

Sustainable, Safe and Carbon-Free Nuclear Energy

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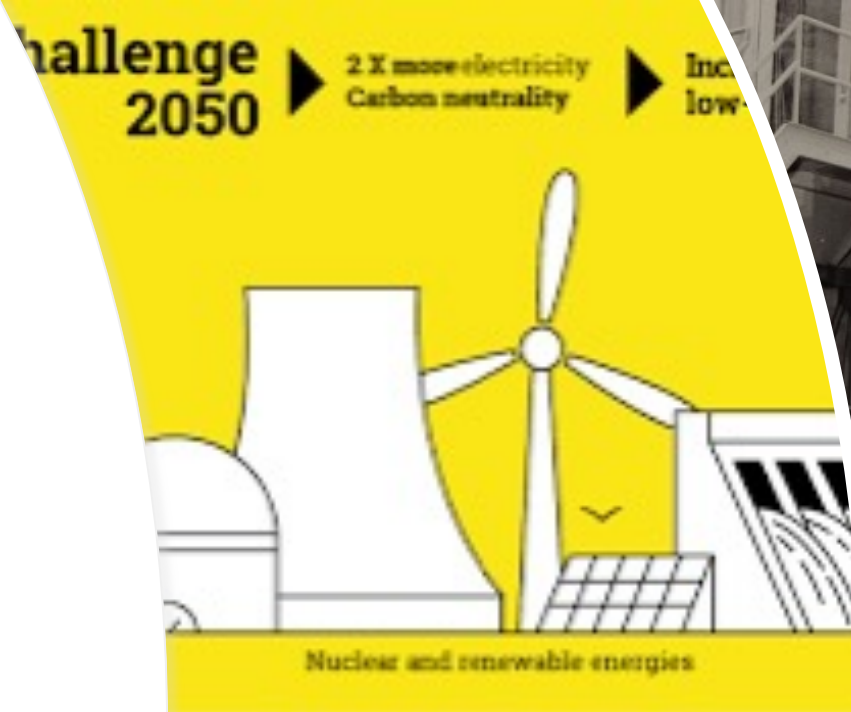
Department of Mechanical Engineering

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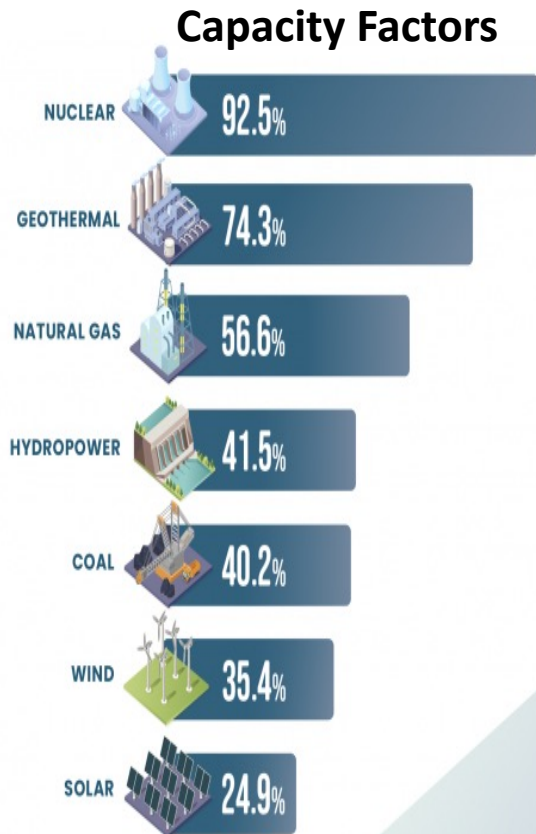
Sustainability at College Park



Source: NuScale Corp

Facts

- U.S. ranks highest in production of nuclear energy.
- Nuclear power plants don't emit greenhouse gases.
- They generate many jobs and have low operating costs
- Electricity from nuclear is a nonintermittent base-load.



Source: U.S. DOE

INTERESTING FACTS ABOUT NUCLEAR REACTORS



Just one uranium fuel pellet - roughly the size of the tip of an adult's little finger - contains the same amount of energy as 17,000 cubic feet of natural gas, 1,780 pounds of coal or 149 gallons of oil



Nuclear energy is being used in more than 30 countries around the world, and even powers Mars rovers



A typical nuclear plant can generate enough electricity to power 690,000 houses without creating air emissions



13 percent of the world's electricity comes from nuclear power plants that emit little to no greenhouse gases



A typical nuclear reactor works 24/7 at a 90% average capacity factor

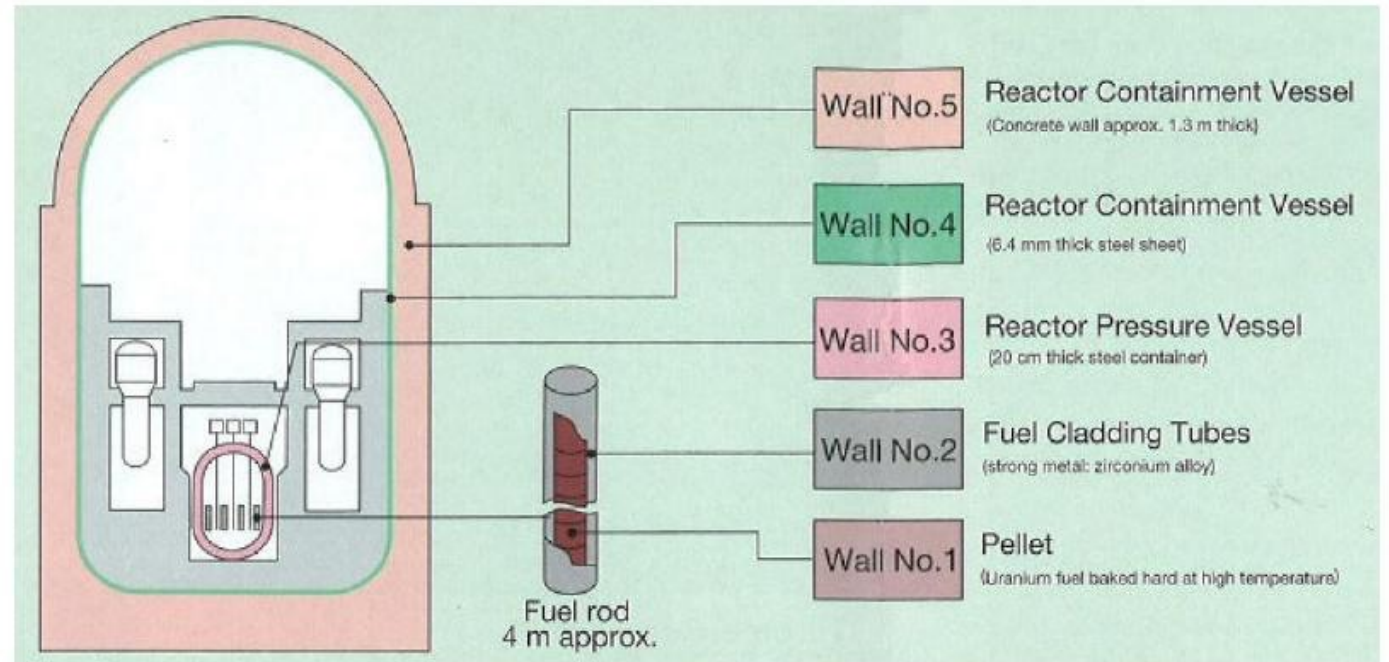


A typical nuclear reactor on an average refuels 1/3rd of fuel every 18th month

Source: NEI

Design for Safety

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



Source: Energy Central

Five Walls of Protection

Economy

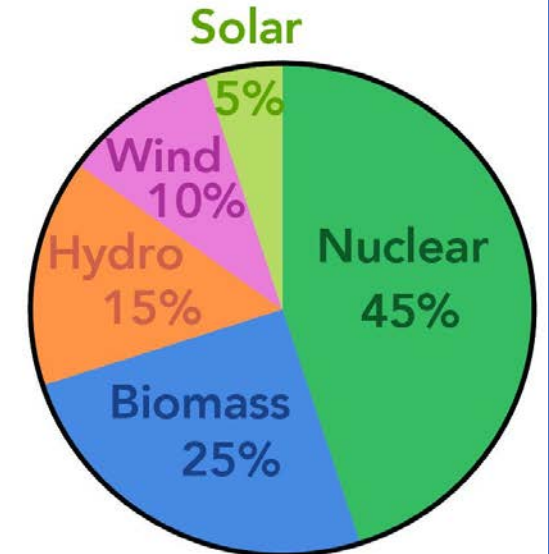
- Nuclear electricity generation is cost competitive
- Fuel costs are a minor part of total generating costs
- Upfront capital costs are much greater
- Decommissioning and waste disposal costs considered
- Average generating costs for nuclear was about 3.4 cents / KW-h in 2021
- Uranium supply is vastly available, and its reserve-to-production ratio is better than oil or natural gas.
- We can generate nuclear power at current levels for a century with just the natural uranium ore deposits already identified.



Source: NuScale

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 yet available
- Hydro limited (Norway, New Zealand) best places already dammed
- Today nuclear provides nearly half of U.S. carbon-free electricity.



Source: U.S. Energy
Information
Administration

Unfounded Dread

Unfortunate Origin

- Manhattan Project
- Hiroshima and Nagasaki

Nuclear safety

- Small risks
- Environmental damage and human risks of fossil fuel far exceeds nuclear
- Global human toll of coal: 8.7m deaths globally in 2018 (Vohara, et al. 2021)

Proliferation concerns

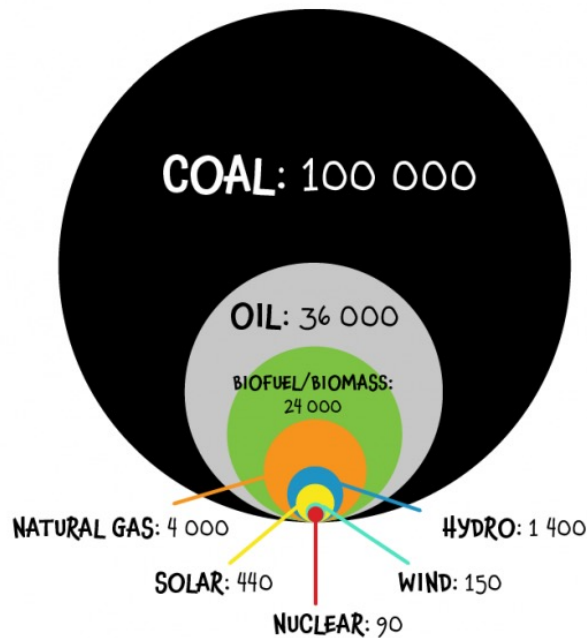
- Most countries with nuclear power have no nuclear weapons
- Of the 32 countries with nuclear power plants, 7 also have nuclear weapons
- Two countries with nuclear weapons don't have nuclear power plants

Nuclear waste a political matter

- By law U.S. DOE is responsible to dispose the waste
- New designs that burn spent fuel
- Reprocessing substantially reduces waste volume
- Yucca mountain site
- Consolidated Interim storage
- Finland leads with a repository site licensed and under construction – starts in 2024

Risks & Land Use Nuclear vs. Solar and Wind

Deaths per 1 000 TWh of electricity production



Data Source
<https://www.forbes.com/sites/jamesconca/2012/04/10/energys-deathprint-a-price-always-paid/#450709be709b>

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Land Use
for 1 GW
Power
Plant
(Square
miles)

Nuclear: 1
Solar: 16
Wind: 49

**A 1 GW
nuclear
power plant**
93% capacity factor



produces the same amount of power as...

11 million solar panels



320 W panel, 27% capacity factor

939 wind turbines



3 MW turbine, 33% capacity factor

OR

Sources: nuclearnow.com.au/sources

Source: <https://nuclearnow.com.au/why-nuclear/>

Is Nuclear Fuel Renewable?

- Nuclear Power is sustainable
- Yes, nuclear fuel is also renewable!
- Other renewable energies: solar, wind, hydro, 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.



Future: Small and Microreactors

What are microreactors?

U.S. developers are currently focused on gas and heat pipe-cooled designs that could debut in the mid-2020s.

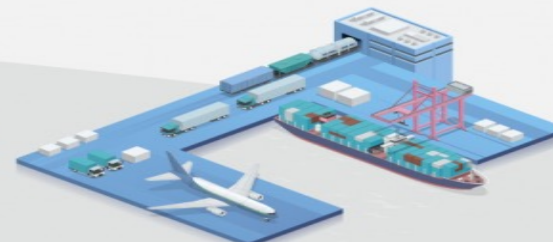
Microreactors are simple and compact reactors capable of producing **1-20 MEGAWATTS** of thermal energy used directly as heat or converted to electric power.



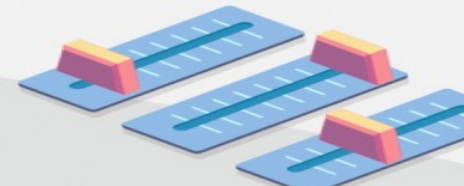
Microreactors have 3 main features:



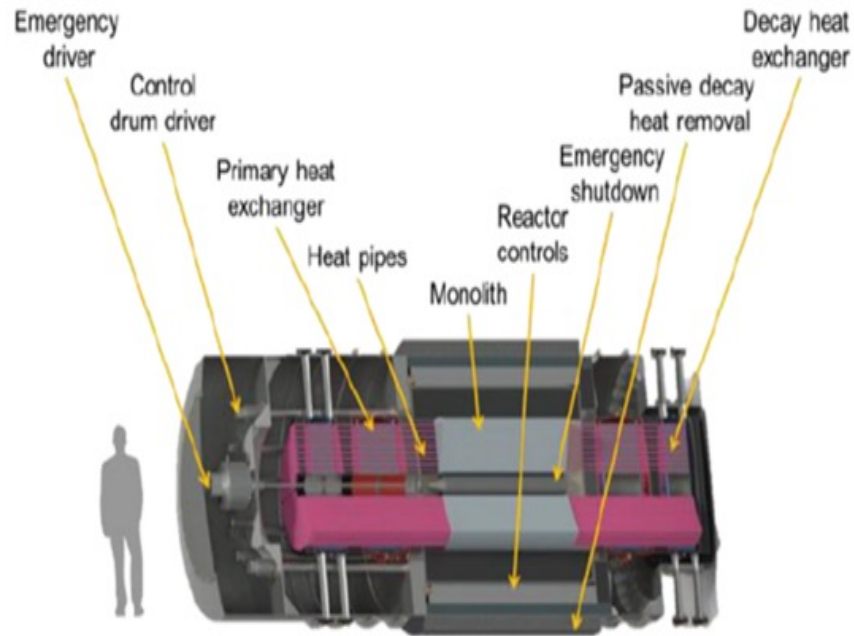
FACTORY-FABRICATED



TRANSPORTABLE

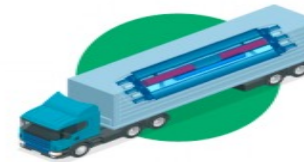


SELF-ADJUSTING



Conceptual Design of the eVinci SMR - Image: Westinghouse

What are the benefits of microreactors?



SMALL & PORTABLE

Fits on the back of a semi-truck and can be deployed to remote locations and military bases for reliable heat and power.



SIMPLE DESIGN

Fail-safe and self-adjusting designs that require fewer components, maintenance and operators.



QUICK ON-SITE INSTALLATION

Can be connected and generating power within months of arriving on-site. Some, possibly within weeks.

Universities and Nuclear Power

[Penn State wants a Westinghouse eVinci microreactor on campus](#)

Thu, May 19, 2022

[Nuclear News](#)



Several universities to experiment with micro nuclear power

By JENNIFER McDERMOTT– AP News

February 9, 2023

- “Purdue University in Indiana is working with Duke Energy on the feasibility of using advanced nuclear energy to meet its long-term energy needs.”
- The University of Illinois “plans to apply for a construction permit for a high-temperature, gas-cooled reactor developed by the **Ultra Safe Nuclear Corporation** and aims to start operating it by early 2028.”

Conclusion

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

Coordinated governmental, industrial and policy changes needed to overcome fear

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

We need to overcome high cost of construction. Encouraging new small modular reactor designs can supply energy economically

Technologies for permanent and safe disposal of the nuclear waste exist. Political ramifications are more complex

Nuclear power from seawater is renewable with a lower lifecycle carbon footprint than solar and wind

Well paid and highly demanding employment opportunities in engineering and some other disciplines