

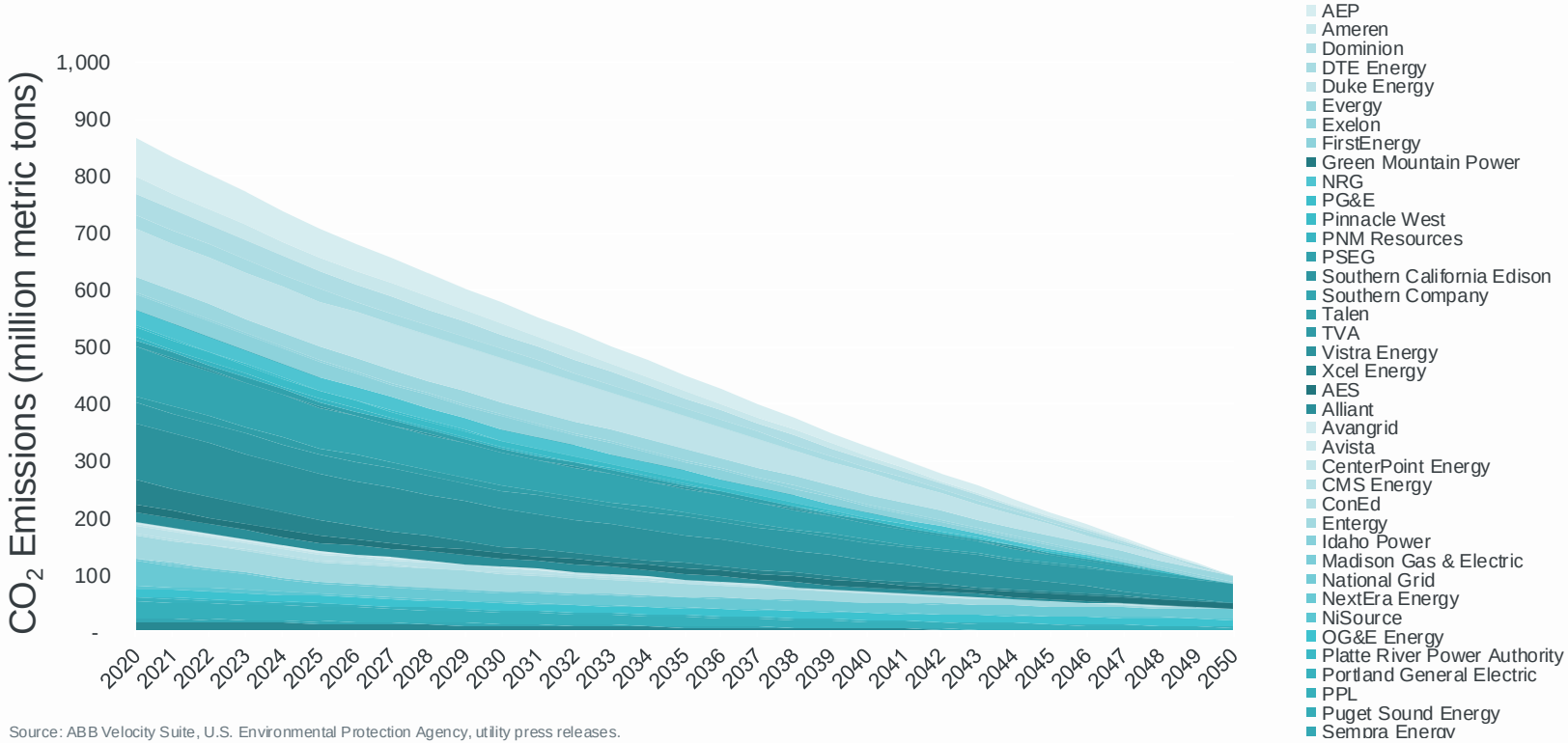
Locations Innovations Data and Security Efficiency 24/7 Carbon-Free Energy Gallery Life@ Podcast Discover

24/7 Carbon-Free Energy by 2030

From 2010 to 2023, we signed more than 115 agreements totaling over 14 GW of clean energy g
third decade of climate action, we've set a goal to run on 24/7 carbon-free energy on every grid w
every hour of every day. Achieving this will also increase the impact of our clean energy procurem

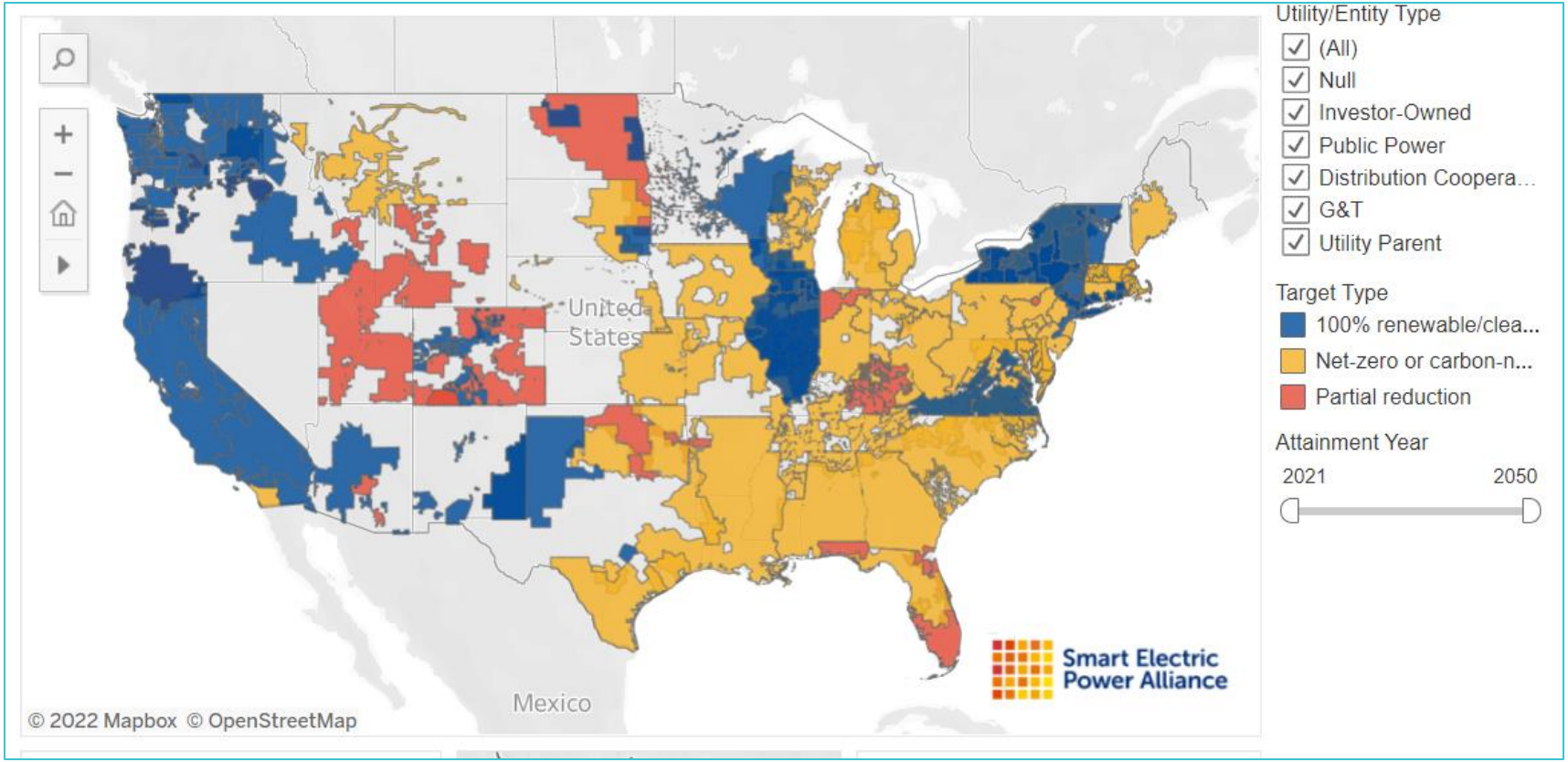
>9,700 COMPANIES WITH CARBON REDUCTION TARGETS

Utility Carbon Emission Projections Based on Pledges



Source: ABB Velocity Suite, U.S. Environmental Protection Agency, utility press releases.

Utilities With Emissions Reduction Targets



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

Growth Rates Increasing Almost Everywhere

From 2022 to 2023, the 5-year national forecast for peak demand shot up by about 50% – from 0.63% annual growth to 0.93%.

Annual growth rates are measured using the Compound Annual Growth Rate (CAGR). The CAGR represents the rate at which the initial load forecast or current load needs to grow annually to match the forecasted load in the final year assuming an annually compounded growth rate.

CAGRs can be useful to compare forecasted load growth of different utilities regardless of the size of the utility.

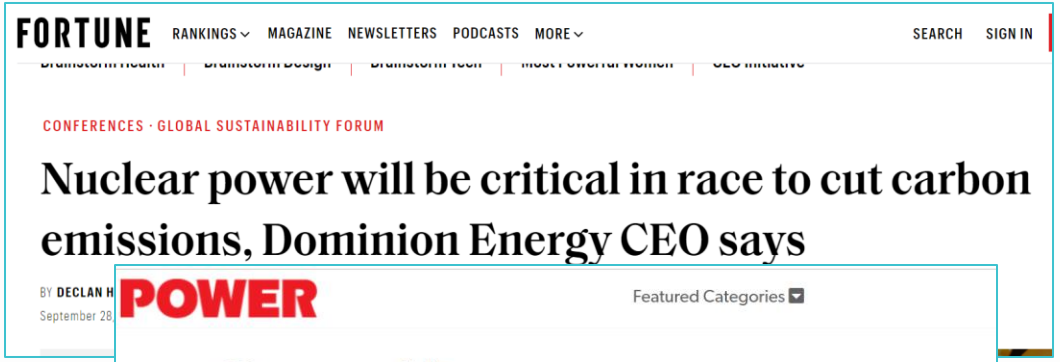
The only region where the CAGR decreased in 2023 is MISO. However, as discussed in the MISO profile, expedited new load projects are flooding MISO's planning process and should drive an increase in future load forecasts.

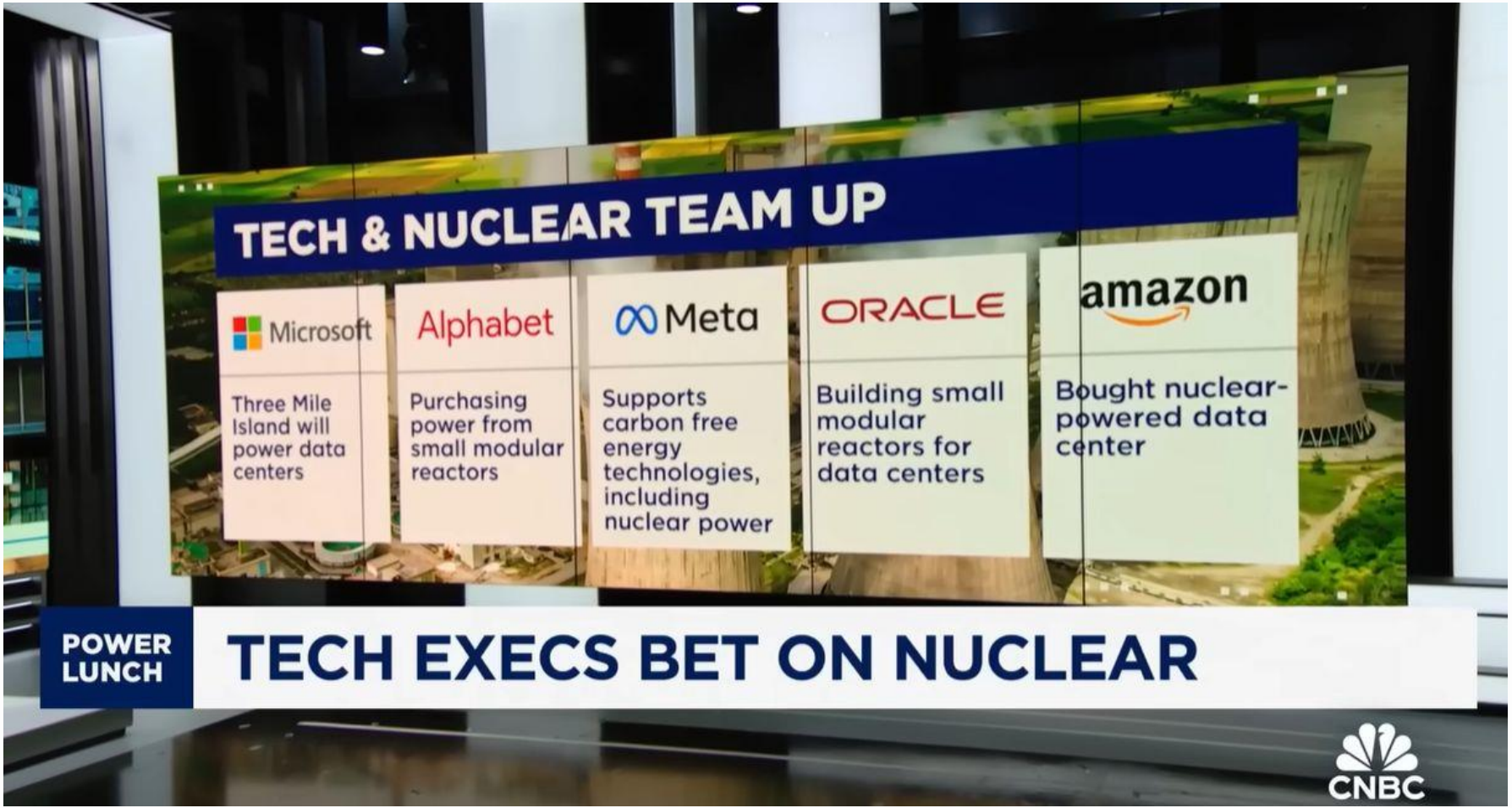
NOTE | The "Southwest" region includes some utilities that might be characterized as central western.

GridStrategies

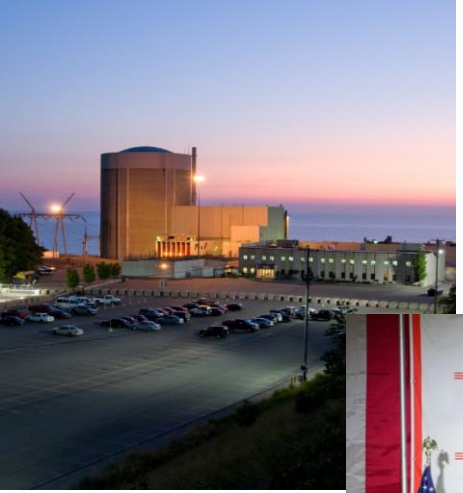
Source: https://gridstrategiesllc.com/wp-content/uploads/2023/12/National-Load-Growth-Report-2023.pdf

Utilities Including New Nuclear In Future Resource Planning




TECH & NUCLEAR TEAM UP
Microsoft
Three Mile Island will power data centers
Alphabet
Purchasing power from small modular reactors
Meta
Supports carbon free energy technologies, including nuclear power
ORACLE
Building small modular reactors for data centers
amazon
Bought nuclear-powered data center
POWER LUNCH
TECH EXECS BET ON NUCLEAR
CNBC

Reactor Restarts



Energy Secretary Granholm announces DOE loan commitment at Palisades (Courtesy: Holtec)

- Palisades
  - 800 MWe
  - Prematurely closed in May 2022
  - Broad-based support from federal, state, and community partners to repower
- Crane Clean Energy Center
  - 835 MWe
  - (Three Mile Island Unit 1) Prematurely closed in Sept. 2019
  - Power purchase agreement with Microsoft will return unit to service

Quote on TMI restart by PA State Rep. Tom Mehaffie (Courtesy: Constellation)

Second License Renewals ensure reliable carbon-free electricity well into the 2050s

21
Future Applications Expected

H.B. Robinson 2
Hatch 1 & 2
Prairie Island 1 & 2
D.C. Cook 1 & 2
Salem 1 & 2
Hope Creek 1
Cooper
Millstone 2 & 3
Watts Bar 1
Farley 1 & 2
Nine Mile Point 1 & 2
Ginna
Palisades
Crane Clean Energy

14
Reactors Under Review

Point Beach 1 & 2
Oconee 1, 2 & 3
St. Lucie 1 & 2
Monticello 1
V.C. Summer 1
Browns Ferry 1, 2 & 3
Dresden 2 & 3

8
Reactors Approved

Turkey Point 3 & 4
Peach Bottom 2 & 3
Surry 1 & 2
North Anna 1 & 2

Source: U.S. Nuclear Regulatory Commission and news articles
Updated: December 2024

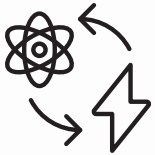
Recent Survey of NEI's U.S. Utilities

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

SLR

>90% of fleet expects to operate to at least **80 years**

GW



100 GWe of new nuclear opportunity by **2050s**

SMRs

Translates to roughly **300 SMR-scale plants**

NEI utility member companies produce nearly half of all US electricity.

More than half have *more* interest than in 2022 (prior survey year)

Key Federal Policies

Bipartisan Infrastructure Law
November 15, 2021

Advanced Reactor Demonstration Program (ARDP) Funding
$2.5B for two commercial demos

Nuclear Hydrogen Hub
$8B total

Civil Nuclear Credit Program
$6B to support financially challenged plants

Inflation Reduction Act
August 16, 2022

Production Tax Credit (PTC) for Operating Plants
Up to $15 per MWh

Technology-Inclusive PTC for Clean Electricity
$30 per MWh

Technology-Inclusive Investment Tax Credit (ITC) for Clean Electricity
30% + 10% in energy communities + 10% using U.S. components

Clean Hydrogen Credit
$3 per kilogram

118th Congress

Nuclear Fuel Security Act
LEU/HALEU domestic production authorizing legislation in FY 2024 NDAA (December 22, 2023)

FY 2024 Appropriations Legislation
$2.72 Billion for domestic fuel production (March 9, 2024)

Additional $800 Million for Small Modular Reactors (March 9, 2024)

40 Year Reauthorization of the Price-Anderson Indemnification Act (March 23, 2024)

ADVANCE Act
Increase regulatory efficiency & reduce regulatory costs (July 9, 2024)

Federal Funding Opportunities for New Nuclear

Tax Credits

- PTC: At least $30/MWh for 10 years
- ITC: 30% of investment
- Bonuses for energy communities and domestic supply

Demonstrations (Awarded)

- DOE funding 12 different designs, >$5B over 7 years
- ARDP Demos, Risk Reduction, Early development

Loan Guarantees

- Up to $40B in expanded authority

Deployments (New)

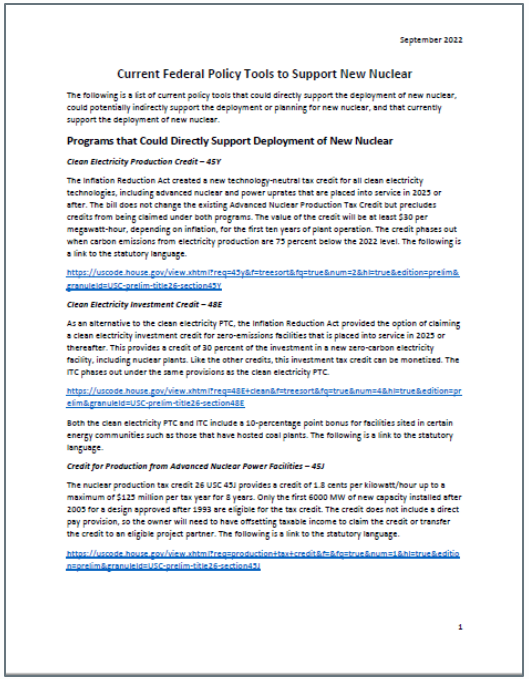
- $800 Million for utility use of light-water SMRs

Fuel and Supply Chain

- HALEU Fuel - $700M
- $2.7 Billion for fuel (conditional on Russian import ban)

Other Support

- GAIN Vouchers
- NRIC Partnerships



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 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=4&hl=true&edition=prelim&granuleId=USC-prelim-title26-section45J

1

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

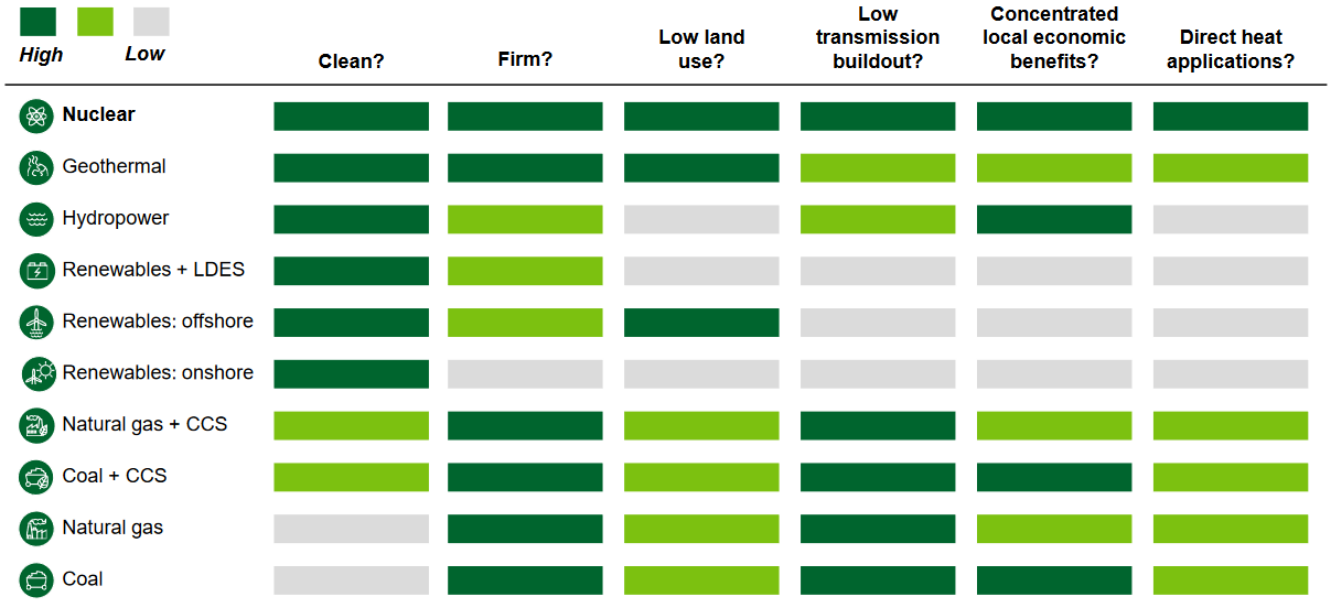
States Taking Action for Nuclear

Exploring Nuclear Technology with Studies, Working Groups, Commissions and Task Forces	Connecticut, **Florida, Indiana, Kentucky, Louisiana,** Maryland, **Michigan,** Montana, Nebraska, New Hampshire, Ohio, **Pennsylvania,** Tennessee, and **Texas**
Recognizing Nuclear as a Clean Energy Resource	Idaho, Michigan, Minnesota, **North Carolina,** Tennessee, Utah, and **Virginia**
Removing Barriers and Signaling Support	Repealing Nuclear Moratoriums: Connecticut, Illinois, Kentucky, Montana, West Virginia, and Wisconsin Signaling Regulatory Support: **Indiana, Louisiana, Mississippi, New York, North Carolina,** and **South Dakota**
Incentivizing Nuclear Technology and Supply Chain	Kentucky, Michigan, Tennessee, Virginia, Washington, and Wyoming

Current State Policies: https://www.nei.org/resources/reports-briefs/state-legislation-and-regulations
State Policy Options: https://www.nei.org/resources/reports-briefs/policy-options-for-states-to-support-new-nuclear

DOE Pathways to Commercial Liftoff

Nuclear offers a unique value proposition for a net zero grid



Source: https://liftoff.energy.gov/advanced-nuclear/

Advanced Nuclear Designer Members

Types of Advanced Reactors

Range of sizes and features to meet diverse market needs

Water Cooled | Non-Water Cooled | Both

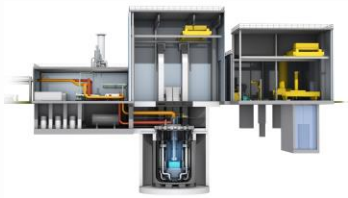
Westinghouse AP1000® (shown)
ABWR

GEH BWRX-300(shown)
NuScale
Holtec SMR-300
Westinghouse AP300

High Temp Gas Reactors

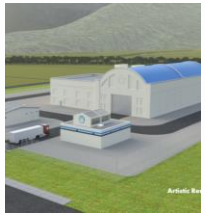
X-energy (shown)

Liquid Metal Reactors



TerraPower Natrium™ (shown)

Molten Salt Reactors



Kairos Hermes (shown)

Oklo (shown)
Last Energy
Radiant
Westinghouse eVinci

Large ~1000 MWe | Small Modular Reactors < 300 MWe | Micro < 50 MWe

Learn more about innovative technologies with the Nuclear Innovation Alliance.

Advanced Nuclear Versatility

Spectrum of Sizes and Options

Micro

Small

Large

Variety of Outputs

Electricity

Isotopes

Hydrogen

Process Heat

Multitude of *New* Customers

Energy Transitions

Data Centers

Military Bases

Petrochemical

Cement

Steel

Oil & Gas

District Energy

Space

Pulp & Paper

Block Chain Mining

Transportation

Rail

Aviation

Maritime

Mining

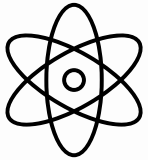
Agriculture

Fashion

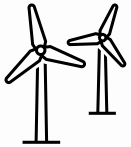
Desalination

Lowest System Cost Achieved by Enabling Large Scale New Nuclear Deployment

Lowest Cost System

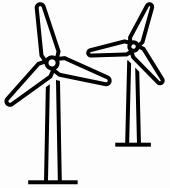


Nuclear is 43% of generation (>300 GW of new nuclear)

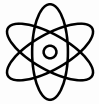


Wind and solar are 50%

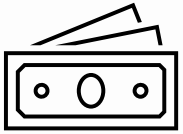
Energy System with Nuclear Constrained



Wind and Solar are 77% of generation



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



Increased cost to customers of $449 Billion

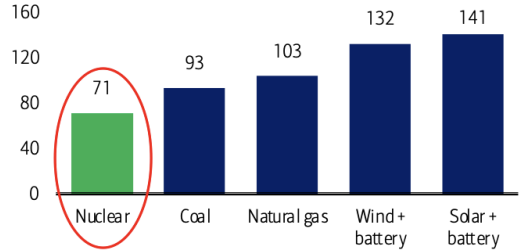
Both scenarios are successful in reducing electricity grid GHG emissions by over 95% by 2050 and reducing the economy-wide GHG emissions by over 60%

Scan to view the complete study.

Nuclear Energy is Affordable

"Nuclear appears to be the cheapest scalable, clean energy source by far."

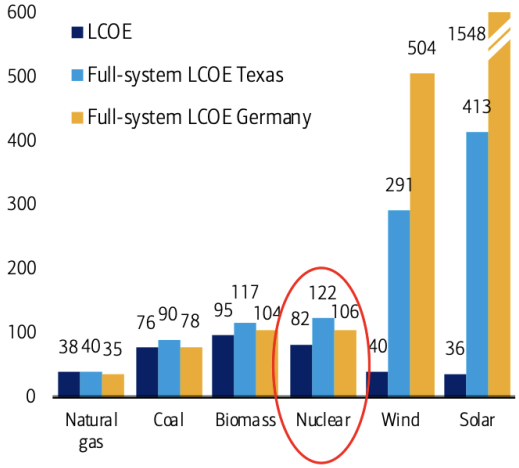
Exhibit 20: Nuclear is cost-effective…
Cost of generation, different sources ($/MWh)



Source: BofA Research Investment Committee, Lazard, Entler, et al. (2018). Note: nuclear, coal, and natural gas price estimates from Entler, et al. Wind and solar cost estimates are from Lazard's 2023 Levelized Cost of Energy+ report. Wind + battery and solar + battery use estimates from California's Independent System Operator (CAISO) and assume a 4-hour lithium-ion battery storage system to account for firming costs. All cost estimates show unsubsidized costs.

BofA GLOBAL RESEARCH

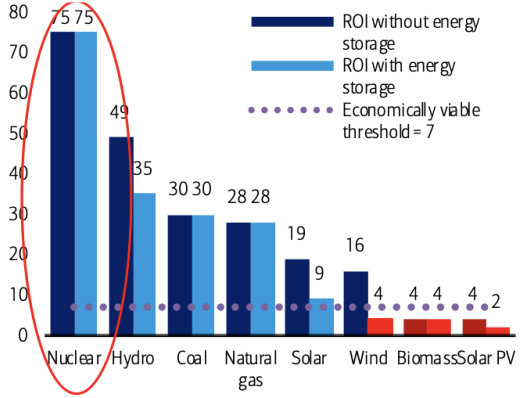
Exhibit 21: …especially on an "all-in basis"…
LCOE & LFSCOE calculations by energy source



Source: BofA Research Investment Committee, Idel 2022

BofA GLOBAL RESEARCH

Exhibit 22: …and has the highest energy ROI
Energy returned on energy invested, by source



Source: BofA Research Investment Committee, D. Weißbach, G. Ruprecht, A. Huke, K. Czerski, S. Gottlie, A. Hussein; Red signals EROI below economically viable threshold

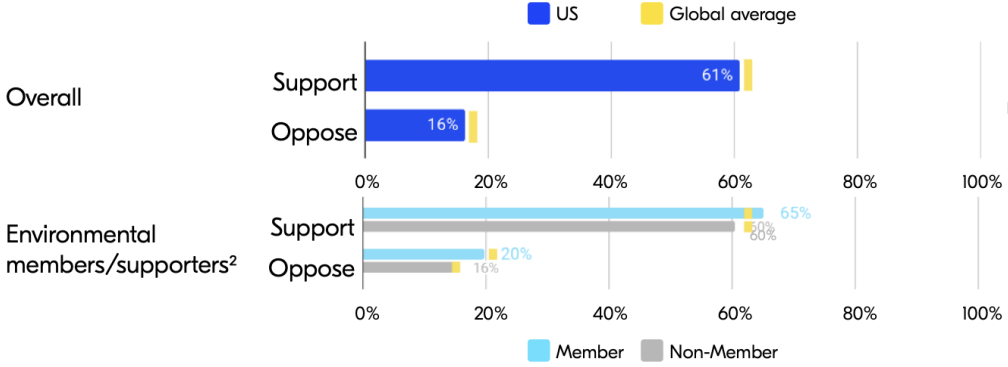
BofA GLOBAL RESEARCH

Bank of America Analyst Report: https://advisoranalyst.com/wp-content/uploads/2023/05/bofa-the-ric-report-the-nuclear-necessity-20230509.pdf

Strong Public Support for Nuclear Energy

US

Support vs. opposition[1]



n=4,250

Support by...

Gender

Men	73%
Women	50%

Age

18-34	58%
35-54	62%
55+	62%

Income

Low income (under 50k USD)	52%
Medium income (50k-100k USD)	60%
High income (100k+ USD)	70%

Political Affiliation

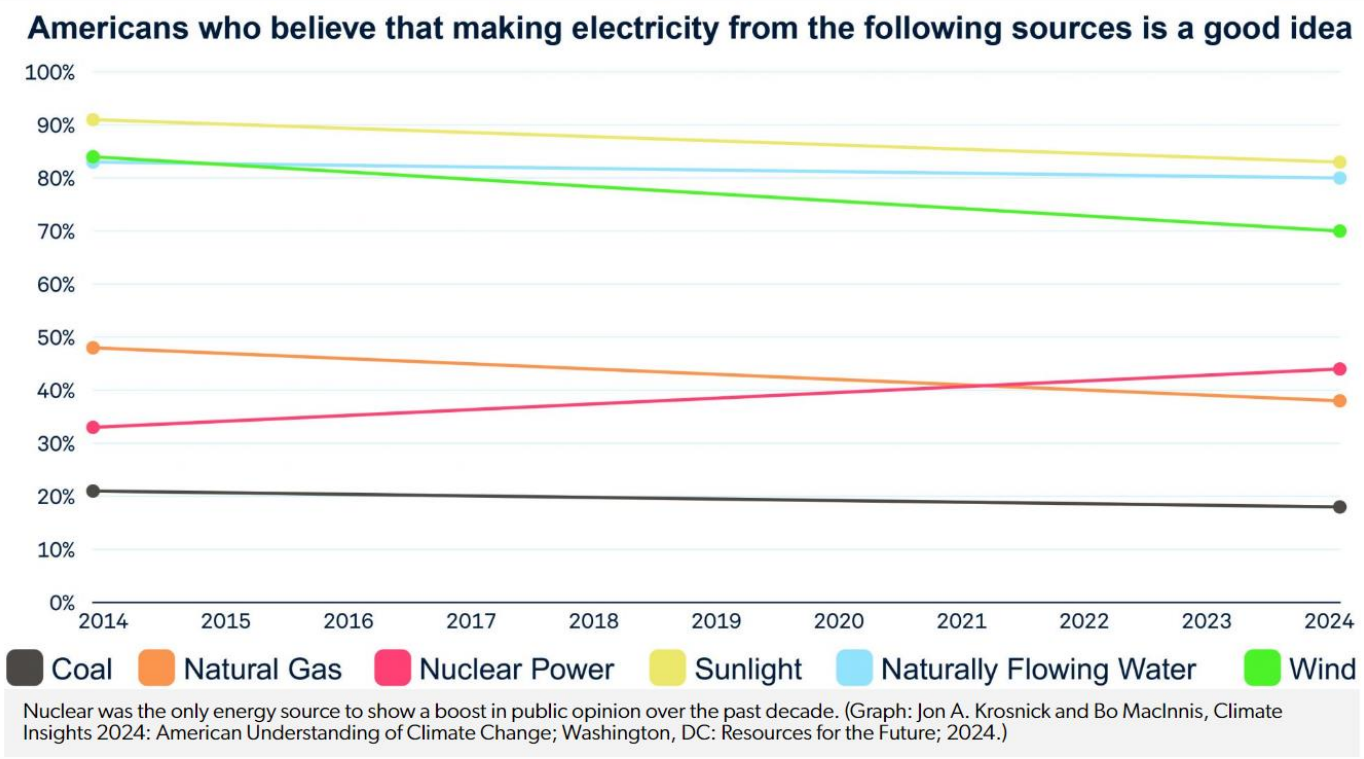
Democrat	61%
Independent	60%
Republican	66%

Top 5 nuclear sentiments[3]
(% agree)

We need a way to produce more and more energy for our economy to keep growing	76%
We need to be building capacity for more energy, not just trying to use less	63%
We need nuclear energy in the mix, along with renewables, if we are to meet our climate goals	60%
Leaving nuclear waste behind is just wrong, however safe it is	59%
We should use advanced nuclear energy to reduce our dependence on other countries	58%

Source: Potential Energy, 2023, https://potentialenergycoalition.org/wp-content/uploads/NewNuclear_Report_May2023.pdf

Growth in Favorability



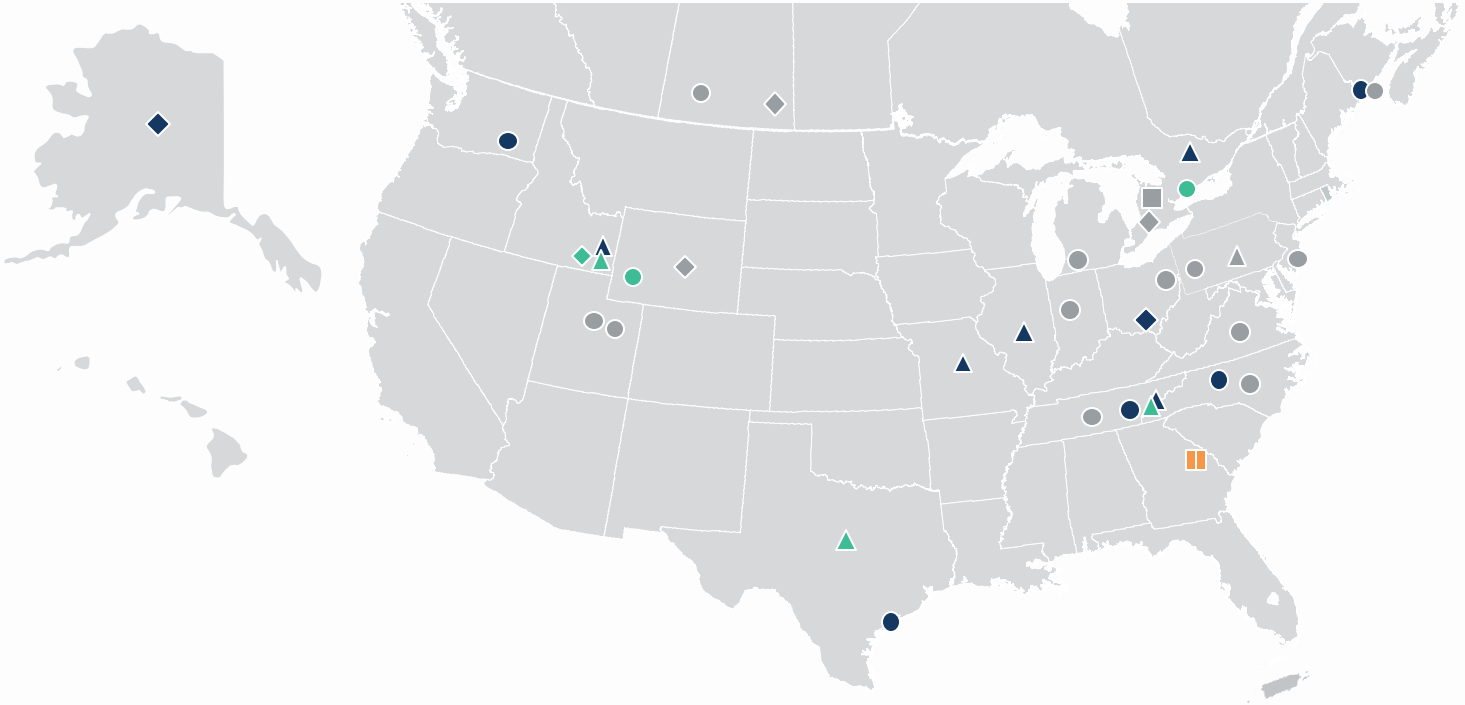
Nuclear was the only energy source to show a boost in public opinion over the past decade. (Graph: Jon A. Krosnick and Bo MacInnis, Climate Insights 2024: American Understanding of Climate Change; Washington, DC: Resources for the Future; 2024.)

https://www.ans.org/news/article-6236/americas-voting-public-shows-inertia-on-climate-change-but-nuclear-support-is-up/

Advanced Nuclear Deployment Plans

Projects that may be in operation by early 2030s

Updated 09/25/2024



Legend

- Considered project
- Planned project
- Under construction
- Operating
- Large (1,000 MWe)
- Small (<300 MWe)
- Micro-reactor (<50 MWe)
- University / Research / Test

TerraPower/GEH – Natrium™ Reactor

Liquid Sodium Fast Reactor (SFR) SMR

- Design
  - 345 MWe; 500 MWe with storage
  - Requires HALEU for metallic fuel
  - High temperatures for expanded non-electricity applications
- Licensing
  - Construction permit application submitted to NRC March 2024
- Project Development
  - ARDP (DOE Award of $2B for first plant and fuel facility)
  - PacifiCorp project broke ground, Kemmerer, WY June 2024
  - PacifiCorp IRP for four more Natrium reactors in early 2030s

Kairos Power – Hermes Demo Reactors

Fluoride Salt-cooled, High Temperature Reactor

- Design
  - Hermes, 35 MWth – will not produce electricity
  - Hermes 2, 35 MWth x2 – will demo electricity production
  - Requires HALEU for TRISO pebble fuel
  - High temperatures for expanded non-electricity applications
- Licensing
  - Hermes – received NRC construction permit Dec. 2023
  - Hermes 2 (2 units) – received NRC construction permit Nov. 2024
- Project Development
  - DOE Risk Reduction Award
  - Hermes and Hermes 2 in East Tennessee (near Oak Ridge)
  - Hermes construction began July 2024
  - Commercial design (140 MWe) expected in early 2030s
  - Google agreement to buy 500 MWe (from 6-7 reactors)

Natura Resources – MSRR at ACU

- Design
  - 1 MWth – research reactor; will not produce electricity
  - Molten Salt coolant
  - Requires HALEU for liquid fuel; dissolved in Flibe salt
  - High temperatures for expanded non-electricity applications
- Licensing
  - MSRR – received NRC construction permit Sept. 2024
  - MSRR – OL application anticipated to NRC in 2025
- Project Development
  - DOE commitment in 2019 to provide fuel and salt for the MSRR
  - Science and Engineering Research Center at Abilene Christian University will house the MSRR
  - Commercial design (100 MWe) to provide reliable energy, medical isotopes, and clean water

Molten Salt Reactor (MSR)

Oklo – Aurora Powerhouse

- Design
  - 15 MWe and 50 MWe
  - Requires HALEU for metallic fuel
  - 10+ years between refueling
  - Pursuing recycling options for fuel
- Licensing
  - Nov. 2024 completed the environmental compliance process addressing the DOE requirements for site characterization at Idaho National Lab
  - COL expected to be submitted to NRC in 2024
- Project Development
  - Demonstration planned at INL in late-2020s
  - Southern Ohio: 30 MWe announced, plan for 1,000+ MWe
  - Data Centers (up to 3,000 MWe): VA, AZ, OH, TX, PA
  - Arizona Community: 75 MWe
  - Permian Basin: 50 MWe

Liquid Sodium Fast Reactor (SFR) Micro-reactor

DoD Pursuit of Micro-Reactors

Movable

Project Pele

RFP (2019) → Operate (2024) → Fleet (TBD)

https://www.cto.mil/pele_eis/

Fixed

e.g., Eielson Air Force Base

RFP (2023) → Construct (2025) → Operate (2027)

https://www.eielson.af.mil/microreactor/

Also, Army, Navy/Marines, Joint Base San Antonio…

QUESTIONS?

By Third Way, GENSLER

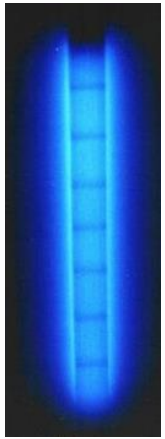
Addressing Waste

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

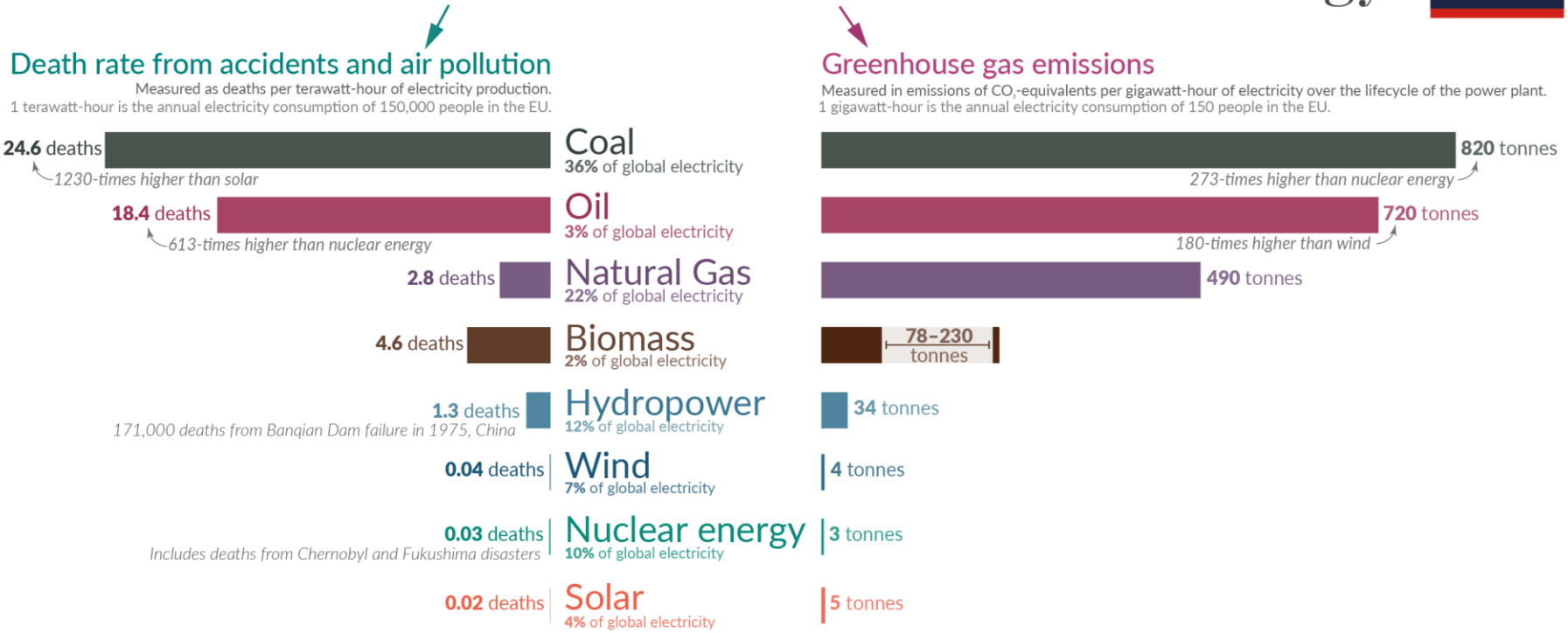
Nuclear Fuel

The Life Cycle of Used Fuel in The U.S.



What are the safest and cleanest sources of energy?

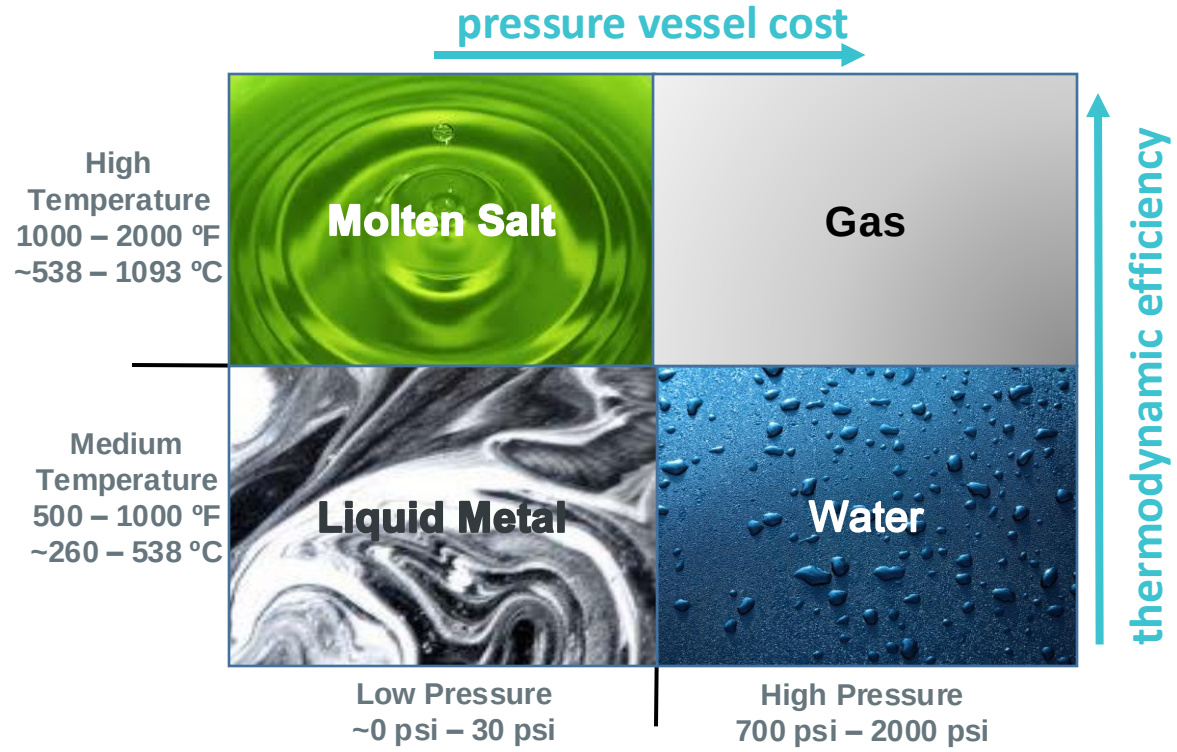
Our World in Data

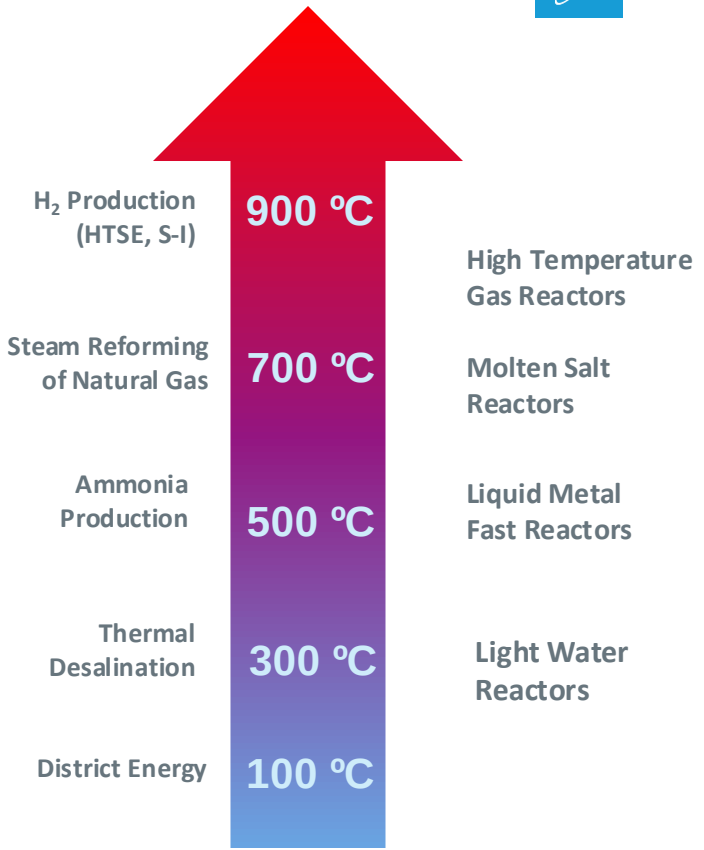


Death rates from fossil fuels and biomass are based on state-of-the art plants with pollution controls in Europe, and are based on older models of the impacts of air pollution on health.
This means these death rates are likely to be very conservative. For further discussion, see our article: OurWorldinData.org/safest-sources-of-energy. Electricity shares are given for 2021.
Data sources: Markandya & Wilkinson (2007); UNSCEAR (2008; 2018); Sovacool et al. (2016); IPCC AR5 (2014); Pehl et al. (2017); Ember Energy (2021).

Source: https://ourworldindata.org/safest-sources-of-energy

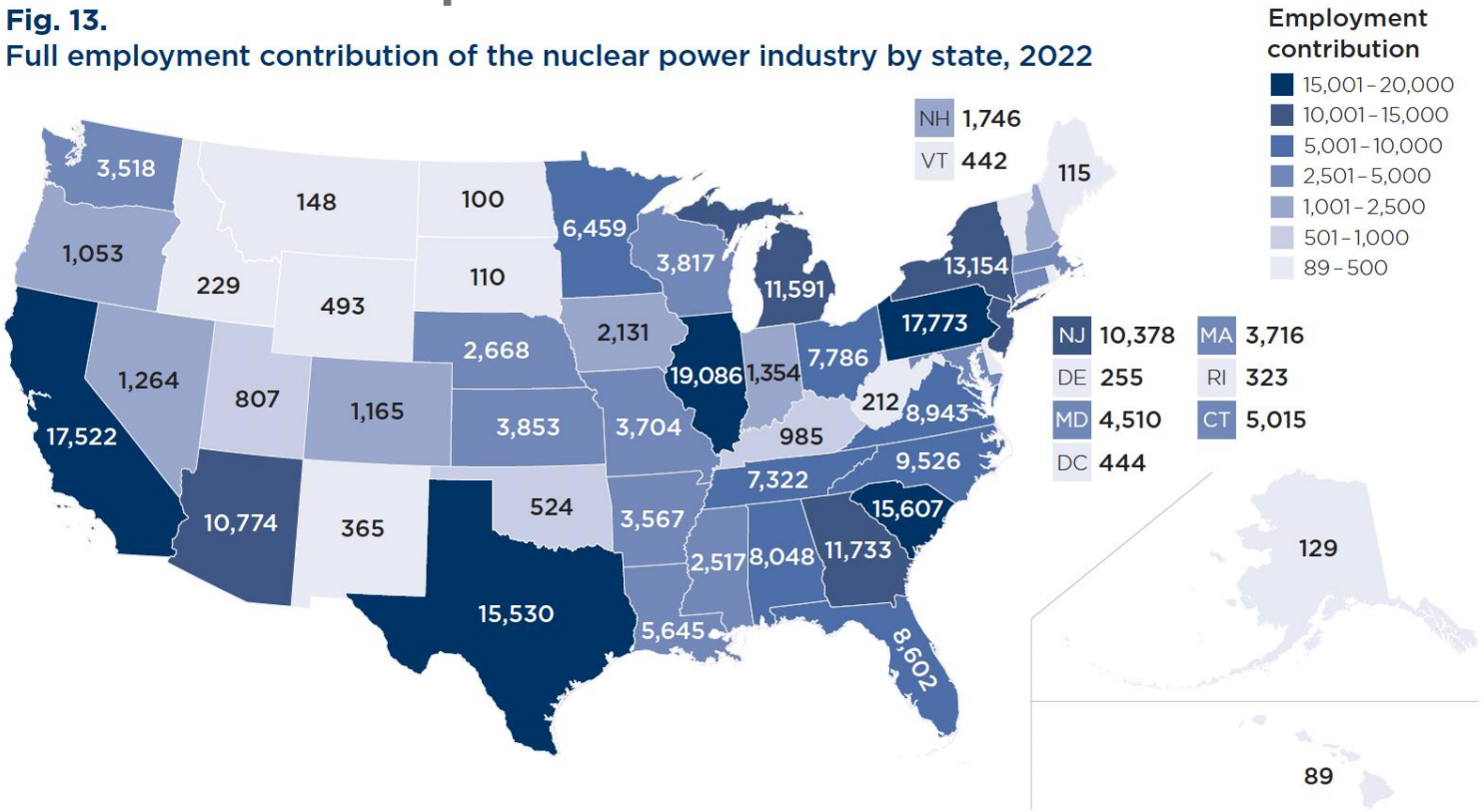
Technology and Temperature





Economic Impacts of Nuclear in the U.S.

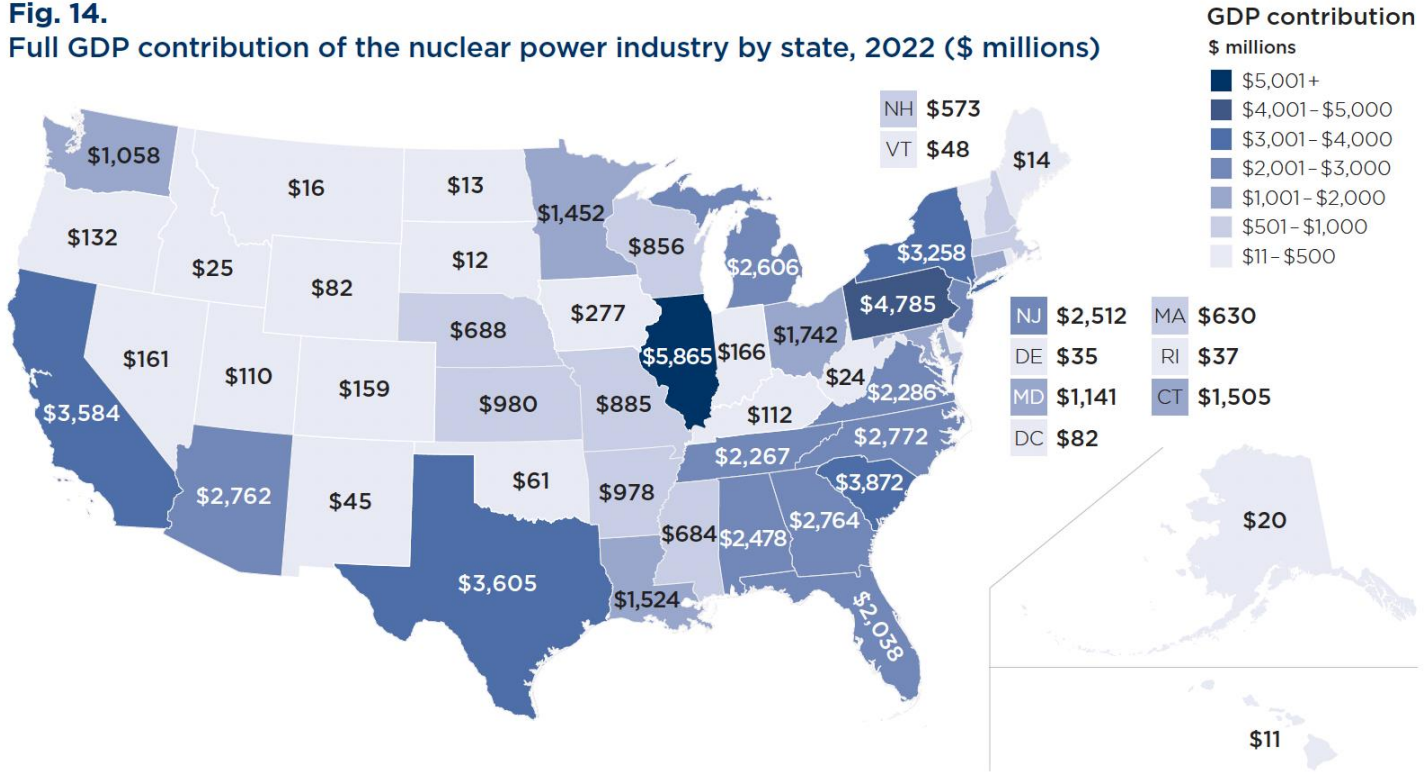
Fig. 13.
Full employment contribution of the nuclear power industry by state, 2022



Source: https://www.oxfordeconomics.com/resource/the-economic-contribution-of-the-us-nuclear-power-industry/

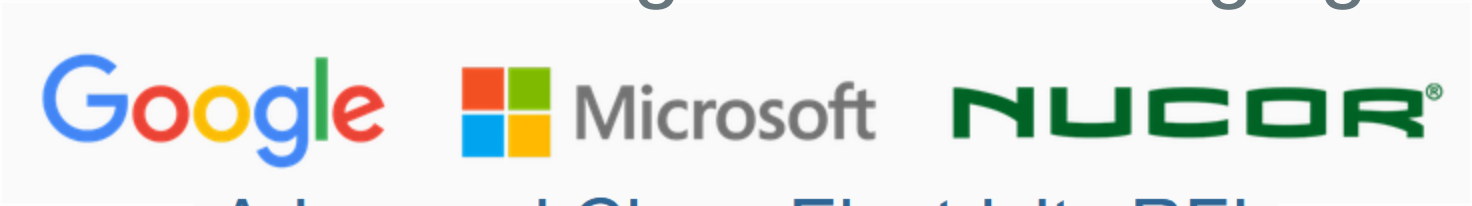
Economic Impacts of Nuclear in the U.S.

Fig. 14.
Full GDP contribution of the nuclear power industry by state, 2022 ($ millions)



Source: https://www.oxfordeconomics.com/resource/the-economic-contribution-of-the-us-nuclear-power-industry/

Private Financing Models Emerging



Advanced Clean Electricity RFI

Project delivery framework:

- offtake agreements for technologies early on the cost curve
- clear customer voice to policymakers on long-term ecosystem improvements
- new enabling tariff structures in partnership with energy providers and utilities

Criteria will consider (among other factors):

- operational around 2030
- leveraging the ability to produce hourly energy attribute certificates,
- project capacity of greater than 50 MWe (open to aggregating projects)

https://www.advancedcleanelectricity.com

