Nuclear Energy

EES 3310/5310

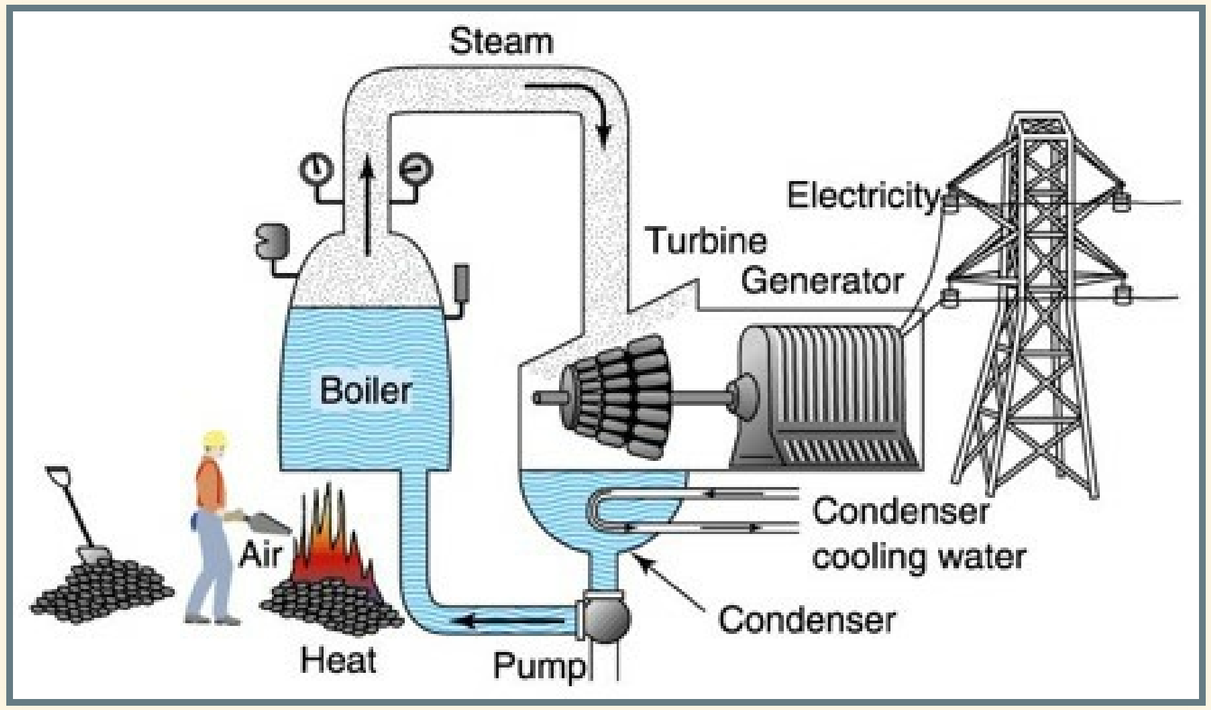
Global Climate Change

Jonathan Gilligan

Class #35: Monday, Nov. 12 2018

Moment of Silence

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)

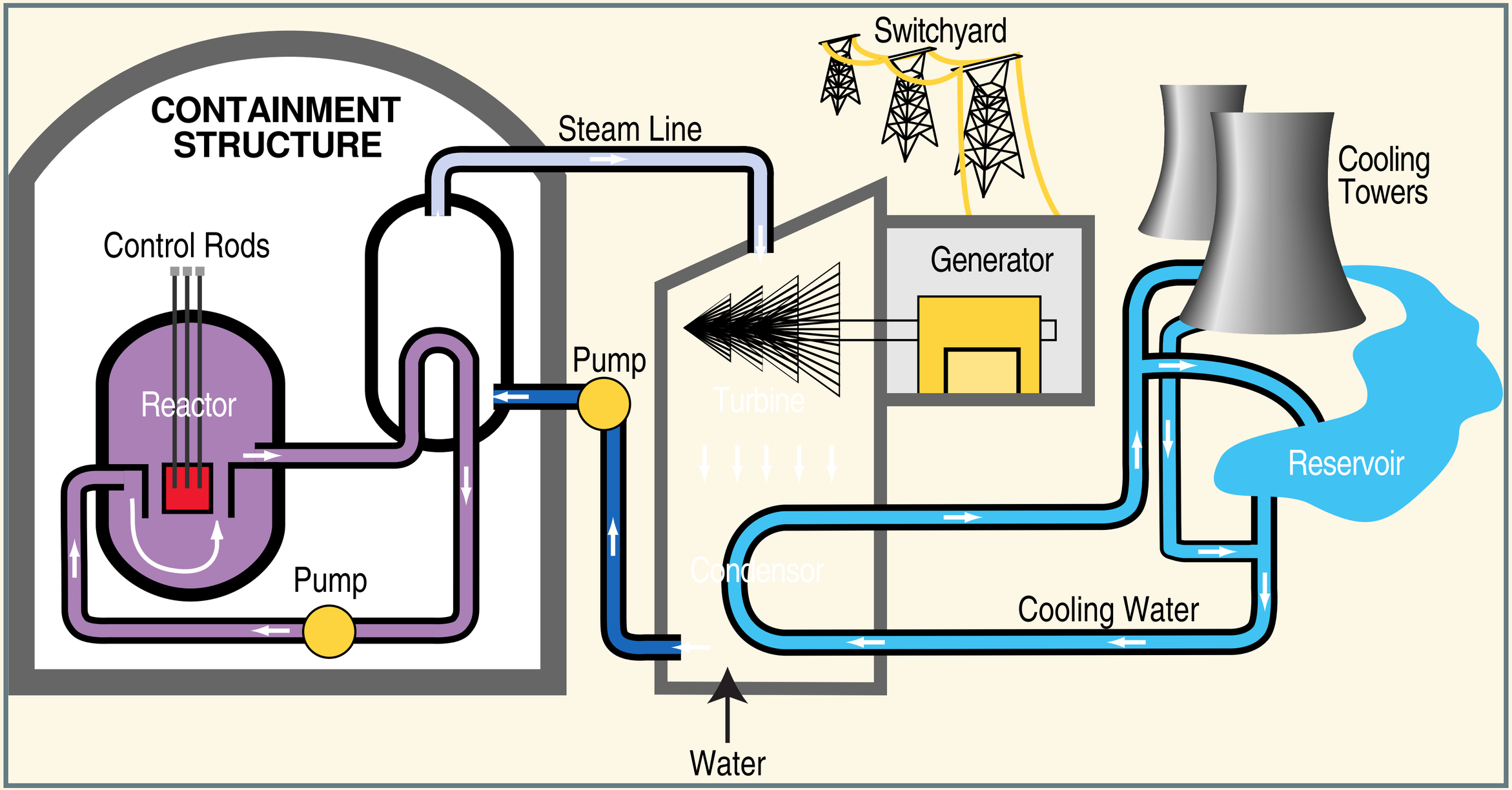
Fuel Requirements for a 1000 MW Plant

- 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

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

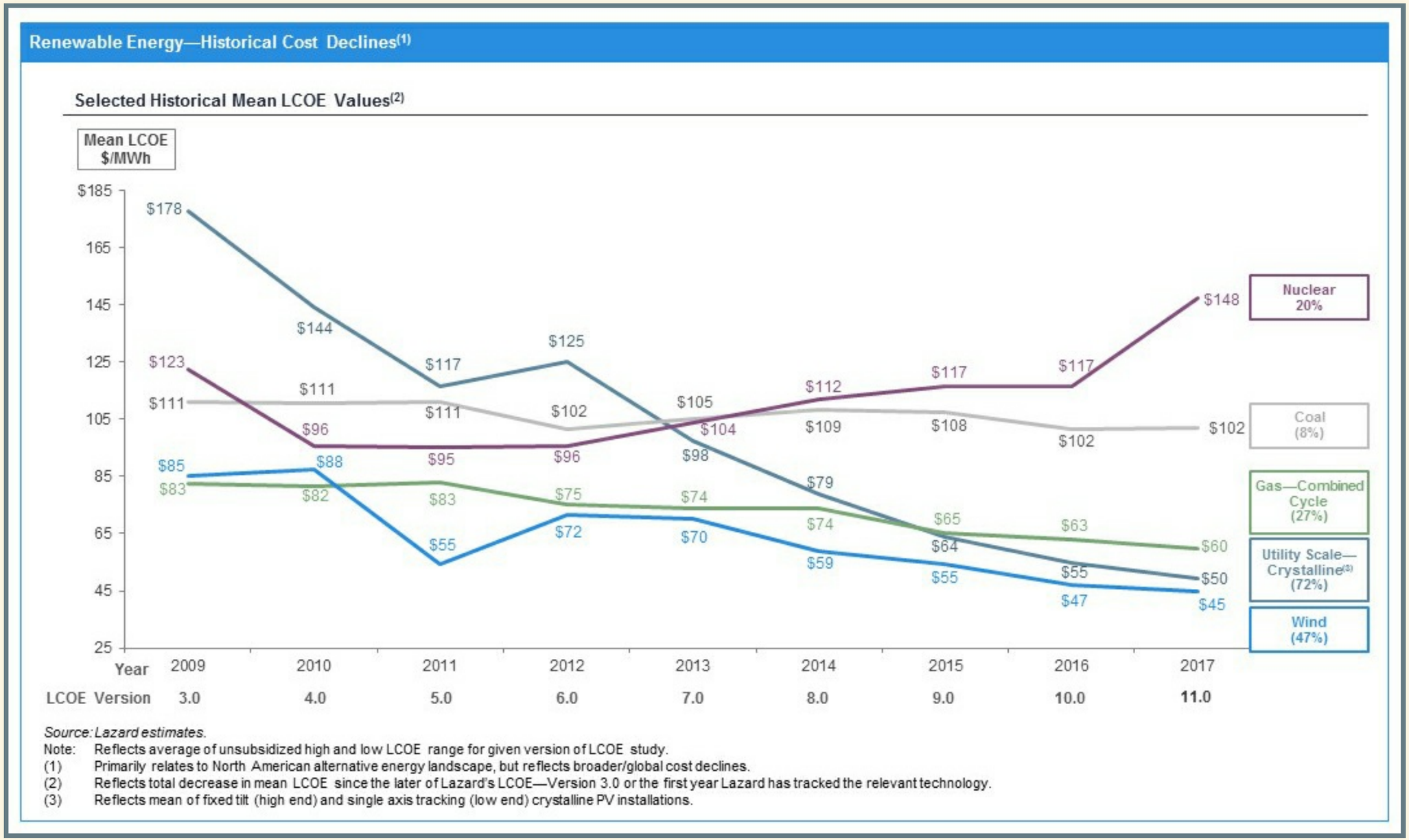
Investor View

*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

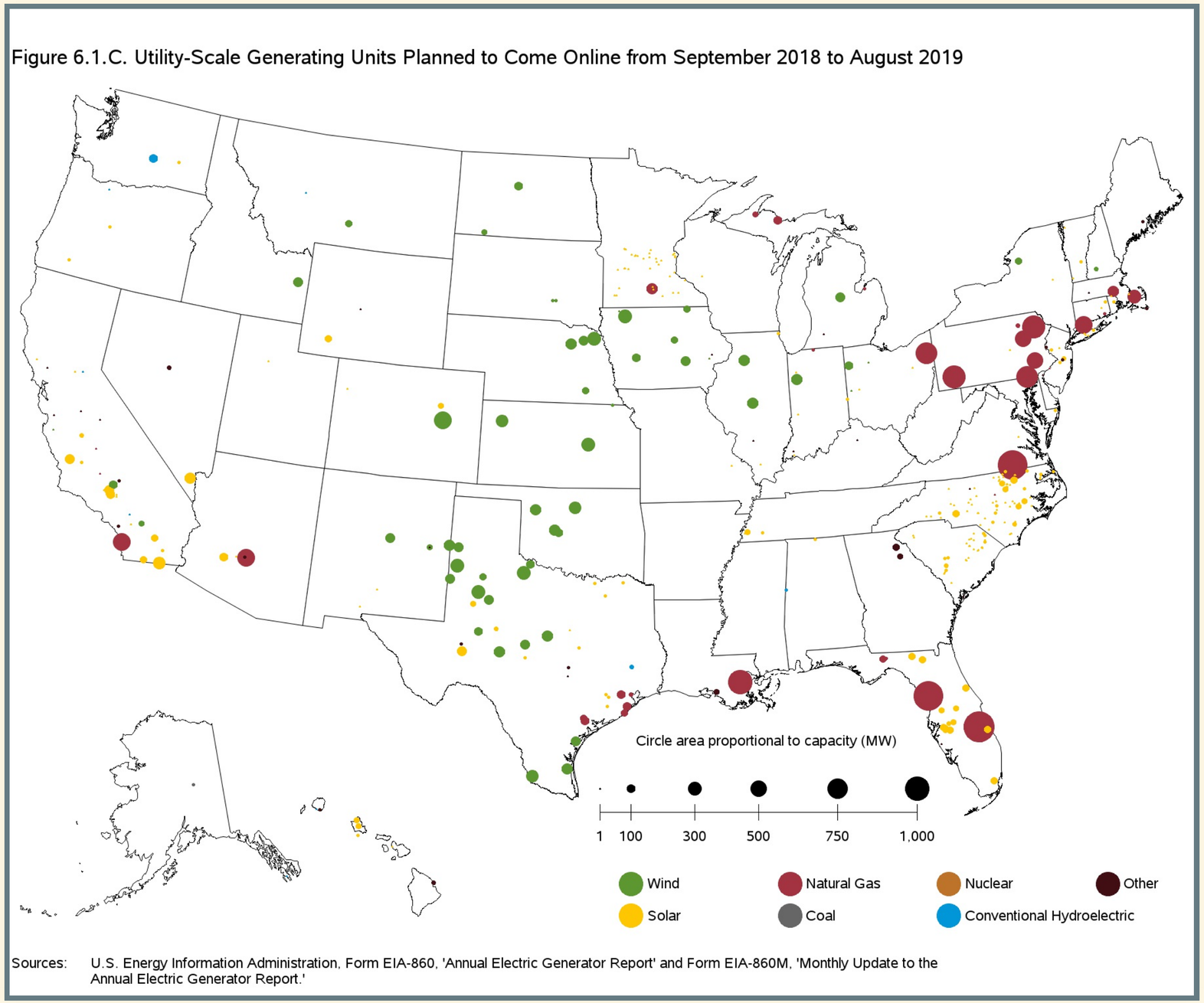
Recent Trends



Source: Lazard estimates.
Note: Reflects average of unsubsidized high and low LCOE range for given version of LCOE study.
(1) Primarily relates to North American alternative energy landscape, but reflects broader/global cost declines.
(2) Reflects total decrease in mean LCOE since the later of Lazard's LCOE—Version 3.0 or the first year Lazard has tracked the relevant technology.
(3) Reflects mean of fixed tilt (high end) and single axis tracking (low end) crystalline PV installations.

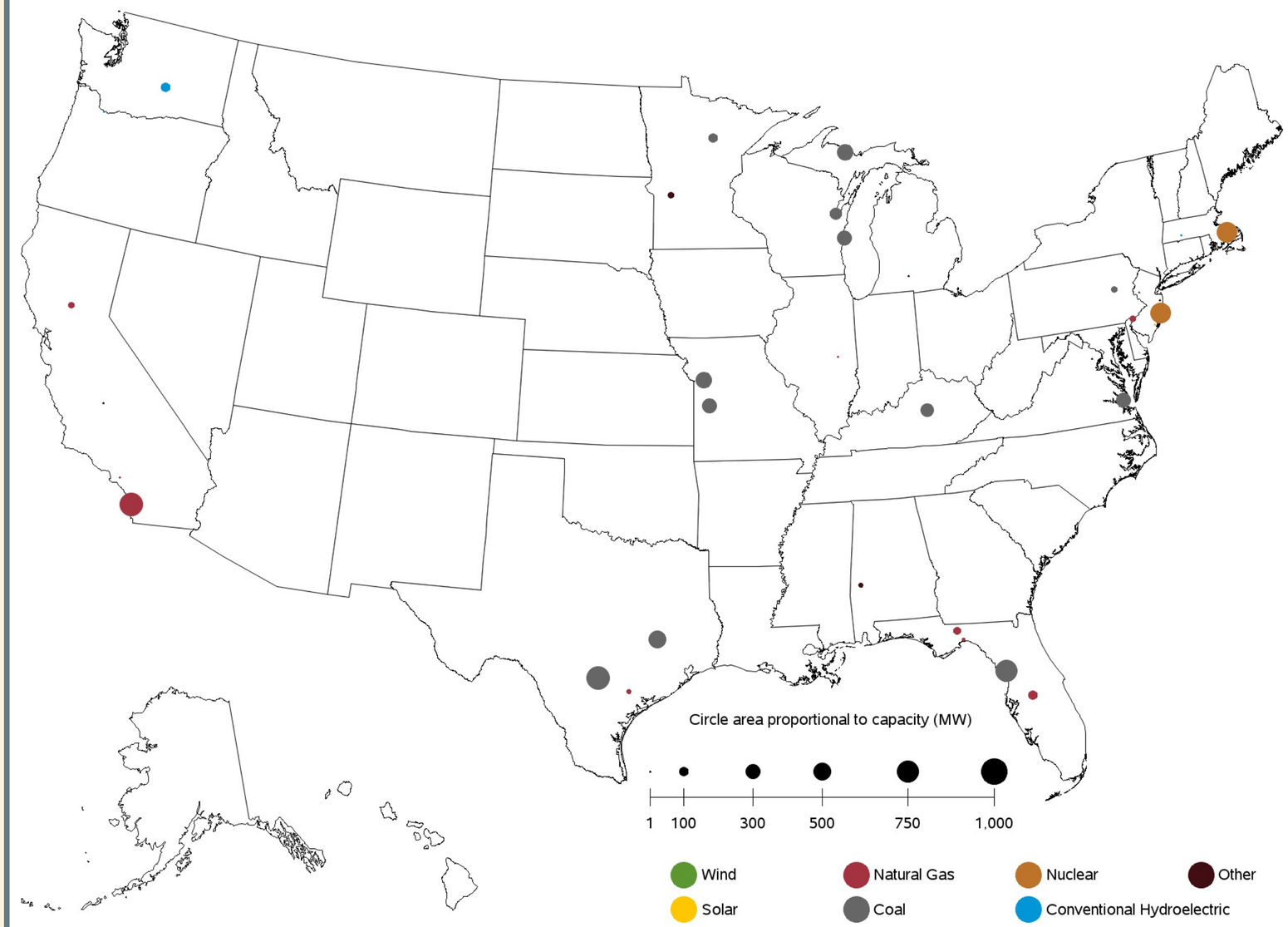
Source: 2017 Lazard Annual Levelized Cost of Energy Analysis https://www.lazard.com/perspective/levelized-cost-of-energy-2017/

New Power Plants for 2018–2019



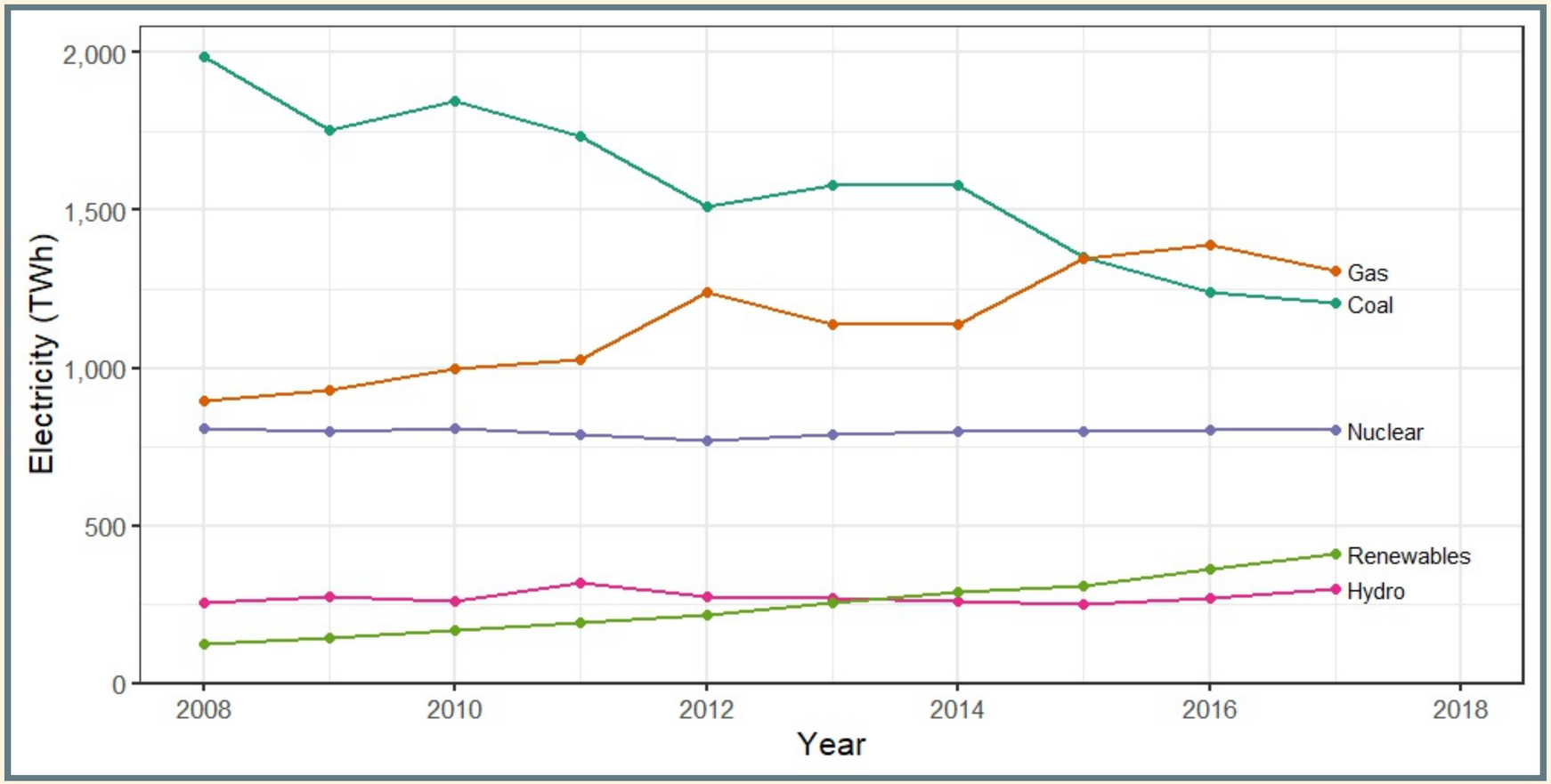
Power Plants Retiring in 2018–2019

Figure 6.1.D. Utility-Scale Generating Units Planned to Retire from September 2018 to August 2019



Sources: U.S. Energy Information Administration, Form EIA-860, 'Annual Electric Generator Report' and Form EIA-860M, 'Monthly Update to the Annual Electric Generator Report.'

Trends in Electricity



Growth Rates

Coal	Gas	Nuclear	Hydro	Renewables
-5.3%	4.8%	0.0%	0.3%	13.0%

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
- But as renewables become a greater fraction of all power, intermittency becomes a greater, more expensive challenge.
- Fear is a great challenge.