

# Nuclear Energy

EES 3310/5310

Global Climate Change

Jonathan Gilligan

Class #35: Friday, April 15 2022

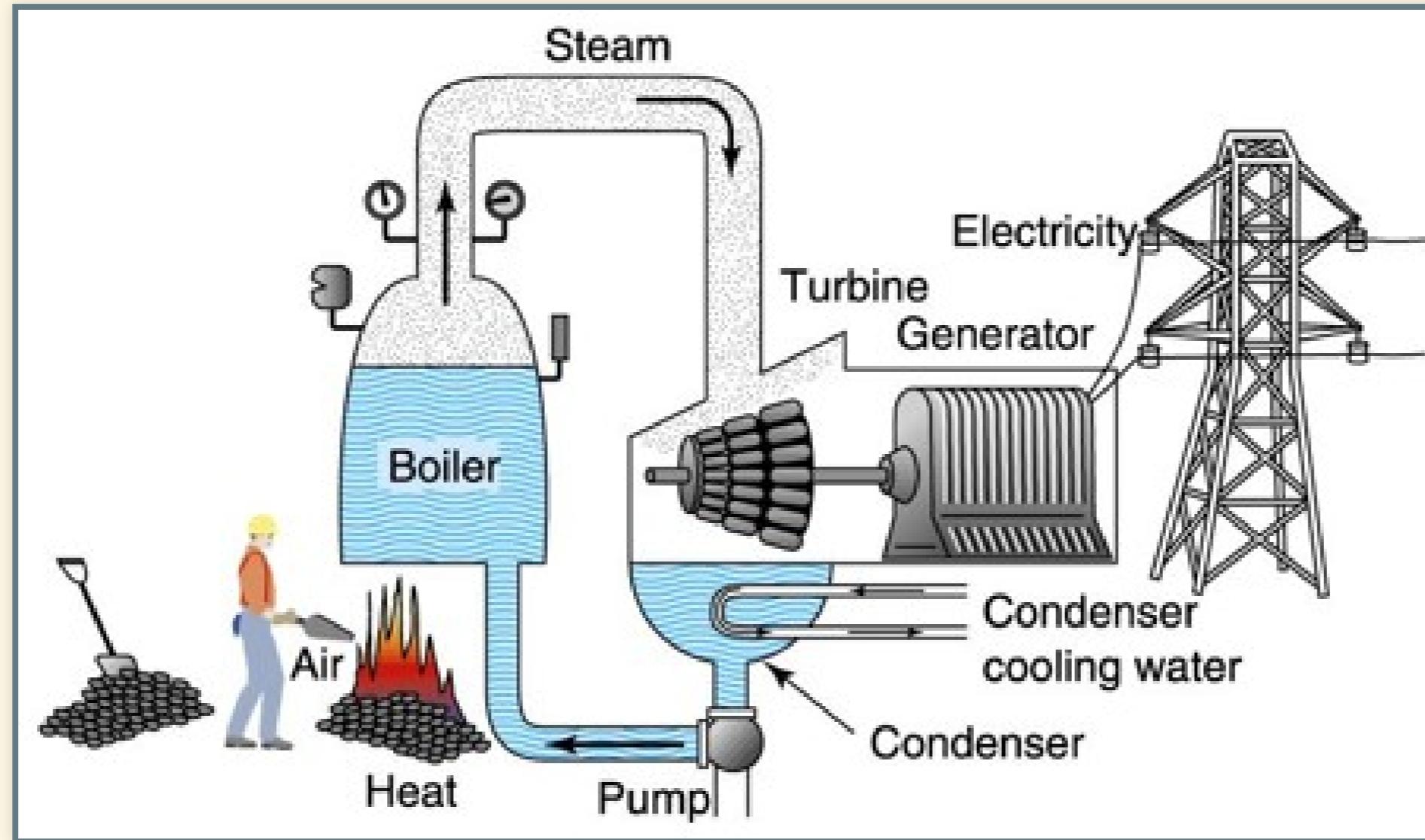
Preparing for Lab on Monday April 18

# Preparing for Lab on Monday April 18

- Be sure to read through the assignment before coming to lab  
[https://ees3310.jgilligan.org/lab\\_docs/lab\\_12\\_preparation/](https://ees3310.jgilligan.org/lab_docs/lab_12_preparation/)
- Do the exercises to practice calculations we'll do in lab
  - You don't need to turn this in.

# 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  $^{235}\text{U}$

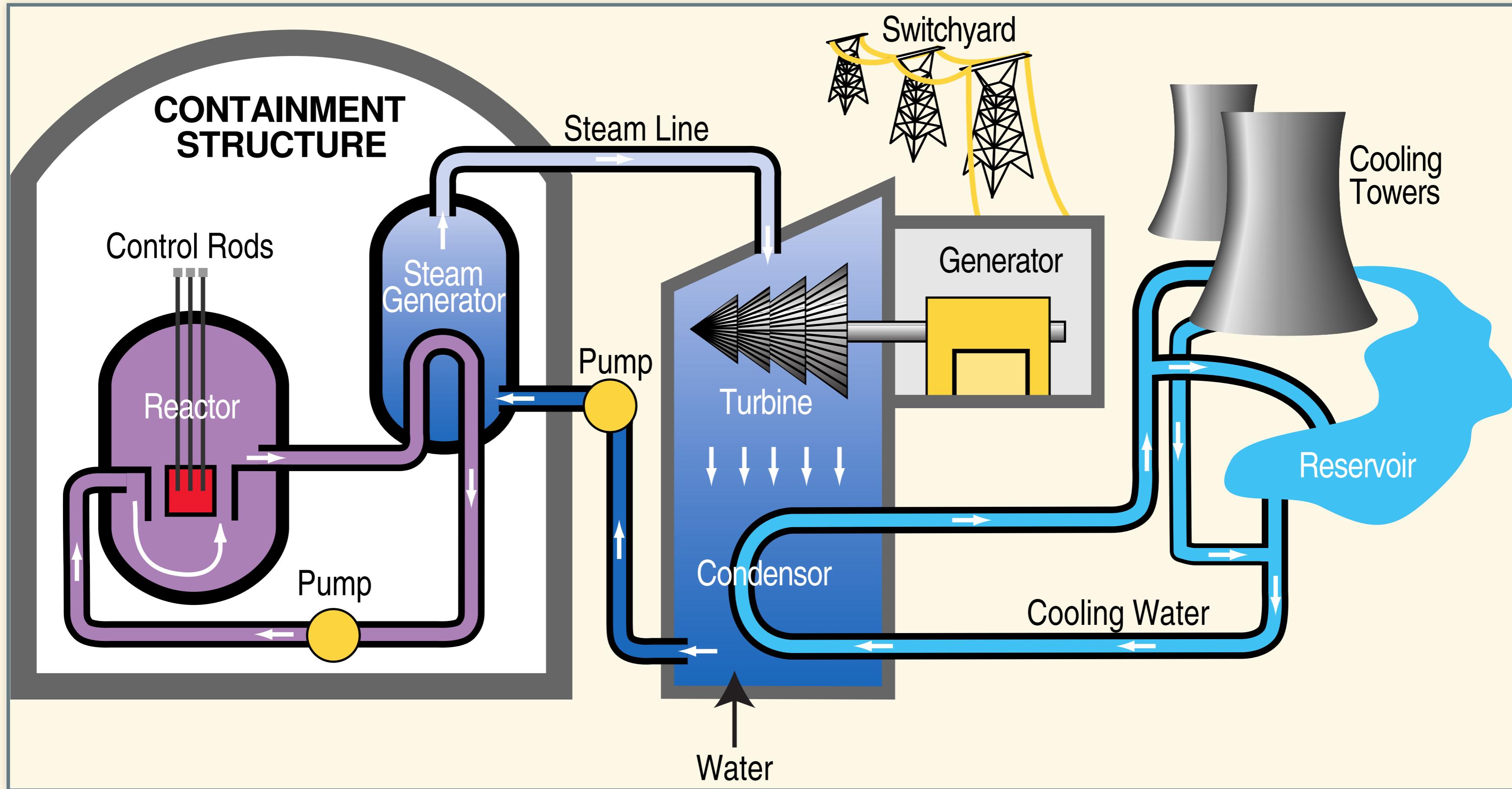


# Watts Bar Nuclear Plant



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

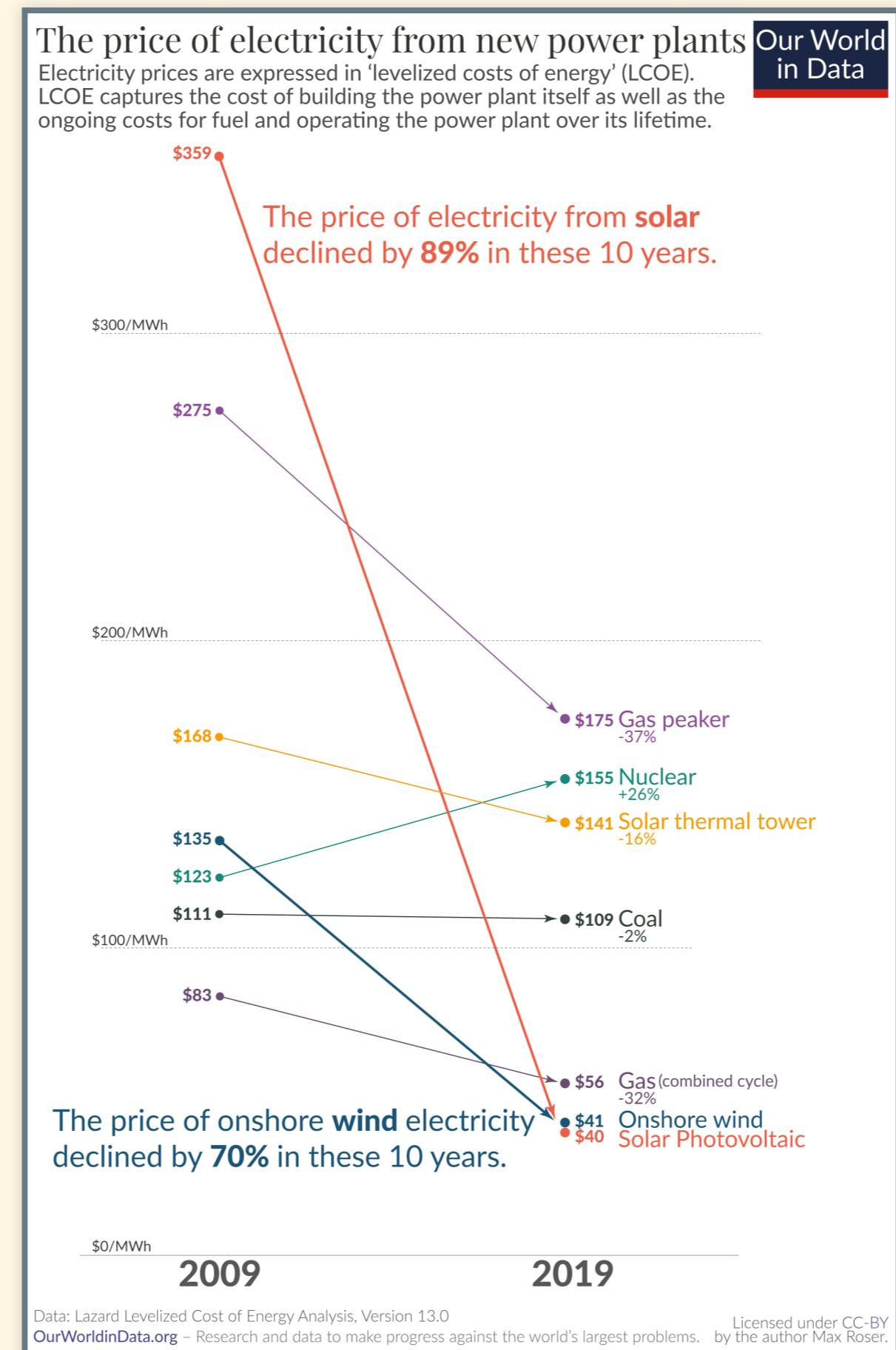
# Investor View

*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*

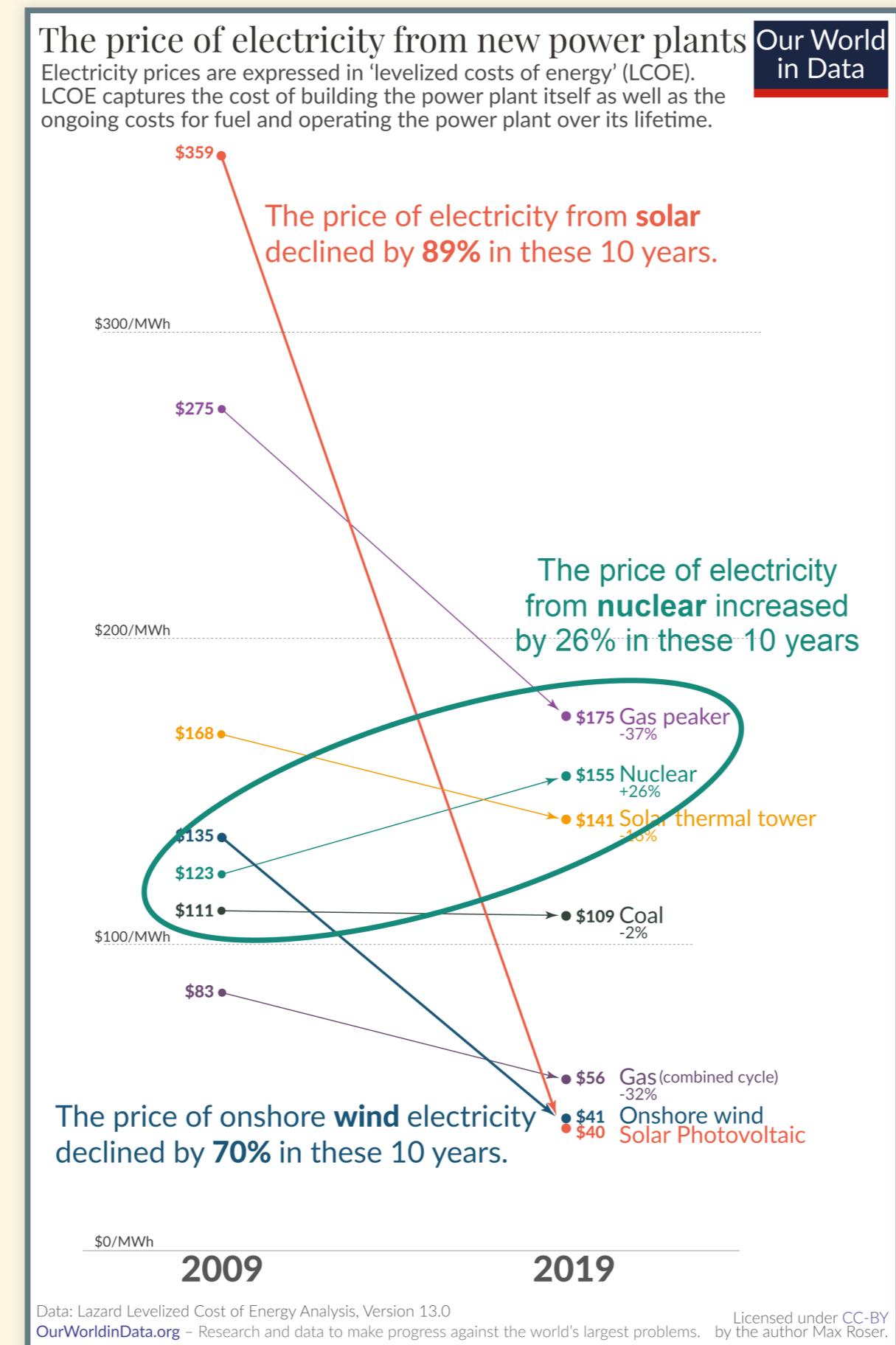
*—Peter A. Bradford,  
Former Commissioner,  
Nuclear Regulatory Commission Senate Testimony  
3/24/2009*

# Recent Trends in Nuclear

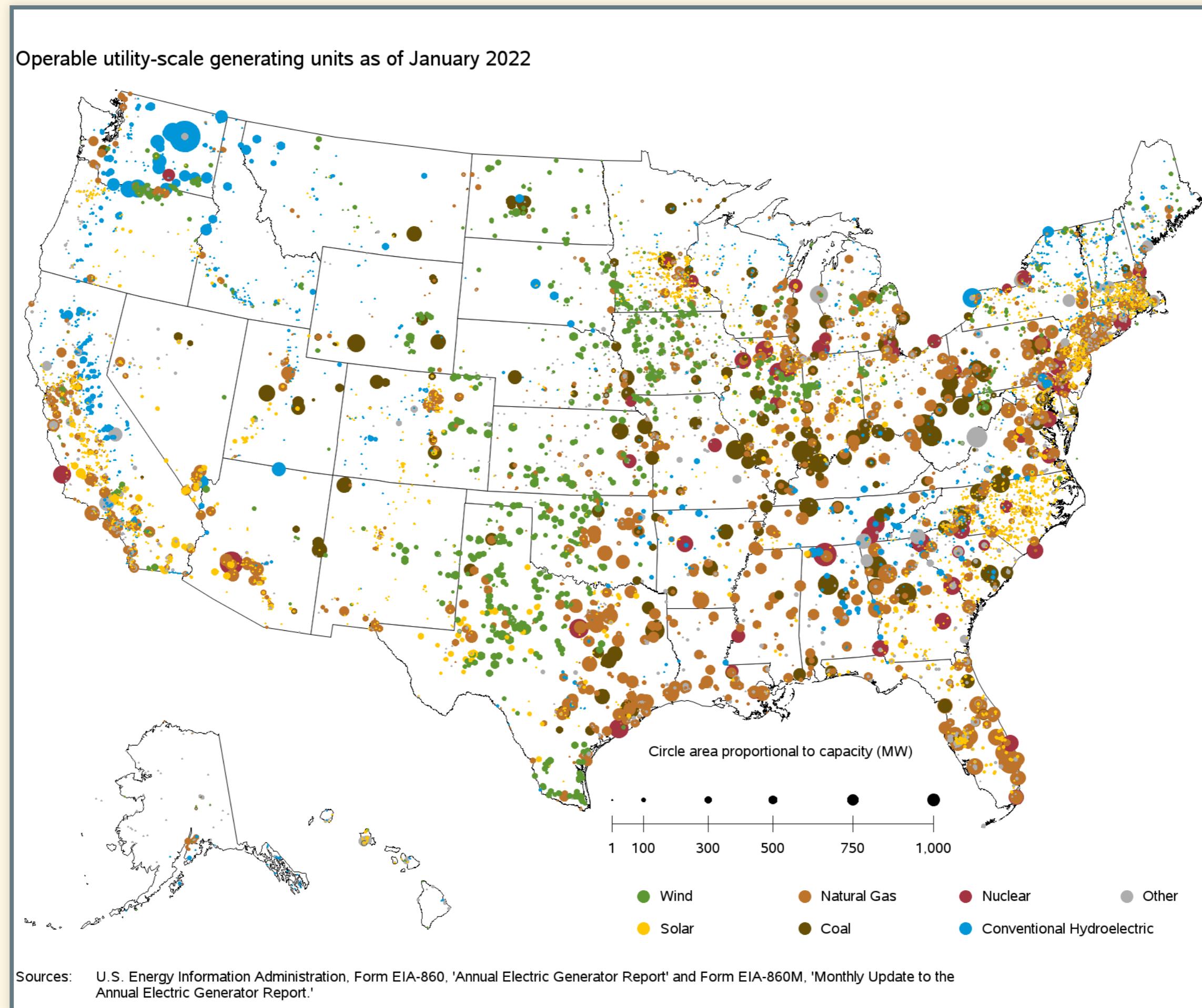
# Recent Trends



# Recent Trends

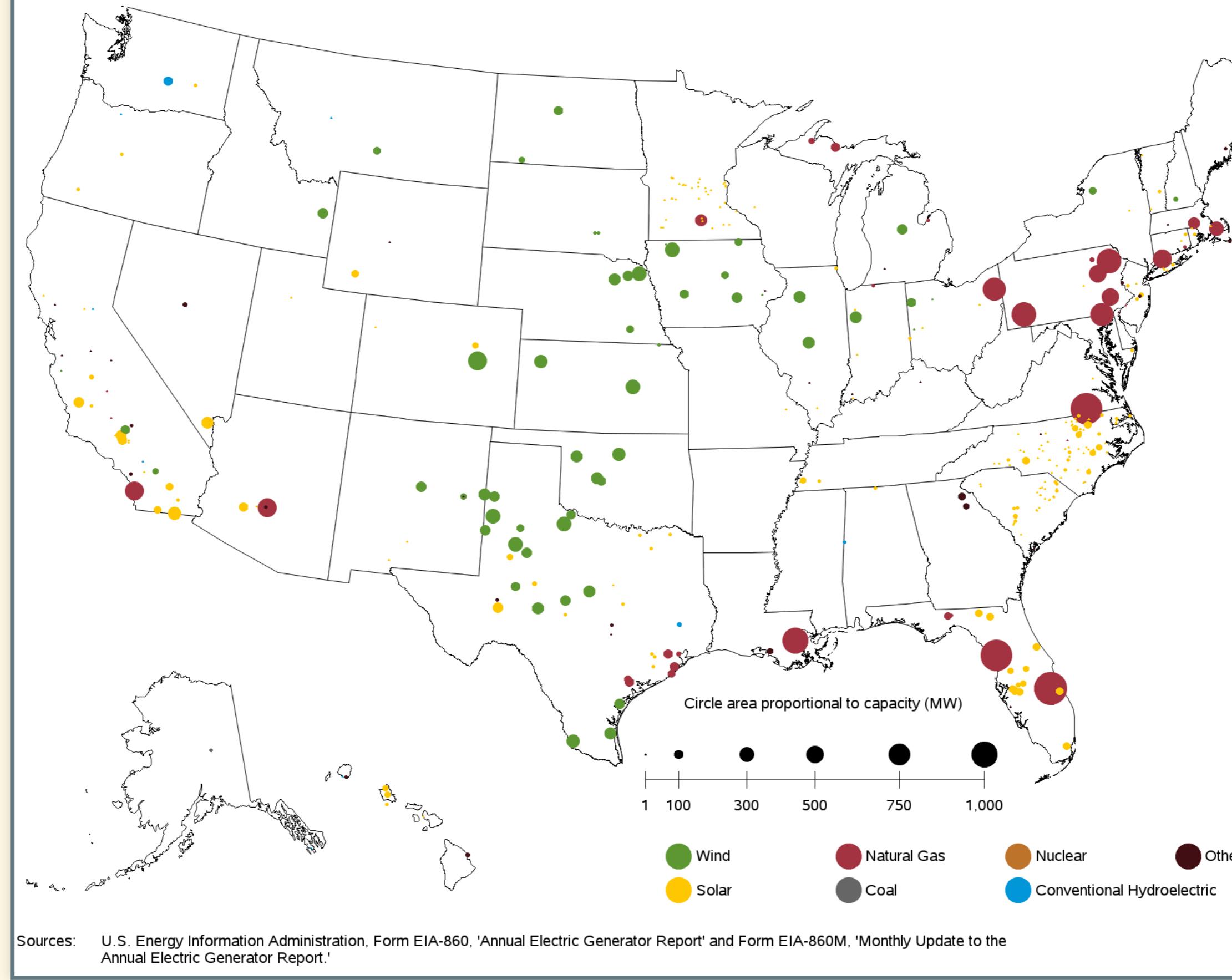


# Current Power Plants

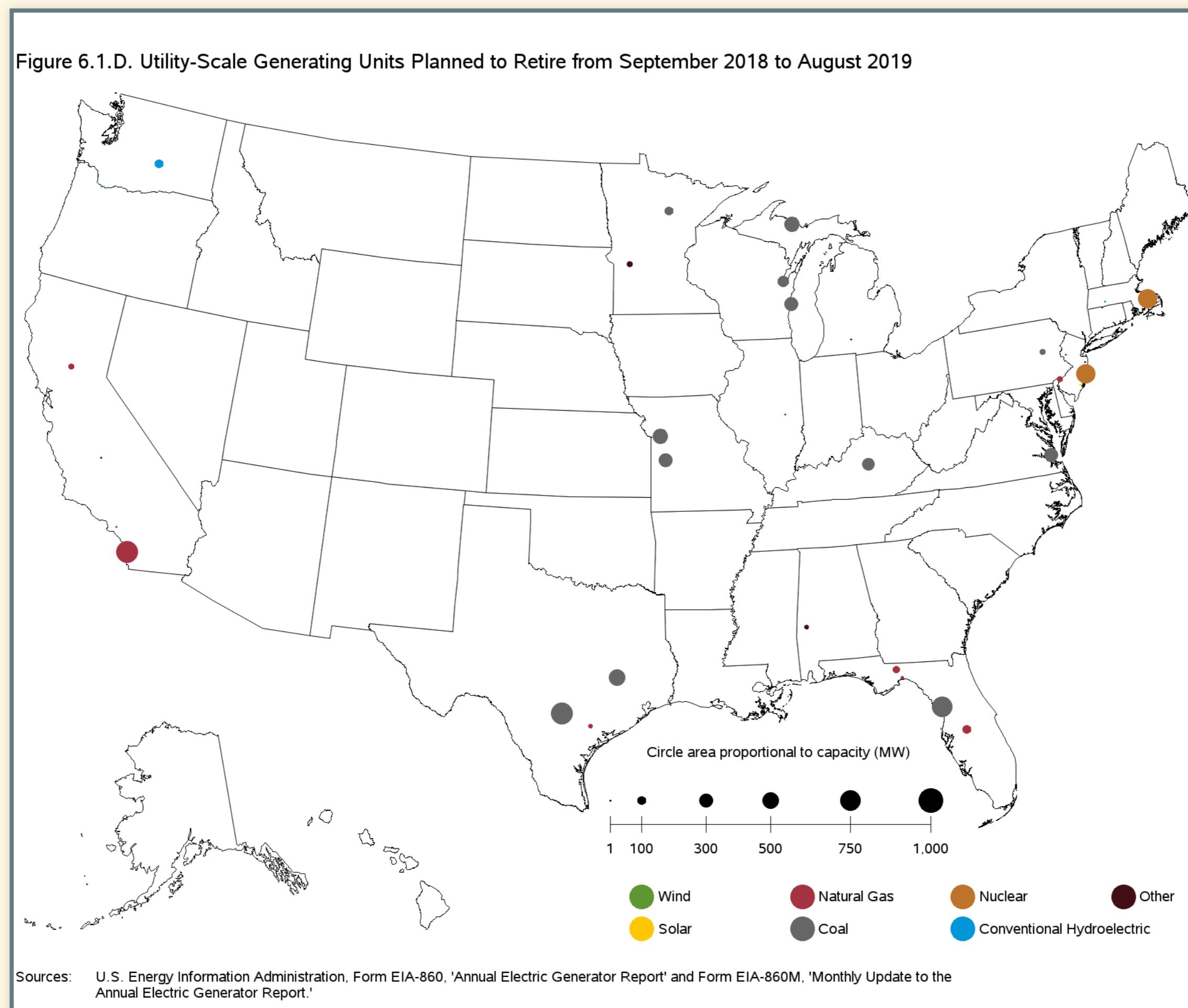


# New Power Plants for 2018–2019

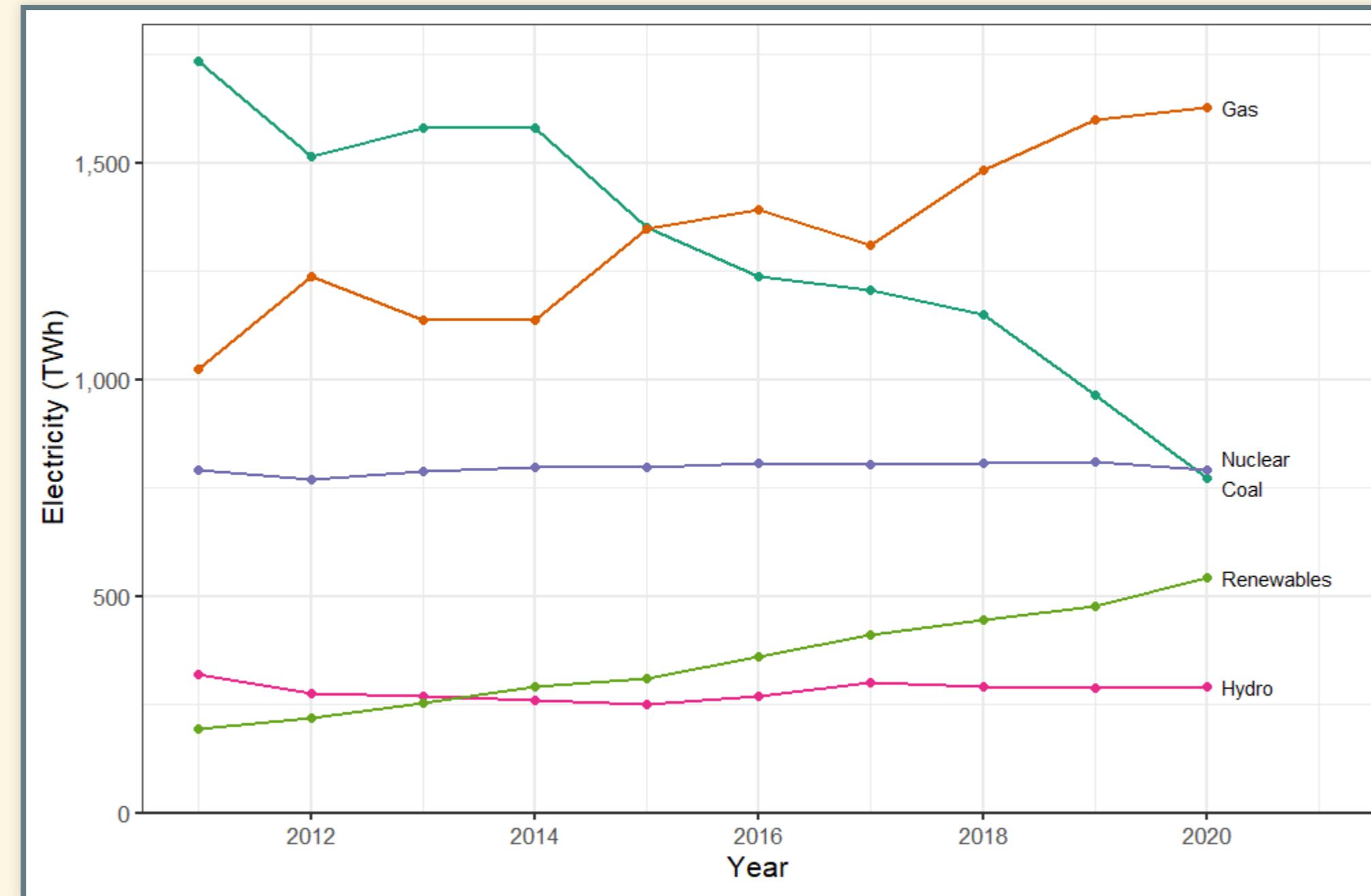
Figure 6.1.C. Utility-Scale Generating Units Planned to Come Online from September 2018 to August 2019



# Power Plants Retiring in 2018–2019



# Trends in Electricity



## Growth Rates

Coal	Gas	Nuclear	Hydro	Renewables
-7.8%	4.7%	0.3%	0.2%	11.3%

# Promise for Nuclear

# Promise for Nuclear

- China, Russia, and India are investing heavily in nuclear:
  - 19 reactors under construction in China, 7 in Russia, 6 in India
- Private sector is investing heavily:
  - 30 research and development projects
  - \$1.3 billion in private investment
  - TerraPower (founded by Bill Gates)
  - 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: \$4 billion
    - Now estimated to launch 2022
      - 10 years late
    - Current budget: \$20 billion
      - 5 times original
- But as renewables become a greater fraction of all power, intermittency becomes a greater, more expensive challenge.
- Fear is a great challenge.

