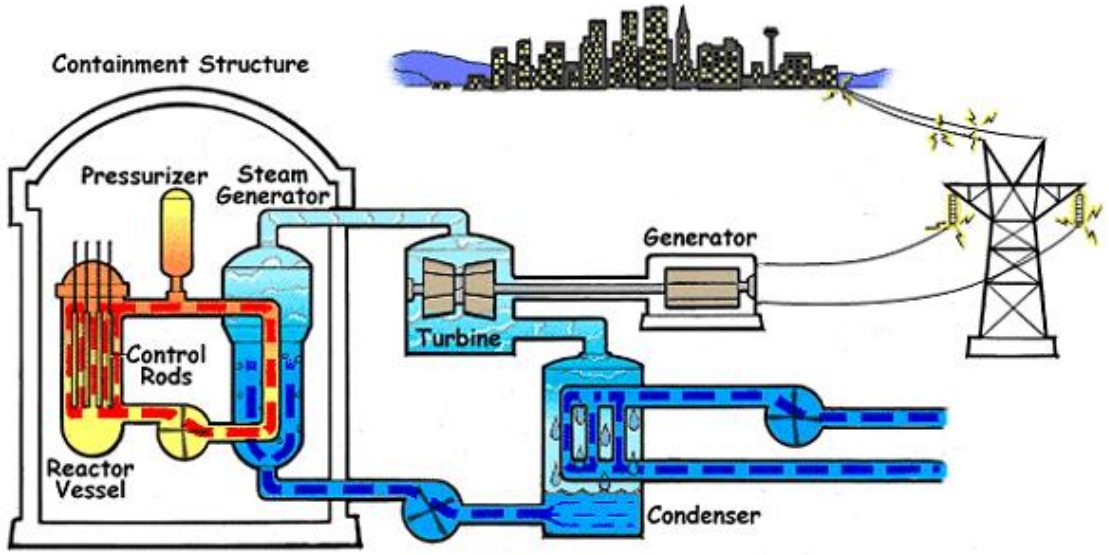

Courtesy: U.S. NRC

Sustainable, Safe and Clean Nuclear Energy

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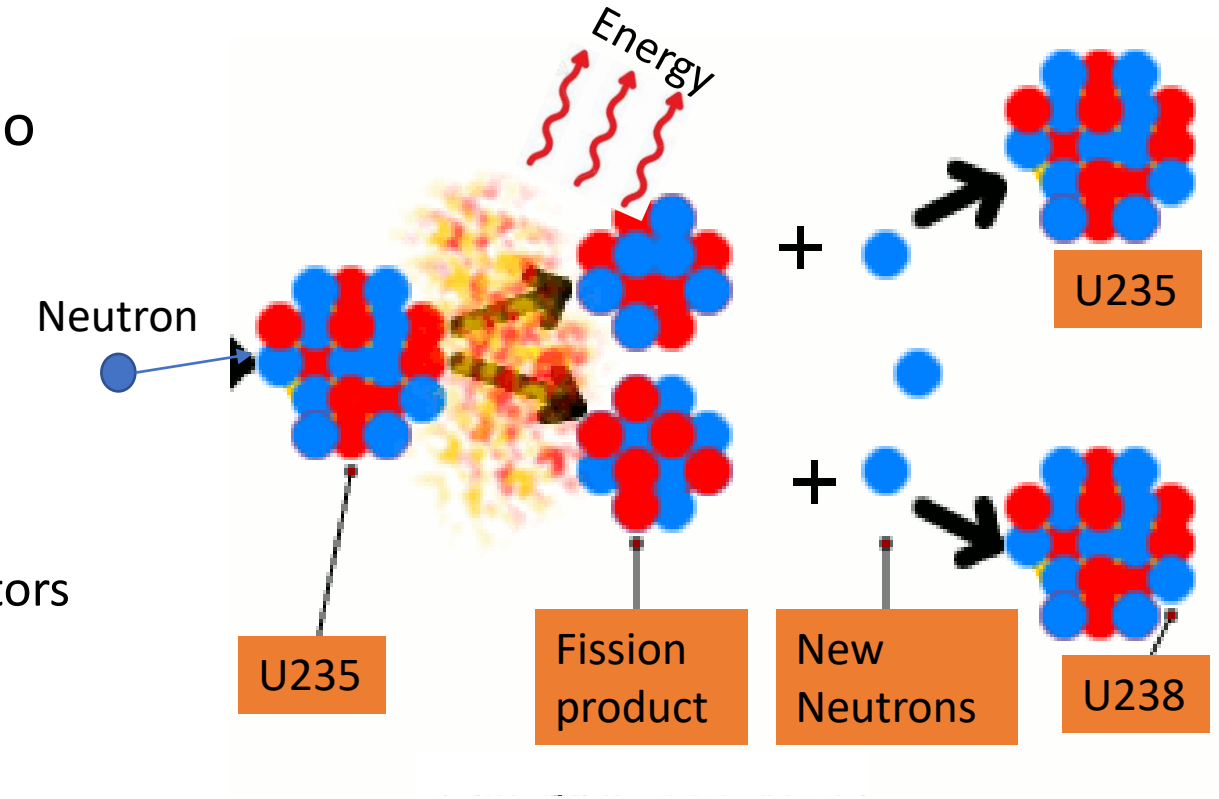
21 April 2020

A Lecture Presented at
ARCH 289i:
Sustainability at the University of Maryland

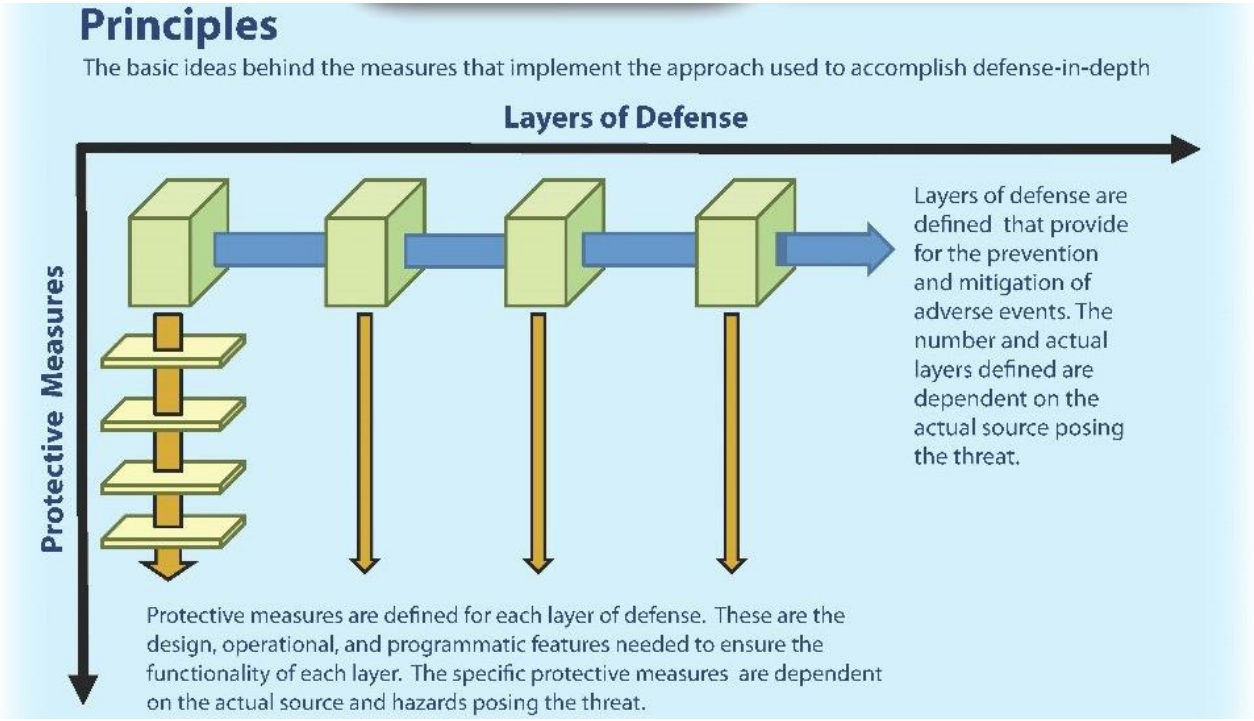
Design

- Fuel: Mostly Uranium, but Thorium and Plutonium too
- Process: Fission
- High density of energy
- Designs:
  - Light water reactors
  - Molten salt reactors
  - High temperature gas reactors
  - Breeder reactors
  - Small modular reactors



Safety

- Defense in Depth
- Active Systems
- Passive Systems
- Strict regulation and inspection
- Excellent safety record
- Over 70 years of experience



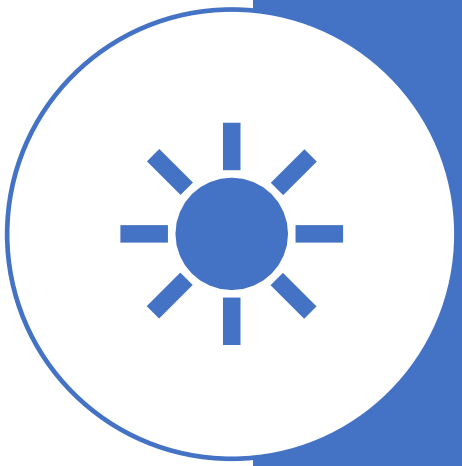
Souce: Mary Drouin, U.S. NRC

Economy

- Nuclear electricity generation is cost competitive
- Fuel costs are a minor part of total generating costs
- capital costs are much greater
- Decommissioning and waste disposal costs considered
- Construction is a large infrastructure projects
- The average total generating costs for nuclear in 2017 of 3.35 cents / KW-h

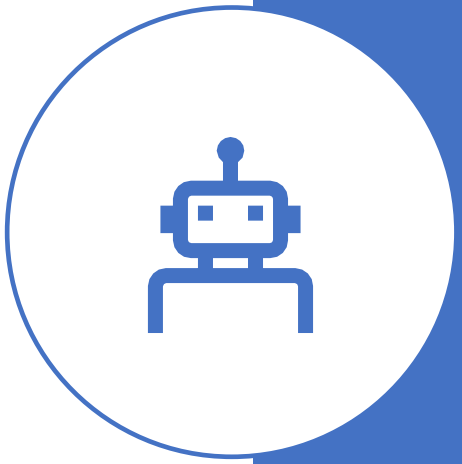
Clean and Climate Friendly

- Need to Decarbonize the grid
- Fast growing needs for electricity in remote areas
- Electricity needed to remove excess carbon
- Wind and solar
  - Becoming cheaper
  - Not available 24/7
  - Batteries that could power mega cities not available
- Germany’s example not encouraging
- Hydro limited (Norway, New Zealand) best places already dammed
- Proven rapid decarbonization: France and Sweden



Nuclear Power in U.S.

- U.S. pioneered the technology
- 20% of U.S. electricity from 98 nuclear plants
- Why not more? Economics and Fear!
- Nuclear plants are expensive to build
  - Need standardization and centralized manufacturing
  - Complications due to safety concerns and public fear
  - Lost expertise
  - China and S. Korea’s costs are far smaller
  - Small Modular Reactors overcoming these obstacles
- SMRs enjoy bipartisan support in Congress



Unfounded Dread

Unfortunate Origin

- Manhattan Project
- Hiroshima and Nagasaki

Nuclear accidents

- Small risks
- Environmental damage and human risks of fossil fuel
- Human toll of coal
- Human loss in 70 years of nuclear is less than one-month of coal operation

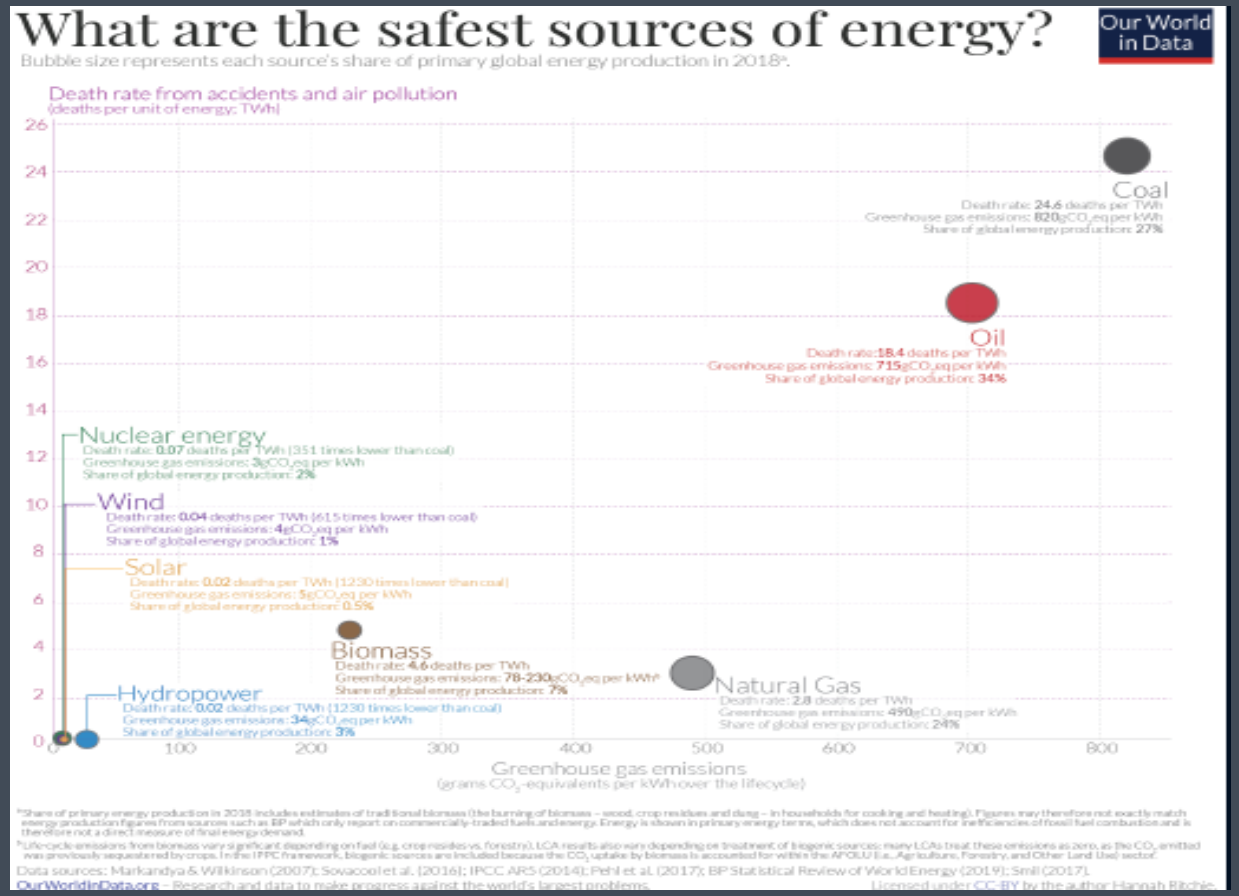
Proliferation concerns

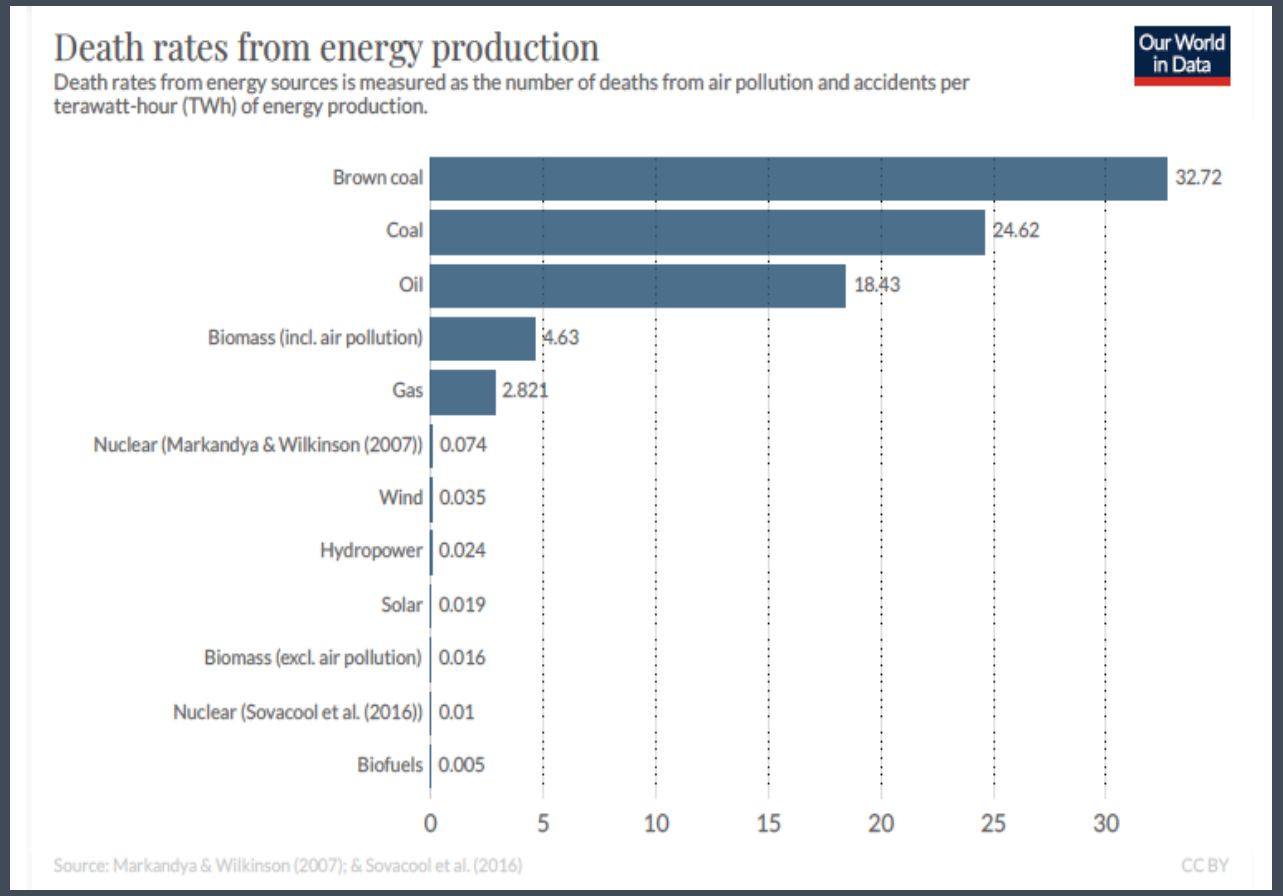
- Most countries with nuclear power have no nuclear weapons

Nuclear waste a political matter

- New designs that burn spent fuel
- Reprocessing
- Yucca Mountain

Safety: Nuclear vs. other Sources

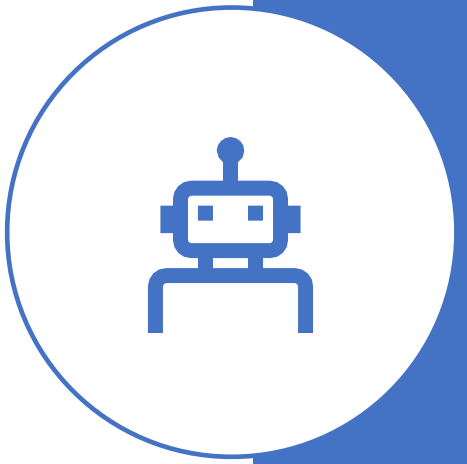




Source: What are the safest sources of energy? by Hannah Ritchie, Feb. 2020, https://ourworldindata.org/safest-sources-of-energy

Sustainability

- Vast reserves of nuclear fuel (U & Th) can last for a long period of human history—so making it truly sustainable
- Natural gas come close to be sustainable
- Small Modular Reactors (SMRs) more efficiently use fuel
- Molten Salt Reactors extract 10 times more energy from the fuel
- Fuel from existing Uranium **mines** used in SMRs, couple with fast reactors burning spent fuel can provide 10,000 terra-Wh/year for over 1000 year making it fully Sustainable



Renewable Nuclear Power

- Yes, nuclear is renewable!
- Other renewable energies: solar, wind, hydro, tidal, and geothermal
- Geothermal is renewable but not sustainable! (can’t be regenerated fast enough)
- Using uranium from seawater makes nuclear renewable
- 3.3 micrograms/liter of uranium in seawater (or 4.4 billion tons!)
- But U extracted from seawater is replenished continuously from balanced chemical reaction between sea water and the bed rocks
- Seawater extraction should be economical for this paradigm to work.

Conclusion

Nuclear power a powerful solution to the climate crisis—possibly the most challenging problem facing humanity and its survival

Coordinated governmental, industrial and policy change needed to overcome fear

Nuclear is a proven, safe, sustainable, economical, proliferation proof and reliable source of energy

Encouraging new designs can supply unlimited energy economically

Nuclear Power is sustainable

Nuclear power is renewable, green having a lower carbon footprint than solar and wind