



*Nuclear Energy for a  
Peaceful and  
Sustainable Future*

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# In a couple of words, describe your ideal energy source.



# Outline

1. The role of nuclear energy in a sustainable grid
  - a. Every place that has shut down their nuclear plants saw increased emissions (or very slow improvement)\*. (\*Unless that place has a significant amount of hydro power.)
  - b. Every place that has appreciably decarbonized has a large fraction of nuclear energy.
  - c. Good news! Poland has announced a plan to build 6 reactors by 2040.
2. Nuclear energy in Illinois
  - a. Over half of the electricity produced in Illinois is from nuclear power.
  - b. Less than 1% of the electricity produced in Illinois is from solar power.
3. The future of nuclear energy in Illinois
  - a. One of the appeals of solar panels is the idea that communities could set up their own electricity sources. Could that be done with nuclear energy?
  - b. What if Highland Park had its own nuclear reactor?
    - i. would that make sense? → yes, HP has its own water utility.
    - ii. how much would we need?
  - c. UIUC is pioneering advanced nuclear technology!
4. Political obstacles

# *The State of Nuclear Power*

## Reactors in the United States

- Fuel: Uranium-235
- Fuel Enrichment: 3-4%
- Coolant: Water
- Power: 1000 MW (electric)  
(=1GW)

There are 99 operating reactors in the United States.

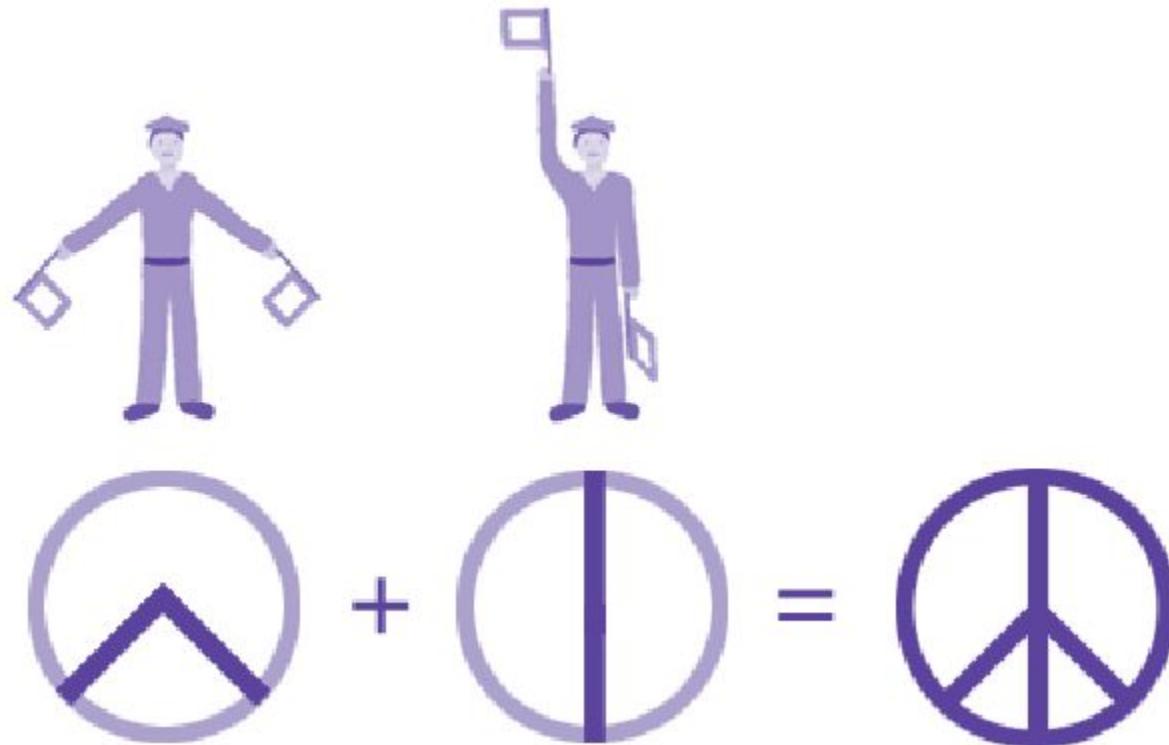
A ***single*** nuclear reactor can power almost ***one million homes***.

1 GW Capacity = 3.125 million solar panels  
(320 Watts per panel)





***N + D = Nuclear Disarmament***



# *Nuclear Energy Promotes Peace*



**20,000**

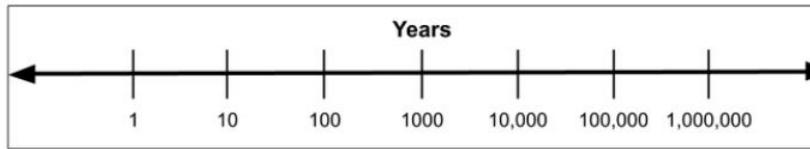
NUCLEAR WARHEADS ELIMINATED

TO PRODUCE

**7,000,000,000**

MEGAWATT HOURS

# How many years could Megatons to Megawatts power the city of Highland Park (a town of 28,000)?



# *Nuclear Energy Promotes Peace*

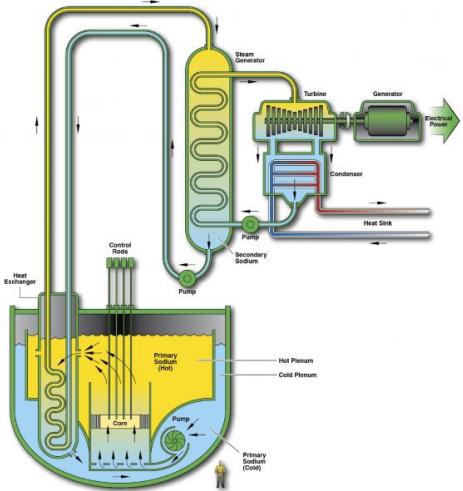


Enough electricity to:

1. power all of Highland Park for **75,000 years.**
2. power all of Illinois for almost **500 years.**

# *Megatons to Megawatts... Plutonium?*

Sodium-Cooled Fast Reactor design



- Requires a type of advanced reactor called a “fast reactor.”

Possible Designs

- GE-Hitachi: PRISM Reactor
- TerraPower: Molten Chloride Fast Reactor (MCFR)

Weapons Stewardship

# What substance is coming out of these towers at a nuclear power plant?



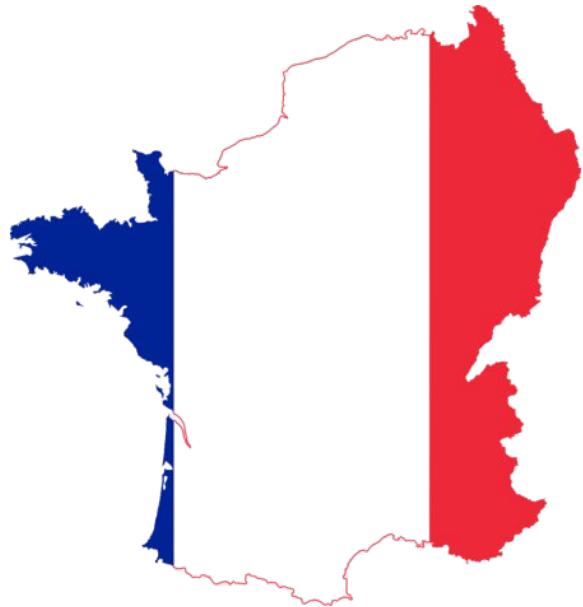


***Answer: Water!***

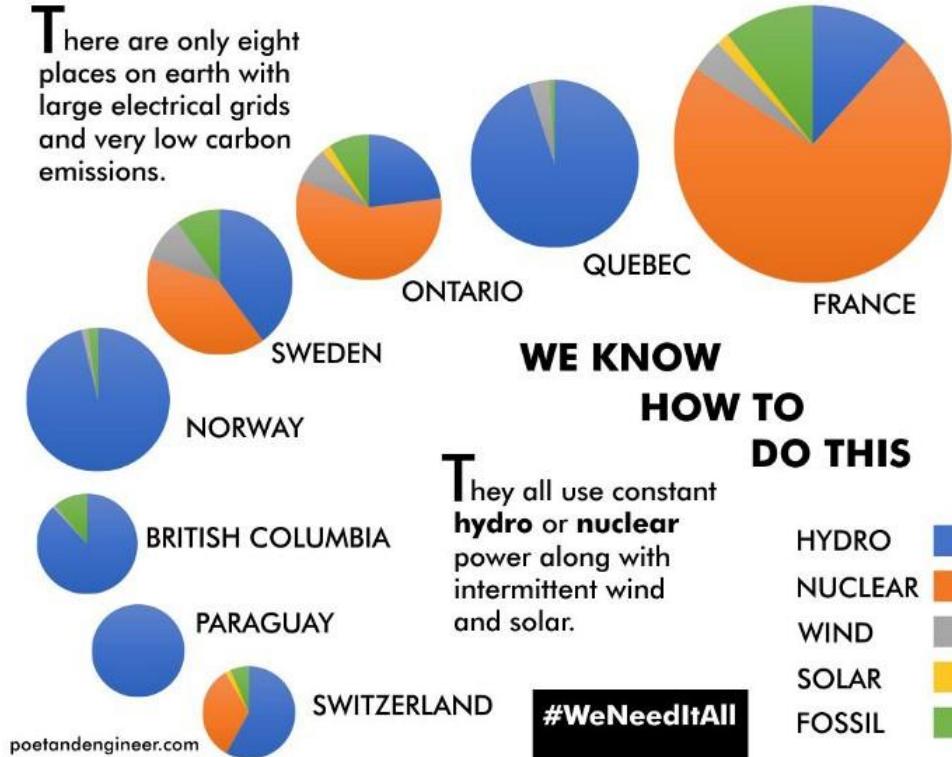
***Also accepted:***

- steam***
- water vapor***

# *Nuclear Power for Sustainability*



There are only eight places on earth with large electrical grids and very low carbon emissions.

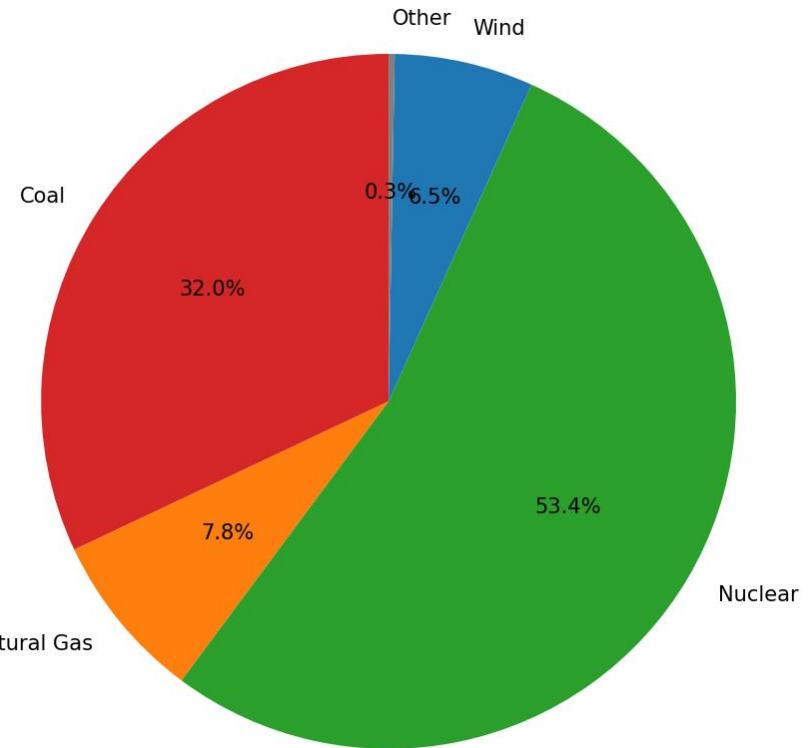


- When poll is active, respond at **PollEv.com/samueldotson352**
- Text **SAMUELDOTSON352** to **22333** once to join

# How much of Illinois' electricity comes from nuclear?



Illinois Electricity Generation by Source, 2018



**Answer: C / 50-55%**

- Other < 1% : Biomass, Petroleum, Solar, Hydro

Data Source: Energy Information Agency, Illinois 2018

When poll is active, respond at **PollEv.com/samueldotson352**

Text **SAMUELDOTSON352** to **22333** once to join

## Nuclear accounts for 53% of Illinois electricity: How many nuclear plants are there?

3 nuclear plants

6 nuclear plants

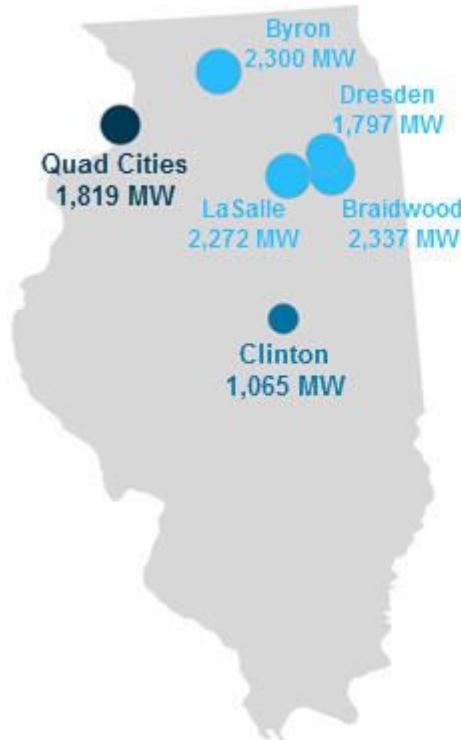
11 nuclear plants

18 nuclear plants

25 nuclear plants



Nuclear power plants in Illinois (2016)



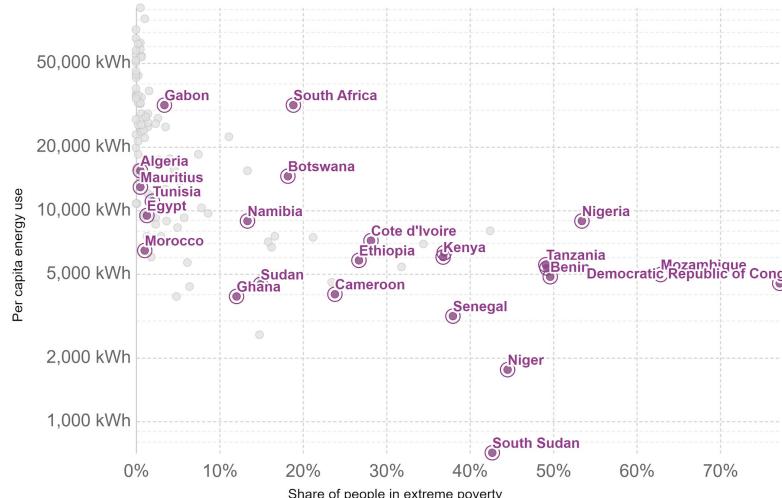
*Answer: 6 nuclear plants*

That's a lot of electricity.

# Energy and Quality of Life

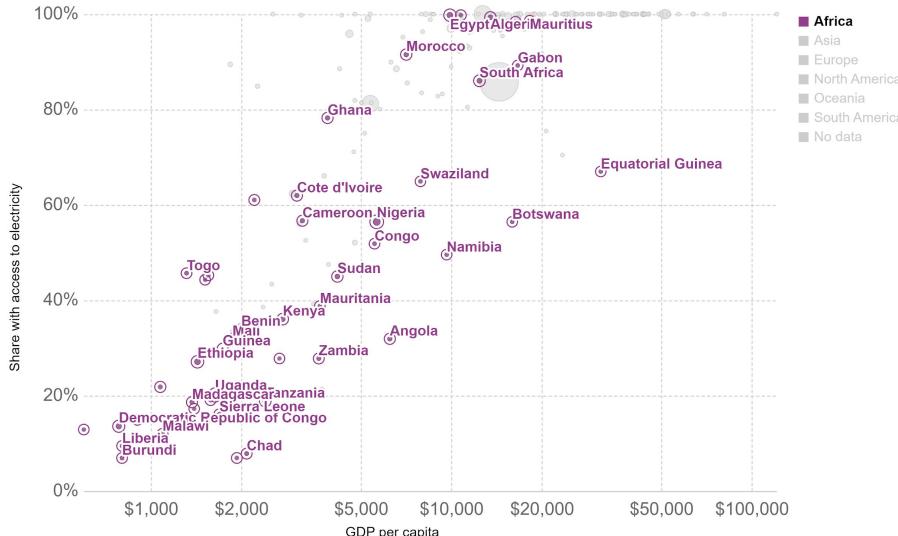
**Energy use per capita vs. share of population in extreme poverty, 2014**  
 Per capita energy use is measured in kilowatt-hours (kWh) per year. Extreme poverty is defined as living at a consumption (or income) level below 1.90 "international-\$" per day. International \$ are adjusted for price differences between countries and price changes over time (inflation).

Our World  
in Data



**Access to electricity vs. GDP per capita, 2014**

GDP per capita is adjusted for price differences between countries and inflation and measured in international-\$.



Source: International Energy Agency (IEA) via The World Bank

OurWorldInData.org/energy-production-and-changing-energy-sources/ • CC BY

Source: The World Bank - World Development Indicators (WDI)

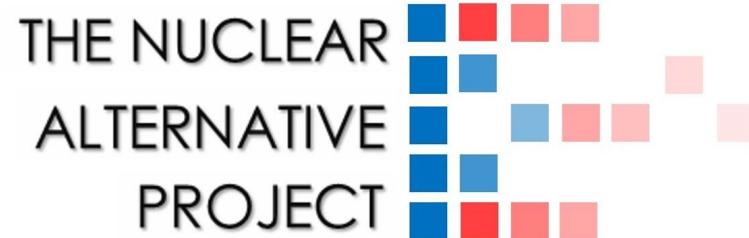
OurWorldInData.org/energy-access • CC BY

# ***Emerging Market for Small and Micro-Nuclear***

- Factory assembled
- Walk away safe because of their size
- Easily transportable

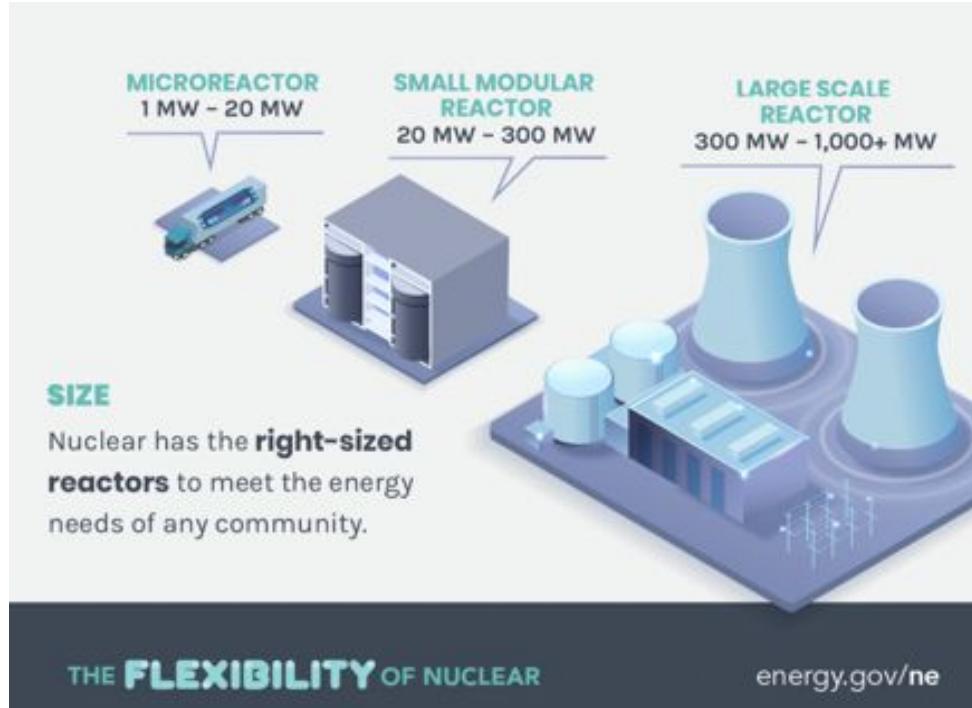
USNC is building reactors for:

- Remote locations
- Developing grid systems



# *What is a micro-reactor?*

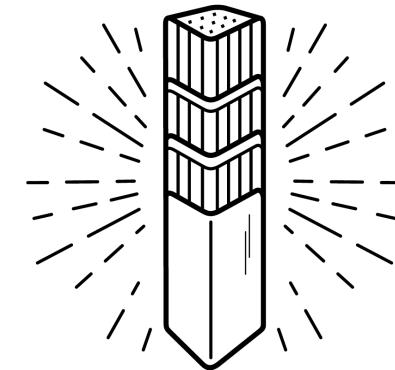
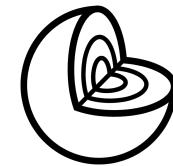
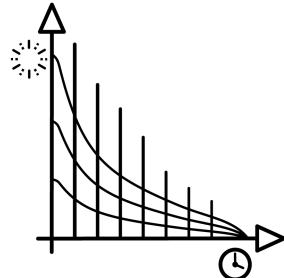
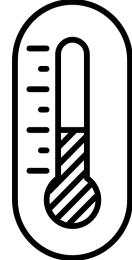
- Small physical size
- Transportable
- Factory built
- ***Walk-away safe***



# *Nuclear Demonstration: Illinois Micro-Reactor Initiative*



# Walk-Away Safety



Physics-limited core temperature



Passive decay heat removal

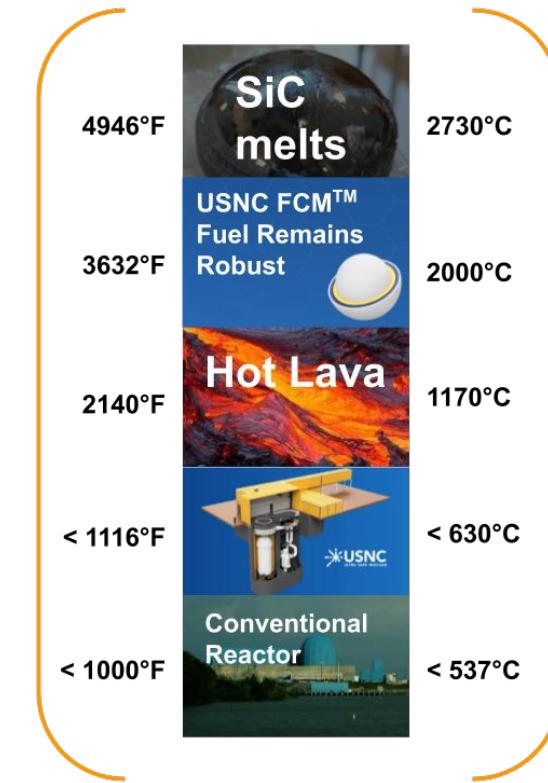
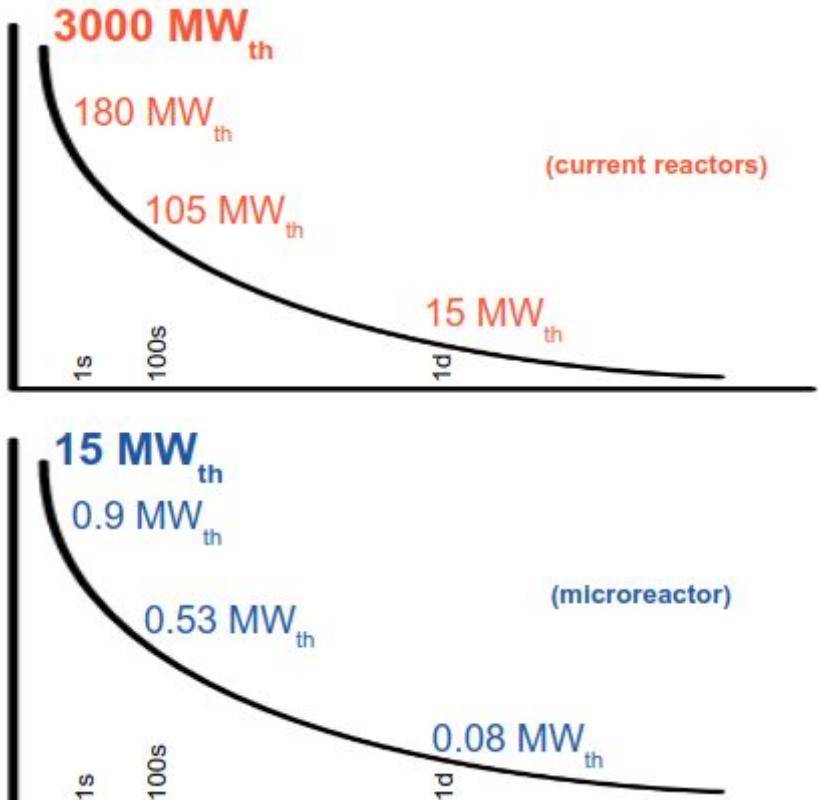


Extremely thermally robust fuel



Fission products retained in any accident scenario.

# ***Small Size + Robust Fuel = Safe***



Courtesy of Prof. Kathryn D. Huff

# *Community Nuclear*



- Just three micro-reactors could power Highland Park
- All three could fit easily inside the water treatment plant!



# *The Future of Nuclear Energy in the U.S.*

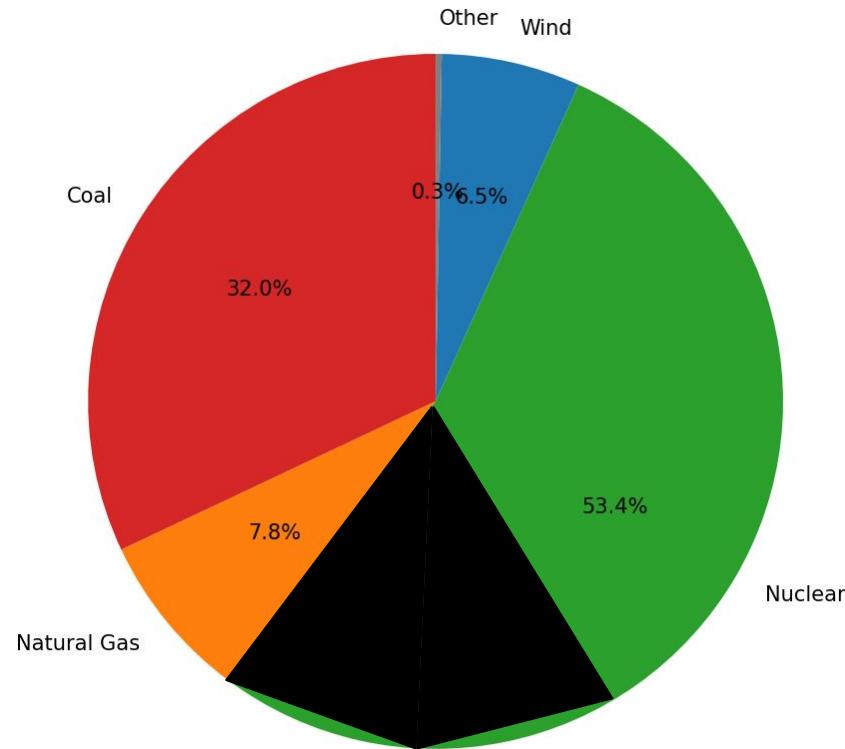
Illinois Electricity Generation by Source, 2018

The good news:

- A new plant in Georgia is nearly complete!

The bad news:

- Several nuclear plants are at risk of closure
- Two Illinois reactors are scheduled to close by Fall 2021
  - With two more at risk of premature closure.



# **Summary**

- Nuclear energy promotes **peace** by reducing the nuclear stockpile.
- Nuclear energy is important for solving **climate change**
- **Advanced nuclear could benefit communities** like Highland Park but also
  - remote locations
  - island nations
  - developing grids
- The existing Illinois fleet is at **risk of shutdown**
  - But we can keep them online!

Q & A

# Q&A: What would you like to know more about?

Top



# *For more questions:*



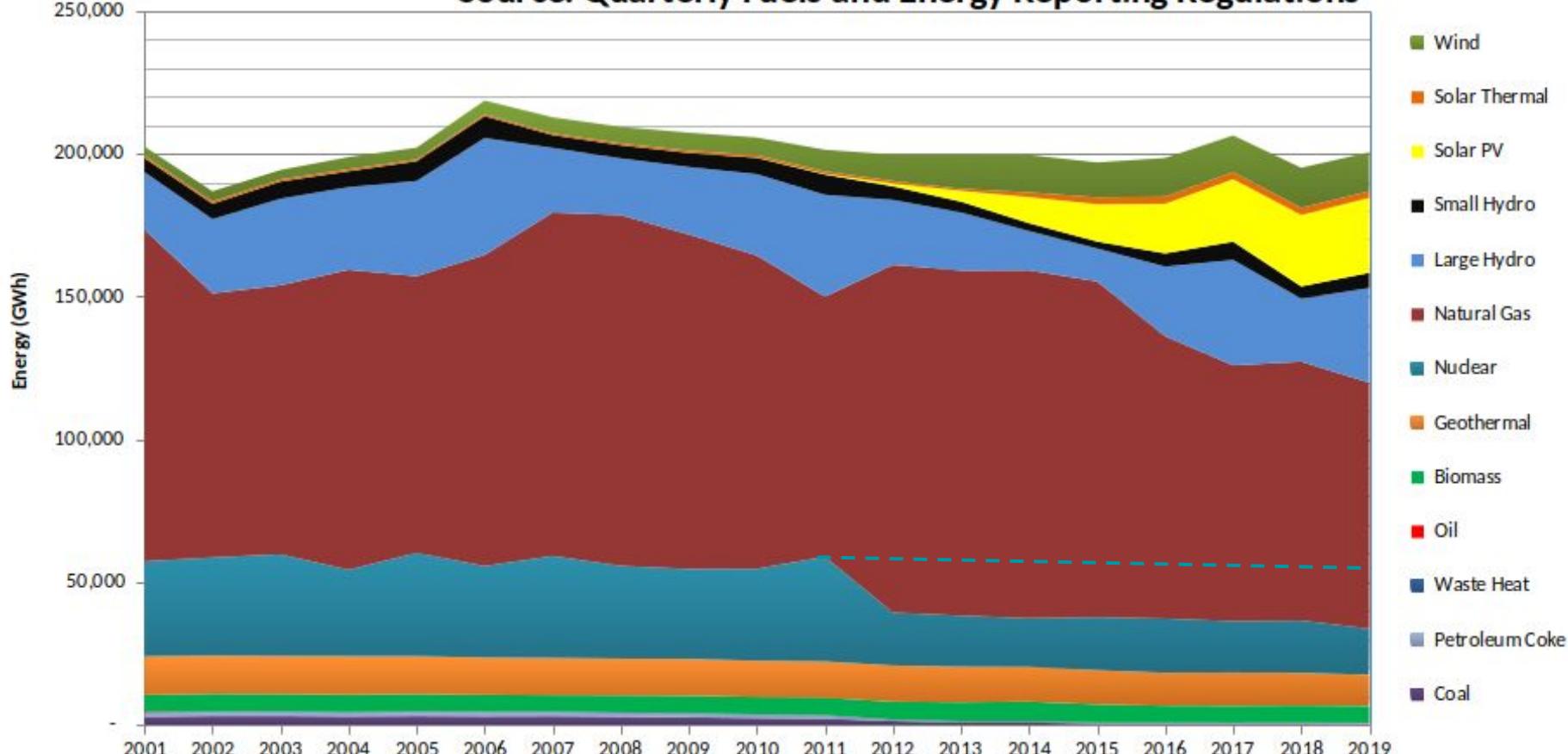
@samgdotson

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*How do you know that nuclear will be replaced  
by natural gas and not wind?*

# In-State Electric Generation by Fuel Type

Source: Quarterly Fuels and Energy Reporting Regulations



Source: California Energy Commission Almanac

# New Blackouts Darken California

CALIFORNIA

**California power prices have skyrocketed. Is this normal — or more Enron-style ‘manipulation’?**

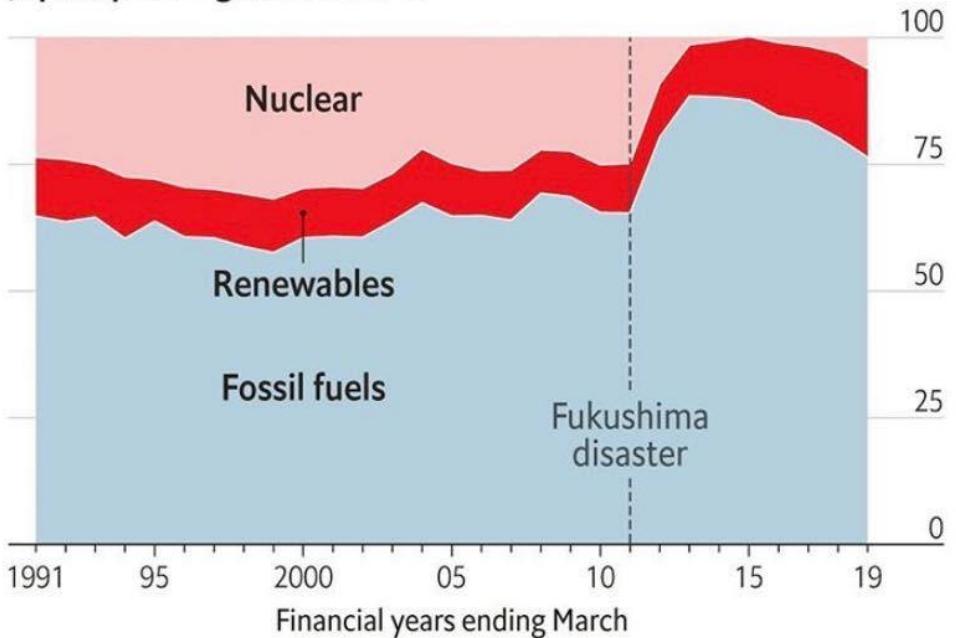
CALIFORNIA

**Rolling blackouts ‘likely’ with California power grid expected to near record demand due to extreme heat**

**‘Mad Max’ in California? Energy crisis is avoidable**

## Why can't Japan transition to renewable energy?

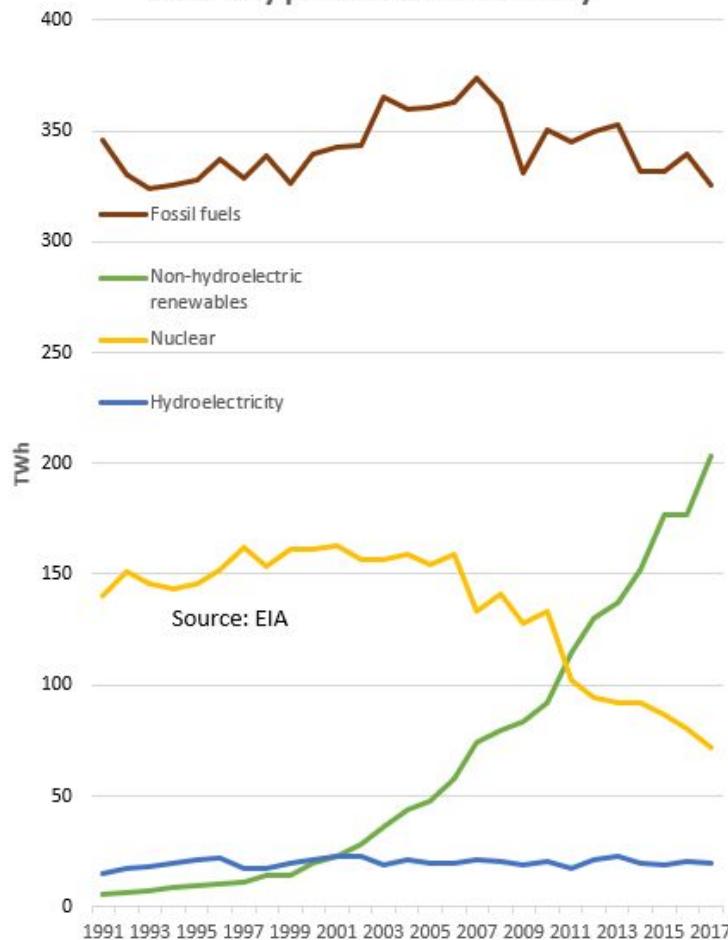
Japan, power generation, %



Source: Institute for Sustainable Energy Policies

The Economist

### Electricity production in Germany

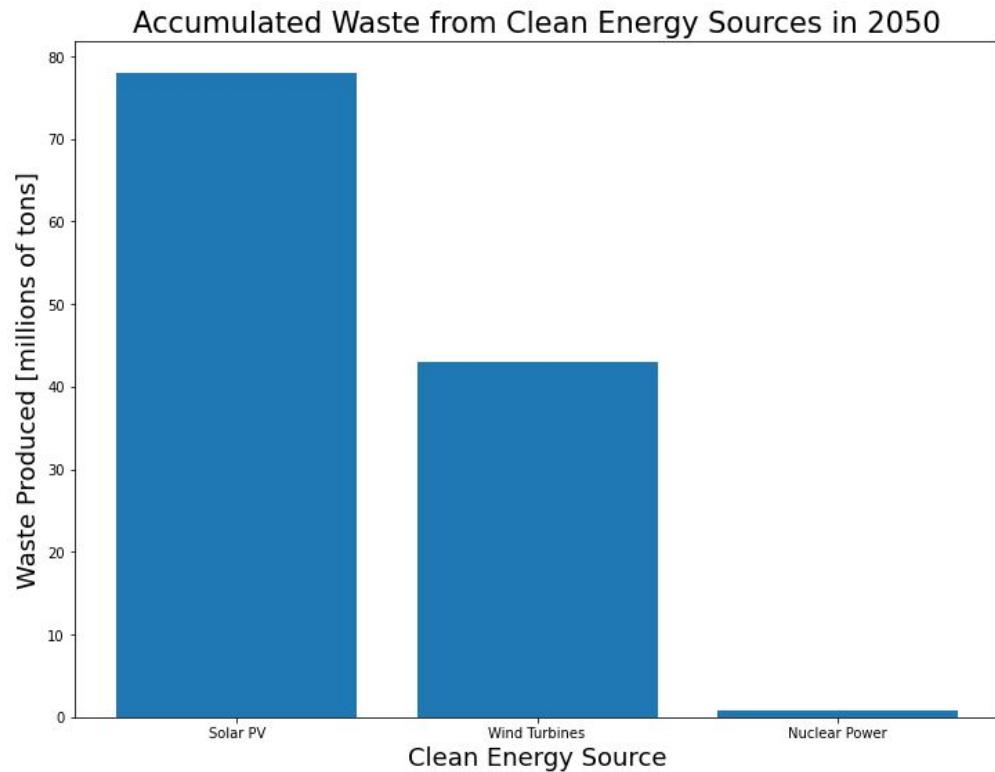


***What are we going to do about the nuclear waste?***

# ***Waste: A Problem Shared By All***

We need to consider:

1. The waste form (solid, liquid, gas)
2. How much volume
3. The toxicity of the waste



# **Nuclear “Waste”: A solved problem!**

Nuclear “waste” = Spent Nuclear Fuel

1. Dry cask storage
2. Geologic repository
3. Recycle it!

***It's solid!***

***There isn't a lot!***

***We can recycle 96% of “waste!”***

# *Dry Cask Storage*



Dry casks at Dresden Generating Station, Morris, IL

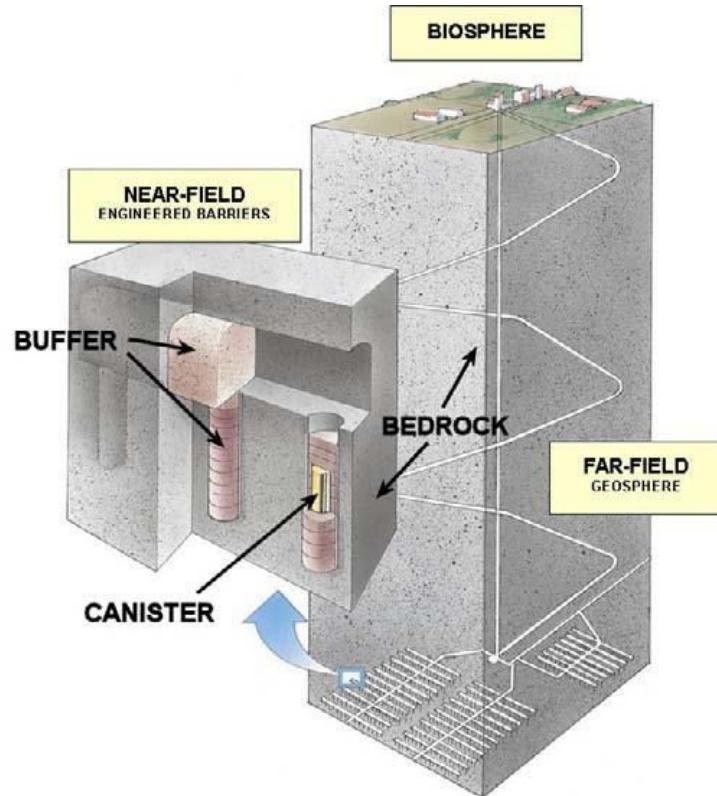
# Dry Cask Storage



Dilan and Anna in front of dry casks at Dresden Generating Station, Morris, IL. February, 2020

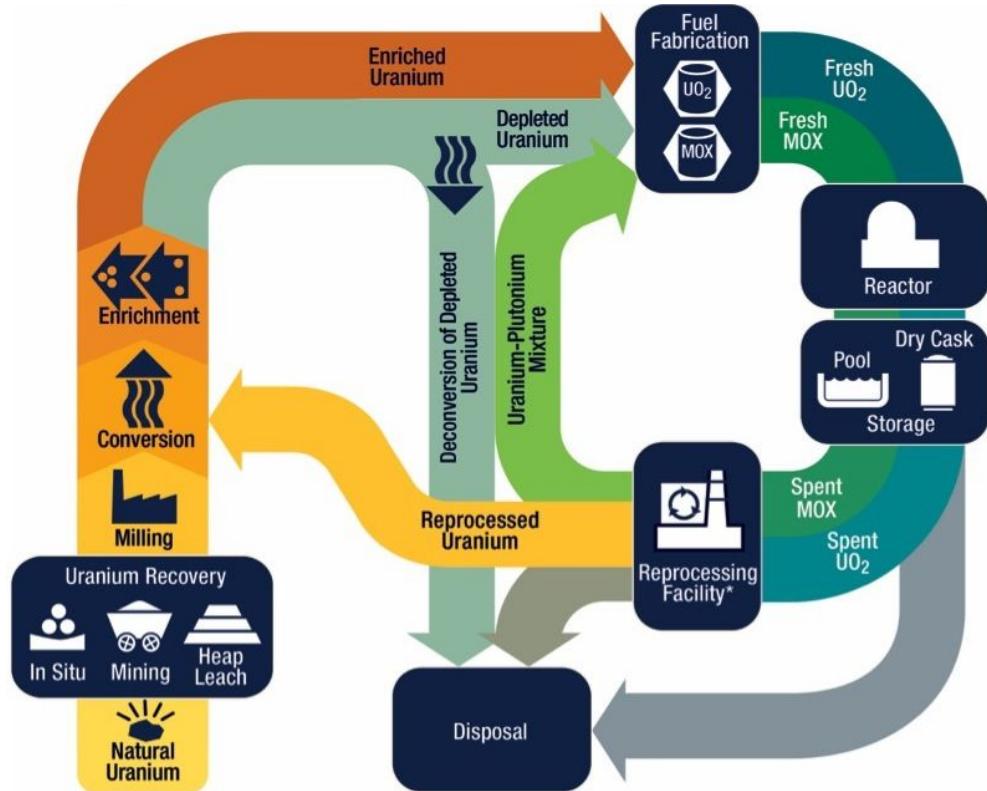
# Geologic Repository

- The NRC *approved* Yucca Mountain in Nevada
- Cancelled for political reasons
- Several countries have repositories.



# *Recycling Spent Nuclear Fuel*

- SNF contains 96% of original potential energy.
- Only 4% of the volume is actually “waste.”
- France has been doing this for decades!



***Can't we just build lots of Solar Panels and Wind Turbines?***

## Estimated Land Use Required to Generate 4100 TWh

■ Nuclear ~ 192 km<sup>2</sup>



Chicago ~ 590 km<sup>2</sup>

Wind  
~ 76,960 km<sup>2</sup>



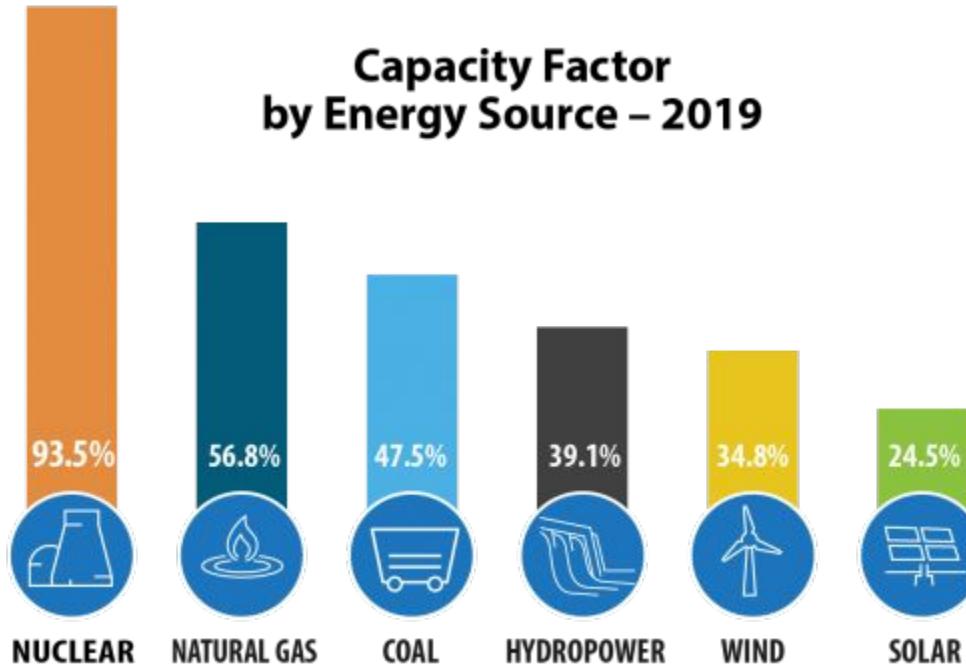
Solar  
~ 86,581 km<sup>2</sup>



Ohio  
~ 116,098 km<sup>2</sup>



# *Capacity Factor*



## ***Nuclear Accidents: Fukushima, TMI, Chernobyl***

# ***Chernobyl: A Systemic Failure***

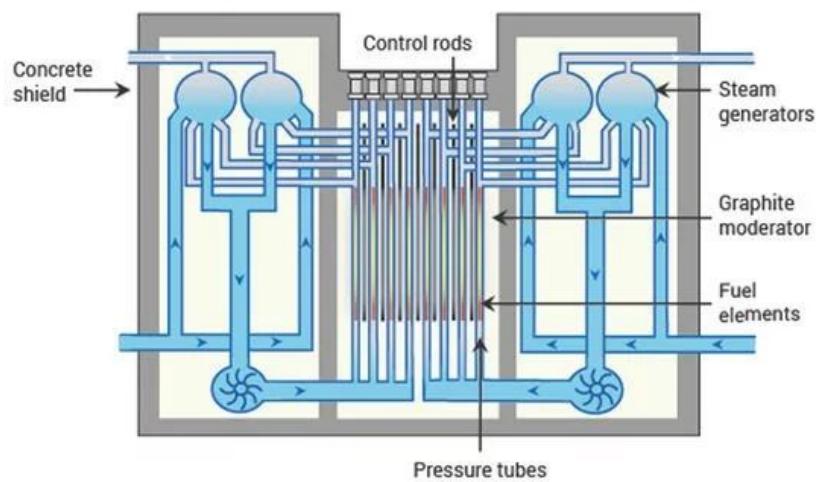
- Caused by human error and government secrecy.
- A ***steam*** explosion.
- No containment building.



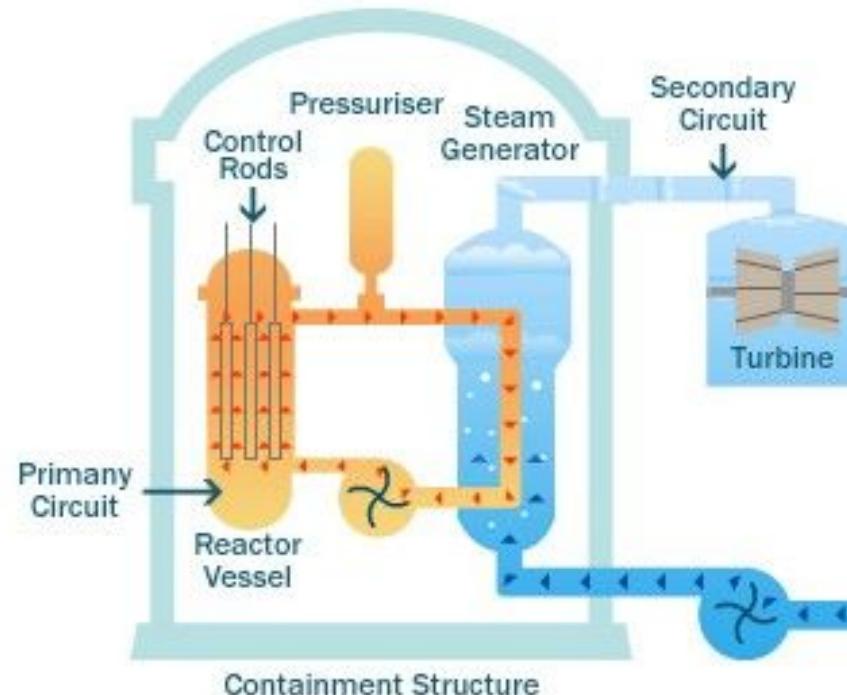
***The Chernobyl Accident is not physically possible in U.S. reactors***

# RBMK (Chernobyl) vs PWR (U.S.)

A Light Water Graphite-moderated Reactor (LWGR/RBMK)



Light Water, Graphite Moderated (RBMK)



Light Water Cooled and Moderated (PWR)

# **Fukushima: A Systemic Failure**

Why:

- Weak Regulator
- Natural Disaster
- Poor Risk Communication + Unnecessary Evacuation = Preventable Loss

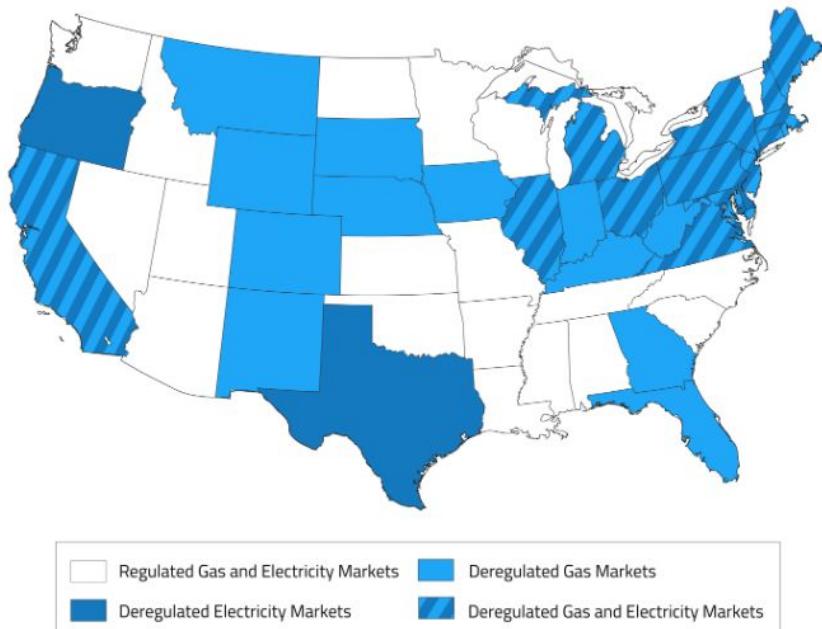
**Zero** deaths caused by radiation from the reactor.

Can it happen in the United States? **No\***

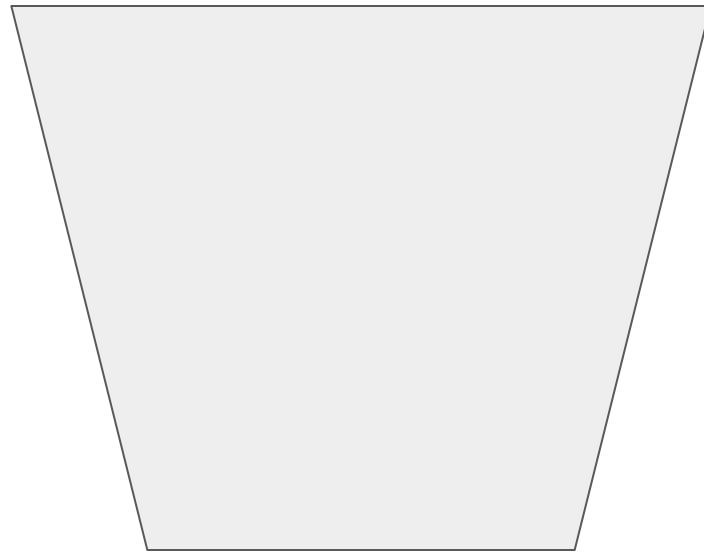
***Why are nuclear plants closing in Illinois (or elsewhere)?***

# *Energy Economics and Nuclear Power*

1. “Always on” power is a blessing and a curse.
2. Deregulated markets force competition.
3. Nuclear is a “price taker”



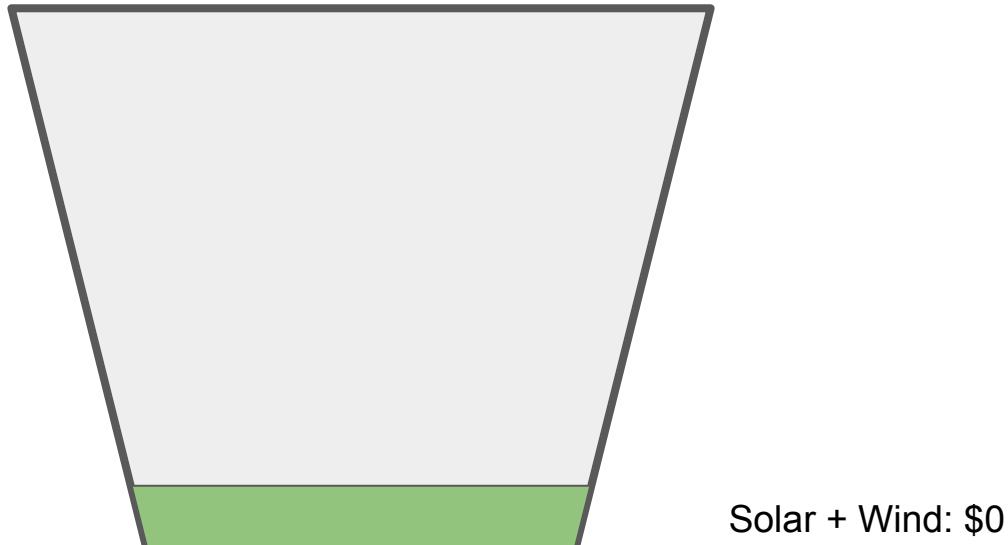
# *Market Clearing Price*



Tomorrow's Electricity Demand

# ***Market Clearing Price***

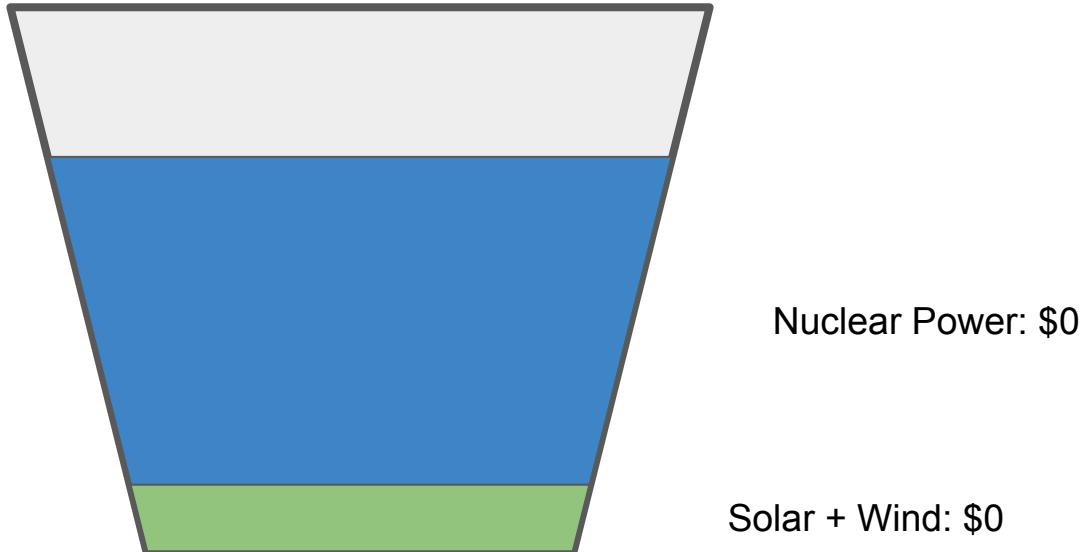
Market Clearing Price



Tomorrow's Electricity Demand

# ***Market Clearing Price***

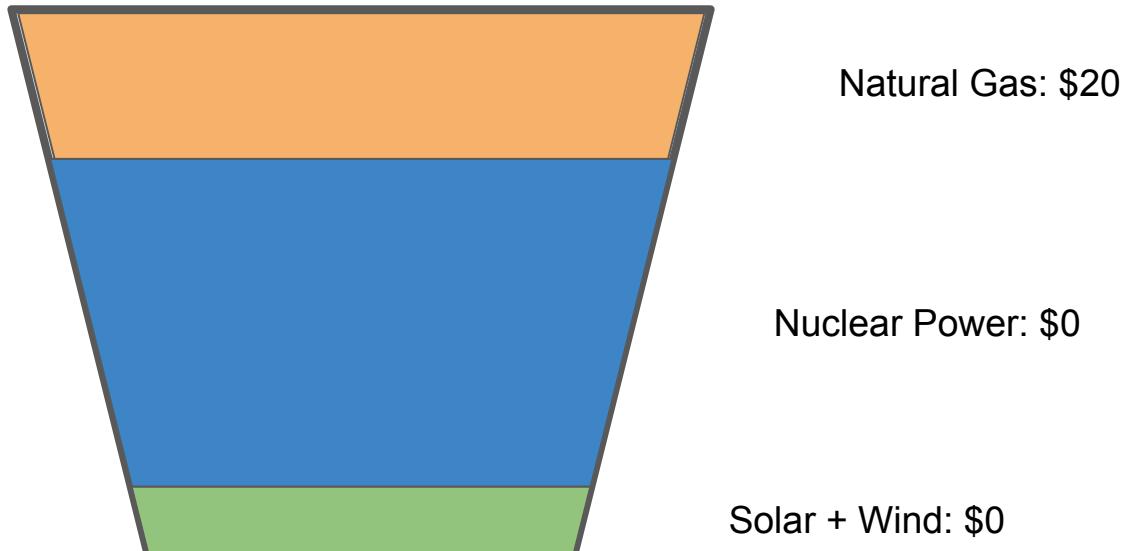
Market Clearing Price



Tomorrow's Electricity Demand

# *Market Clearing Price*

Market Clearing Price



Tomorrow's Electricity Demand

# *Market Clearing Price*

Market Clearing Price

Natural gas fills up  
remaining demand!

Everyone below gets  
paid \$20 per unit.

Coal: \$25

Natural Gas: \$20

Nuclear Power: \$0

Solar + Wind: \$0

Tomorrow's Electricity Demand

# **Rewarding Clean Energy**

- Solar and Wind benefit from Renewable Energy Credits
- Nuclear plants can (and should) get a similar reward through “Zero Emissions Credits”

## ZECs in Illinois

- Future Energy Jobs Act *introduced* ZECs
- Clean Energy Jobs Act should *expand* ZECs

# *Radiation*

## Living within 50 miles of a nuclear power plant for a year

Living near a nuclear power plant for a whole year exposes you to less radiation than eating one banana – and less than living near a coal power plant.



0.9 BANANAS  
0.09  $\mu\text{Sv}$

## Airport security scan

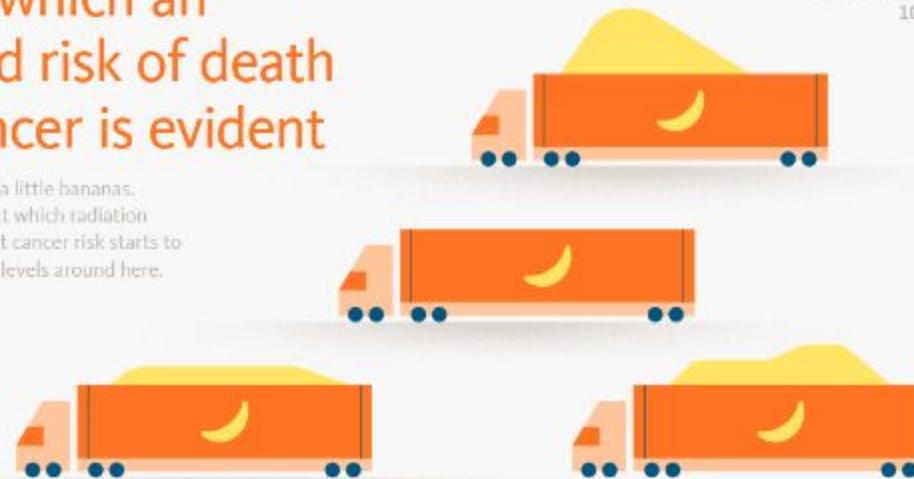


2.5 BANANAS  
0.25  $\mu\text{Sv}$

## Dose at which an increased risk of death from cancer is evident

Now it's starting to get a little bananas.  
There's no precise line at which radiation becomes dangerous, but cancer risk starts to increase to measurable levels around here.

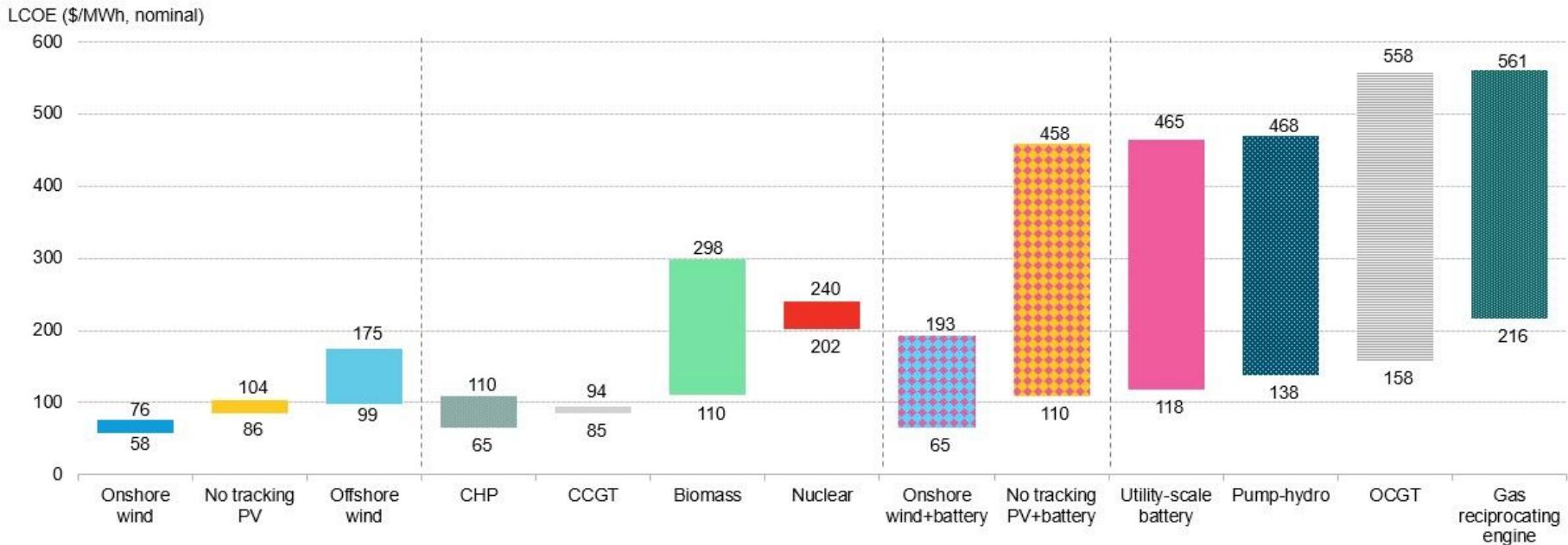
1 MILLION BANANAS  
100,000  $\mu\text{Sv}$



***Won't expanding nuclear energy lead to more nuclear weapons?***

*Isn't Nuclear Power Too Expensive?*

# *Levelized Cost of Electricity*



Source: WindEurope, 2019 -- <https://windeurope.org/policy/topics/economics/>

*Don't Nuclear Power Plants Take Too Long to Build?*