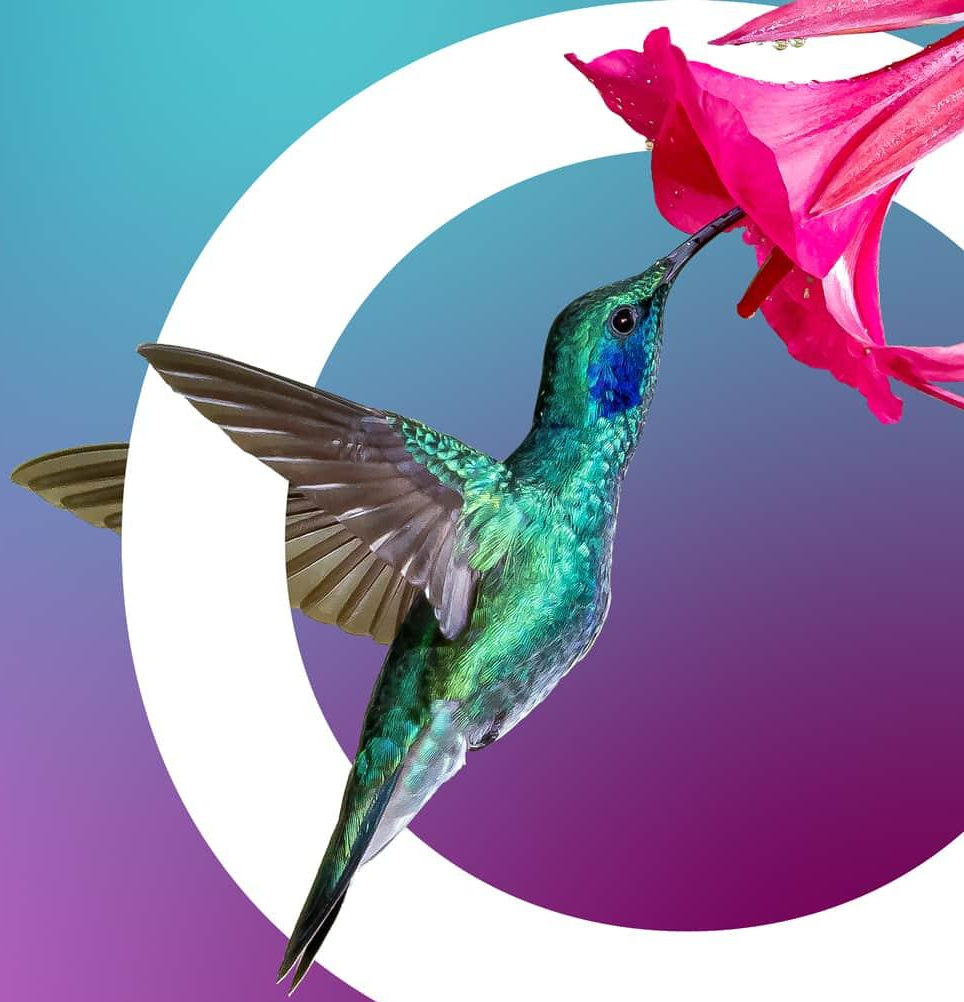
Artificial Intelligence:

A High Level Perspective on Environmental Aspects

Geoff Bennett
Director, Solutions and Technology



Copilot: “Bullet point summary of how AI will benefit mankind”

- Healthcare
  - Personalized Medicine
  - Early Disease Detection
  - Robotic Surgeries
  - Drug Discovery
- Education
  - Personalized Learning
  - Intelligent Tutoring Systems
  - Administrative Efficiency
- Environment
  - Climate Change Mitigation
  - Resource Management
  - Wildlife Conservation
- Economic
  - Increased Productivity
  - Job Creation
  - Enhanced Decision-Making
- Transportation
  - Autonomous Vehicles
  - Efficient Public Transport
  - Smart Traffic Management
- Daily Life
  - Smart(er) Homes
  - Personal Assistants
  - Entertainment

WORLD ECONOMIC FORUM

Explore this link to find more specific examples

Will AI really be good for the environment?

This is the focus of my presentation

The Good News?

"AI will be help rather than hindrance in hitting climate targets, Bill Gates says"

The Guardian

Link to story

"Growth in global electricity demand is set to accelerate in the coming years as power-hungry sectors expand"

IEA

Link to story

The world's electricity consumption is forecast to rise at its fastest pace in recent years, growing at close to 4% annually through 2027

"Can the climate survive the insatiable energy demands of the AI arms race"

The Guardian

Link to story

Dgtl Infra — Data Center Water Usage: A Comprehensive Guide

ING — Growth in water consumption of data centres needs more attention

World Economic Forum — Why circular water solutions are key to sustainable data centres

But why do we seem to be ***rushing headlong*** into an AI future?

The “once in a lifetime” AI opportunity

…and …

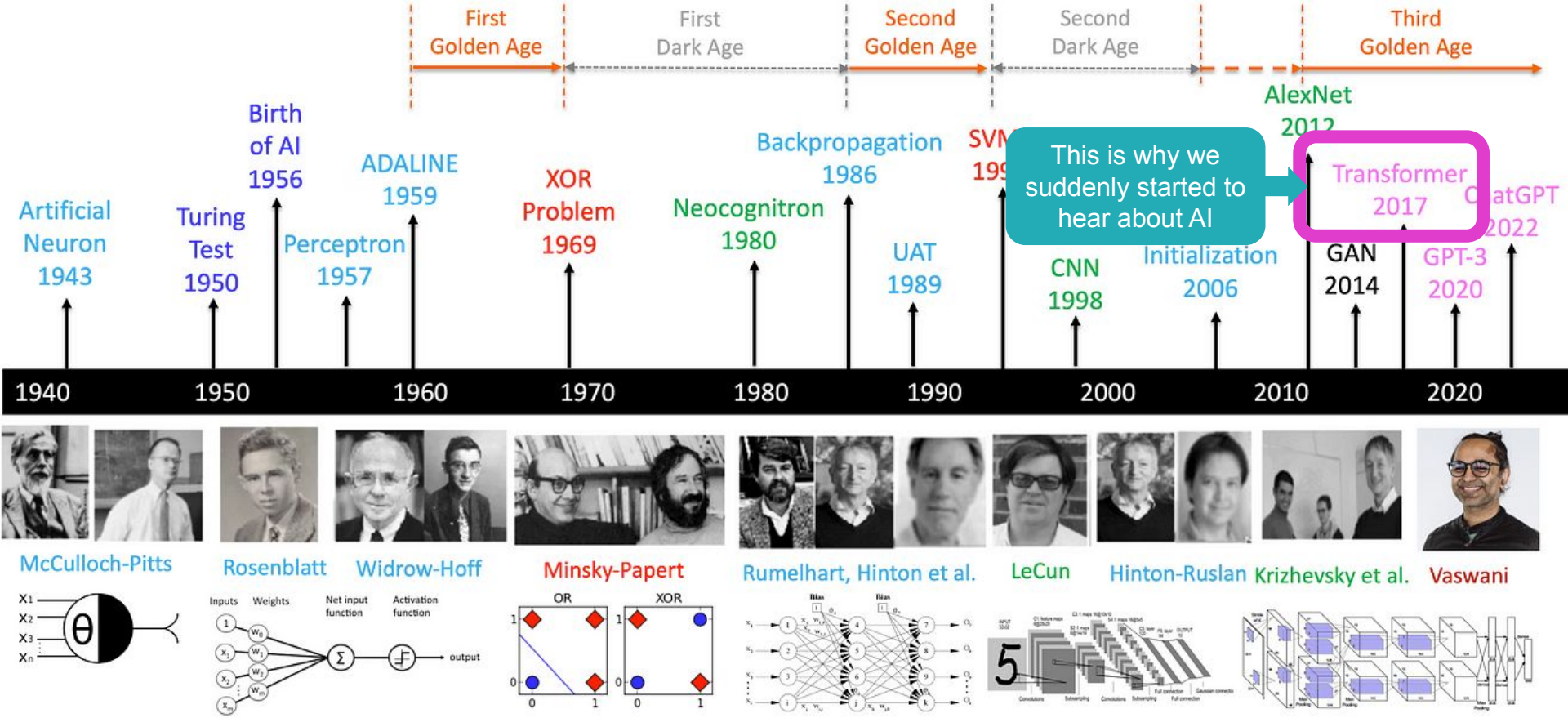
Why companies are building huge AI data centers

Here’s a clue ☺

Yes…but why now?

A Brief History of AI with Deep Learning

Author: LM Po



Read the full article here – highly recommended!

2017 Seminal Paper by Google

Introduced a new Deep Learning architecture called the ***Transformer***

Attention Is All You Need

Ashish Vaswani* Google Brain avaswani@google.com

Noam Shazeer* Google Brain noam@google.com

Niki Parmar* Google Research nikip@google.com

Jakob Uszkoreit* Google Research usz@google.com

Llion Jones* Google Research llion@google.com

Aidan N. Gomez* † University of Toronto aidan@cs.toronto.edu

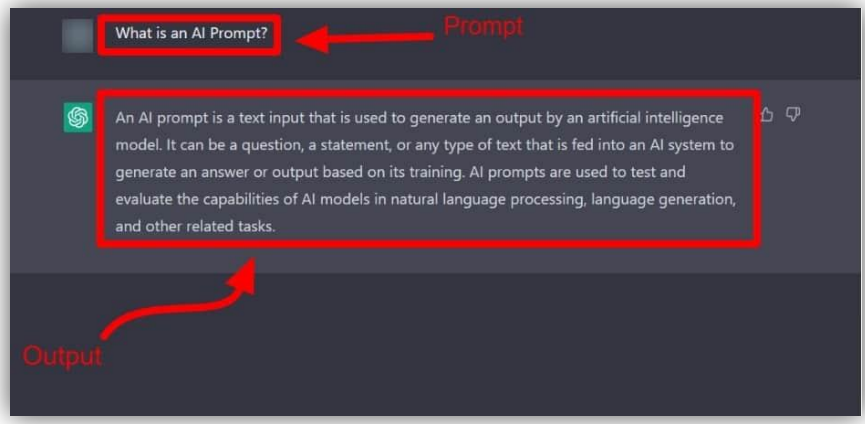
Łukasz Kaiser* Google Brain lukaszkaiser@google.com

Illia Polosukhin* ‡ illia.polosukhin@gmail.com

The AI you are using is probably based on a ***Transformer*** architecture

Transformers change an input sequence into an output sequence.

They do this by learning context and tracking relationships between sequence components using ***Attention Mechanisms***.



By predicting the next word, AI chatbots started to really seem “intelligent”

The Once-In-A-Lifetime AI Opportunity - $$$

How did we get to the doorstep of the next leap in prosperity?

In three words: *deep learning worked*.

In 15 words: *deep learning worked,* ***got predictably better with scale, and we dedicated increasing resources to it***

Altman, OpenAI

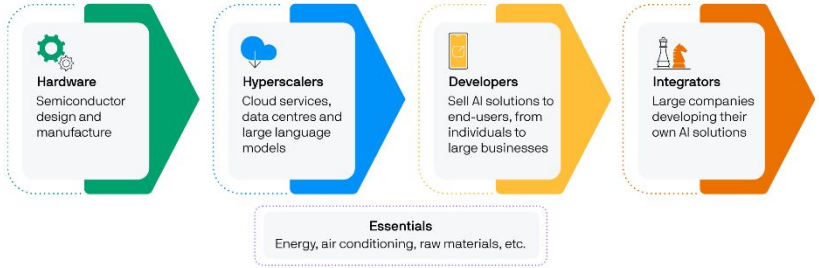
Growing valuations

Magnificent Seven valuation, earnings and share price performance

	Alphabet	Amazon	Apple	Meta	Microsoft	Nvidia	Tesla
12m fwd P/E ratio 1 year ago	20x	48x	28x	20x	32x	31x	56x
12m fwd P/E ratio today	21x	35x	30x	24x	31x	39x	106x
1-year change in 12m fwd earnings	35%	100%	13%	54%	18%	145%	-19%
1-year price change	37%	46%	20%	78%	14%	207%	53%

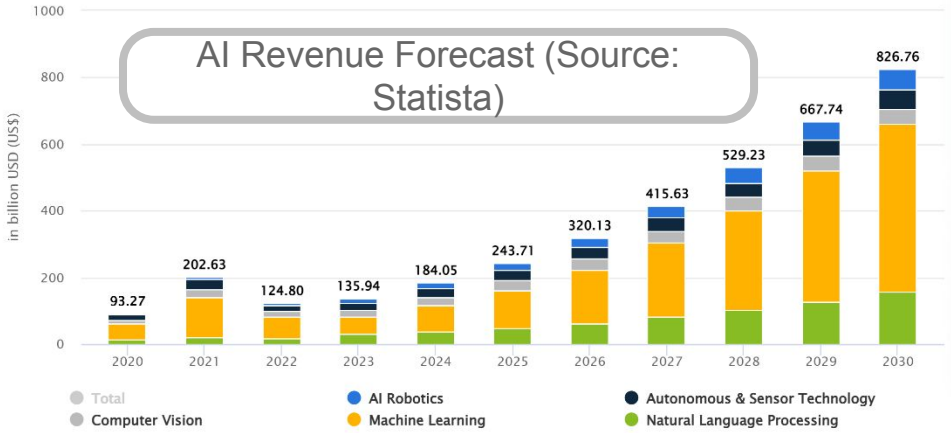
Source: IBES, LSEG Datastream, J.P. Morgan Asset Management. Forward P/E ratio is price to 12-month forward earnings, calculated using IBES earnings estimates. Past performance is not a reliable indicator of current and future results. Data as of 12 November 2024.

Emerging AI Ecosystem



Source: J.P. Morgan Asset Management, as of November 2024.

AI Revenue Forecast (Source: Statista)



The Drive For Better AI: We can view this two ways…

In regulated industries we can enforce standards

Absolute

Specialized Medical AI

My AI has to be good enough to beat a human surgeon or diagnostic consultant

Legal AI

My AI has to be good enough so that it does not make stuff up!

Relative

Google wants a better AI than Microsoft, Meta and Amazon

Microsoft wants a better AI than Google, Meta and Amazon

Meta wants a better AI than Google, Microsoft and Amazon

Amazon wants a better AI than Google, Microsoft and Meta

It’s Getting Harder to Make Transformers Better

High Computational Cost

Transformers lead to specific Scaling Laws – and the only solution is to use more compute power for longer

Inability for Continuous Learning

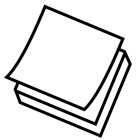
Once trained, LLM parameters remain fixed, so model cannot learn during Inference phase

Lack of Explainability

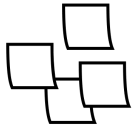
Transformer LLMs are basically a “black box” – difficult in applications that emphasize transparency and safety

Large Training Data Sets

Quadratic Complexity



+



If you have an existing context window limit of **C**

…and you would like to extend this by **N** tokens…

…you will need $CN + N^2$ more memory

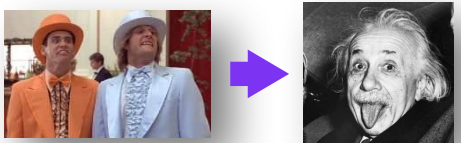
Known as ***Quadratic Complexity***

There are tuned or enhanced algorithms, like ***Flash Attention***, that are designed to mitigate Quadratic Complexity

Check out: A Look Back and a Glimpse Ahead At Transformers in AI

The Computation Cost of Transformers

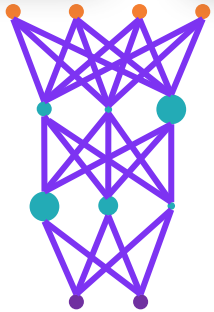
Source: OpenAI - Scaling Laws for Neural Language Models



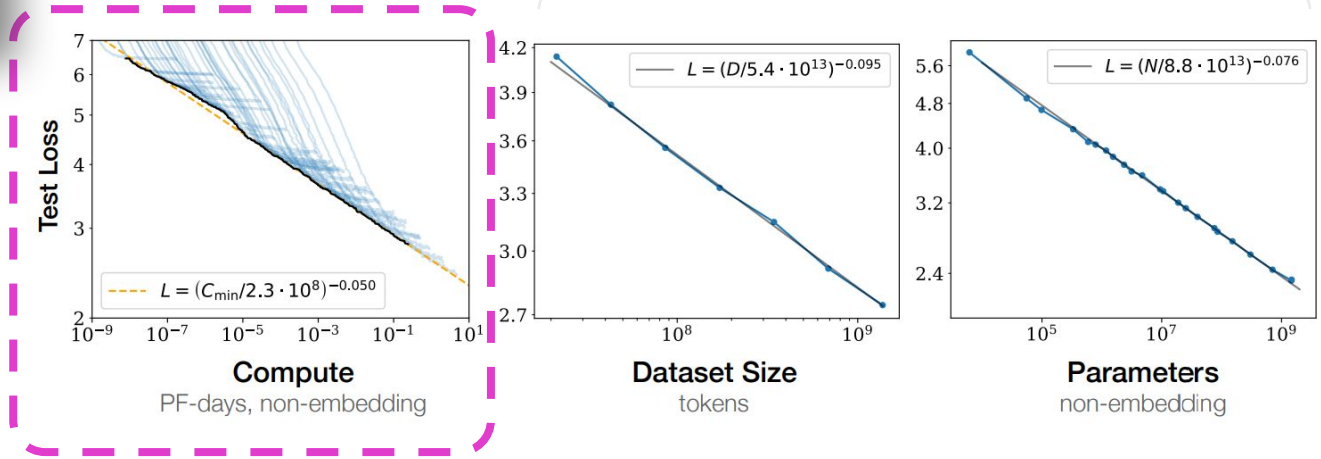
Can only scale…

Data Set Size
Parameters
Compute

But scaling these means…



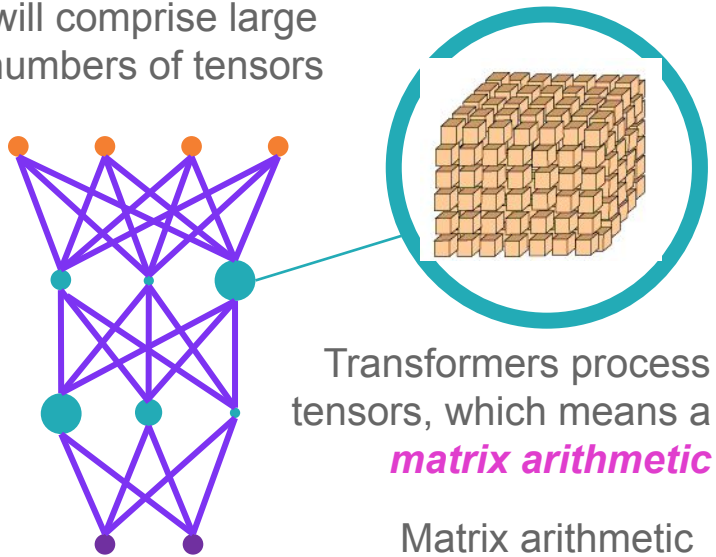
Direct consequence of the Transformer architecture



More Compute = More Electrical Power

Why GPUs became a favored option for AI processing

A deep learning model will comprise large numbers of tensors



Transformers process the tensors, which means a lot of ***matrix arithmetic***

Matrix arithmetic responds well to ***parallel processing***

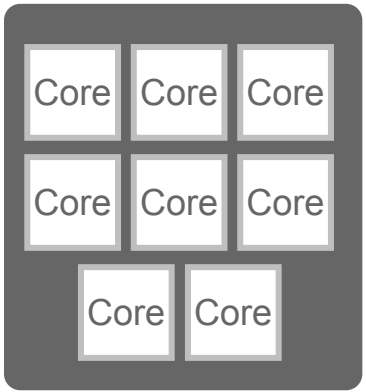
Interesting videos

Why GPUs are used for AI

Why Nvidia seems to have an AI monopoly

Multicore processors are best for *parallel processing*

A modern ***CPU*** might have around ***8 very complex cores***, with multiple threads for each core



A modern ***GPU*** might have ***thousands*** of more simple cores

Nvidia H100

14,592 CUDA cores

528 Tensor cores

per-GPU

Nvidia has ***70-95%*** market share for AI processing

2H24 estimate by Mizuho Securities

Hardware For AI Training: CPU, GPU, TPU, NPU???

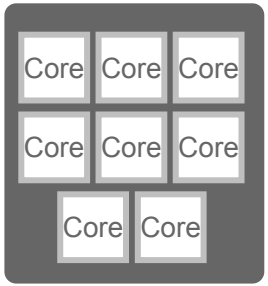
Disclaimer: The real differences for TPUs and NPUs are very subjective. Explanations are often quite poor.

CPU may not have enough parallel processing to excel in AI training

GPU has lots of cores, but also has “baggage” left over from Games graphics processing

GPU uses a lot of power – not optimized for tablets, phones, IoT devices

CPU



A modern ***CPU*** might have around ***8 very complex cores***, with multiple threads for each core

GPU

Nvidia H100

14,592 CUDA cores

528 Tensor cores

per-GPU

A modern ***GPU*** might have ***thousands*** of more simple cores

TPU

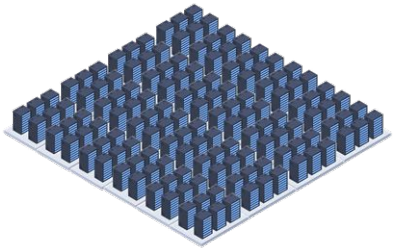
Google seems to be the main user of this term

A ***TPU*** is like a GPU, but with all the legacy baggage stripped out and optimized for either ***Training*** or ***Inference***

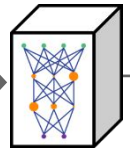
NPU

A ***NPU*** is a dedicated AI *Inference* chip that is optimized for power and size

Deployment: Training vs Inference



Trained Model



Deployment Options include…

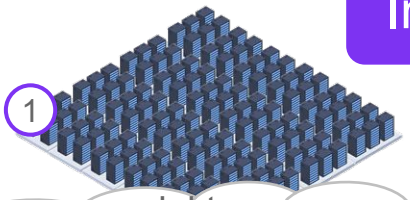
A Training Data Center needs tens (hundreds) of thousands of GPUs running for months to train a model

Training does not require a lot of network capacity outside the Data Center – tends to be location insensitive

Training

Inference

1



Large model to serve large number of users from “local” Data Center

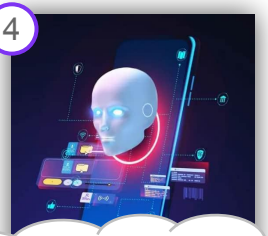
2

A large model deployed for a single enterprise

3

A small model deployed on an autonomous device

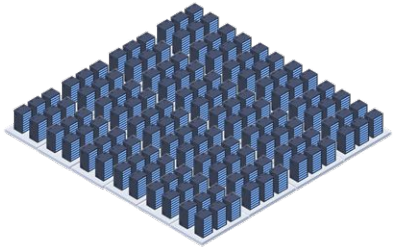
4



A very small model deployed on a phone

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

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

China Telecom IMIP

150 MW

1,000,000 m^2

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

2028

Jeollanam-do Province South Korea

3,000 MW

$35B investment

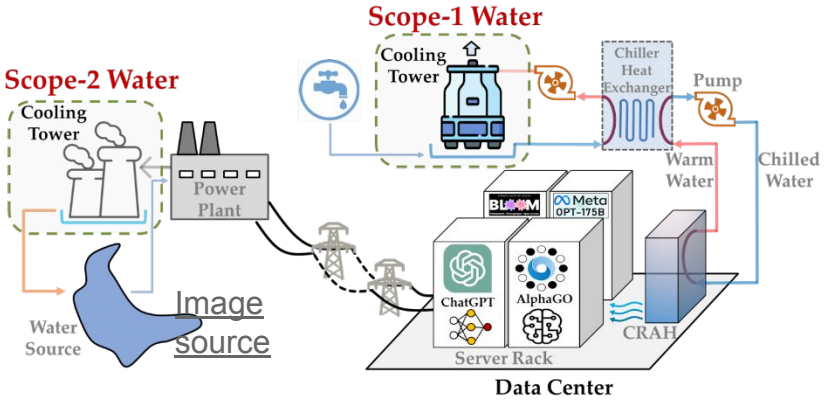
Source: Capacity

So we will be building *a lot* of *BIG* Data Centers

What resources do they consume?

Do Data Centers Use A Lot of Water?

AI Data Center Water Use



Scope 1 water consumption

Primarily in cooling the Data Center

Scope 2 water consumption

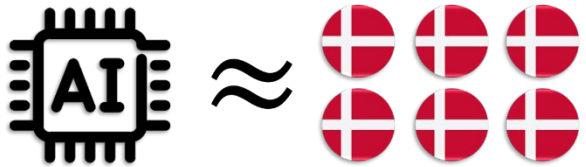
Water used in generating the power

Source: "How much water does AI consume? The public deserves to know"

Shaolei Ren: Associate Professor of Electrical and Computer Engineering, University of California, Riverside

Global AI's Scope 1 & 2 Water Withdrawal in 2027

Est. 4.2~6.6 Billion Cubic Meters



4~6x Annual Water Withdrawal of Denmark

Power Generation Technologies	Efficiency (L/1000 KWh)
Hydroelectric	260
Geothermal	1680
Solar thermal	2970–3500
Fossil fuel thermoelectric	14 200–28 400
Nuclear	31 000–74 900

Source: IEEE Spectrum

Nuclear uses the most water of any electricity generation technology

And this is already causing issues in France

Climate change, water scarcity jeopardizing French nuclear fleet

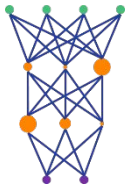
Water Consumption In The AI Supply Chain

Producing the GPU chips

8.3 tonnes of Ultra Pure Water per GPU

100,000 GPUs in Colossus DC

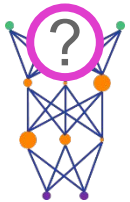
830,000 tonnes



Training the Model (Source: Statista)

4,800,000 tonnes in Iowa

15,000,000 tonnes in Washington



Using the Model (Inference)

500 ml per 50 questions

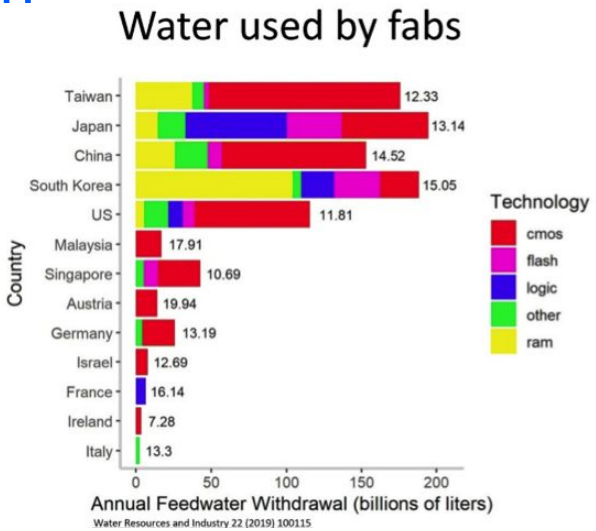
10 million questions per day

36,500 tonnes per year

Source: "How much water does AI consume? The public deserves to know"
Shaolei Ren: Associate Professor of Electrical and Computer Engineering, University of California, Riverside

Water Supply Challenges for the Semiconductor Industry

Link to article



The water challenge for semiconductor manufacturing: What needs to be done?

Link to article

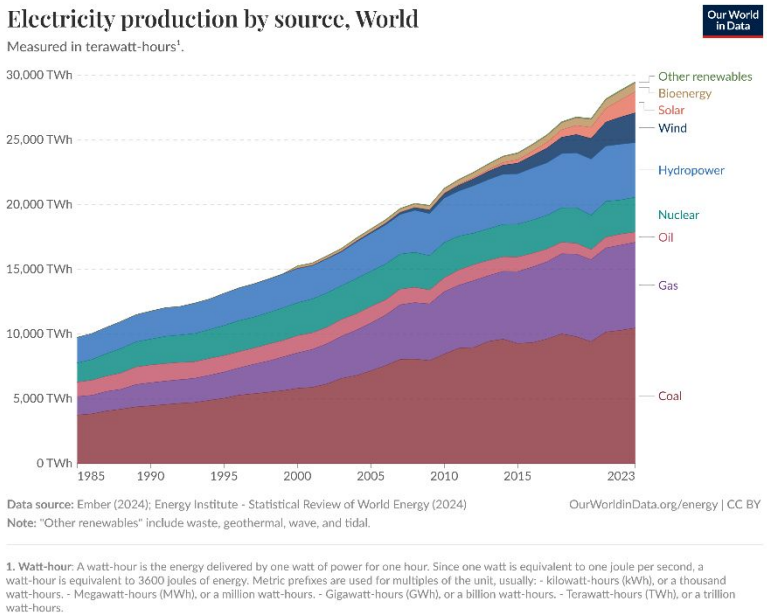
Sustainable Water Management and Energy Use in Semiconductor Manufacturing:

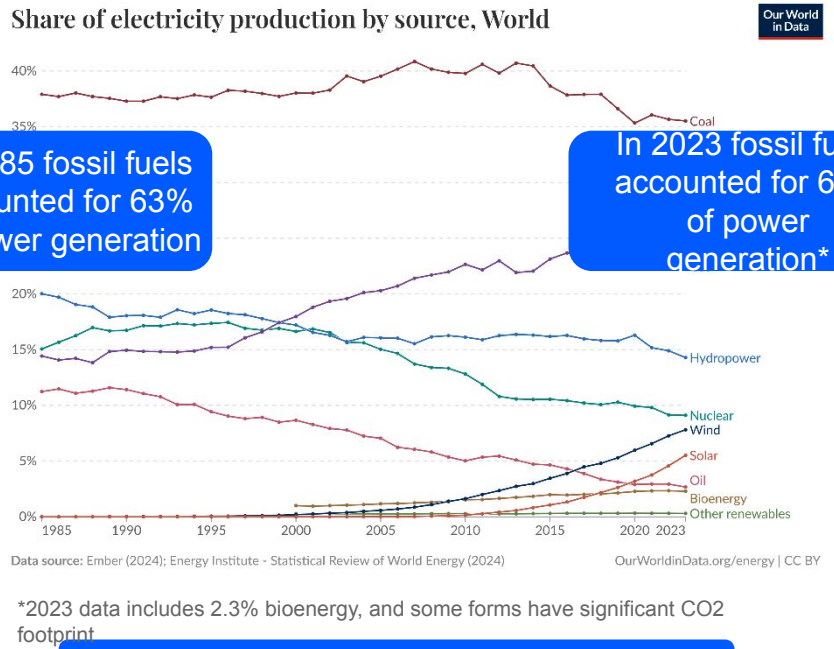
The Path for India's Leadership

Link to article

A Few Basics About Our Electricity

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

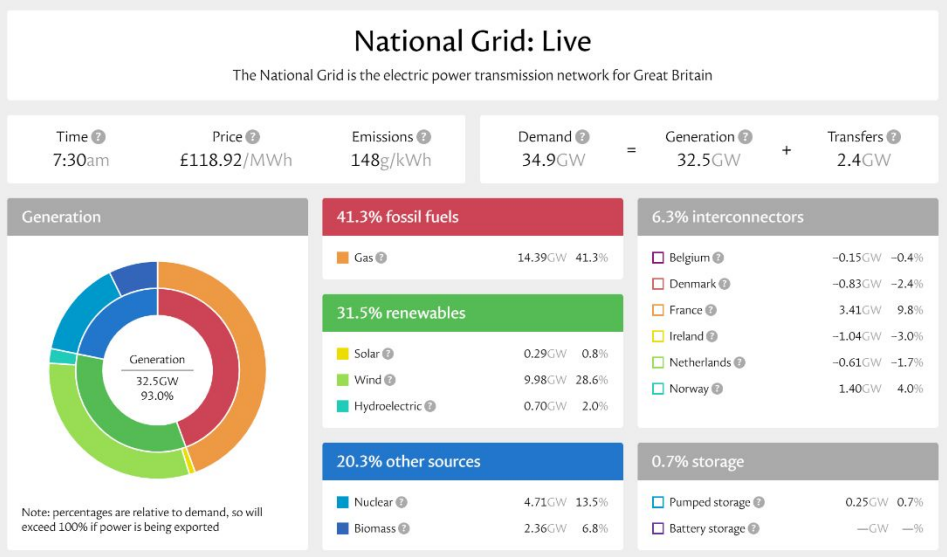
Don't feel guilty that this is chart is rising…

Little or no progress on decarbonization

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

The Power Generation Mix: UK Example

Check out the full dashboard



- The UK gets its electricity from a range of sources
- UK became 1st G7 country to phase out coal fired generation
- Natural gas is the biggest contributor today
- Renewables are coming on stream
- Nuclear is having “issues”
- UK buys a lot of electricity from Europe

1882 Holborn Viaduct first coal fired power station for public use

Link to document

1933 UK creates world’s first National Grid (132 kV)

1952 Bankside B is first oil fired power station

1953 275 kV Supergrid

1962 Calder Hall first nuclear plant

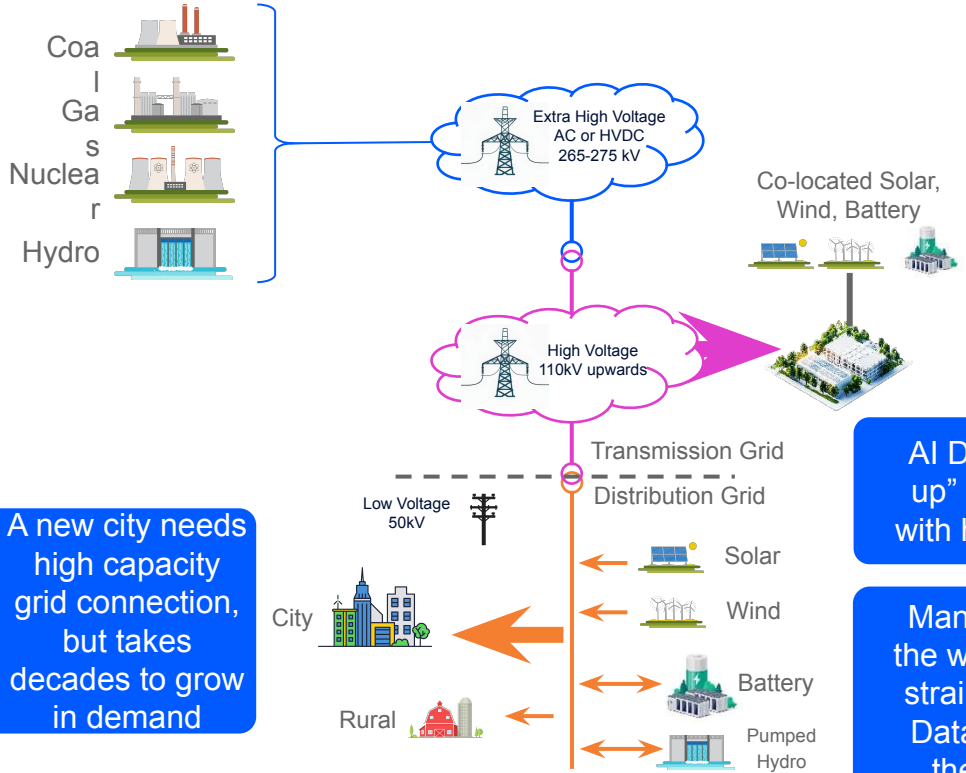
1986 UK-France Interconnector

1991 UK’s first wind farm

2019 More electricity generated from non-CO_2 sources than fossil fuels

2023 First grid-connected solar farm

Regional or National Grids are Crucial



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

Many power grids around the world are already under strain, and Gigawatt scale Data Centers are making the situation far worse

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

The Grid is fed from power stations

And needs different voltage levels for efficient transmission/distribution

Regular customer – like cities and farms – use Distribution Grid

Renewable installations usually feed into the Distribution Grid

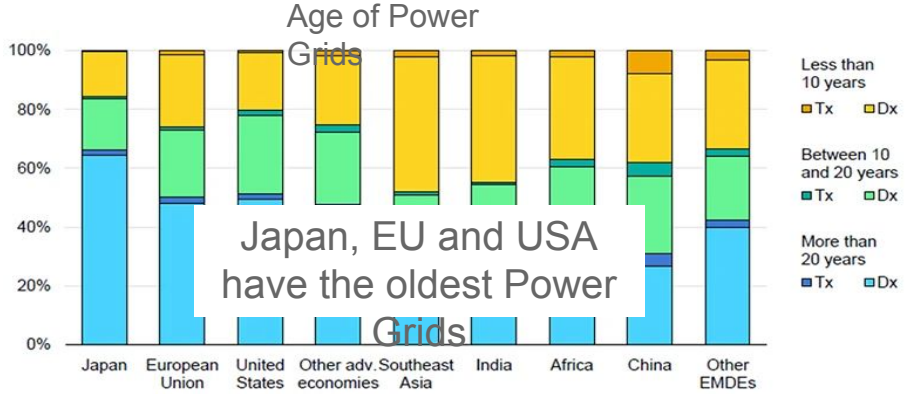
Storage systems also have 2-way connection to Distribution Grid

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

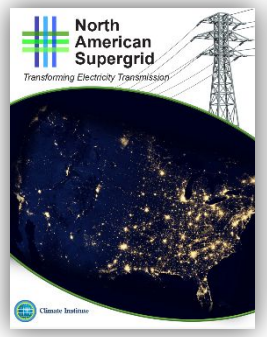
Data Center may have local Solar, Wind and Battery Storage

Needs Grid connection for reliability against intermittent renewables

Power Grids Are Under Pressure



2017: Proposal for North American Supergrid

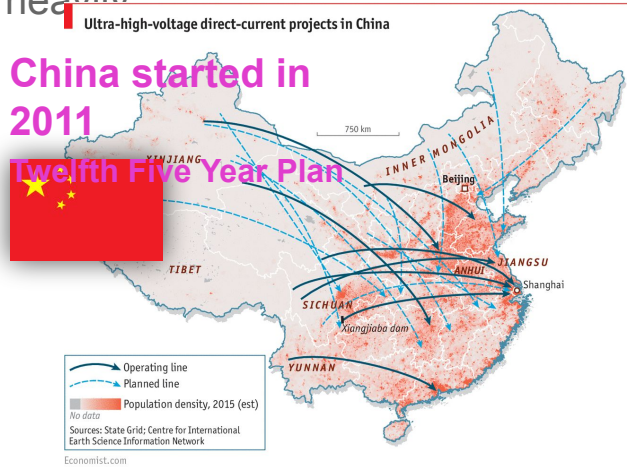


Hypothetical US network following railroad Rights of Way

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

Many Countries Experiencing Grid Congestion Issues

1,100 Renewable Energy Projects Stuck in Grid Queue: Breaking Down the Delays in the UK

Link to article

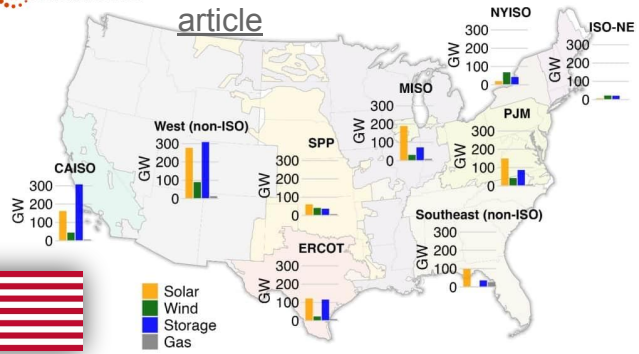
Capacity crunch on National Grid is delaying new homes in UK by years

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

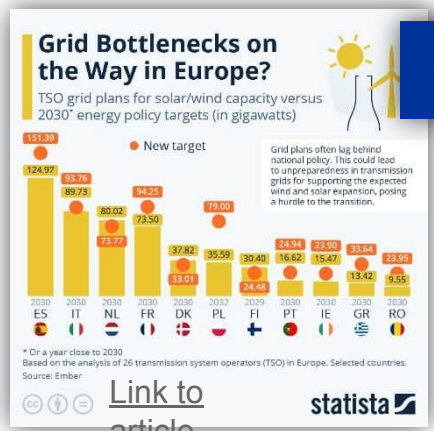
Solar Energy UK

About us So

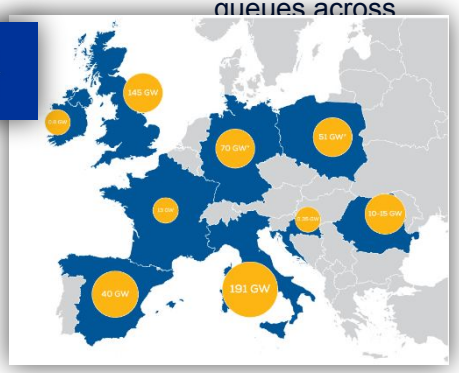
MPs to be told grid delays are descending into farce

Solar Energy UK
7 February 2024

Link to article



Link to article



Size of wind farm connection queues across Europe

Link to article

It’s OK – I ticked the box to offset my carbon footprint 😇

UNIVERSITY OF CAMBRIDGE

Link to report

Millions of carbon credits are generated by overestimating forest preservation

Study analyses 18 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

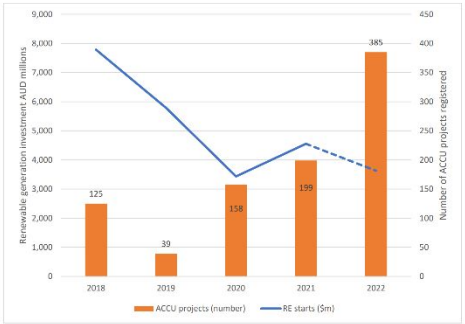
Problem: Carbon credit schemes are poorly regulated and, in a hugely shocking revelation, it seems that humans can be rather unscrupulous

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

Link to report

ACCU = Australian Carbon Credit Units

Figure 7: Renewable generation commencements vs number of ACCU projects



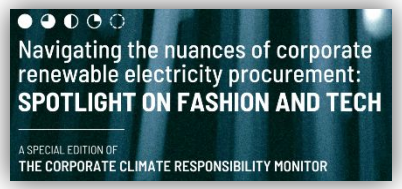
Sources: ABS (2022) Value of renewable energy construction; Emissions Reduction Fund (2023) Emissions Reduction Fund project register. Note: 2022 data for renewable energy starts is only available for March and June quarters. Figure 8 extrapolates the average of the March and June quarters across the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

Clean Energy Agreements

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

Issues in the domestic market…

…and with big corporations



Link to report

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

Let’s pause for some case studies

The Challenges of Data Center Success: Virginia

DataCenter Knowledge

NEWSLETTER SIGN-UP

ENERGY & POWER SUPPLY | DATA CENTER CONSTRUCTION

Data Centers Face Seven-Year Wait for Power Hookups in Virginia

Longer wait times are set to squeeze the development of the large-scale data center projects.

Bloomberg News
August 30, 2024

TREND: BYOP
(Bring Your Own Power)

What do they need?

11 GW of new data center capacity by **2030** in Northern Virginia alone

40% of VA's *peak* demand today

How do they get there?

10-15GW of firm generation capacity

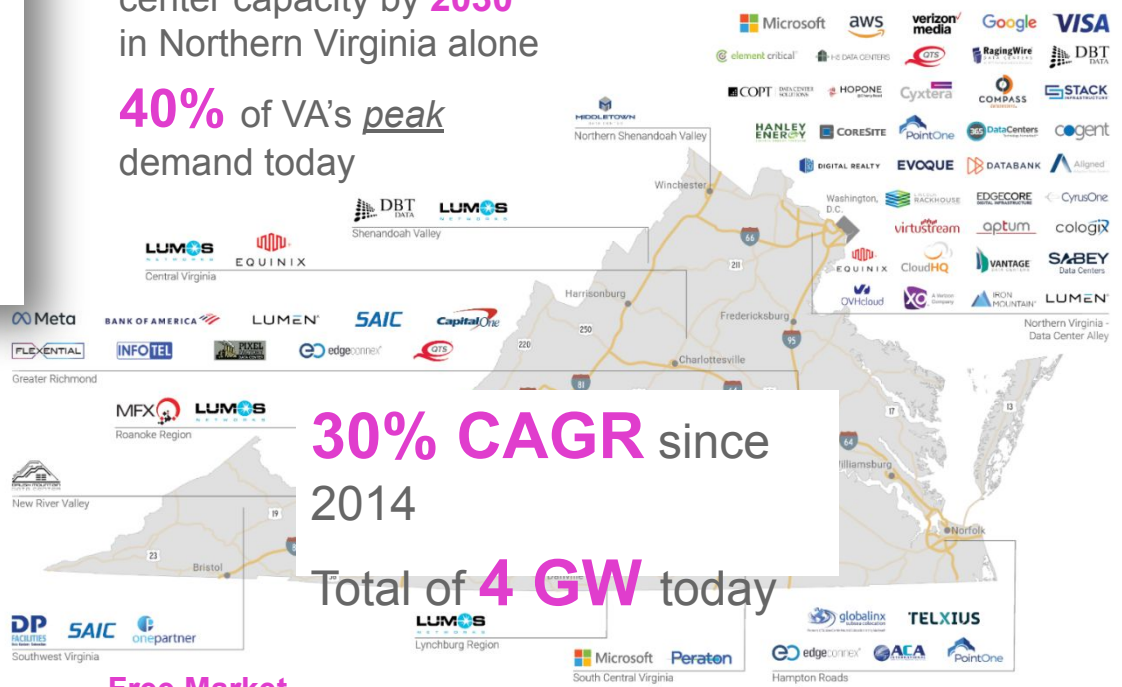
Why is this a challenge?

It can take 3-4 years to approve a new gas-fired generating plant (e.g. 1 GW)

Market prices are too low for developers to build the required capacity

Wasted effort if you can't connect to the grid!

Virginia Data Center Market



30% CAGR since 2014

Total of **4 GW** today

Free Market Challenges!

Is Gigawatt-Scale BYOP Viable? Let's look at xAI's Colossus in Memphis

Today
100,000
H100 GPUs

Tomorrow
200,000
H100 GPUs

100,000 H100s will require **150 MW**

MLGW

Local grid supply*

*As of August 2025

8 MW

Smog levels in Shelby County have exceeded recommended levels for the past 3 years

X14

Natural gas powered mobile generators

35 MW

X4

64 MW

MLGW has agreed to upgrade site to:

50 MW*

*At a cost of $760,000 to local taxpayers

xAI has committed to fund a **150 MW**, $24M new substation

But…where does the power actually come from?

SOUTHERN ENVIRONMENTAL LAW CENTER

The grid is already overloaded*

*Not a direct quote

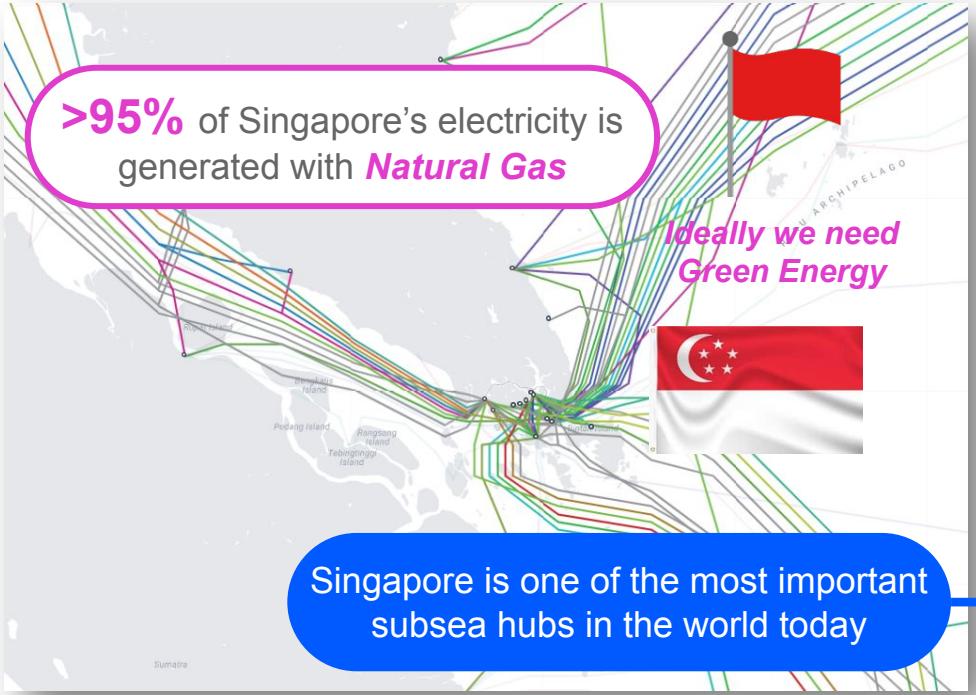
Article: "xAI cluster is now the most powerful AI training system in the world"

Breaking News – xAI to expand Colossus to 1 million nodes!

One million GPUs represents **27%** of Nvidia's 2023 shipments

Where are they going to get 10X (**1,500 MW**) the power?

An International Example: Singapore



26

Operational Submarine Cables

3

Major Cable Landing Stations

Ideally we need more diversity

Subsea hub Data Centers

87 Data Center facilities with **6,933,008 ft²** and consuming **1,026 MegaWatts**

Singapore and Power – Challenges and Opportunities

2019

Singapore issues moratorium on new Data Center builds because of power shortages

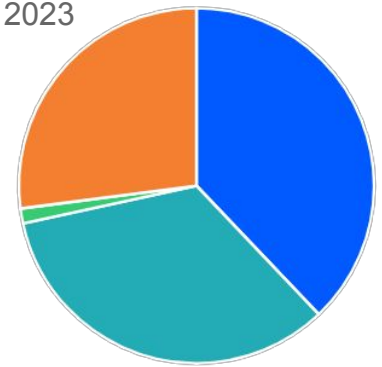
Singapore is trying to recover momentum ***But…by efficiency vs new capacity***

As a result…

Johor Bahru may become the largest DC market in SE Asia in the next 2 years

DC growth in Malaysia while international traffic is moved over the Straits of Johor

Malaysia Generation Mix 2023



Malaysia has a goal to boost Renewables from 27% to 37% by 2030

What can we learn from Singapore?

Plentiful (Green) Power is essential

Proximity to a Hub may be useful

For Malaysia

Don’t become complacent

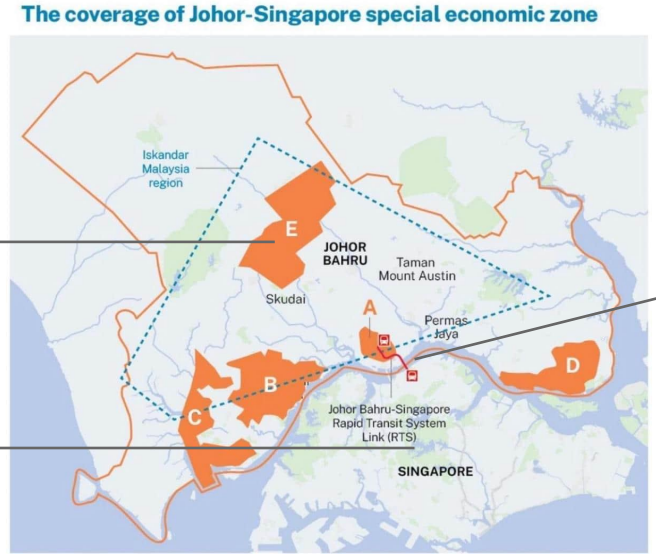
Singapore and Malaysia have had a somewhat lively history

- Independence in 1965
- Disputes over water
- Disputes over islands
- Disputes over port boundaries

But the Data Center opportunity is pushing them towards more cooperation

But this is Johor Bahru in Malaysia, where there is space, power and water for mega data centers

This is Singapore, where the subsea cables terminate



At this point Singapore is <1 km from Malaysia, but…

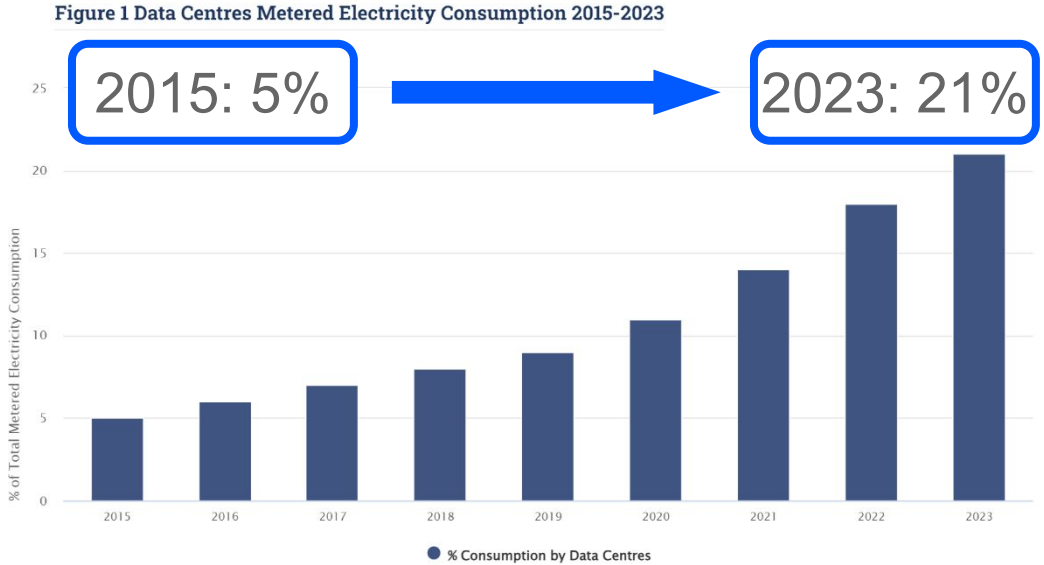
Currently a 2 hour drive, including a customs post at the causeway bridge

After the agreement it will be a 10 minute metro train ride

Ireland – Is The Party Over?

Data Centers account for 21% of Ireland's electrical consumption - predicted to rise to >30% by 2026

Source: CSO



total telecom

Google's planned Dublin data centre rejected amid energy concerns

Posted by Georgia Sweeting | Aug 29, 2024 | TECHNOLOGY, INFRASTRUCTURE, COMPANY NEWS, Data Centres, Europe, News

>50% of Ireland's electricity still generated by fossil fuels

How Do We Power AI Data Centers?

What do AI data center operators really need?

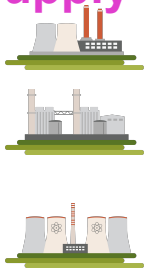
1 Gigawatt Scale

City examples that can be powered with 1 GW*

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

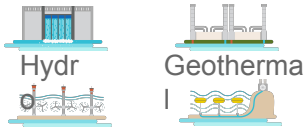
*Assumes a population of around 1 million

2 24/7/365 Energy Supply



24/7/365 Power Sources

Intermittent Power Sources



Location-Specific Power Sources

3 Compact Installation

Co-locate power and Data Center

Avoid grid connection?

4 Low CO_2 Emission (has become "optional")

Google

Goal: "Carbon neutral by 2030"

Reality: 48% increase in CO_2 emissions since 2020

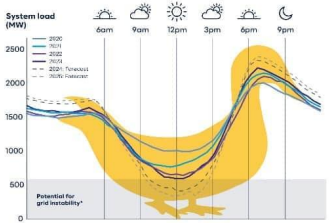
Microsoft:

Goal: "Remove all MSFT CO_2 emissions by 2050"

Reality: 29.1% increase in CO_2 since 2020

Source: Hyperscalers versus the sustainability pushback

What About Batteries?

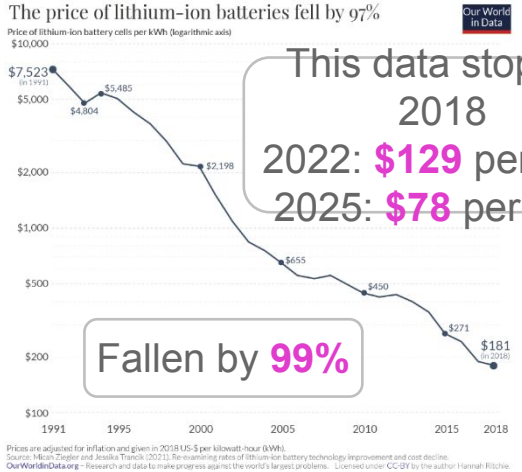


Battery technology is ***specifically intended*** to "flatten the duck curve"

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

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

The largest in Europe for only 40 minutes!



This data stops in 2018

2022: **$129** per kWh

2025: **$78** per kWh

Fallen by **99%**

Solar Panel Waste

$20-30

Cost to recycle a panel

<$2

Send to landfill

Lithium Battery Recycling

What % are recycled today?

Between 5% and 59%*

*Difficult to find accurate estimate because it is unregulated

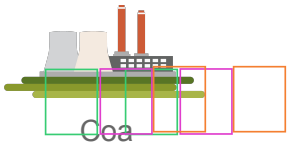
Power Options for AI Data Centers: Two Potential Winners

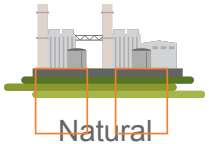
Gigawatt Scale

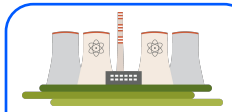
24/7/365
Assume >50% CF

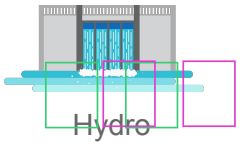
Compact
Assume <5m² per MWh

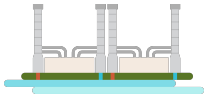
Low CO_2
Assume <50g per kWh

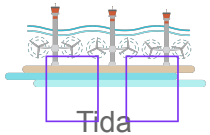

Coal

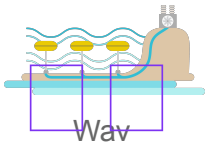

Natural Gas

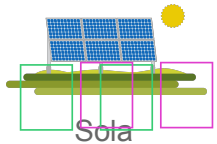

Nuclear

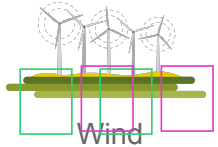

Hydro


Geothermal


Tidal

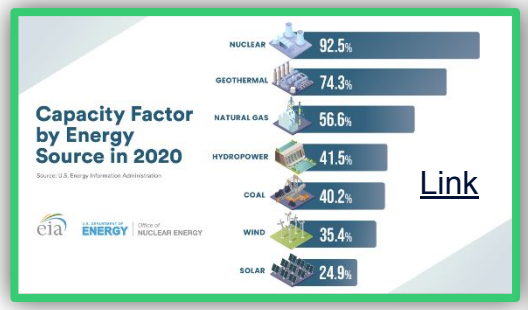

Wave


Solar

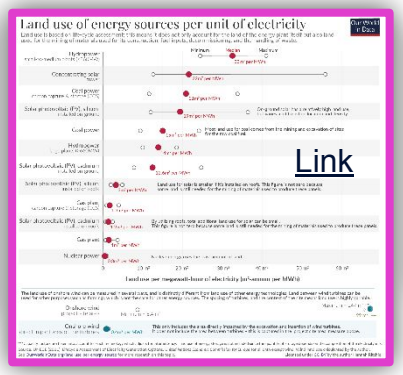

Wind

TYPE	POWER OUTPUT
Hydro	22,500 MW
Wind	20,000 MW
Natural Gas	8,600 MW
Nuclear	7,900 MW
Coal	6,720 MW
Solar	5,000 MW
Geothermal	1,590 MW
Wave	77 MW
Tidal	254 MW

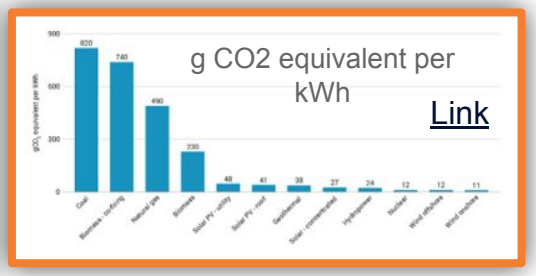
List of largest power stations



Link



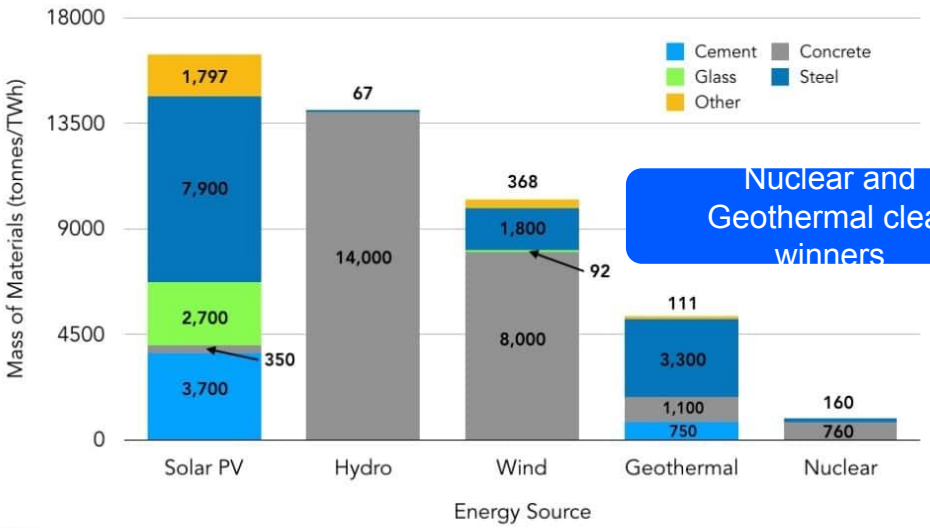
Link



Link

Materials Use By Power Generation Type

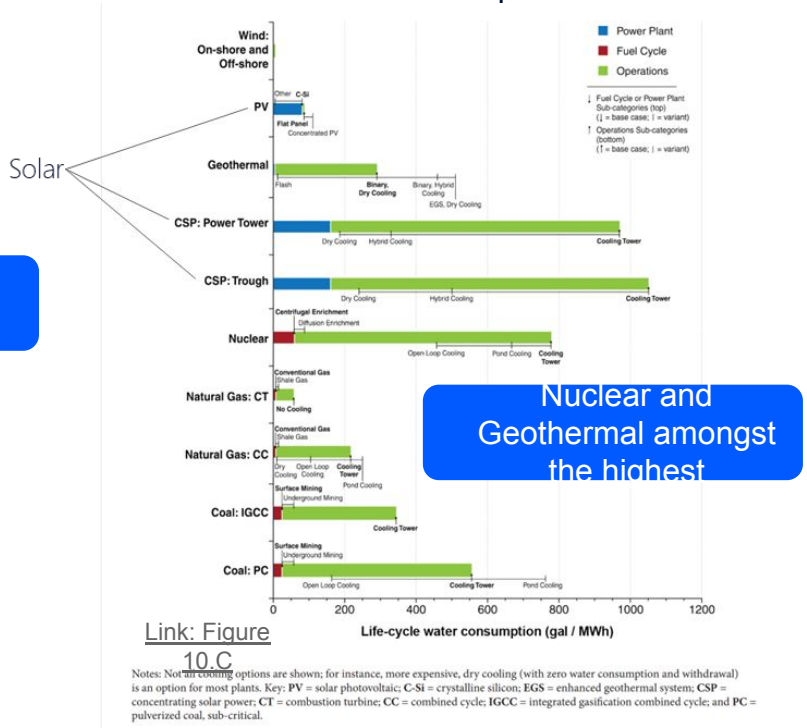
Manufacturing Materials



Nuclear and Geothermal clear winners

"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



Nuclear and Geothermal amongst the highest

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.

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

Enhanced Geothermal Systems use fracking techniques to open up many more locations

Enhanced Geothermal Pros

Potentially low CO_2*

24/7/365 operation

Small footprint

Skillsets match Oil/Gas industry

Enhanced Geothermal Cons

Potential emissions

Potential waste production

Potential for seismic disturbances

Most designs are "megawatt" scale

Potentially need lots of water

New EGS systems are

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

Total cost of ***$600-900M***

*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.

And what you've all been waiting for…

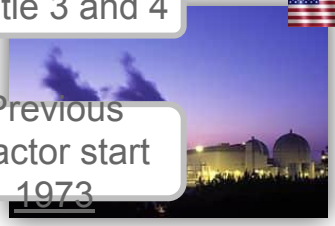
Nuclear

Because nuclear seems like the ***perfect solution*** to power AI Data Centers

Or does it? 😁

Nuclear may have a few…issues…and 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

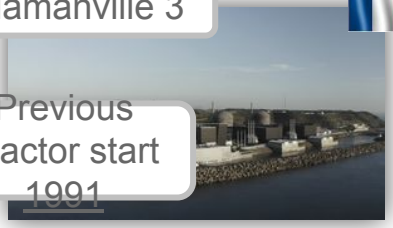
3.2 GW Power Output

Framatome EPR1750 PWR

Original timeframe of **2025** has now slipped to **2029-31**

Costs have risen from

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**

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

TVEL ROSATOM

From Russia with love

☺

The nuclear part's not the only problem…

No mega-project comes in on-time and on-budget anymore, right?

China: 3 Gorges Dam

4.4X over budget

Venice, Italy: MOSE

4.7X over budget

USA, Boston: The Big Dig

8.5X over budget

And it doesn't even need to be on Earth to over-run!

Low Earth Orbit: The ISS

$17B □ $160B

But it turns out we were never that good at project estimates!

1959-7[illegible]3

Sydney, Australia: The Opera House

14.6X over budget

1883-??

Barcelona, Spain: La Sagrada Familia

Nobody even knows!

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 African, S.American or Asian country that would like to build a safe, clean energy source…

…nuclear seems complicated

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

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"

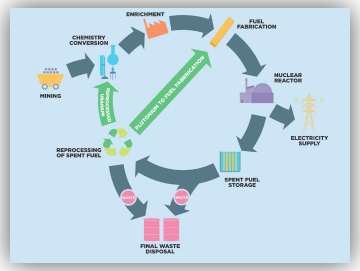
Ready-made for time and budget over-runs

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 article

57 Operational Reactors

30 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

The Hyperscalers' Plans for Power: BYOP*

*(Bring your own power)

SMR = Small Modular Reactor

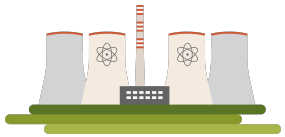
	Short Term	Long Term
amazon	Purchased 900 MW Data Center next to Susquehanna Nuclear Plant	SMR plans in 3 US locations (inc. VA and WA) X energy Anchor investor
Google	*Geothermal investments* FERVO ENERGY	October 2024: Google announced agreement with Kairos Power for SMRs Kairos Power
Microsoft	September 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

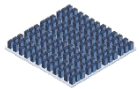
What is a Small Modular Reactor?

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

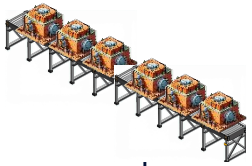
Micro Reactor
10 MW

Power a factory or small Data Center

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

…choose 1 or 2 designs…

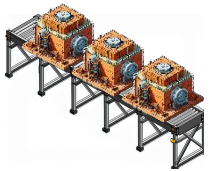
…test them carefully…



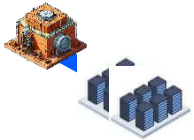
…crank them out

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

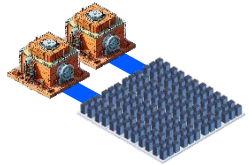
Reduce cost and time to build while improving quality

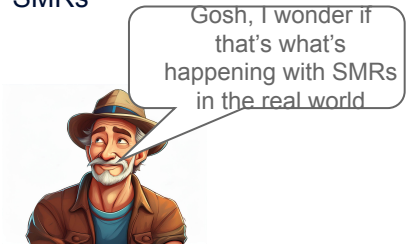


Small enough for co-location to avoid grid connection delays



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





Selection of Companies Building 60+ SMR Designs

10+ Years

Operational

HTGR: Grid connection 2021

OKBM Afrikantov

PWR: Akademik Lomonosov

May 2020

Under Construction

PWR: China National Nuclear Corporation

MSR: Thorium Reactor

LFR: Atomenergoprom

PWR: Comisión Nacional de Energía Atómica

2X

PWR: OKBM Afrikantov

Licensed*

*In at least one country

PWR: Korea Atomic Energy Research Institute

PWR: Nuscale

Seeking License*

*In at least one country

PWR: Rolls Royce

PWR: Holtec

In Design

energy

OKLO

TOSHIBA

HITACHI

Kairos Power

LAST ENERGY

copenhagen atomics

Westinghouse

Glossary

HTGR: High Temp Gas-Cooled Reactor

PWR: Pressurized Water Reactor

MSR: Molten Salt Reactor

LFR: Lead-cooled Fast Reactor

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

Onkalo spent nuclear fuel repository

Store it as glass in geologically stable repositories

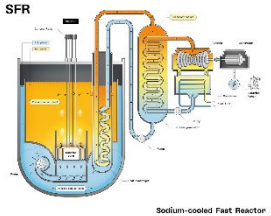
2

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

Management of Spent Fuel from Nuclear Power Reactors

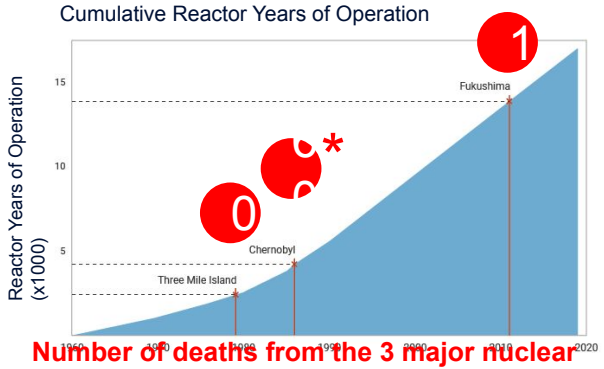
3

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



About 20 FNRs operating since the 1950s

Wait! Isn't 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 ...

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

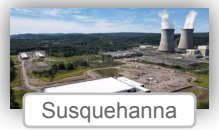
Link to paper

Three Steps For Hyperscalers To Take Now!

1

Grab any spare capacity on ***existing nuclear facilities*** before the competition does!

amazon



Susquehanna

Meta

Extend the life of nuclear plants that were ***scheduled to close***

- In 2022 the DoE warned that "25% of US nuclear plants are at economic risk of closure"
- Map of at-risk nuclear plants
- U.S. Nuclear Plant Shutdowns, State Interventions, and Policy Concerns

2

Restart any ***mothballed*** nuclear facilities you can

- Holtec Pallisades, Michigan
  - May be the first to restart in USA

Microsoft

Three Mile Island

11 nuclear plants shut down prematurely

26 GW of clean energy lost

"no [economically] sensible way of bringing the plants back."

Nadia Jakobi
CFO E.ON

Three Mile island was mothballed for ***economic*** reasons with options to restart

Germany's reactors were shut down "permanently" for ***political*** reasons

Free Market Challenges!

3

Build new, large-scale nuclear plants – if you remember how to do it.

USA has set new COP goals

Nuclear Expansion Goals

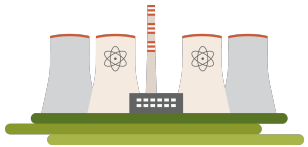
Develop new types of reactors – such as SMRs

Very long term – hope that somebody figures out nuclear fusion

The USA has a goal to deploy **35 GW** of new nuclear power by **2035**

Then **15 GW** of new nuclear power ***per year*** by **2040**

We could assume that…



Nuclear Power is…

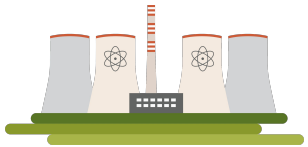
…too expensive, and takes too long to build…

…it has a bad image and people will try to block it

But producing general purpose clean energy is not the AI Hyperscalers' goal

The AI hyperscalers have insane amounts of money to spend on AI Data Center construction

If there's no way to power them…why build them?



Nuclear is not just the ***best option***, it's really the ***only option***

Nuclear Power may not be the right option to produce general purpose clean energy

The dream of cheap, clean, safe and abundant nuclear energy may finally be realized for the whole world

Huzzah for amazon Google Microsoft Meta ORACLE

Once in a lifetime AI opportunity

Need better AI

Absolute

Relative

Bwahahah! Let's go to Mars!

Some of the m

Consequenc es

What's happening today

We were only kidding – carry on burning that coal!

AI provides massive productivity boost

amazon Google Microsoft Meta ORACLE Isn't this great?

But we all lose our jobs ☹

"Better" means more processing power

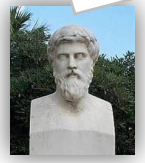
Which implies more electrical power

Pesky corporate sustainability goals!

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

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

Nuclear seems like a great option

But we forgot how to build nuclear stuff!

Bwahaha! We still know how, comrade!

You guys are losers!

>80% of solar panels are made in China

Thank You