

Nuclear Energy

EES 2110

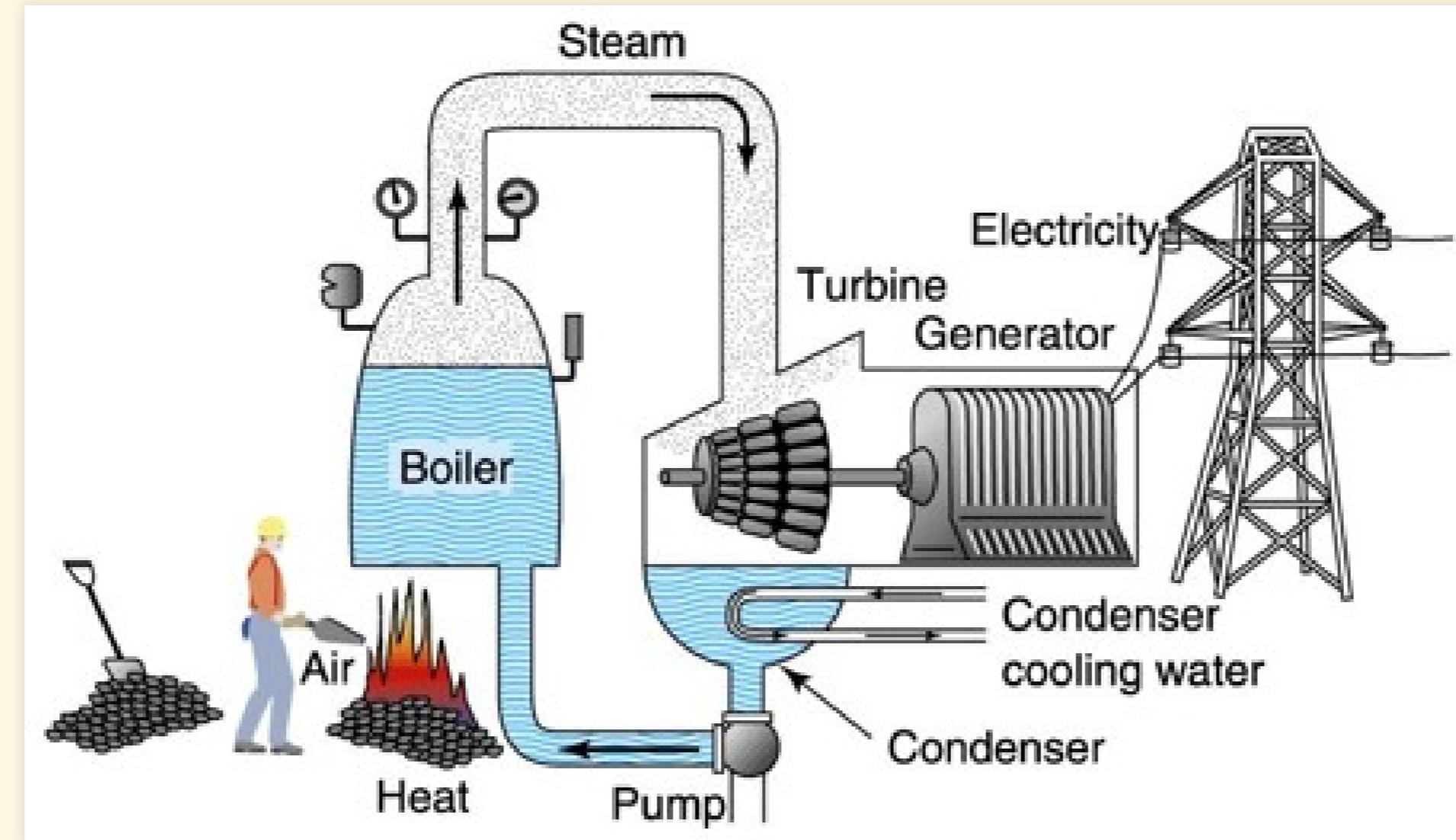
Introduction to Climate Change

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Class #33: Monday, April 03 2023

Thermal Electricity Generation

Thermal Electricity Generation



- Coal, nuclear:
 - Heat boils water
 - Steam spins turbine
 - Turbine turns generator, makes electricity
- Thermodynamics limits efficiency
 - Coal plant: 33% efficient
 - Nuclear plant: 33% efficient
 - Advanced gas plant: 43% efficient

Kingston Fossil Plant (TN)



- 1450 megawatts
- 14,000 tons of coal per day (140 train cars)

Fuel Requirements for a 1000 MW Plant

- Coal: 10,000 tons/day (100 rail cars)
- Diesel: 40,000 barrel/day (1 tanker/week)
- Gas: 240 million cubic feet/day
- Nuclear: 3 kg/day of ^{235}U

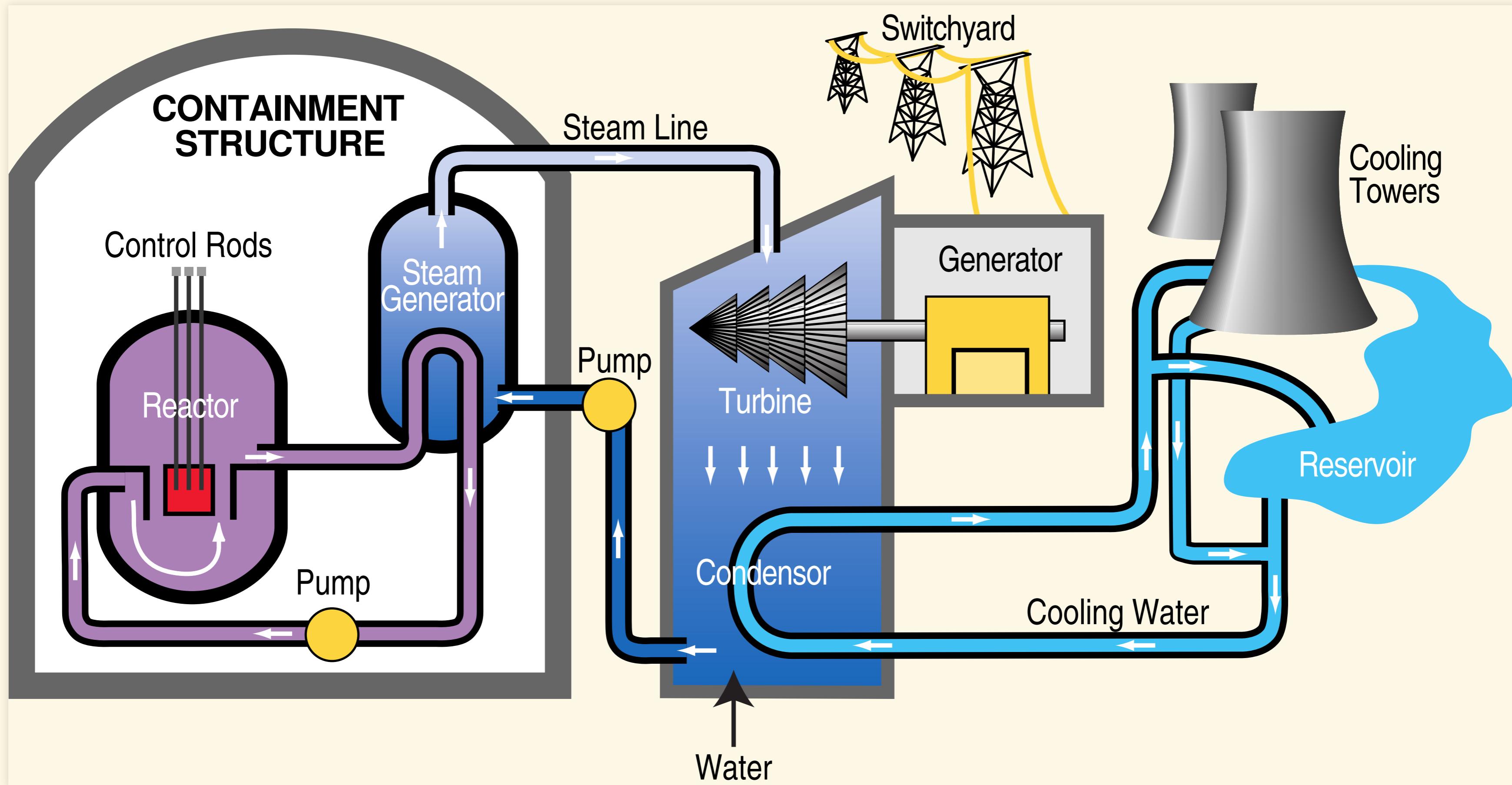


Watts Bar Nuclear Plant



- 2300 megawatts (two units)
- 2.3 tons enriched uranium per year

Nuclear Reactor



Getting Energy from Nuclear Fission

- Nuclear chain reactions produce lots of energy
- Natural uranium:
 - ^{238}U (99.3%): won't fission
 - ^{235}U (0.7%): will fission
 - Must enrich natural uranium:
 - Reactor fuel: 3–5% ^{235}U
 - Bomb: >80% ^{235}U
 - 1 ounce enriched uranium produces as much heat as 2–3 tons coal
- Other fissionable substances:
 - ^{239}Pu (plutonium)
 - Can be produced by hitting ^{238}U with a neutron
 - Byproduct of uranium chain reactions
 - **Breeder reactors**
 - ^{233}U
 - Produced by hitting ^{232}Th with a neutron
 - **Thorium reactors**

Feasibility of Nuclear Power

Feasibility of Nuclear Power

- Nuclear is much safer than coal or gas
 - Properly operating coal power plants in the U.S. alone kill more people in one month than all the nuclear reactor accidents in history in the entire world.
- The biggest challenges are:
 - Irrational public fear
 - Cost
 - In early 2000s, forecast of “nuclear renaissance”
 - Costs of natural gas, wind, and solar fell much faster than anyone imagined
 - New nuclear plants went way over-budget, behind schedule
 - Investor fears:
 - Costs of nuclear much less predictable than other technologies
 - Accidents are far more costly than other technologies

Industry View

*Exelon, the nation's biggest nuclear utility, with 17 plants, estimates that new nuclear plants are **more expensive than any other energy source** except [solar] photovoltaic.*

—Washington Post, 3/16/2011

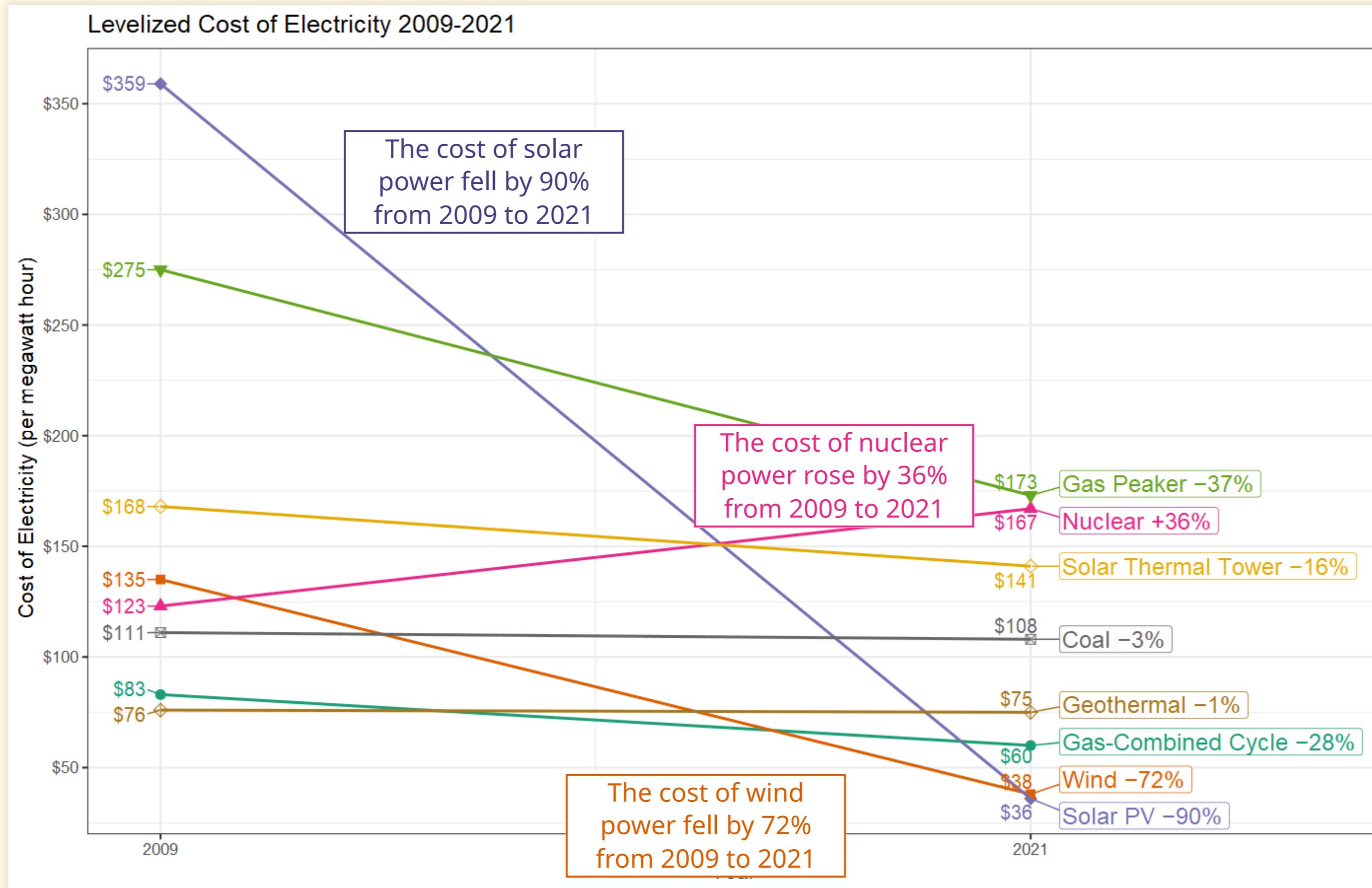
Investor View

*Wall Street learned [from Three-Mile Island] that a group of licensed operators no worse than any other could transform a **billion-dollar asset** into a **two billion dollar clean-up** in ninety minutes*

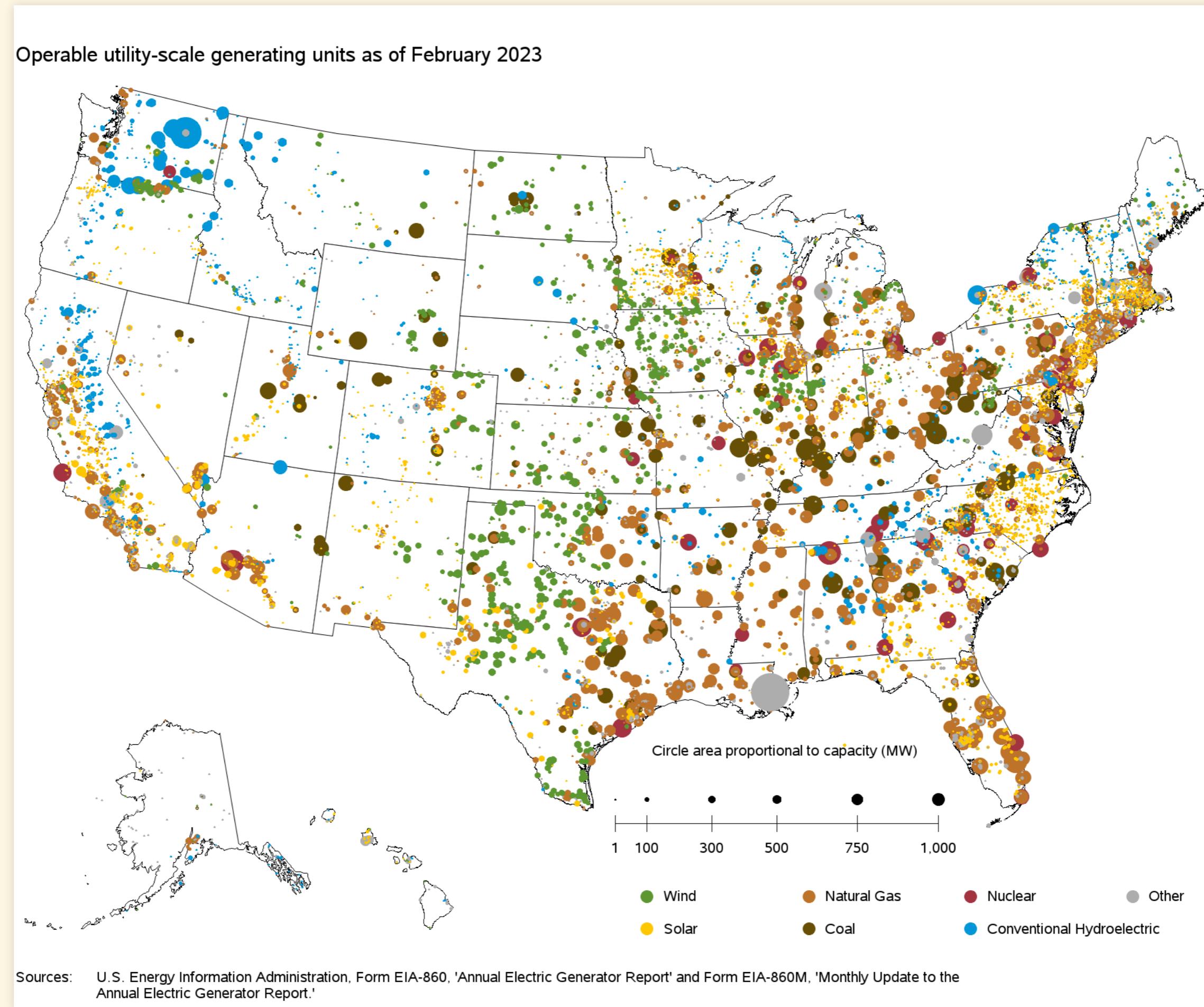
—Peter A. Bradford,
Former Commissioner,
Nuclear Regulatory Commission Senate Testimony
3/24/2009

Recent Trends in Nuclear

Recent Trends

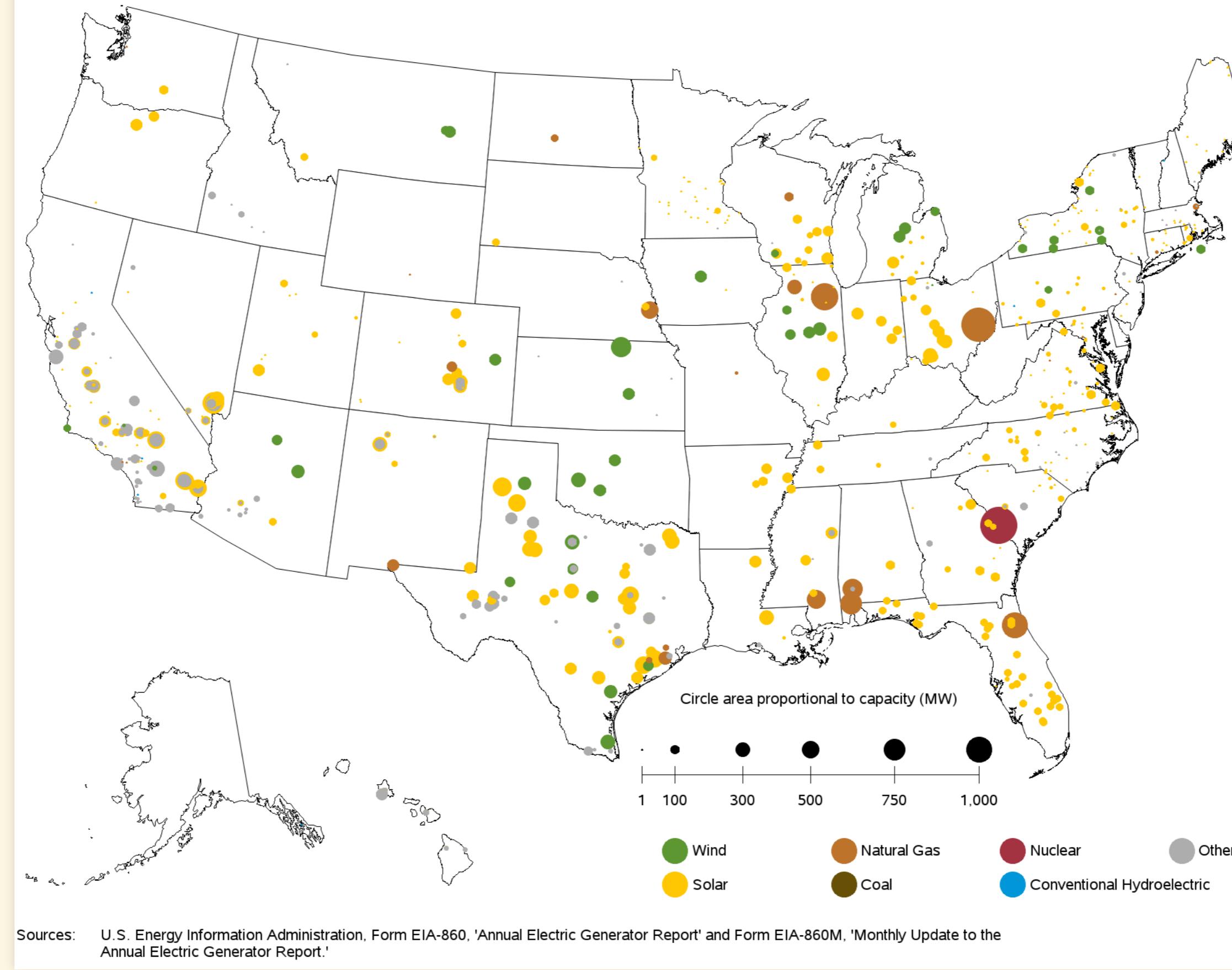


Current Power Plants



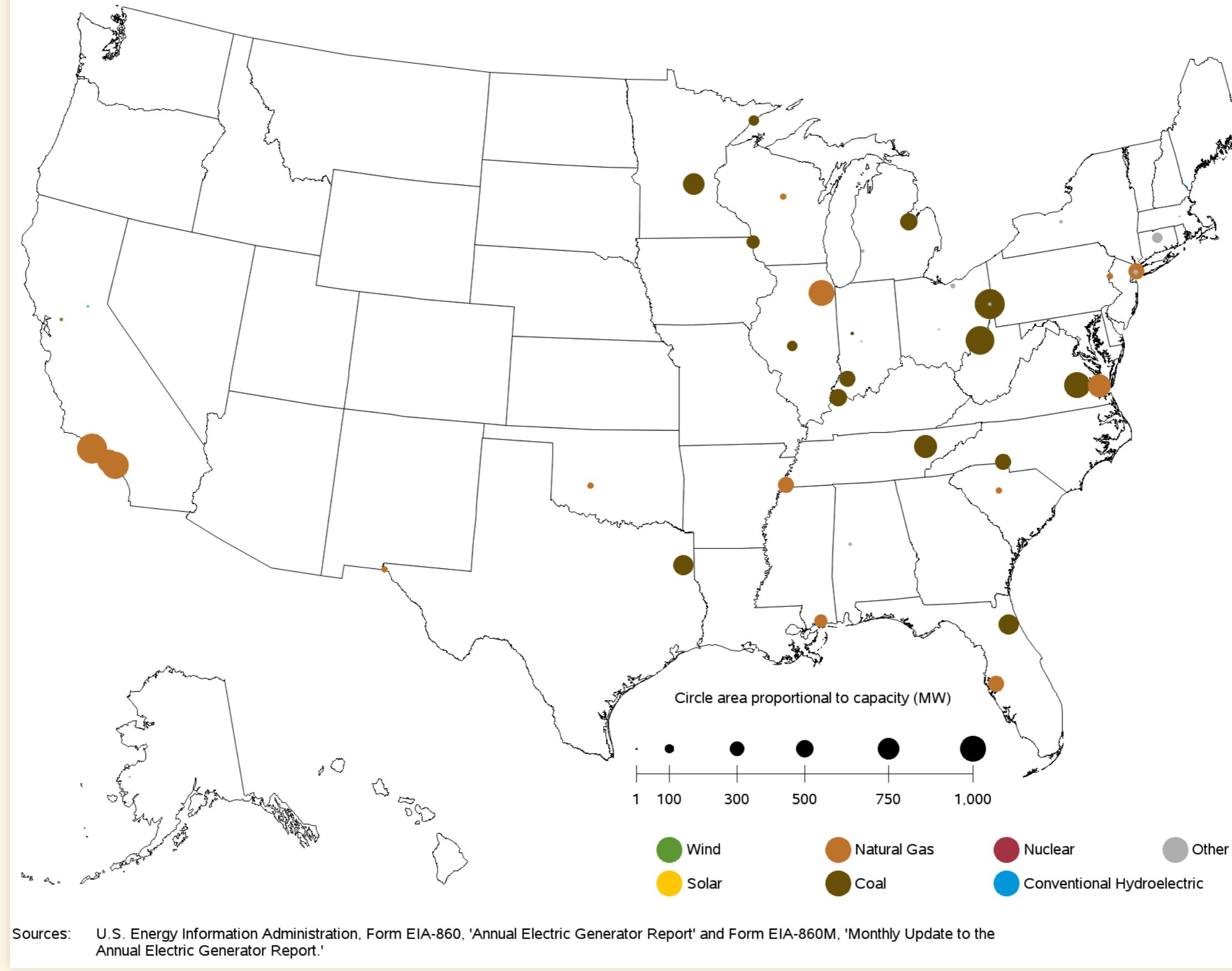
New Power Plants for 2023–2024

Figure 6.1.C. Utility-Scale Generating Units Planned to Come Online from February 2023 to January 2024

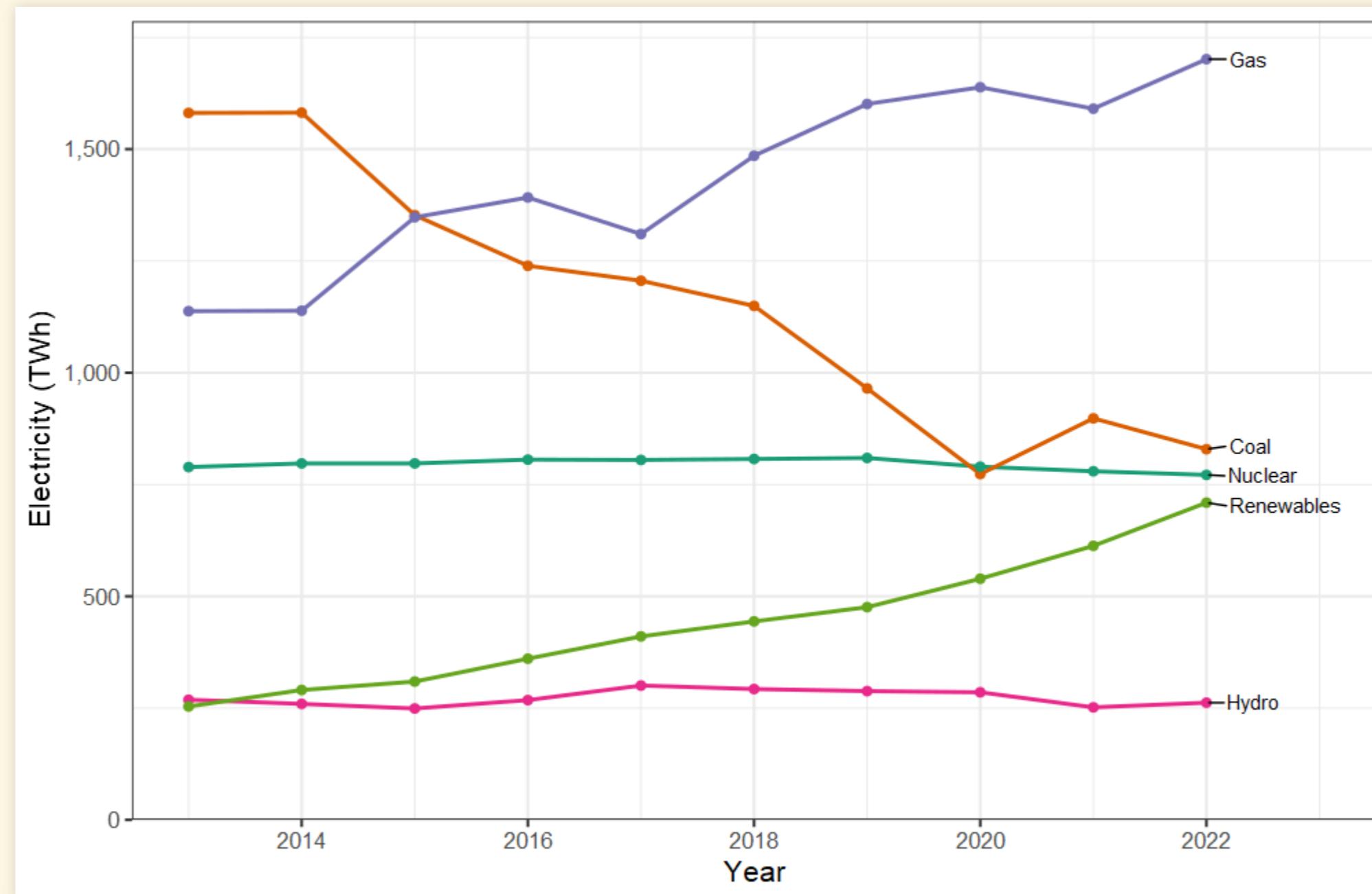


Power Plants Retiring in 2023–2024

Figure 6.1.D. Utility-Scale Generating Units Planned to Retire from February 2023 to January 2024



Trends in Electricity



Growth Rates

Coal	Gas	Nuclear	Hydro	Renewables
-8.1%	4.5%	-0.2%	0.3%	11.0%

Promise for Nuclear

Promise for Nuclear

- China and India are investing heavily in nuclear:
 - 22 reactors under construction in China, 8 in India
- Private sector is investing heavily:
 - 30 research and development projects
 - 2 operating in China
 - 4 under construction (China (2), Russia, Argentina)
 - 2 licensed in USA and Korea
 - 3 licence applications under review (USA (2), UK, Canada, Japan)
 - \\$1.3 billion in private investment, \\$4 billion US government funds
 - Interest in standardized small modular reactors (SMR)
 - Intrinsically safe
 - Benefits of mass production: learning, economies of scale
 - Many sites don't need 1000–2000 megawatts

Challenges for Nuclear

- Currently nuclear is very expensive
 - French Flamanville 3 reactor:
 - Started construction 2007
 - Planned launch: 2012
 - Budget: \$3.5 billion
 - Still not completed (expected 2024)
 - More than 10 years late
 - Current budget: \$14 billion
 - 4 times original
- But as renewables become a greater fraction of all power, intermittency becomes a greater, more expensive challenge.
 - Cost of nuclear vs. cost of batteries
 - Potential for standardized reactor design to cut costs
- Fear is a great challenge.



