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Advancing Technology for Humanity

AI demand and the need for Nuclear Energy

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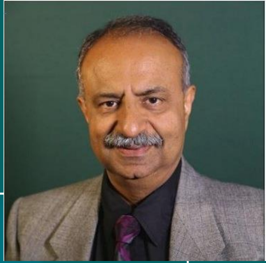
About Me



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Editor of the Section's Monthly Newsletter ~ *Wavelengths*
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* Bob Neff Section Award (2022),
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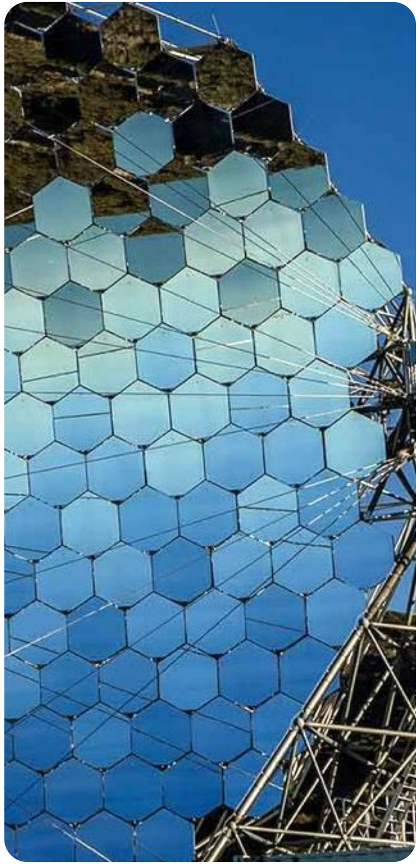
* Engineering Society of Detroit Ann O. Fletcher Award (2024)

Introductions

Outline:
* Demand for AI
* Case for Nuclear



Opening Notes

State of Electricity Installed Capacity

- Total Capacity: ≈ 1,330 GW.
- Natural Gas: ≈ 42.7% of total capacity.
- Coal: ≈ 15-18% of total capacity, with its share declining.
- Renewables (Total): ≈ 28.1%.
    - Solar: A rapidly growing source with a significant portion of new additions.
    - Wind: A substantial contributor to the renewable mix.
    - Hydroelectric: Provides a stable portion of the capacity.
- Nuclear: ≈ 8-9% of total capacity, providing a reliable, carbon-free baseload.
- Other Sources: Including petroleum, geothermal, and biomass, account for the remaining capacity.

Opening Notes

State of Electricity Growth in Capacity

- In 2025: 63 GW (planned)
- Represents a 30% rise!
- In 2024: 48 GW (with renewables – a major portion of this)
- 2025 planned share of Renewables ≈ 80 %.
    - Solar: 32 GW
    - Battery Storage: 18 GW

So what is causing this surge (pun intended)

Multitude of Reasons

- Increase in total demand
- Of this the lion’s share is primarily due to
    - Tech or Compute Infrastructure
    - Takes the shape of new data center construction
    - Root Cause is the massive, seemingly unquenchable thirst for AI

Why is AI so thirsty?

Goes back to the days of HPC growth

- AI has been around with us for several decades
- The ideas behind it have developed early on (e.g. Neural Networks in 1980s)
- The compute in those days was relatively expensive
- This includes pure CPU, memory, storage, interconnect, etc
- Early days: Moore's Law helped us, but we have slowed down (Separate talk)
- Then in the last decade, denser chips in the form of GPUs (graphic processing units) or accelerators appeared

Why is AI so thirsty?

Enter the GPUs

- In mid 2010s – a transformer model of natural language provided a break thru
- Sometimes referred to as Large Language Model (LLM)
- The basic structures behind those algorithms mapped nicely to GPUs
- GPUs were suddenly the “gold mine” for AI
- Prices of all compute related stuff (CPU, memory, storage, interconnect) improved and many tough problems became possible to solve…….

Why is AI so thirsty?

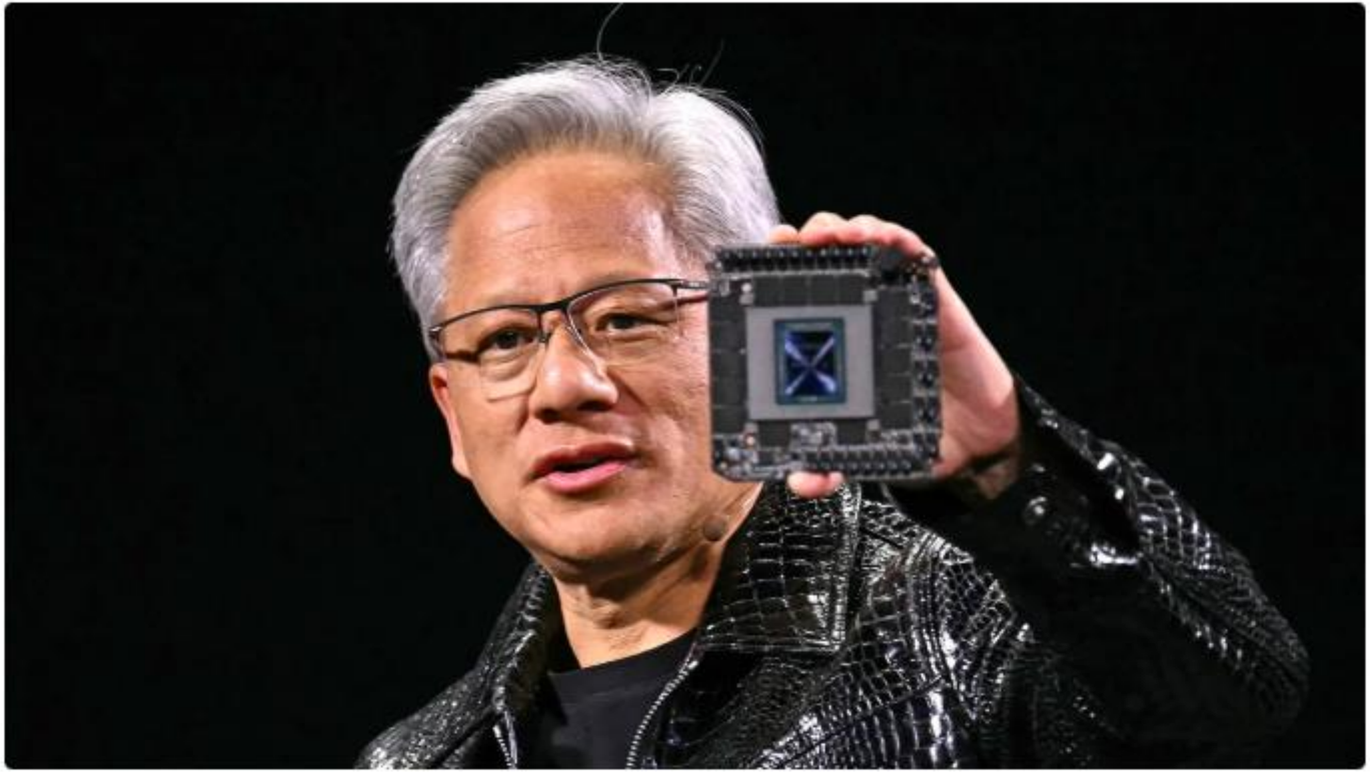
Rise of the GPUs

- GPUs require substantial electricity because they contain billions of transistors that must rapidly switch on and off to process vast amounts of data.
- Modern GPUs are essentially a collection of simplified processors working in parallel. Each transistor consumes power as it charges and discharges its internal capacitance when switching on and off.
- Furthermore - GPUs operate at high frequencies, meaning these transistors are switching on and off billions of times per second, rapidly accumulating power consumption.
- All combined they consume anywhere from 5x to 9x (or more – when we add the supporting elements) energy

Why is AI so thirsty?

Rise of the GPUs

- In early 2020s, the advances in AI software, coupled with availability of GPUs gave us products like ChatGPT, making AI a lot more accessible to all
- Boom!
- Now everyone is scrambling to harness/deploy/use AI in their business, does not matter what (government, retail, science, medicine, cloud, tech, industry, manufacturing, etc.,etc.)
- This has fueled the demand for those data centers to house the combined GPU/AI "digital factories"



Nvidia CEO Jensen Huang at CES 2025 in Las Vegas IMAGE: BLOOMBERG

Our collective response?

Build more Data Centers and more generating capacity to "care" and "feed" them!

- Global data center demand is projected to:
  - Double from $242.72 billion in 2024 to over $584 billion by 2032,
  - This expansion, expected to grow at a 12-15% compound annual rate through 2030,
  - So we need to get past "old" notions and reconsider!
  - Overcome supply constraints,
  - Make substantial investments
  - Add new infrastructure to meet surging demand – such as:
  - High-density AI workloads, Digital transformation, Cloud migration/growth, etc.

Our collective response?

Build more Data Centers and more generating capacity to "care" and "feed" them!

- While renewables is good, it alone is NOT enough
    - Need lots of land….
    - Sources are intermittent…
    - Must have battery storage (need more land and lots of chemicals)
    - Transmission lines….
    - Many other factors – cannot list them all
- Other sources are going to be a hard sell, so for the foreseeable future:
- *Revisit Nuclear*

The case for Nuclear

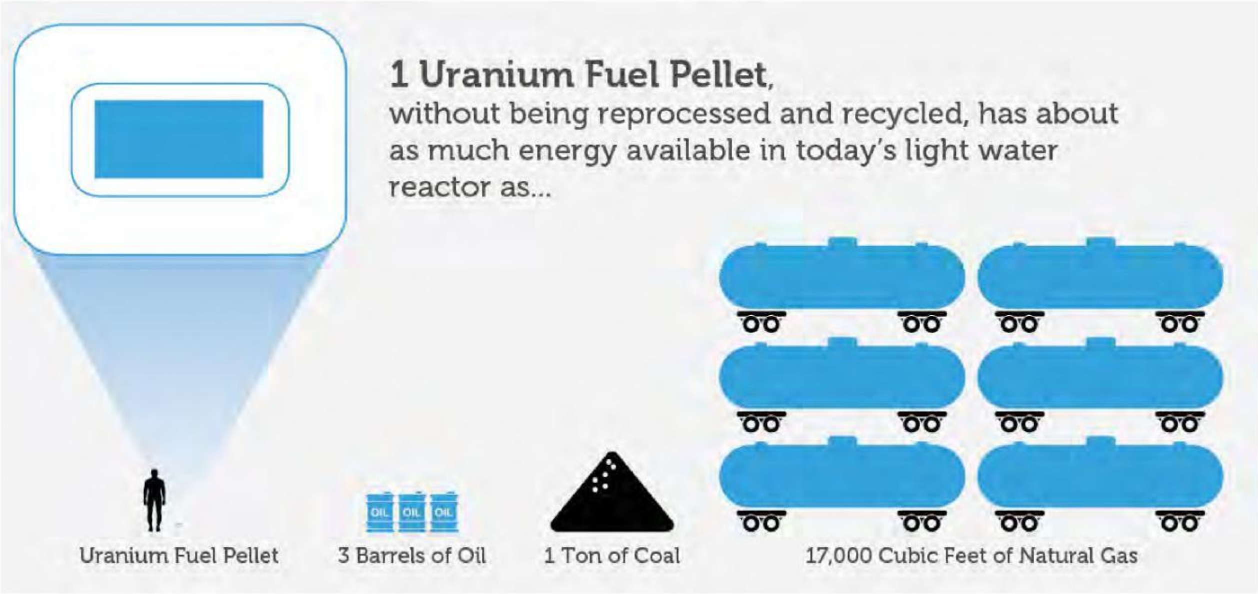
What have we learnt from the last 60 years?

- Will not repeat the nuclear industry history here
- *But share what major objections can be overcome!*

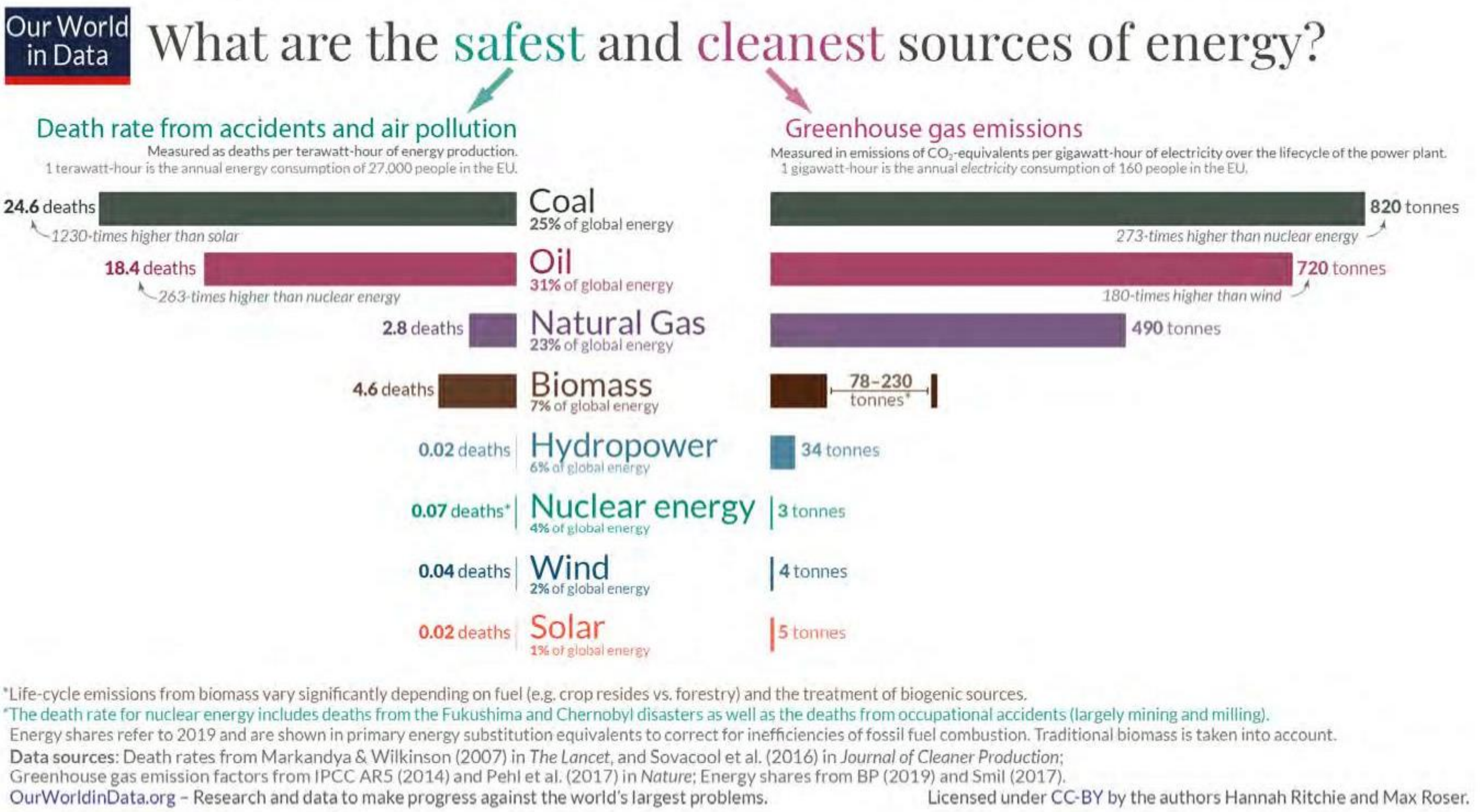
The case for Nuclear (2)

Addressing concerns

- Land Area
    - Requires far less, due to energy density
- Pollution Aspect
    - No CO2, no CO, no Nox, etc
- Costs
    - Capital Intensive, Lead time, Safety, etc
    - Objections are met with newer designs e.g. small modular reactors (SMR)



Source: American Nuclear Society


Our World in Data
What are the safest and cleanest sources of energy?
Death rate from accidents and air pollution
Measured as deaths per terawatt-hour of energy production.
1 terawatt-hour is the annual energy consumption of 27,000 people in the EU.
Greenhouse gas emissions
Measured in emissions of CO₂-equivalents per gigawatt-hour of electricity over the lifecycle of the power plant.
1 gigawatt-hour is the annual electricity consumption of 160 people in the EU.
24.6 deaths
1230-times higher than solar
Coal
25% of global energy
820 tonnes
273-times higher than nuclear energy
18.4 deaths
263-times higher than nuclear energy
Oil
31% of global energy
720 tonnes
180-times higher than wind
2.8 deaths
Natural Gas
23% of global energy
490 tonnes
4.6 deaths
Biomass
7% of global energy
78-230 tonnes*
0.02 deaths
Hydropower
6% of global energy
34 tonnes
0.07 deaths*
Nuclear energy
4% of global energy
3 tonnes
0.04 deaths
Wind
2% of global energy
4 tonnes
0.02 deaths
Solar
1% of global energy
5 tonnes
*Life-cycle emissions from biomass vary significantly depending on fuel (e.g. crop resides vs. forestry) and the treatment of biogenic sources.
*The death rate for nuclear energy includes deaths from the Fukushima and Chernobyl disasters as well as the deaths from occupational accidents (largely mining and milling).
Energy shares refer to 2019 and are shown in primary energy substitution equivalents to correct for inefficiencies of fossil fuel combustion. Traditional biomass is taken into account.
Data sources: Death rates from Markandya & Wilkinson (2007) in The Lancet, and Sovacool et al. (2016) in Journal of Cleaner Production;
Greenhouse gas emission factors from IPCC AR5 (2014) and Pehl et al. (2017) in Nature; Energy shares from BP (2019) and Smil (2017).
OurWorldinData.org – Research and data to make progress against the world's largest problems.
Licensed under CC-BY by the authors Hannah Ritchie and Max Roser.

The case for Nuclear (3)

Introducing SMR

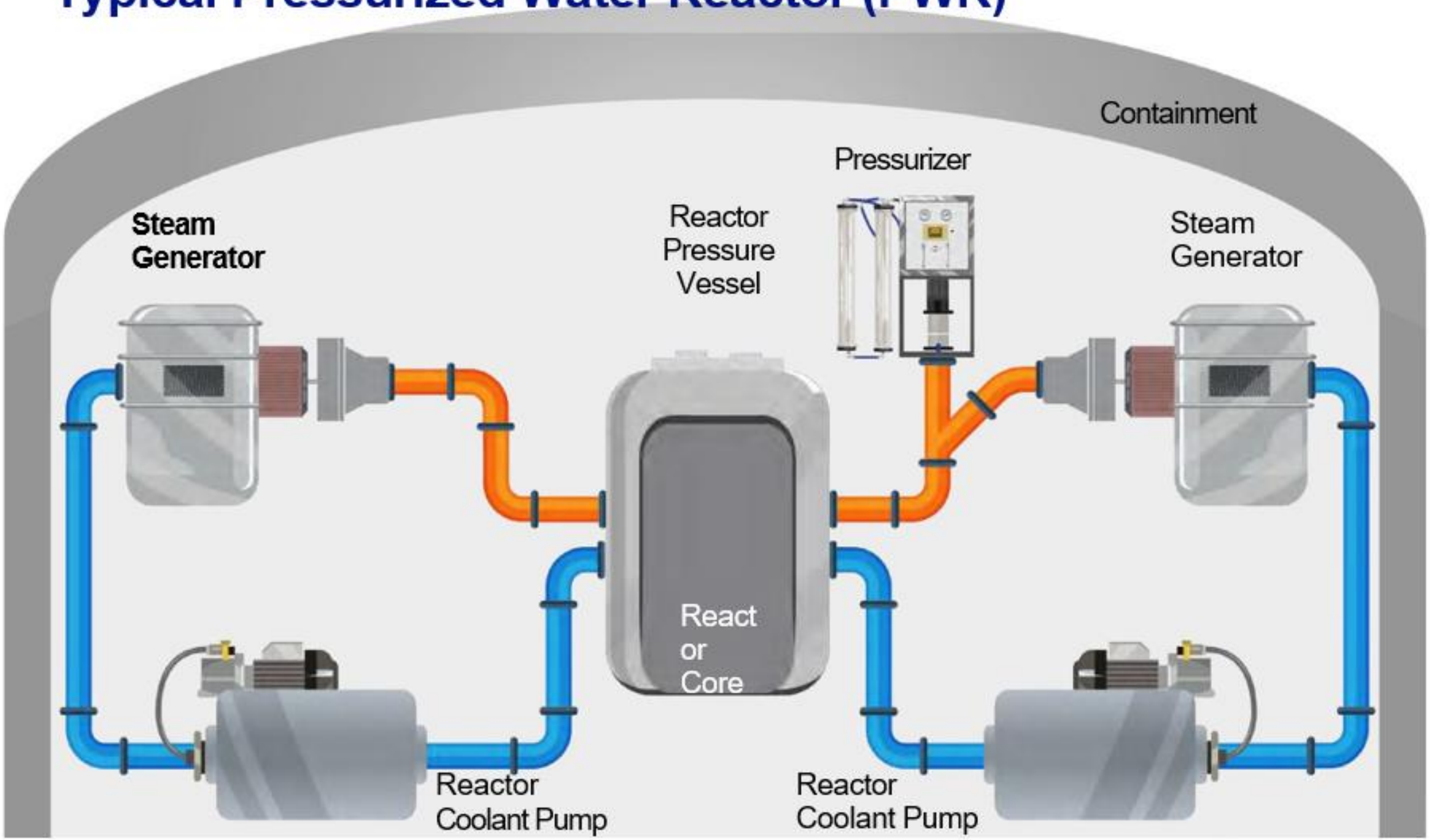
- All examples and data based on NuScale – but there are several others!
- Back in 2000 US Department of Energy (DoE) MASLWR concept/design
- NuScale Power (2007) develops the SMR Power Module ™
- Design review vetted by the NRC (Nuclear Regulatory Commission)
- Design Approval granted in 2020
- Total costs between $1-2 billion (est)

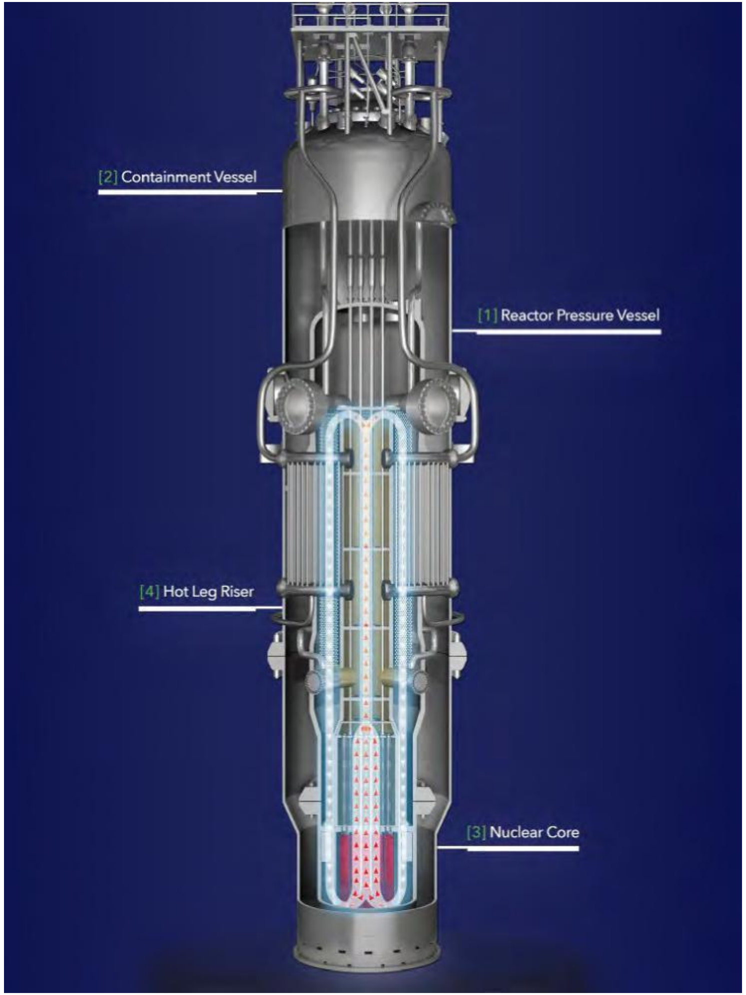
The case for Nuclear (4)

Introducing SMR

- NuScale Power Module (NPM) includes everything in 1 package
    - Reactor Vessel
    - Steam generator
    - Pressurizer
    - Containment
- Simple design eliminates many possible points of failure
- Each NPM produces upto 77 Mwe
- Can be clustered in 4, 6 modules plants

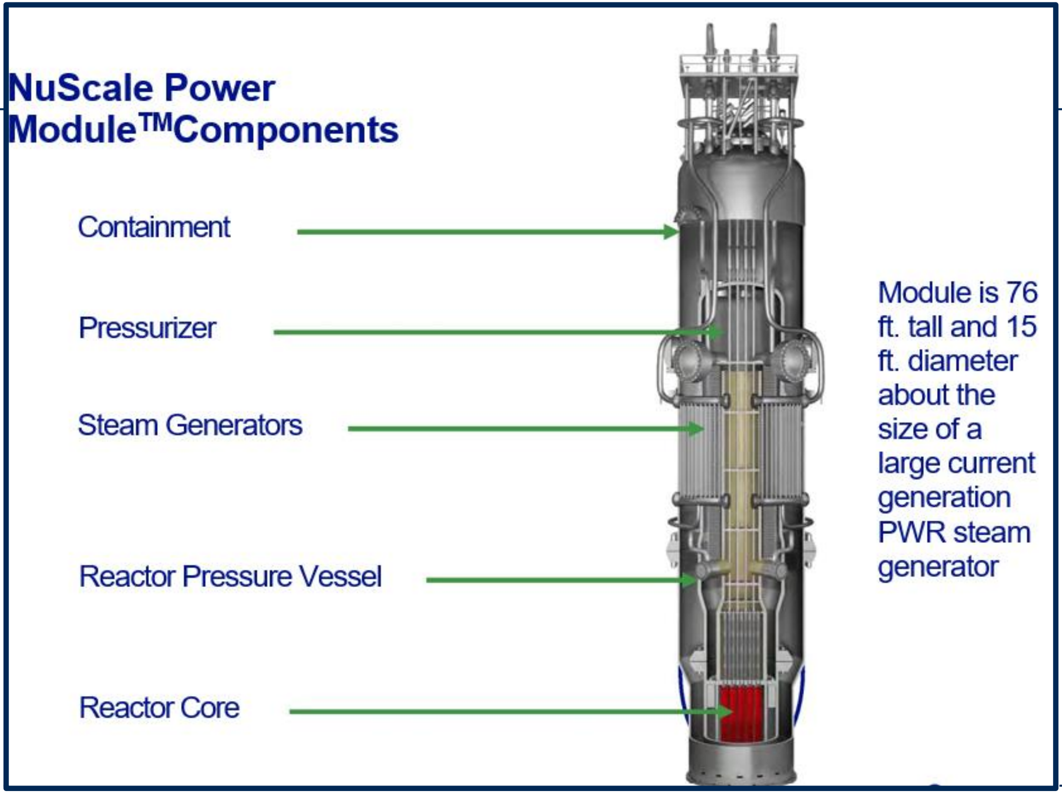
Typical Pressurized Water Reactor (PWR)




[2] Containment Vessel
[1] Reactor Pressure Vessel
[4] Hot Leg Riser
[3] Nuclear Core

The case for Nuclear (5)

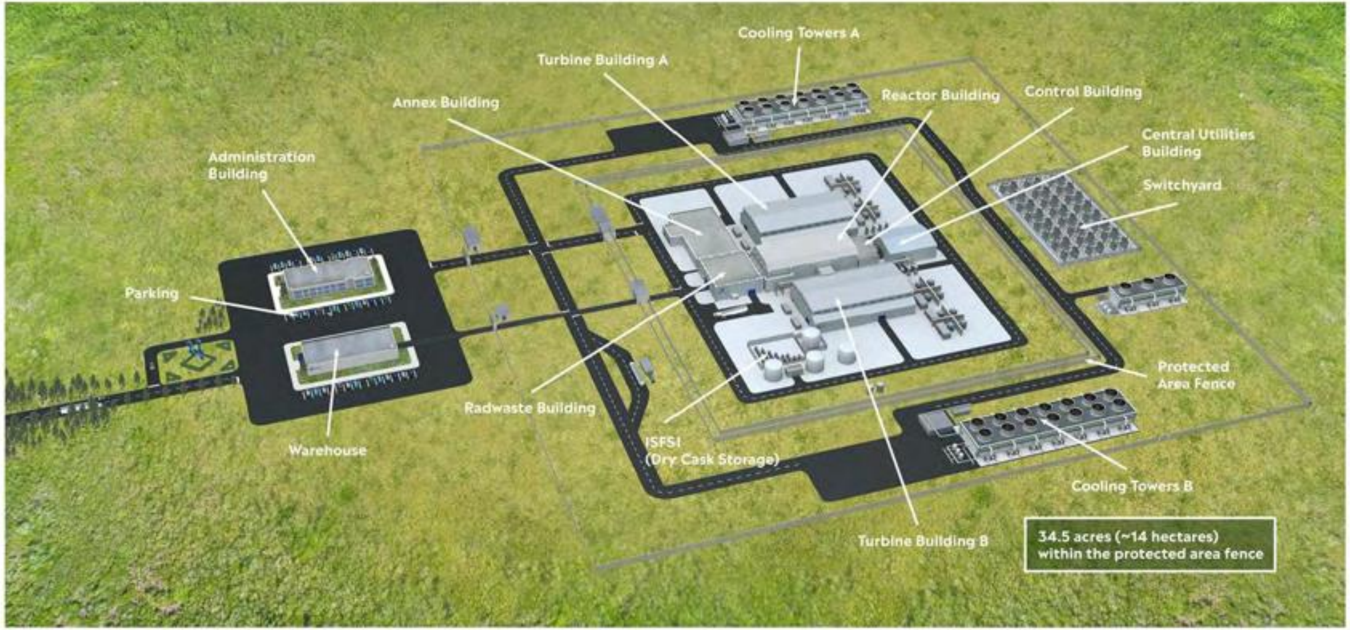
More SMR Aspects



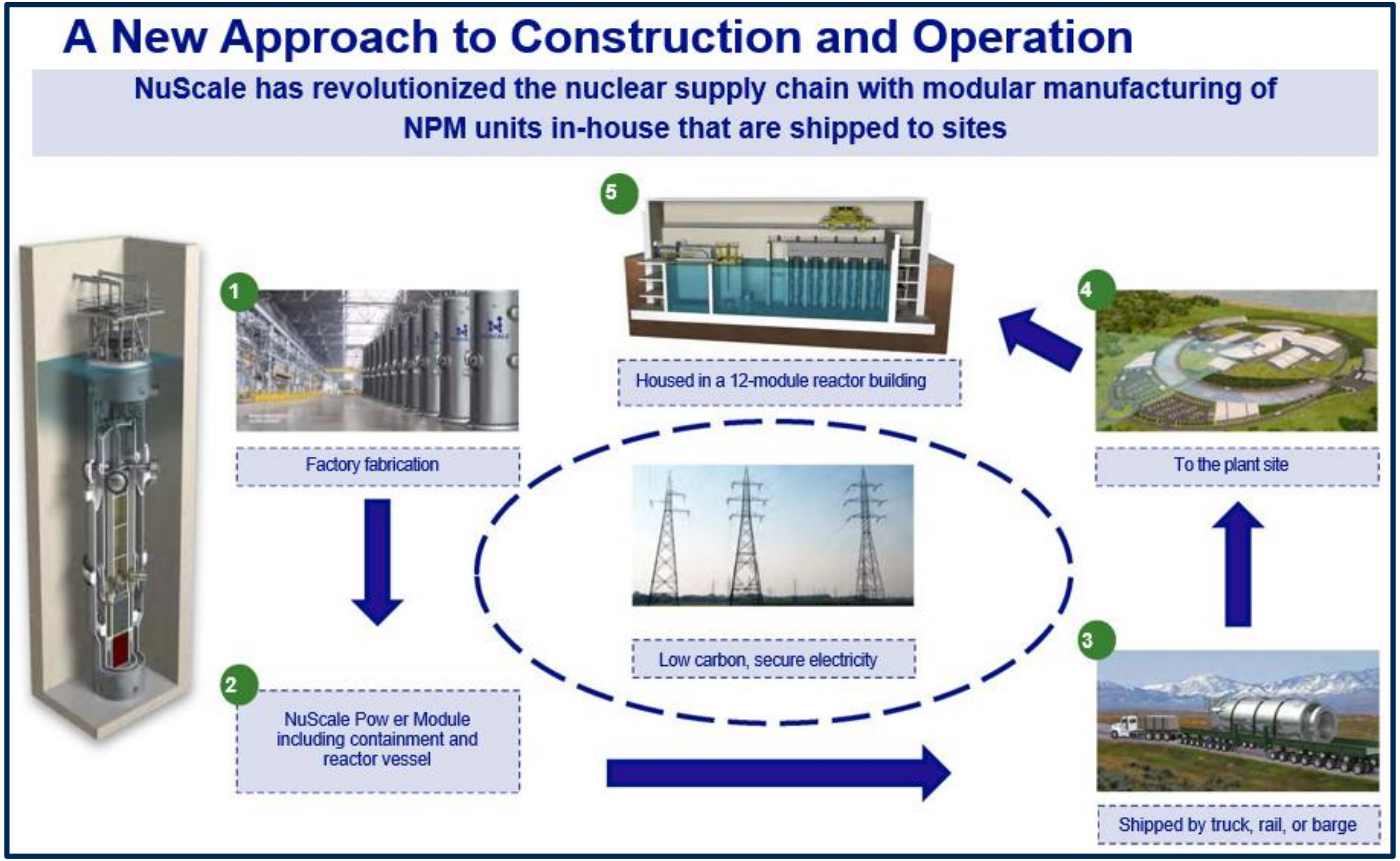
The case for Nuclear (4)

More SMR Aspects

- Designed to re-use old coal plants!



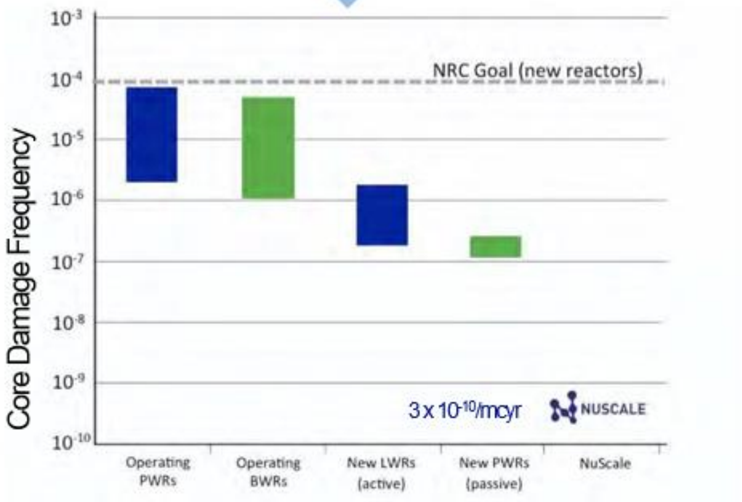
The case for Nuclear (5)

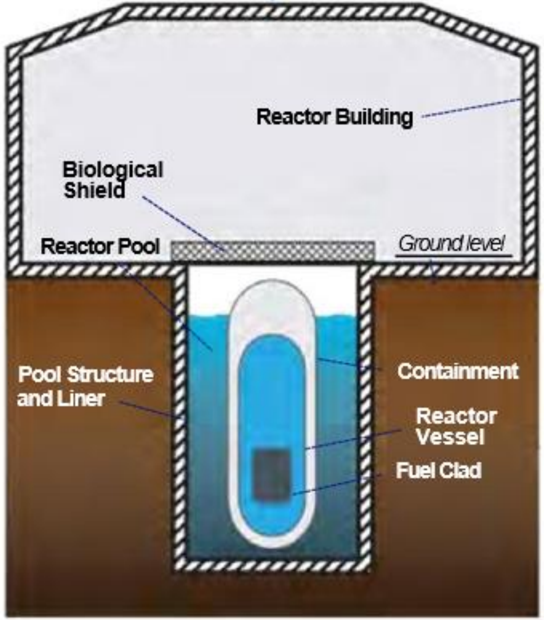


The case for Nuclear (6)

Reducing Plant Risk

Risk = (frequency of failure) X (consequences)





Probability of core damage (full power, internal events) due to NuScale reactor equipment failures is ***1 event per module every ~3 Billion Years.***

Four additional barriers to release of radioactivity from a NuScale

The case for Nuclear (7)

Reducing Plant Risk

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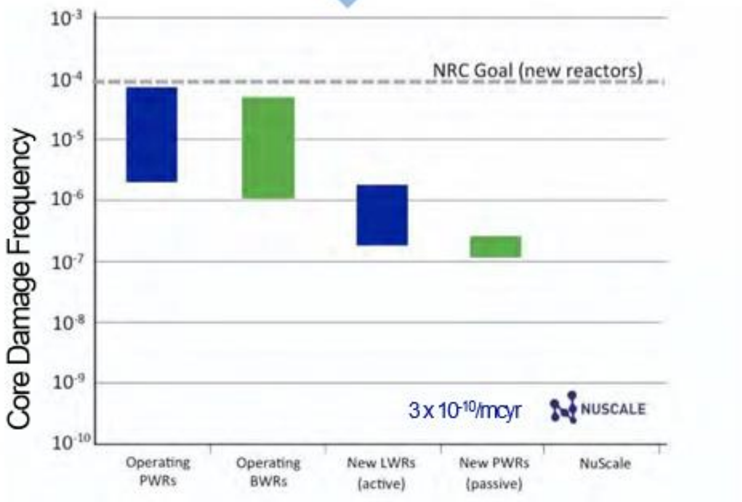

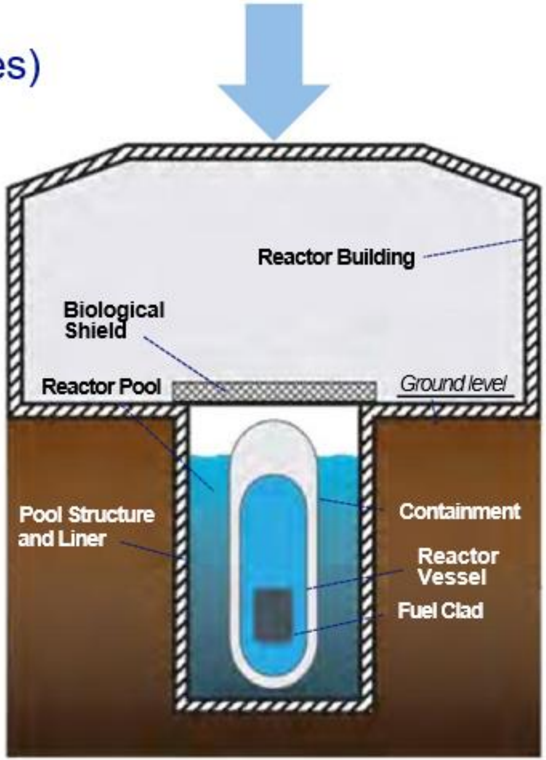

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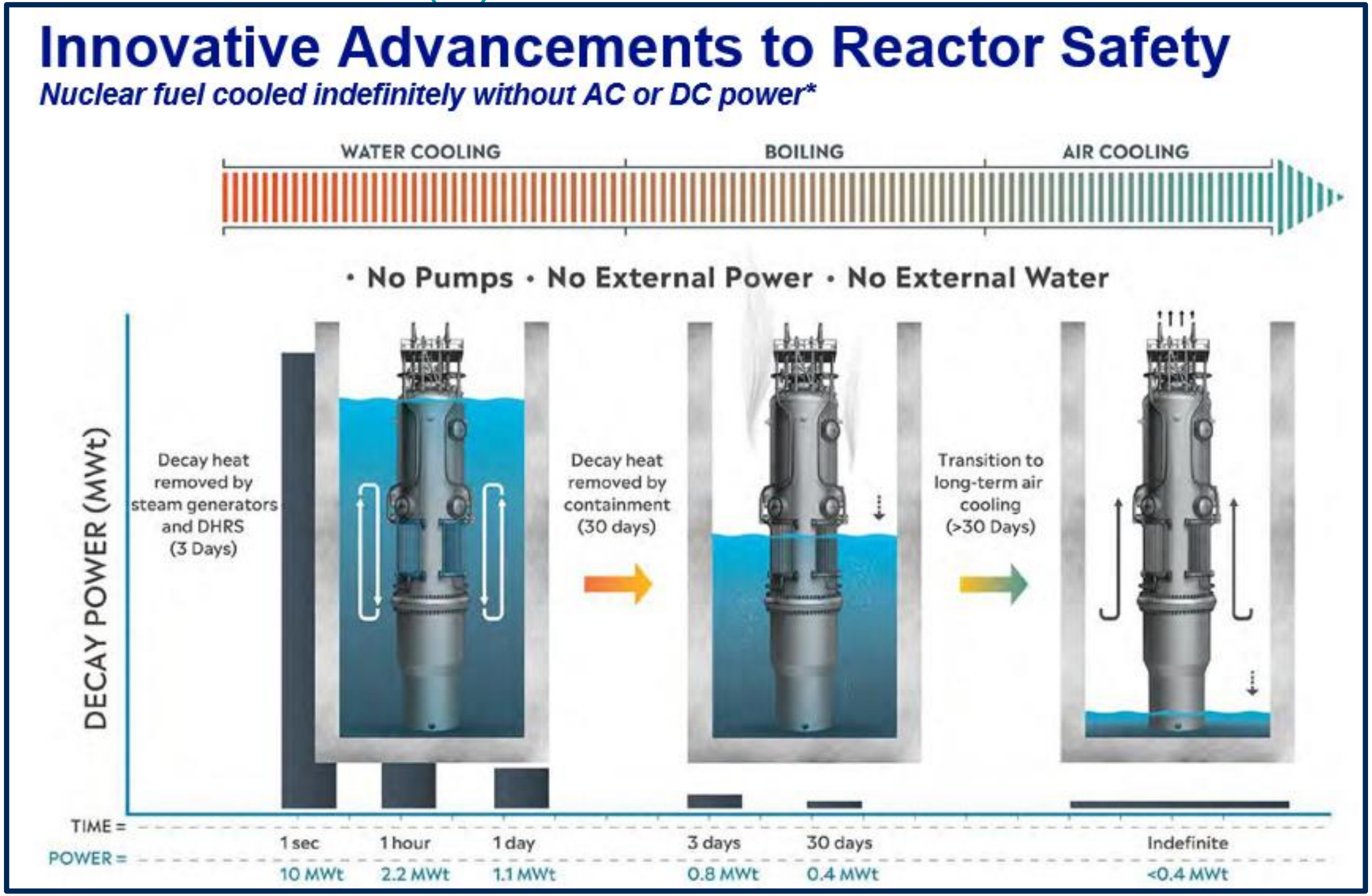
The case for Nuclear (8)



Backup Data

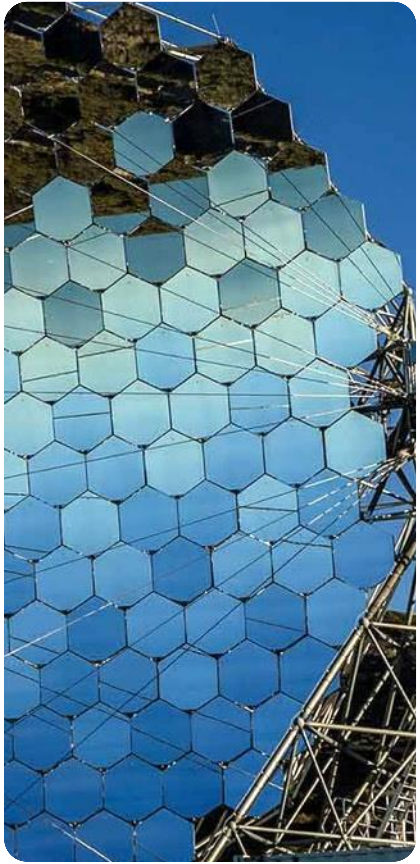
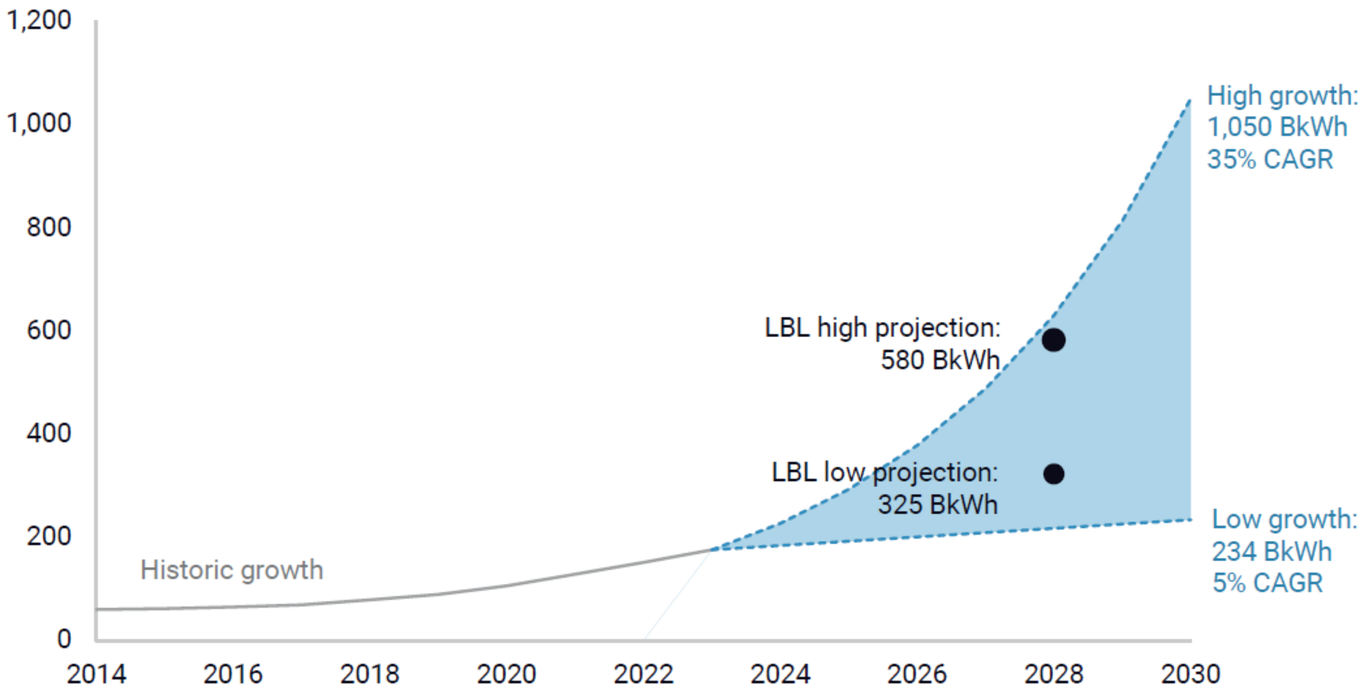


FIGURE 1

Historical and expected electricity demand growth from data centers, 2014-2030

Billion kilowatt-hours



Source: Rhodium Group, Lawrence Berkeley Lab

https://eta-publications.lbl.gov/sites/default/files/2024-12/lbnl-2024-united-states-data-center-energy-usage-report.pdf

France - example

Contrasting Approach

- In 2024, nuclear energy was by far the largest source of electricity in France.
- Total ≈ 19.9 TWh.
- Generation by Source (2024)
- Nuclear: ~67%
- Renewables: ~28%
  - Hydropower: The second-largest source of electricity.
  - Wind: Significant contribution.
  - Solar: Showed significant growth and contributed to a new record.
  - Biofuels & Waste: Also contributed to renewable energy totals.
- Fossil Fuels: Remained at very low levels, with gas, oil, and coal generation at their lowest levels in decades.
- Summary: Overall nuclear and renewable energy is 95% of the power mix in 2024 (low carbon sources)

France - example

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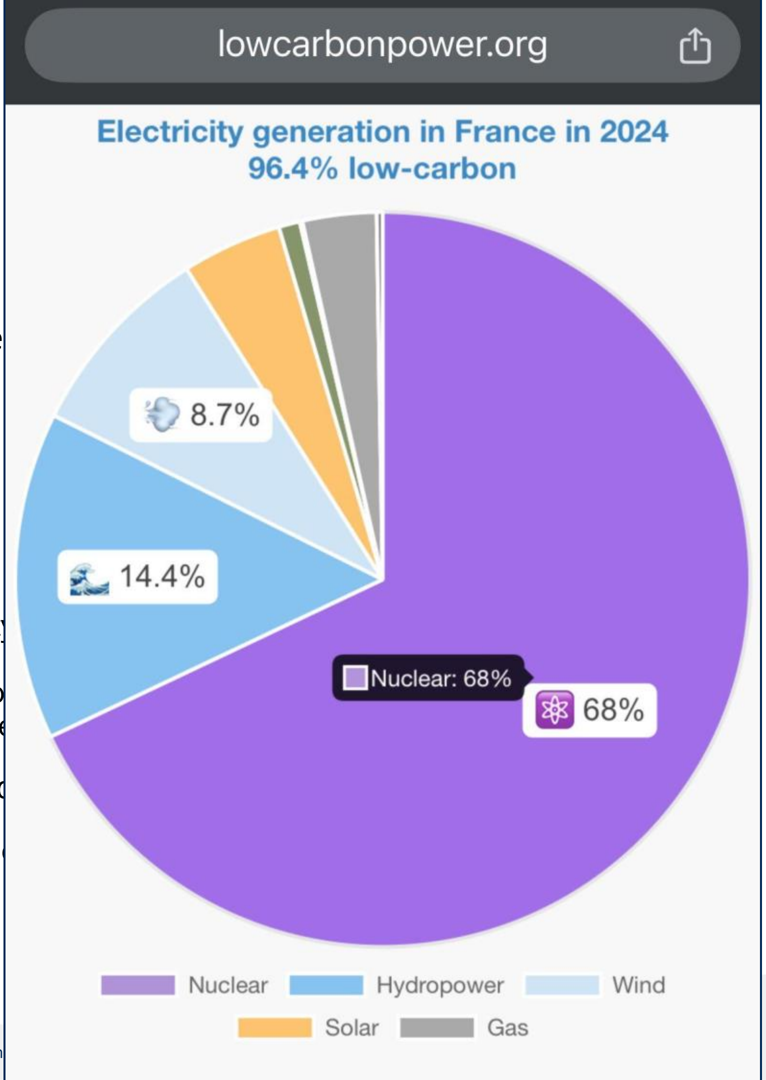

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Nuclear Accidents

Compare with slide #18

- 3 major incidents globally
- Fukushima, 3 Mile Island and Chernobyl
- See http://www-pub.iaea.org/books/IAEABooks/Publications_on_Accident_Response

Nuclear Accidents

Another way of looking at this