

Sustainable, Safe and Clean Nuclear Energy

Mohammad Modarres University of Maryland Department of Mechanical Engineering 21 April 2020

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

Principles

The basic ideas behind the measures that implement the approach used to accomplish defense-in-depth



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 onemonth 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

Our World

in Data

What are the safest sources of energy?

Bubble size represents each source's share of primary global energy production in 2018* Death rate from accidents and air pollution (deaths per unit of energy; TWh) 26 24 Death rate: 24.6 deaths per TWE house gas emissions: 820gCO, eq per kWh 22 Share of global energy production: 27% 20 18 Oil Death rate:18.4 deaths per TWh Greenhouse gas emissions: 715gCO, eq per kWh Share of global energy production: 34% 14 -Nuclear energy Death rate: 0.07 deaths per TWH (351 times lower than coal) Greenhouse gas emissions: 36CO, ea per WH Share of global energy production: 2% 12 10 -Wind Death rate: 0.04 deaths per TWh (61.5 times lower than coal) Greenhouse gas emissions: 4gCO, eg per kWh Share of global energy production: 1% 8 Greenhouse gas emissions: 5g00, eq per kWh Share of global energy production: 0.5% 6 14 Biomass Death rate: 4.6 deaths per TWh Greenhouse gas emissione: 78-230gCO, eq per kWh* Natural Gas -Hydropower Stare of global energy prod Death rate: 0.02 deaths per TWh (1230 times lower than coal) Share of global energy production: 7% 2 Death rate: 2.8 deaths per TWh Greenhouse gas emissions: 490gCO.aqper KWh Greenhouse gas emissions: 34gCO/ Share of global energy production: 24% Share of global energy production: 3% 400 400 100 200 300 200 800

Pare of privary energy production in 2023 includes estimates of traditional bioanships of bioasses — encod, crop traitiens and datage. In browships of bioasses in the service of traditional bioasses are service of traditional bioasses in the service of traditional bioasses are service of traditional bioasses in the service of traditional bioasses in the service of traditional bioasses are service of traditional bioasses are service of traditional bioasses in the service of traditional bioasses are service of traditional bioasses

Death rates from energy production

Death rates from energy sources is measured as the number of deaths from air pollution and accidents per

Our World in Data



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