Power *From* The People

The Power Requirements of AI Data Centers

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Two Ways To Look at AI

AI-generated 'slop' is slowly killing the internet, so why is nobody trying to stop it?

Arwa Mahdawi

The Guardian Link

Low-quality 'slop' generated by AI is crowding out genuine humans across the internet, but instead of regulating it, platforms such as Facebook are positively encouraging it. Where does this end?

The Explosion of "AI Slop"

With 'AI slop' distorting our reality, the world is sleepwalking into disaster

Nesrine Malik

The Guardian Link

A perverse information ecosystem is being mined by big tech for profit, fooling the unwary and sending algorithms crazy

Protein structure prediction breakthrough

Mapping the human brain

AI-assisted brain computer interfaces

AI in mathematical reasoning breakthroughs

Astrophysical discoveries

AI-assisted weather forecasting

Material science breakthroughs

AI/Quantum algorithms for chemistry simulations

AI-created algorithms

A Golden Era for Science

Robotic-assisted scientific discovery cycles

Climate change modelling

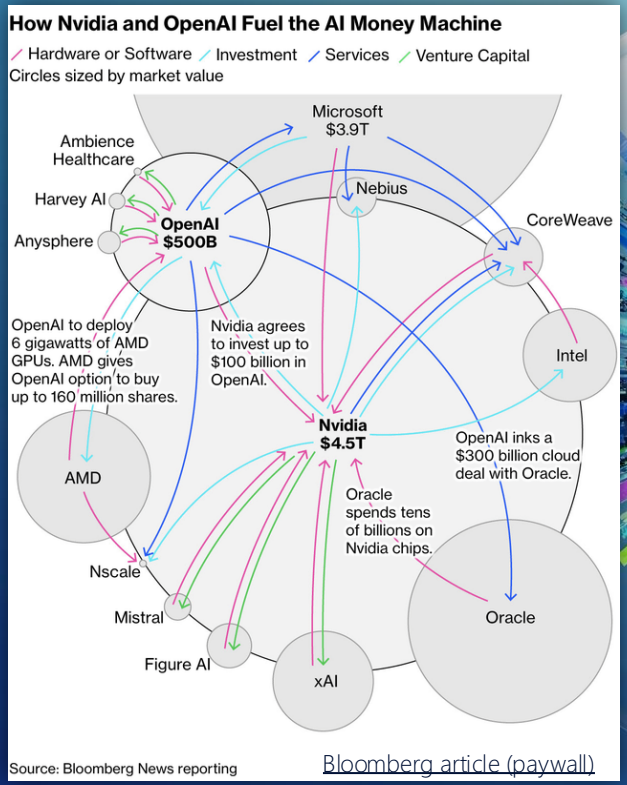
AI medical image analysis

AI Spatial Intelligence

The emergence of Quantum Processing for AI

Similar lists for business, industry, healthcare and the military

Recently we've seen concerns appearing…



Bloomberg article (paywall)

TLDR NEWS

Is the US economy just one big AI bubble?


OpenAI
Prosperity for whom? Just checking ☺
How did we get to the doorstep of the next leap in prosperity?
Deep learning worked, got predictably better with scale, and we dedicated increasing resources to it.
Sam Altman, OpenAI
Scaling deep learning means scaling compute power, which means bigger, more power hungry data centers

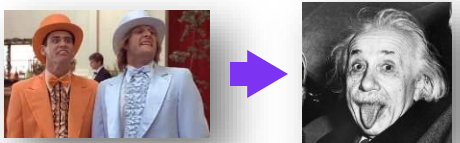
Why does AI need so much power?

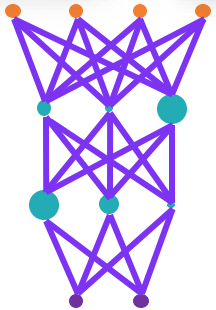
How does AI get smarter?

Source: OpenAI - Scaling Laws for Neural Language Models

Can only scale…

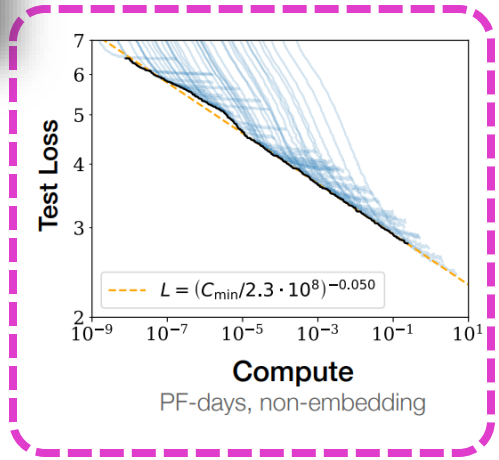
Data Set Size
Parameters

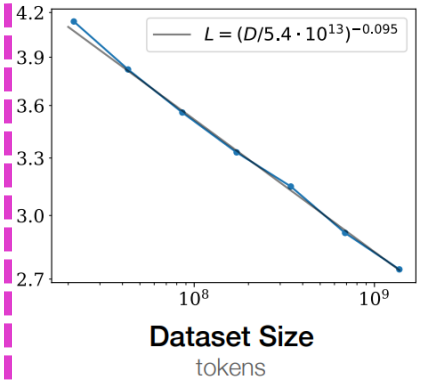


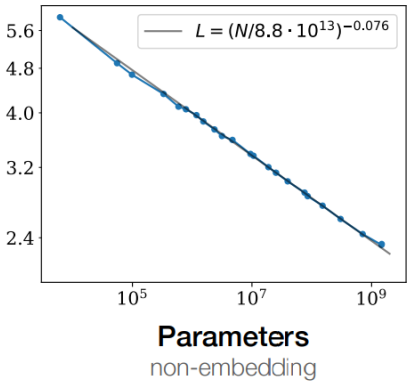


Direct consequence of the Transformer architecture

But scaling these means…

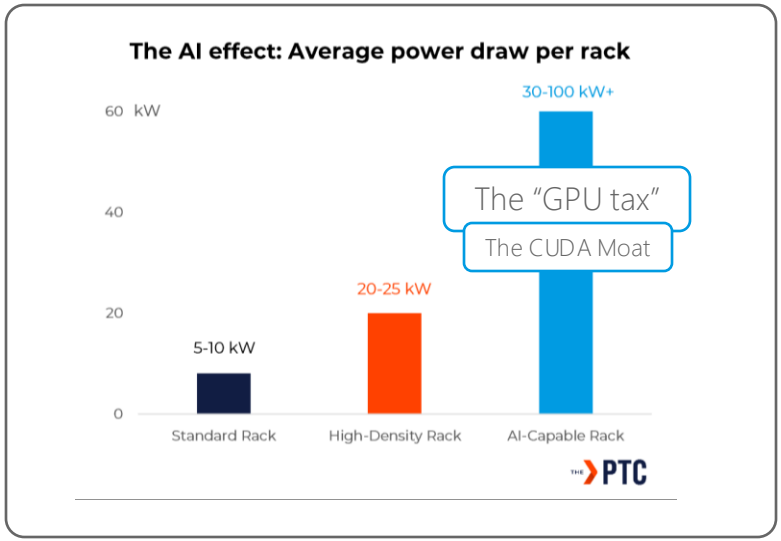






More Compute = More Electrical Power

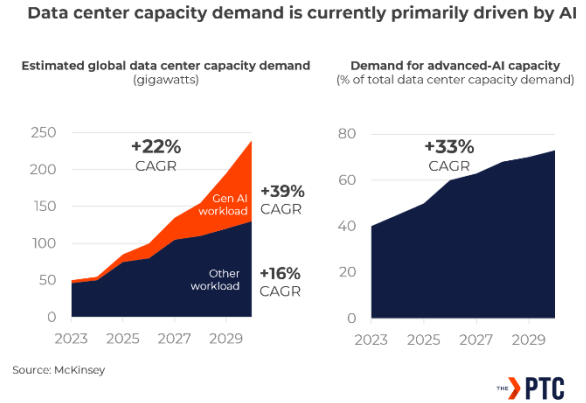
Dramatic growth in AI electrical power demands



Difficult to find the electrical power to build data centers in one location

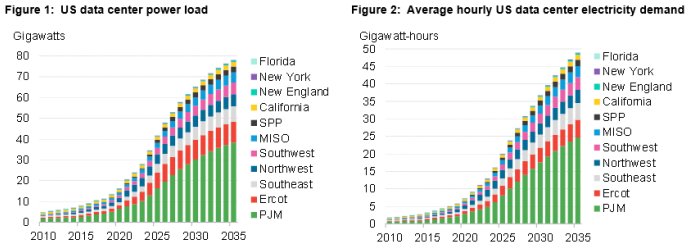
Implies AI data must move to where the power is

Global



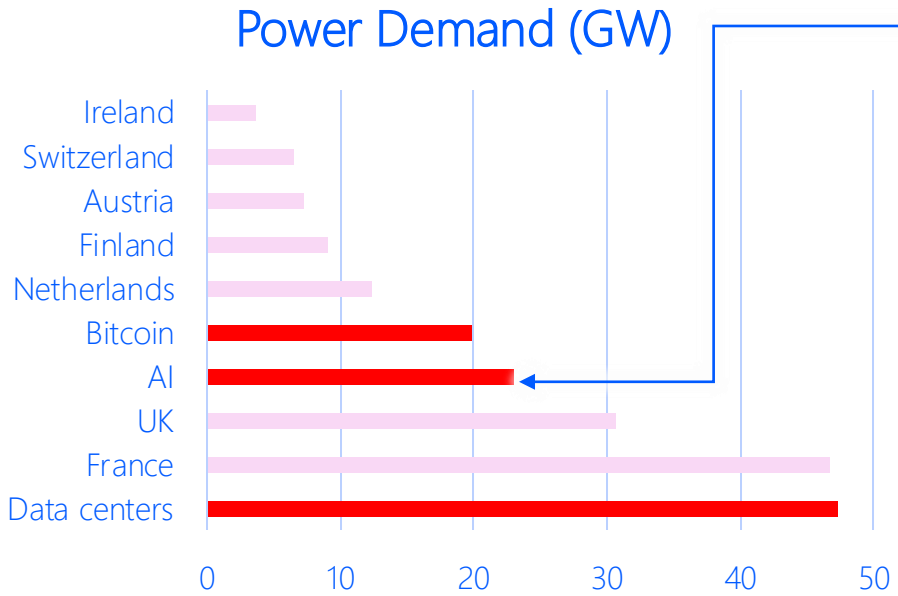
Heading towards Gigawatt scale Data Centers

USA



Note: PJM Interconnection is the largest Regional Transmission Organization (RTO) in the United States, managing the electric power grid for parts of 13 eastern states and the District of Columbia.

AI power demands in context



The Guardian

AI could account for nearly half of datacentre power usage 'by end of year' (2025) Link

CNBC

Google says U.S. is facing a power capacity crisis in AI race against China

PUBLISHED WED, FEB 12 2025 1:02 PM EST Link

MIT Technology Review

"We did the math on AI's energy footprint. Here's the story you haven't heard." Link

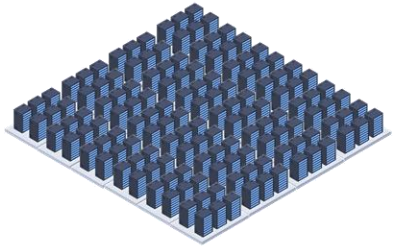
Source: Alex de Vries-Gao. "Artificial intelligence: Supply chain constraints and energy implications": Link

Notes: situation at the end of 2024, AI end 2025. 'Datacenters' excludes crypto mining. AI is considered 'all-in' including training power consumption, for instance.

NOKIA

Data centers are getting bigger!

Note: These examples are to show the headlong rush to mega scale data centers is real. The actual ranking of current future data centers is not clear cut – especially in China, where past claims have been challenged.



AI is resetting the expectation of what a "large Data Center" is

2013

Then…largest DC in Europe

Meta's Lulea Data Center

30 MW*

84,000 m^2

*267,471 MWh of electricity annually and withdraws 25.4 million litres of water

Source: Baxtel

2025

Largest DC in the World

China Telecom IMIP

150 MW

1,000,000m^2

Note – China occupies the first 7 places in at least one Data Center Top 10 list

2028

~~Largest DC Announced~~

Jeollanam-do Province South Korea

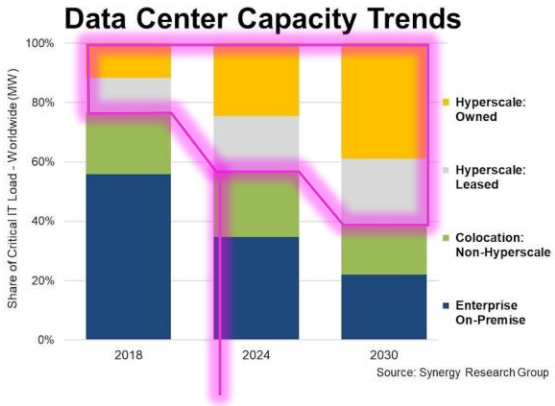
3,000 MW

$35B Investment

Source: Capacity

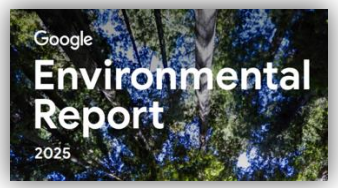
But they all use green energy, right?

AI Hyperscaler CO_2 Committments



More and more DC capacity is being driven by hyperscalers Link

Thank goodness they have the best interests of the planet at heart



Source: Hyperscalers versus the sustainability pushback

Google

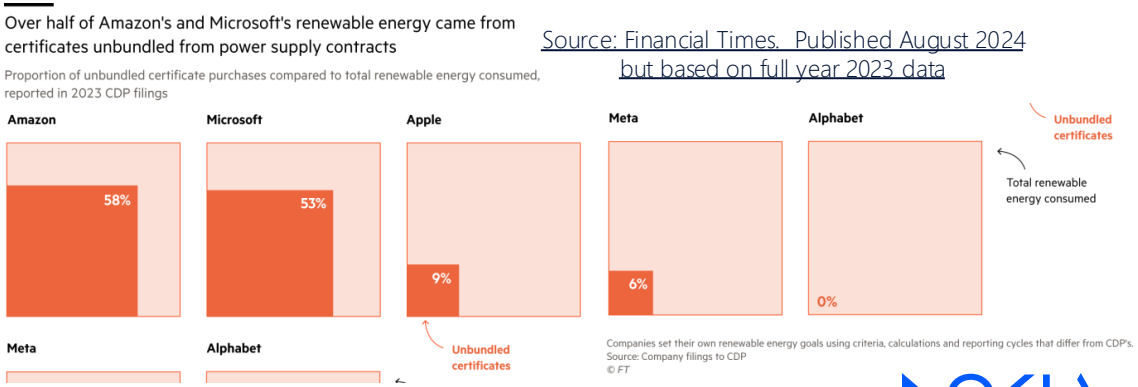
Goal: "Carbon neutral by 2030"

Reality: *48% increase in CO_2 emissions since 2020*

Microsoft:

Goal: "Remove all MSFT CO_2 emissions by 2050"

Reality: *29.1% increase in CO_2 since 2020*



Source: Financial Times. Published August 2024 but based on full year 2023 data

RECs, CECs and GOs: The “subprime derivatives” of Clean Energy

UNIVERSITY OF CAMBRIDGE

Link to report

Millions of carbon credits are generated by overestimating forest preservation

Study analyses major carbon offset projects, and finds that – of a potential 89 million credits – only 5.4 million (6%) were linked to additional carbon reductions through tree conservation.

Reel

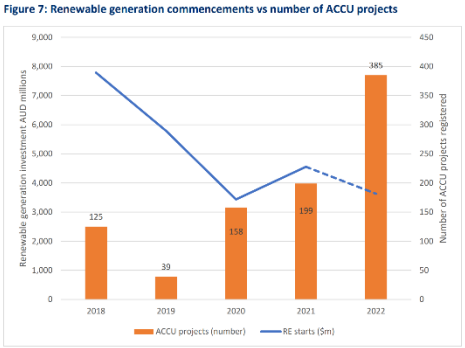
The Problem With “Green” Energy Certificates

Link to article

Australia’s experience – Carbon Credit Schemes increasing while Renewable Energy projects decreasing

Link to report

ACCU = Australian Carbon Credit Units



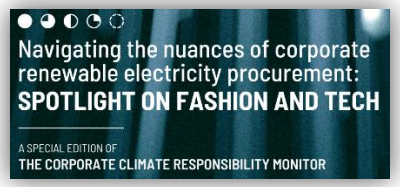
Sources: ABS (2022) Value of renewable energy construction; Emissions Reduction Fund (2023) Emissions Reduction Fund project register. Note: 2022 data for renewable energy starts is only available for March and June quarters. Figure 8 extrapolates the average of the March and June quarters across the calander year.

Clean Energy Agreements

Why use “real” clean energy when you can buy “virtual” clean energy?

Issues in the domestic market…

…and with big corporations



Link to report

Problem: Carbon credit schemes are *poorly regulated* and, in a hugely shocking revelation, it seems that humans can be rather unscrupulous

Problem: Companies are trading in Clean Energy Contracts as a quick fix – allowing them to delay or avoid taking *effective* energy decisions

Long term this actually reduces the number of real clean energy projects being started

NOKIA

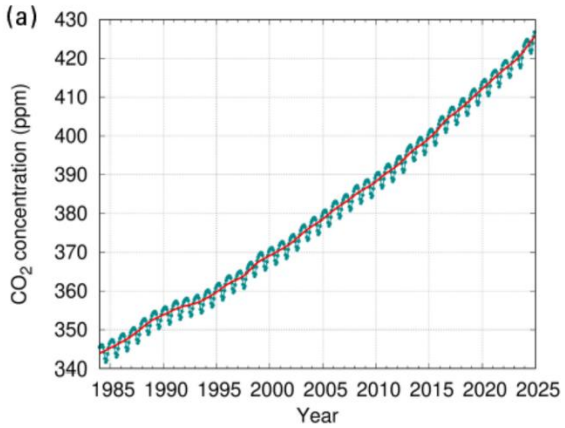
This should be top of our “to do” list – “Item 1: Save the planet”

2024 saw the biggest annual rise in CO2 emissions

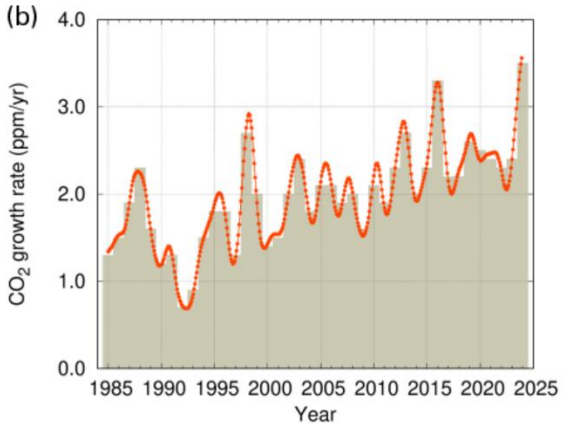
Source: WMO 2024-25 Report

WORLD METEOROLOGICAL ORGANIZATION

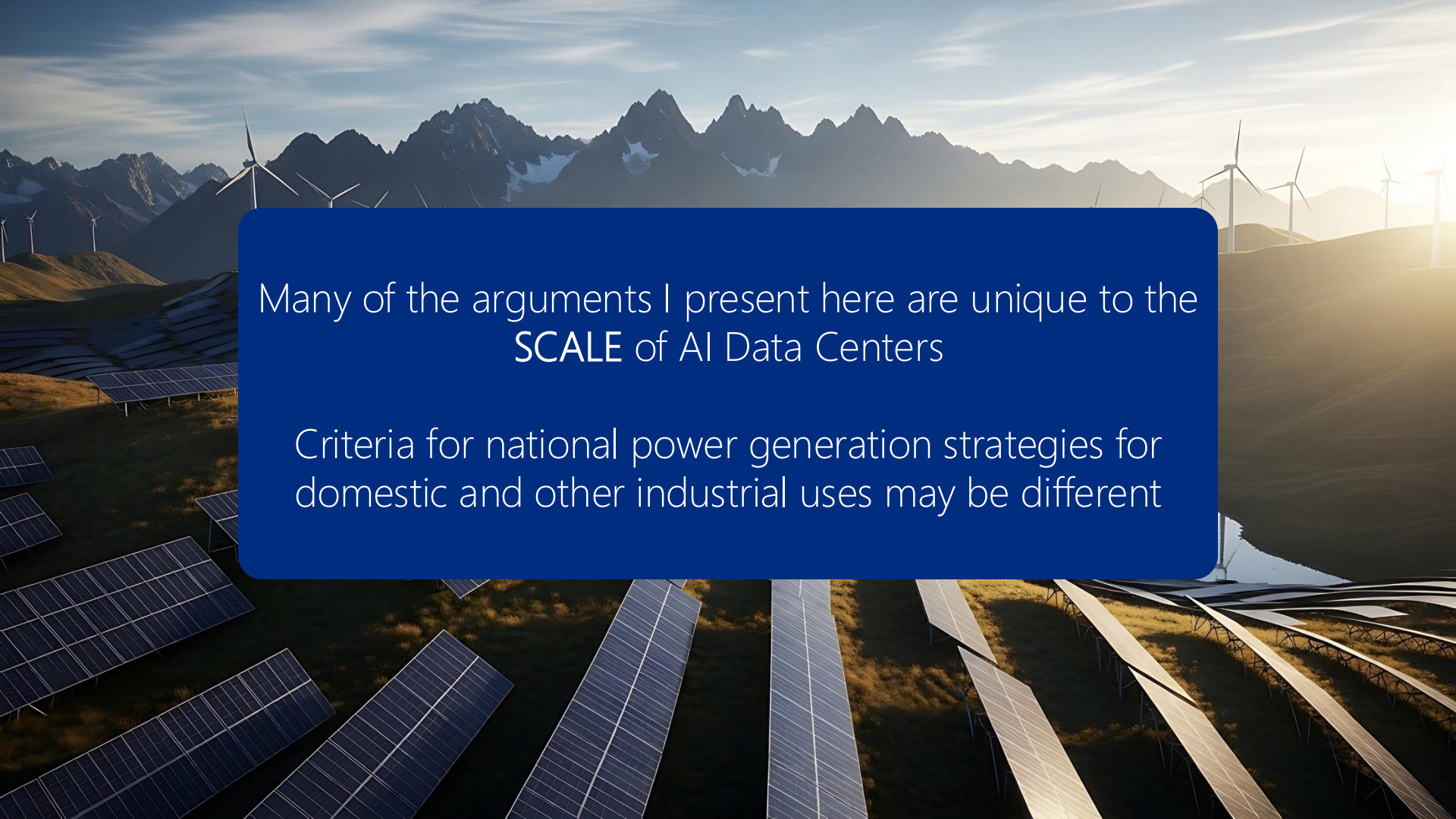
It’s not just the absolute concentration…



…CO_2 growth rate is bad…really bad




Why are we failing our
C02 targets?

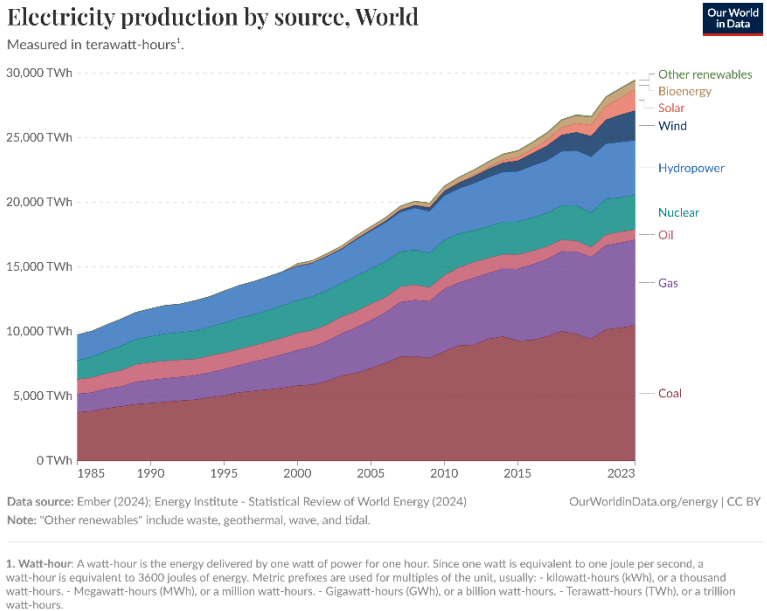


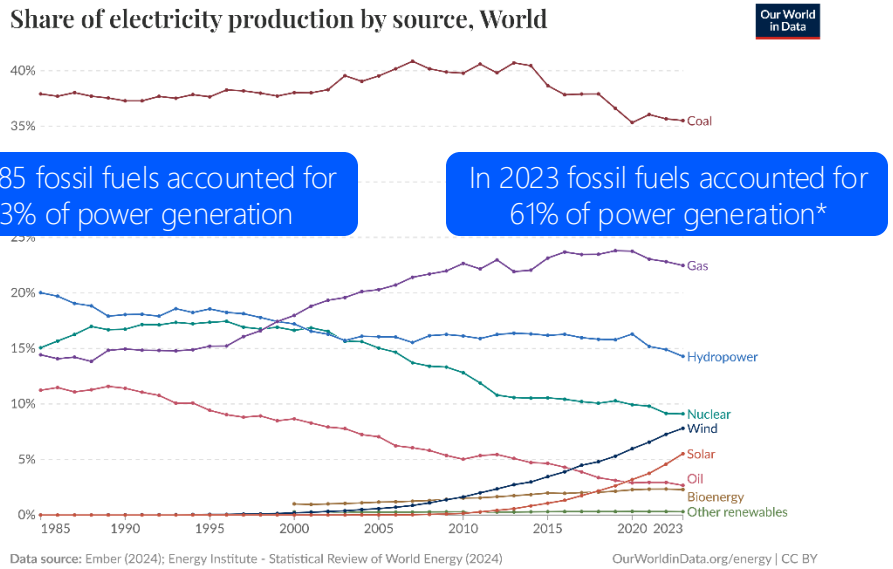
Many of the arguments I present here are unique to the **SCALE** of AI Data Centers

Criteria for national power generation strategies for domestic and other industrial uses may be different

Renewables

How does the world generate electricity?





In 1985 fossil fuels accounted for 63% of power generation

In 2023 fossil fuels accounted for 61% of power generation*

*2023 data includes 2.3% bioenergy, and some forms have significant CO2 footprint

Energy consumption is rising

This is a good thing! Energy = Prosperity
Don't feel guilty that this is chart is rising…

Little or no progress on decarbonization

…we need to be far more focused on ***how*** we generate this power

Solar and Wind At Gigawatt Scale

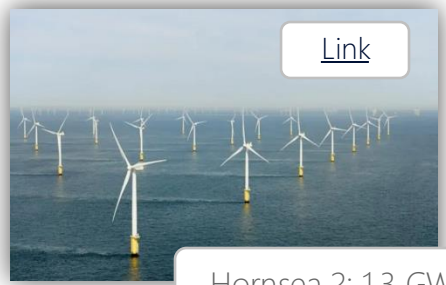
- 864 MW of solar PV
- 3,287 MWh of battery storage

The largest BESS in the world could only power a Gigawatt-scale data center for 3 hours!*

The largest BESS in Europe would only last 40 minutes!

*BESS Battery Energy Storage System

45X larger than Colossus 2 Data Center
But solar only has a 25% energy factor
So the real area would be almost 200X



Hornsea 2: 1.3 GW 114,000 acres

Offshore wind has a 35% energy factor, so would need to be about 3,000X larger than the Data Center itself

And it would be nowhere near the Data Center

Solar and Batteries can be “problematic”

>80% of solar panels are made in China

- 98% of solar wafers
- 92% of solar cells
- 85% of solar modules (panels)

Link

Use of forced labor (Uyghur)

Xinjiang's forced labour practices and the solar industry's dependence Link

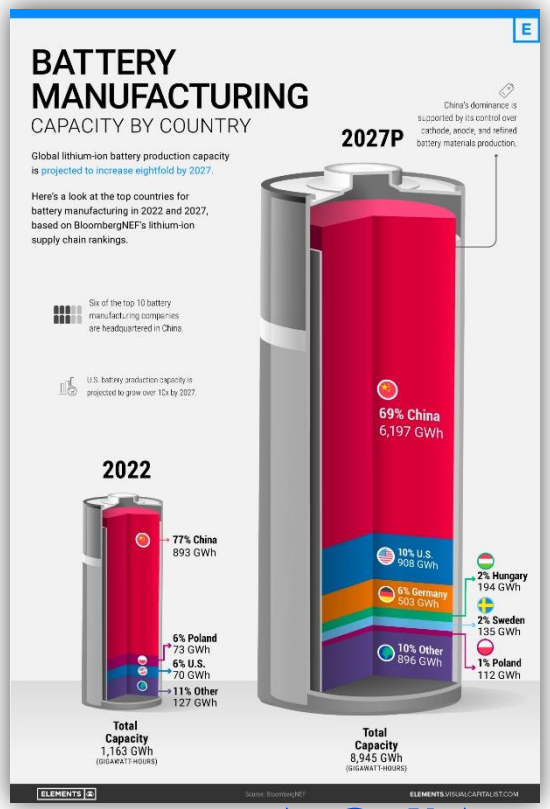
<10% of solar panels are recycled and newer panels are even more difficult to recycle Link

>70% of lithium batteries are made in China

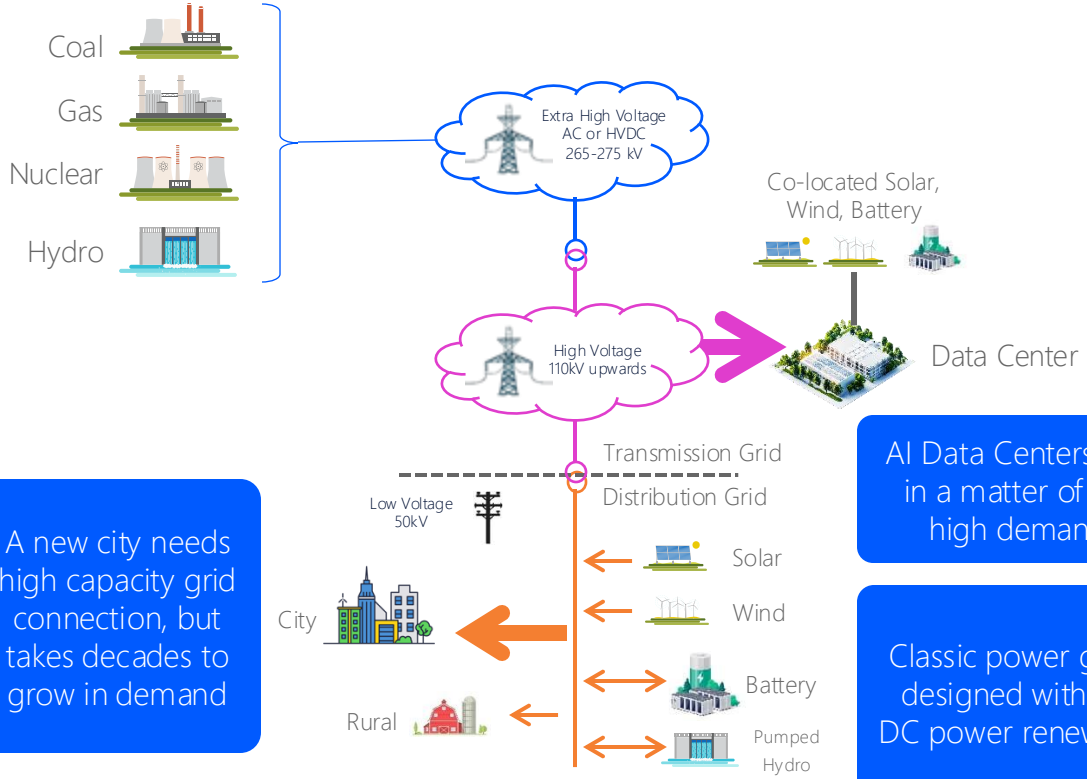
Link

Impossible to find reliable data on battery recycling, or on what constitutes “successful material extraction”

BUT…The EU now has legislation in place



The role of power grids



A new city needs high capacity grid connection, but takes decades to grow in demand

AI Data Centers can "pop up" in a matter of months with high demand on Day 1

Classic power grids were not designed with intermittent, DC power renewables in mind

Think about grid in same way as the internet – a cloud…maybe ☺

The Grid is fed from power stations that generate AC

Different voltage levels for efficient transmission and distribution

Normal scale users – like cities and farms – use Distribution Grid

Renewable installations usually feed into the Distribution Grid – and generate DC

Storage systems also have 2-way connection to Distribution Grid and may generate DC or AC

Very high demand users will connect directly to the HV transmission grid

Data Center may have local Solar, Wind and Battery Storage

Needs Grid connection for reliability against intermittent renewables

Grid congestion issues already caused by move to renewables

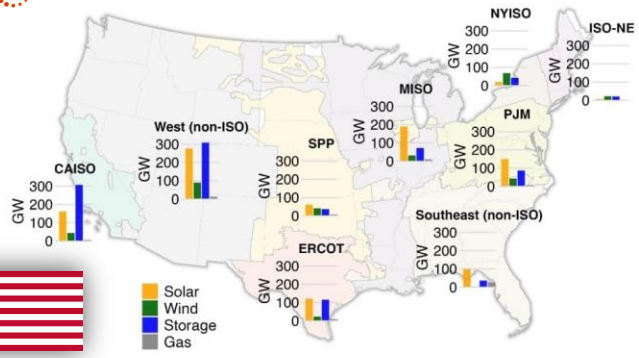
Link to article

Capacity crunch on National Grid is delaying new homes in UK by years

Council leaders warn of 'infrastructure crisis' that will also affect green energy schemes and hinder growth

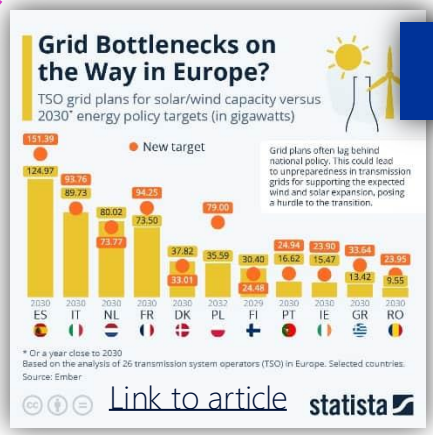
Link to article

Reuters Link to article



Size of grid connection queues across USA

Link to article



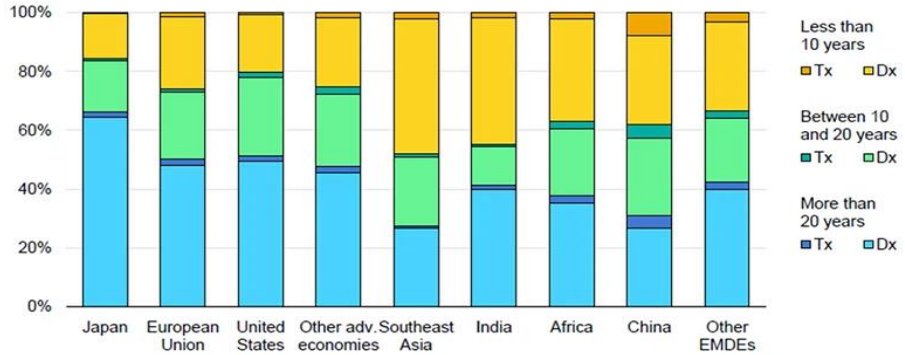
Link to article

Size of wind farm connection queues across Europe

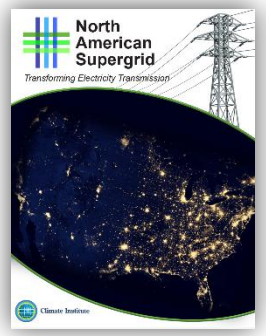
Link to article

Power grid investments

Age of Power Grids



2017: Proposal for North American Supergrid

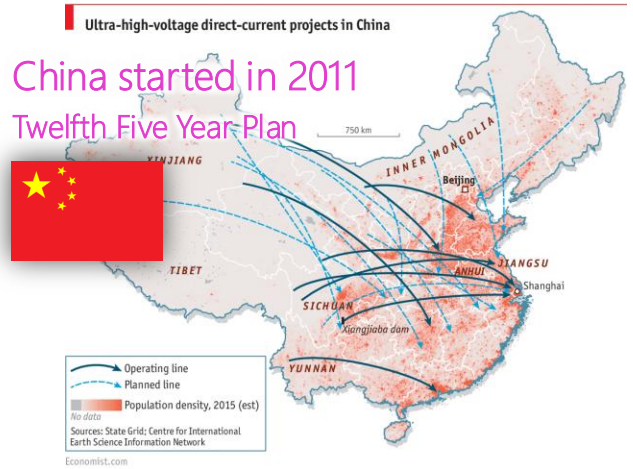


Hypothetical US network following railroad Rights of Way

On average Europe's power grids are >40 years old

Renewables are putting significant strain on today's grid infrastructure in Europe

But somebody is investing heavily…



April 2025: China has completed

- 38 Ultra High Voltage lines
  - 18 of these are AC
  - 20 are DC
- Carry power from Solar, Wind, Coal, Hydro and Nuclear

What are Hyperscalers saying that they are doing to solve the AI power problem?

The Hyperscalers' Plans for Clean Energy

SMR = Small Modular Reactor

	Short Term	Long Term
amazon	Purchased 900 MW Data Center next to Susquehanna Nuclear Plant	SMR plans in 3 US locations (inc. VA and WA) X energy Anchor investor
Google	*Geothermal investments* FERVO ENERGY	October 2024: Google announced agreement with Kairos Power for SMRs — Kairos Power Elementl Power and Google Sign Strategic Agreement to Develop Locations for Advanced Nuclear Projects — ELEMENTL
Microsoft	September 2024: Microsoft sign agreement to reactivate reactor at Three Mile Island & CEC and SMR deal with OPG	Nuclear Fusion deal with Helion — HELION
ORACLE	Talking about a 130k Nvidia cluster	"Intention to build Gigawatt-scale AI data centers powered by Small Modular Nuclear Reactors"
Meta	Plan to build Data Center near nuclear facility blocked by discovery of rare bees	August 2024: Agreement with Sage Geosystems for Geopressurized Geothermal System — SAGE GEOSYSTEMS

Geothermal

Focus on promoting new geothermal

International Energy Agency Report: Future of Geothermal Energy 2025

The Future of Geothermal Energy (US-specific report)

The ground below the earth's surface is hot because of the *radioactive decay* of natural elements like uranium and thorium

In some places around the world this heat is easier to get to – *Conventional Geothermal*

Conventional Geothermal provides *less than 1%* of global energy today – because it tends to be used in the "easiest" geothermal locations

United States, Iceland, Indonesia, Turkey, Kenya, Italy

*Geothermal may release CO_2 from underground. This *can* be removed before release, but the USA is not a Kyoto treaty signatory so it is unclear if CO_2 emissions would be monitored or enforced for EGS plants.

Enhanced Geothermal Systems use fracking techniques to enable many more locations

Enhanced Geothermal: The Bottom Line*

Promising technique *in countries that accept fracking*

Can provide employment for former oil/gas workers

Probably not as "green" as the claims – especially at scale

Probably more of a *"tens of megawatt" scale solution, not gigawatt*

But it's early in the development of EGS – keep an open mind

*The author's opinions – please read the reports and draw your own conclusions

Potential to create *100 GW* of new geothermal generation within *50 years*

Total cost of *$600-900M*

What are the safest and cleanest sources of energy?

Our World in Data

Link to paper

Death rate from accidents and air pollution

Measured as deaths per terawatt-hour of electricity production.
1 terawatt-hour is the annual electricity consumption of 150,000 people in the EU.

Coal
24.6 deaths
1230-times higher than solar
36% of global electricity

Oil
18.4 deaths
613-times higher than nuclear energy
3% of global electricity

Natural Gas
2.8 deaths
22% of global electricity

Biomass
4.6 deaths
2% of global electricity

Hydropower
1.3 deaths
171,000 deaths from Banqiao Dam failure in 1975, China
12% of global electricity

Wind
0.04 deaths
7% of global electricity

Nuclear energy
0.03 deaths
Includes deaths from Chernobyl and Fukushima disasters
10% of global electricity

Solar
0.02 deaths
4% of global electricity

Greenhouse gas emissions

Measured in emissions of CO_2-equivalents per gigawatt-hour of electricity over the lifecycle of the power plant.
1 gigawatt-hour is the annual electricity consumption of 150 people in the EU.

Coal
970 tonnes
160-times higher than nuclear energy

Oil
720 tonnes
65-times higher than wind

Natural Gas
440 tonnes

Biomass
78–230 tonnes

Hydropower
24 tonnes

Wind
11 tonnes

Nuclear energy
6 tonnes

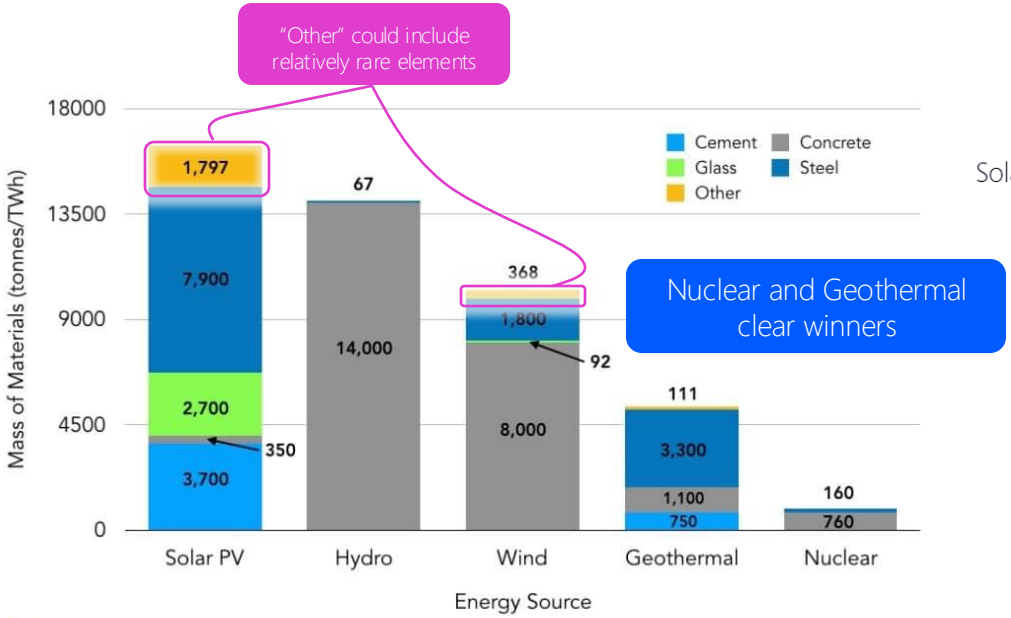
Solar
53 tonnes
(8 – 83 tonnes, depending on technology and location)

Nuclear is the safest and cleanest gigawatt-scale, grid-friendly, and reliable way to generate electricity

Death rates from fossil fuels and biomass are based on state-of-the art plants with pollution controls in Europe, and are based on older models of the impacts of air pollution on health. This means these death rates are likely to be very conservative. For further discussion, see our article: OurWorldinData.org/safest-sources-of-energy. Electricity shares are given for 2021.
Data sources: Markandya & Wilkinson (2007); UNSCEAR (2008; 2018); Sovacool et al. (2016); IPCC AR5 (2014); UNECE (2022); Ember Energy (2021).

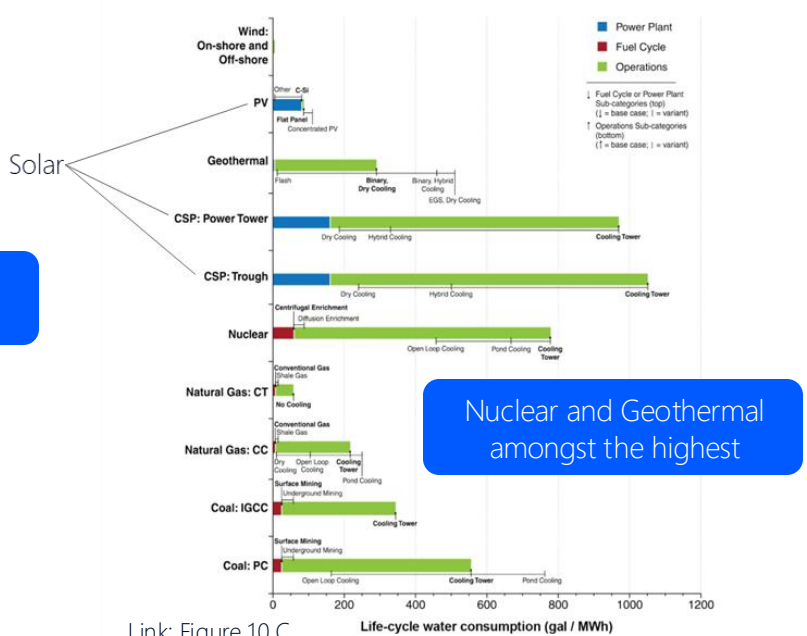
Materials Use By Power Generation Type

Manufacturing Materials



"Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities," Table 10. September 2015. United States Department of Energy. Nuclear and hydro require 10 tonnes/TWh and 1 tonne/TWh of other materials, respectively, but are unable to be labeled on the graph.

Water Consumption

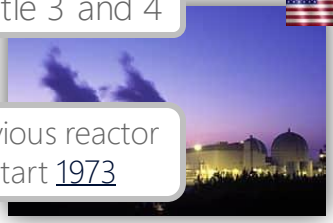


Link: Figure 10.C

Notes: Not all cooling options are shown; for instance, more expensive, dry cooling (with zero water consumption and withdrawal) is an option for most plants. Key: **PV** = solar photovoltaic; **C-Si** = crystalline silicon; **EGS** = enhanced geothermal system; **CSP** = concentrating solar power; **CT** = combustion turbine; **CC** = combined cycle; **IGCC** = integrated gasification combined cycle; and **PC** = pulverized coal, sub-critical.

Nuclear has…real issues… we've lost lost a generation of experience

Vogtle 3 and 4



Previous reactor start 1973

Georgia, USA

4.5 GW Power Output

Westinghouse AP1000 PWR

Original timeframe of 2017 slipped to 2025

Costs have risen from $14B to $37B (over 2.6X)

Hinckley Point C

Previous reactor start 1988

Somerset, UK

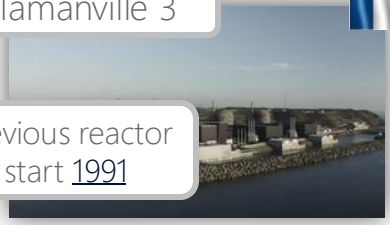
3.2 GW Power Output

Framatome EPR1750 PWR

Original timeframe of 2025 has now slipped to 2029-31

Costs have risen from $12B to $56B (over 4X)

Flamanville 3



Previous reactor start 1991

Normandy, France

1.65 GW Power Output

Areva EPR1750 PWR

Original timeframe of 2012 has now slipped to 2025

Costs have risen from $3.4B to $19.6B (almost 6X)

Fun fact: where do all these reactors get their fuel from?

TVEL ROSATOM

From Russia with love ☺

LINK: Nuclear energy and international relations: the external strategy of Russia's Rosatom

LINK: Russian nuclear energy diplomacy and its implications for energy security in the context of the war in Ukraine

Does ***anybody*** still know how to build nuclear power stations?

In 2007 Vladimir Putin ordered the total integration of >350 individual companies in the Russian nuclear supply chain

ROSATOM

Imagine you are an "unaligned" country with no nuclear experience, but a desire to deploy clean energy

...nuclear seems complicated

If you approach the USA, France or Korea – they can only help with part of the solution

Example: Google working with ElementL for nuclear reactor projects

?

Site planning
Finance
Project management
Personnel training
Operational support
Fuel supply
Waste management

It's either "your problem" or you have to work with "partners"

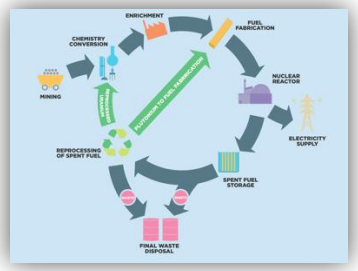
Ready-made for time and budget over-runs

But they still have a very "Soviet" attitude towards secrecy

LINK: What caused a plume of radioactive ruthenium in Europe in 2017?

Rosatom is a one-stop shop

ROSATOM



Not just for fuel

Site planning
Finance
Project management
Personnel training
Operational support
Fuel supply
Waste management

And others have huge ambitions

Link to artide

57 Operational Reactors

28 under construction

Goal to build 150 new reactors by 2040

Replace *all coal fired plants* by 2060

Goal to sell 30 reactors to Belt and Road partners by 2030

22 Countries Pledge to Triple Nuclear Capacity in Push to Cut Fossil Fuels

COP28 Nuclear Agreement

Lots of political celebration ☺

Little or no action* ☹

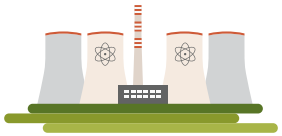
*Apart from Russia and China

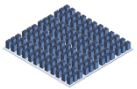
What is a Small Modular Reactor?

Source IAEA

The SMR Booklet 2022

Conventional Nuclear Reactor
700 MW-1.6 GW





Power a city or Mega Data Center

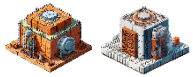
Small Modular Nuclear Reactor
<700 MW

Power a town or regular Data Center

Micro Reactor
10 MW

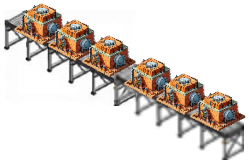
Power a factory or small Data Center

In a world of "joined up" thinking you would…



…choose 1 or 2 designs…

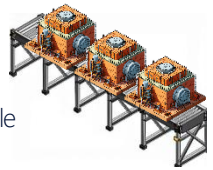
…test them carefully…



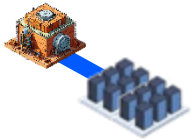
…crank them out

The idea is to build SMRs in factories on a production line

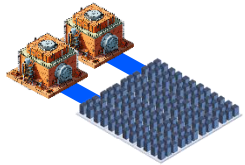
Reduce cost and time to build while improving quality

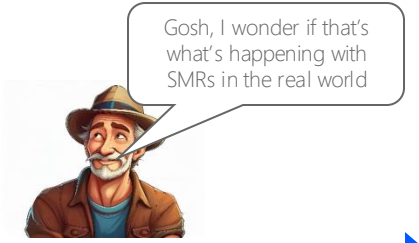


Small enough for co-location to avoid grid connection delays



If you need more power or resilience, just deploy more SMRs





OK…lots of Press Releases about nuclear and geothermal

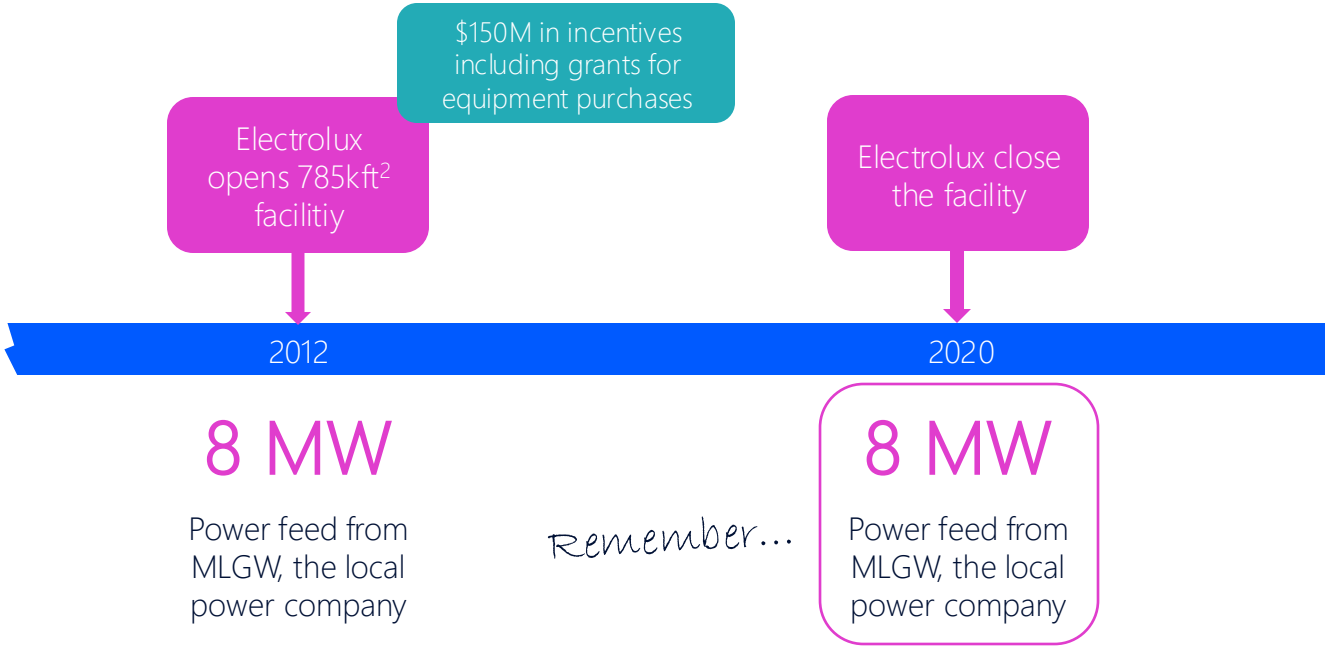
How are hyperscalers actually getting power in a hurry?

The Colossus Data Center (Memphis, Tennessee)

The city of Memphis has almost 2X the US poverty level

Link

The Boxtown area has a long history of industrial pollution with the cancer rate 4X national average

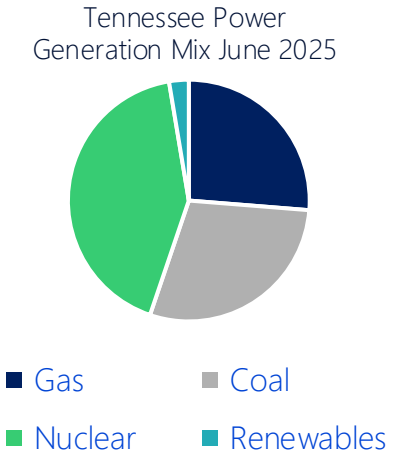


The Colossus Data Center (Memphis, Tennessee)

Electrolux close the facility

xAI chooses site for Colossus

Where does Tennessee's grid power come from?



2020

2024

8 MW

Power feed from MLGW, the local power company

8 MW

Power feed from MLGW, the local power company

Colossus Phase 1 is 100,000 H1 GPUs
150 MW power

xAI commits to upgrade substation feed to 150 MW

Meanwhile…

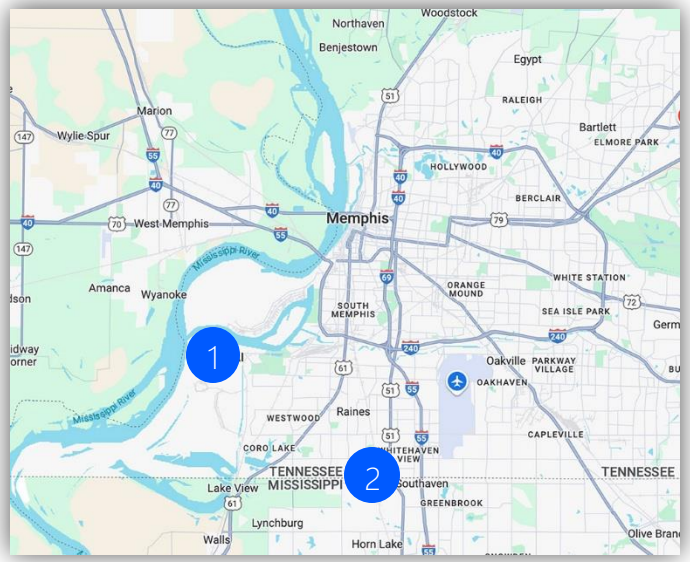
xAI files a permit ***request*** for 15 gas turbine generators, but went ahead and deployed 35

Link

The county health department only regulates gas-burning generators if they are on-site for more than 364 days

2025: Colossus 2

xAI took a totally different approach



Step 1: Buy a disused gas fired power station site – for the transmission lines

Step 2: Buy site for Data Center near to existing power station

Data center, power station and former power station all very close to each other

Step 3: Buy a decommissioned 2 GW gas power station in Europe

Step 4: Disassemble and rebuild it in Memphis on former power station site with ready-made grid access

Link: New Colossus: The World's Largest AI Datacenter Isn't What It Seems

And xAI is not alone…

Microsoft $75B

Google $75B

amazon $100B[1]

All planning multi-GW data centers

[1]Reported as total CapEx, not just DC

OpenAI ORACLE Crusoe SoftBank MGX

Up to $500B

Meta $60B

Posted by Mark Zuckerberg, but very exaggerated

- Hyperion Data Center
- 2250 acres in Louisiana
- 4 million square feet of buildings

Short term: 1.5 GW
Longer term: 5 GW

Partnering with entergy

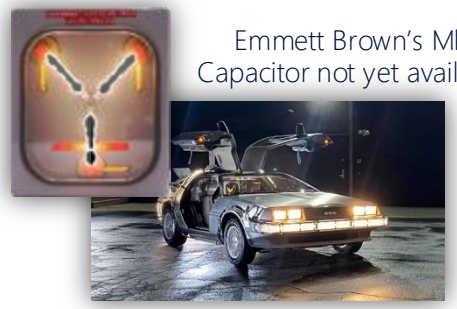
100-mile, 500kV transmission project for $1.2B

3 x CCGS Plants → 2.25 GW

*City examples that can be powered with 1 GW**

Dublin	Southampton
Nice	Liverpool
Islamabad	
Amsterdam	Forth Worth
Cologne	Jacksonville
Oslo	Austin
Cartagena	San Jose

*Assumes a population of around 1 million, Source: Wikipedia



Emmett Brown's Mk1 Flux Capacitor not yet available, so…

Stargate 1 is building a 1.21 GW Gas Plant

Can Natural Gas be green?

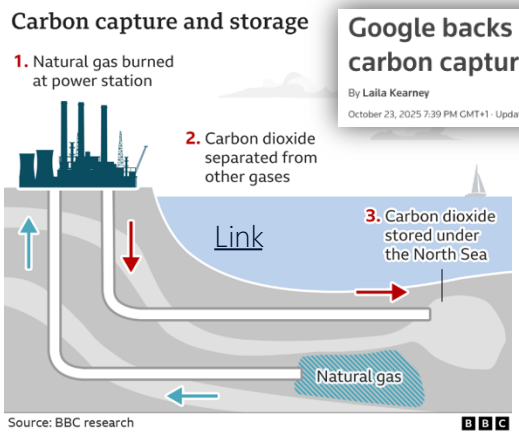
In 2024 37% of natural gas used in the EU was LNG

The EU is importing more LNG than pipeline gas: How bad is it for the climate?

Overall, the greenhouse gas footprint for LNG as a fuel source is 33% greater than that for coal

Link

Carbon Capture



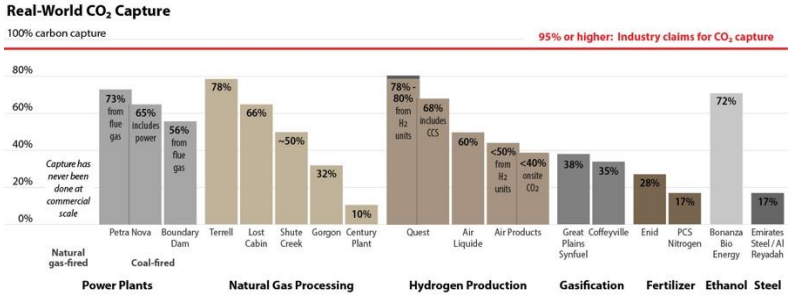
Google backs US gas power plant with carbon capture for Midwest data centers

By Laila Kearney

October 23, 2025 7:39 PM GMT+1 · Updated October 23, 2025

Reuters Link

Link



Survey of 19 CCS projects (about half of operational facilities)
No project has achieved >80% capture and most are around 50%

Link

- CCS history dates back to 1920s
- 30 operational CCS projects worldwide
- 24 are associated with oil or gas extraction
- CO2 is used to enhance production
- Regulation is "patchy" around the world so it's not clear how long the CO2 remains captured in most cases

Norway's Sleipner* and Snøhvit CCS: Industry models or cautionary tales? Link

1997 - first CCS project for purely environmental reasons

It would appear that, after >50 years of CSS there is no project around the world that has achieved its initial objectives

Experts point out that it's far easier not to generate the CO_2 in the first place than to generate and capture (permanently)

Huzzah for us!

Once in a lifetime AI opportunity

Need better AI

AI provides massive productivity boost

Isn't this great?

But we all lose our jobs ☹

Wait...who buys all our stuff?

"An imbalance between rich and poor is the oldest and most fatal ailment of all republics."

Plutarch
CE46-120

"Better" means more processing power

Which implies more electrical power

Pesky corporate sustainability goals!

Nuclear seems like a great option

But we forgot how to build nuclear stuff!

Absolute

Relative

Some of ~~us~~ them

Bwahahah! Let's go to Mars!

What's happening today

We were only kidding – carry on burning that coal and gas!

Consequences

But renewables aren't a great fit for AI Data Centers

Bwahaha! We still know how, comrade!

You guys are losers!

>80% of solar panels are made in China

>70% EV batteries are made in China

Thank You

Geoff Bennett
geoff.bennett@nokia.com

Additional Material

Slides I have used to answer questions about nuclea power

Please remember I am not a total fan of nuclear. There are many *genuine* issues to be addressed about the cost of large scale nuclear, and the immaturity of SMRs. In discussions with people (and I used to be one of them) who have accepted the views presented in the mainstream media I feel that we can be distracted by "nuclear problems" that really aren't problems at all…but that we are told are "show-stoppers".

When influential political groups in certain countries fall into this trap they make bad decisions. So…

If you have long-held feelings along the lines of…
- Nuclear power is too dangerous and we should be closing it down in favour of renewables
- If we *were* to scale up nuclear power we don't have enough uranium on the planet
- After decades of nuclear power generation we still have no long-term solution to the problem of nuclear waste

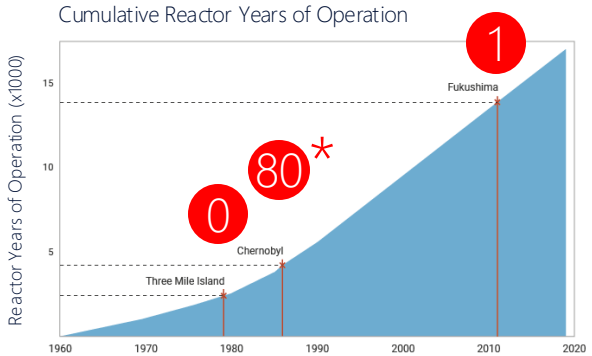
…then I'd like to present some alternative evidence.

- The dangers of other types of industrial accidents. Getting back to a real perspective.
- How many people have died in nuclear accidents?
- What do we do with nuclear waste?
- Is there enough nuclear fuel?
    - Option 1: if we stick with uranium
    - Option 2: if we add thorium as a fuel source

Industrial Accidents over 10X More Deadly than Chernobyl

India 1961	Italy 1963	China 1975	India 1984
Tigra Dam failed >1,000 deaths	Vajont Dam overflow in N.Italy 1,917 deaths	Banqiao Dam failed in China 250,000 deaths	Bhopal chemical leak 8k-16k deaths
Bangladesh 1984	**France 1906**	**Gambia 2002**	**Australia 1940-66**
Rana Plaza collapse in Dhaka 1,129 deaths	Courrieres mine disaster 1,099 deaths	MV Le Joola capsized 1,863 deaths	Wittennoom asbestos mine disaster >2,000 deaths
Manchuko (China) 1942	**Philippines 1987**	**China 1949**	**Red Sea 1991**
Bengxihu colliery disaster 1,549 deaths	Tablas strait ship disaster >4,386 deaths	SS Taiping collision and sinking 1,500 deaths	MV Salem Express sinking 1,600 deaths (est)
Libya 2023	**India 1961**	**Atlantic 1912**	**London 1952**
Derna dam collapse 11,300 deaths	Panchet dam failure 1,000 deaths	RMS Titanic 1,500 deaths	Great Smog of London 12,000 deaths

Is Nuclear Power Dangerous?



Number of deaths from the 3 major nuclear accidents
*Higher estimates exist, but are highly disputed

Following the Fukushima accident in 2011 German leaders committed to phasing out nuclear power by 2022/23

But they had to extend the use of coal, and buy Russian gas

1,100

The number of incremental deaths *per year* in Germany from air pollution caused by coal and gas

$12B

Annual *social cost* of reactor closures

NBER Link to article

Forbes

EDITORS' PICK | BUSINESS > ENERGY

Greta Thunberg Has Embraced Nuclear Power: Will The Greens Follow? Link to article

By Ariel Cohen, Contributor. Ariel Cohen is a D.C.-based contributor who covers ... Follow Author

Apr 03, 2023, 09:00am EDT

Organizations arguing that nuclear power is dangerous

CAN Europe — Myth buster: Nuclear energy is a dangerous distraction

Friends of the Earth — Is Nuclear Power Bad for the Environment?

GREENPEACE — 6 reasons why nuclear energy is not the way to a green and peaceful world

In the UK, 6,000 people die each year in home accidents

"We calculate a mean value of 1.84 million human deaths prevented by world nuclear power production from 1971 to 2009"

Environmental Science & Technology — Article — pubs.acs.org/est

Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power

Pushker A. Kharecha* and James E. Hansen

NASA Goddard Institute for Space Studies and Columbia University Earth Institute, 2880 Broadway, New York, New York 10025, United States

Link to paper

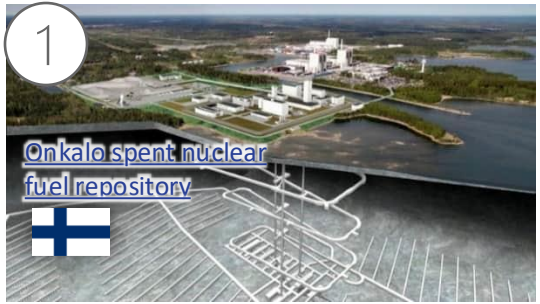
Nuclear Waste: It's a choice, not an inevitability

All of the high level waste produced 70 years of global commercial nuclear power fit into a space the size of a football stadium piled 14 feet deep

Note: *Always* show nuclear waste in corroding barrels, preferably with glowing green ooze leaking out

Nuclear waste is *highly regulated* and is the easiest form of industrial waste to detect and measure

1



Store it as glass in geologically stable repositories

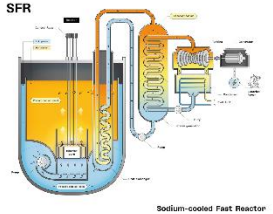
2

Reprocess the >95% of useable nuclear fuel in "spent" fuel rods

Management of Spent Fuel from Nuclear Power Reactors

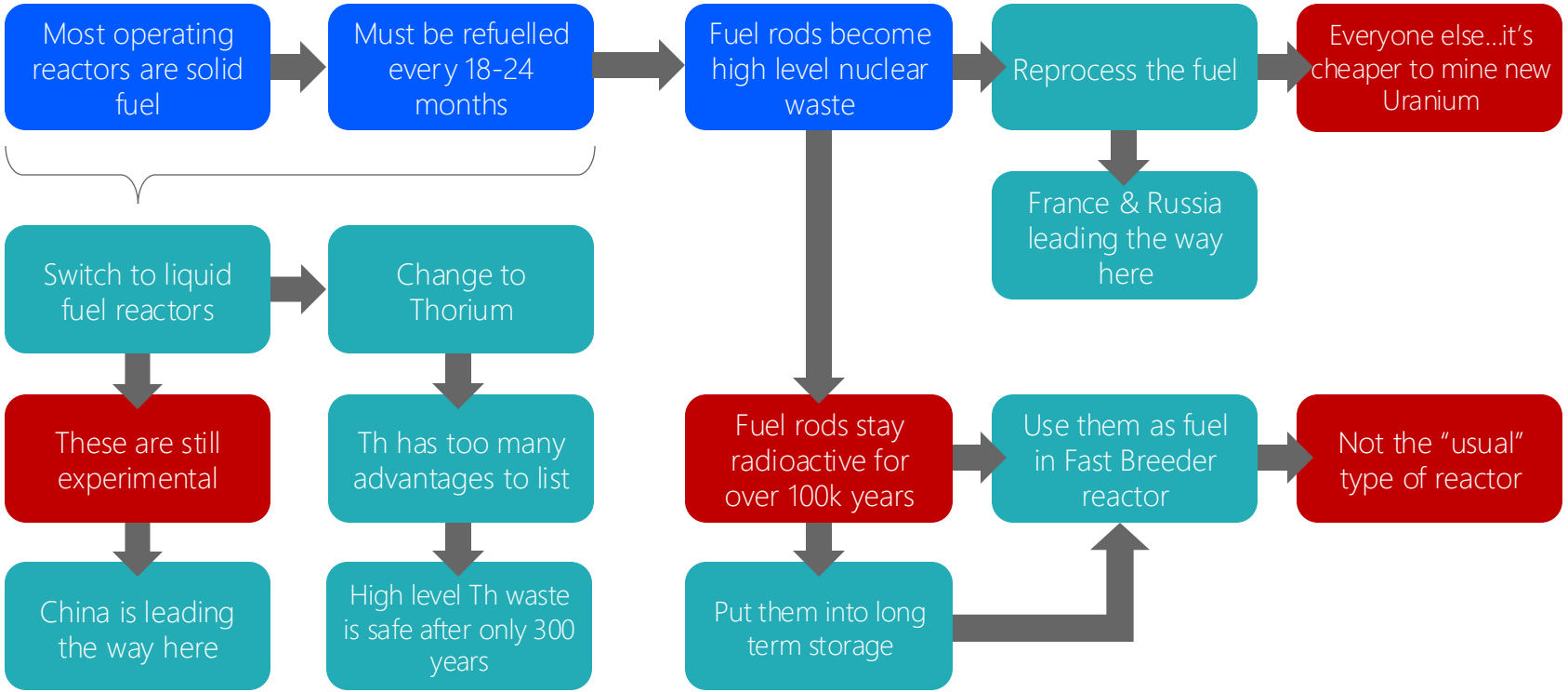
3

Use a fast neutron reactor to process new fuel during normal operation

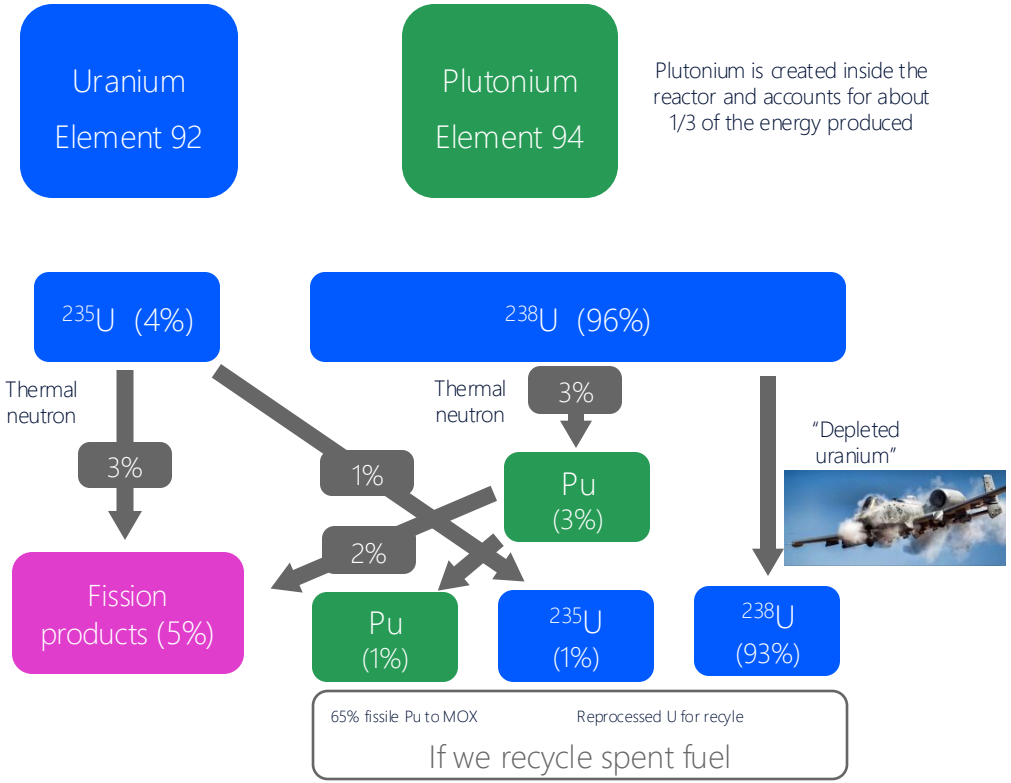


About 20 FNRs operating since the 1950s

Nuclear Waste – Why do I say it's a choice?



The Uranium Fuel Cycle



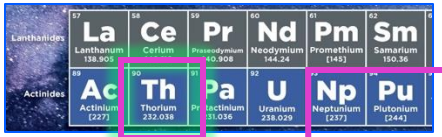
How Much Uranium Do We Have?

- Option 1 "Crust Uranium, no recycling" — 50-100 years
- Option 2 "Recycle high level waste" — 100-200 years
- Option 3 "Fast Breeder Reactors" — >20,000 years
- Option 4 "Seawater Extraction" — >100,000 years

Thorium – The New Nuclear Option

Why are some people getting excited about this fuel option?

What is thorium?



Here it is!
Element 90

A ball of thorium about the size of a golf ball would deliver ***all the power you need for your entire life***

Abundance

About 4X more abundant than uranium

0.7% of uranium is the fuel we need (U235) → 100% of thorium is the fuel we need (Th232)

It's "everywhere"
Australia, Canada, USA, China, India, S.America, Europe, Africa

China has at least 20,000 years supply of thorium

Safe reactor design

Thorium Molten Salt Reactor
The most interesting design

Atmospheric pressure
(vs 300 atm for PWRs)

"Walk-away" safe
Cannot go bang or melt down – it's already molten

Very, very difficult to make bombs
Never say never – evil people are devious

Less nuclear waste

Liquid fuel – continuous reprocessing

Higher temperatures – less waste per GWhr

We can actually use existing waste as extra fuel

"Better" nuclear waste

It's a different element, so has a different set of waste isotopes
Dangerous for 300 years vs 100,000 years

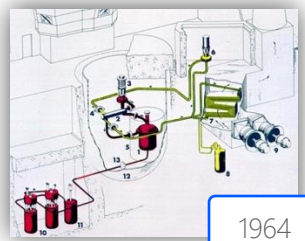
Many of the isotopes in the thorium waste stream can be used for medical applications

But if thorium is so good…why aren't we using it already?

Hmmm…a long, complex and rather sad story of lost opportunities

1956-64

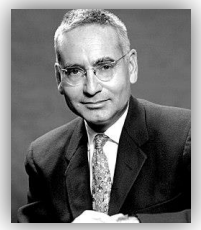
Wikipedia: Crazy ideas - Nuclear powered bombers



1964

Wikipedia: MSRE (Molten Salt Reactor Experiment) at Oak Ridge National Laboratory

1964-69: 5 years of successful and safe operation



Project was led by Alvin Weinberg

All goals achieved – so why was the project terminated?

A compact, lightweight, high temperature reactor design

Perfect for a lunar base

Uranium reactors were already making energy and bomb material

There was a competing research project – the LMFBR – that was seen as "more promising"

"More promising" also meant "more geographically diverse" – more distribution of political funding

The nuclear bomber and lunar base were both cancelled

As the US nuclear industry became more regulated, everything was focused on solid fuel, uranium reactors