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Energy and AI: Challenges for a Sustainable Growth

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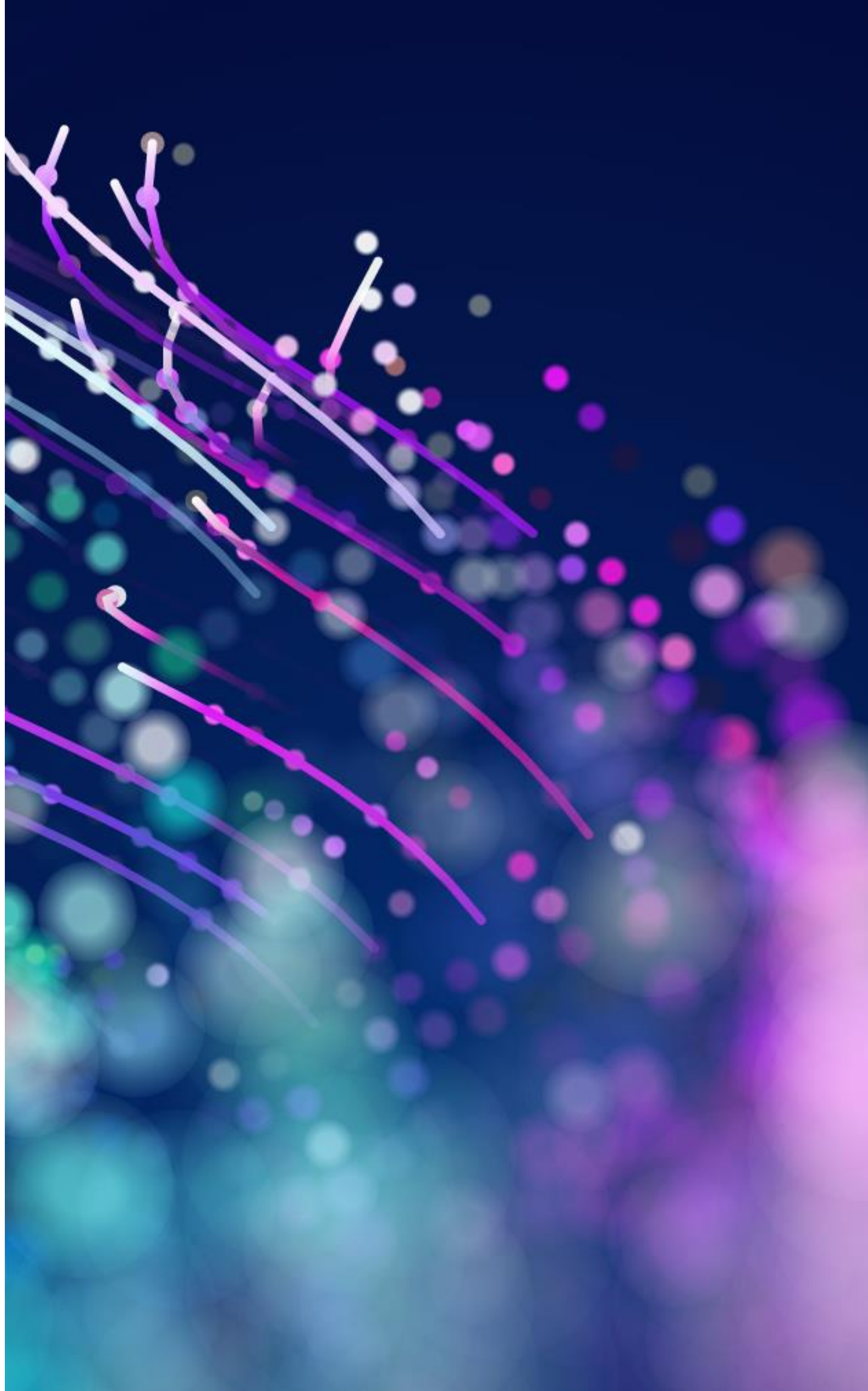
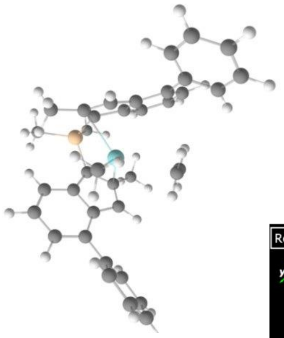
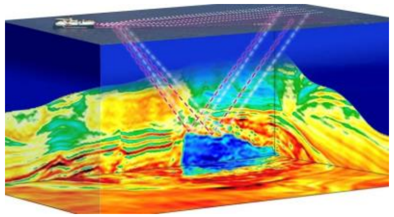
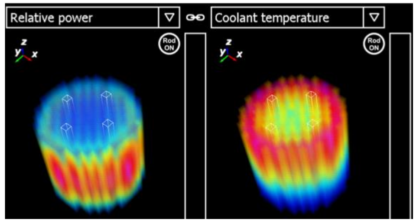


Energy and Computing: A Mutually Beneficial Duo

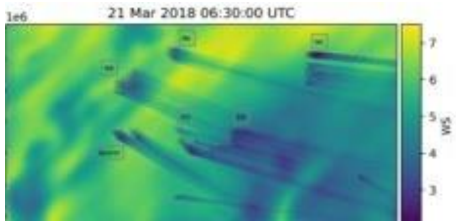


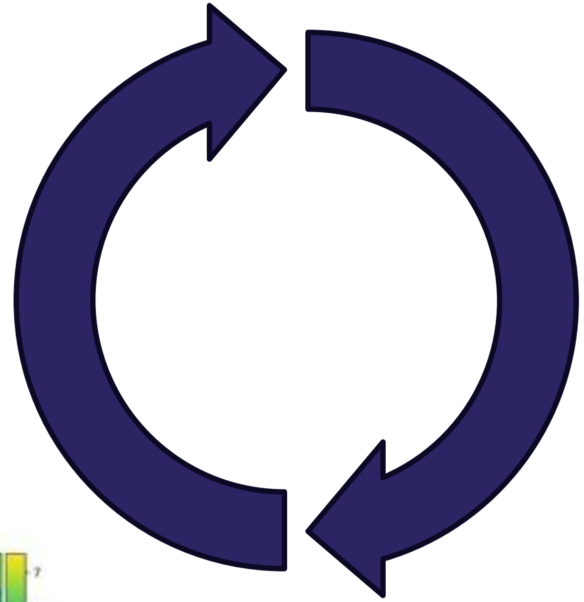




Source: IAEA

Source: LLNL





Energy is compute-intensive

Compute is energy-intensive

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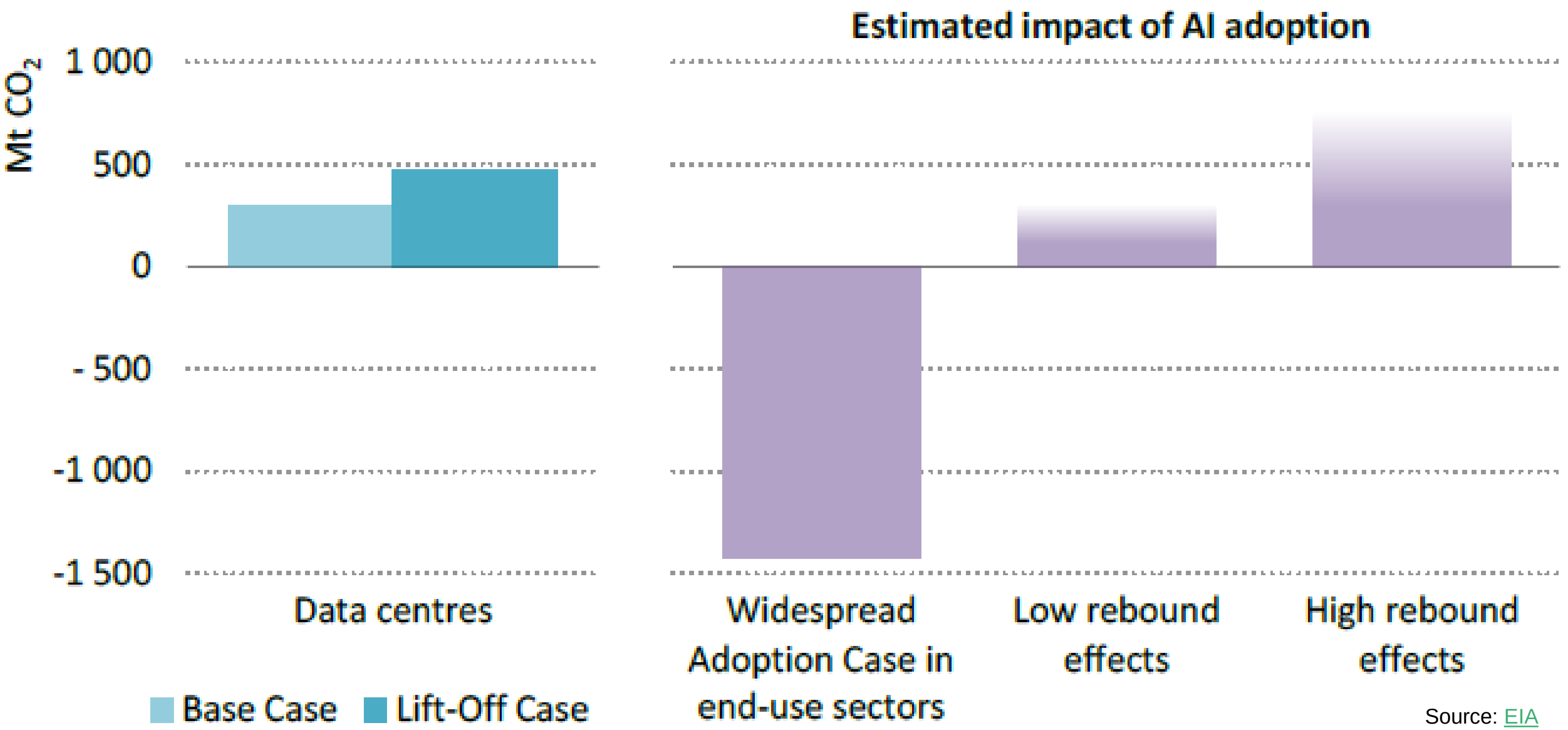
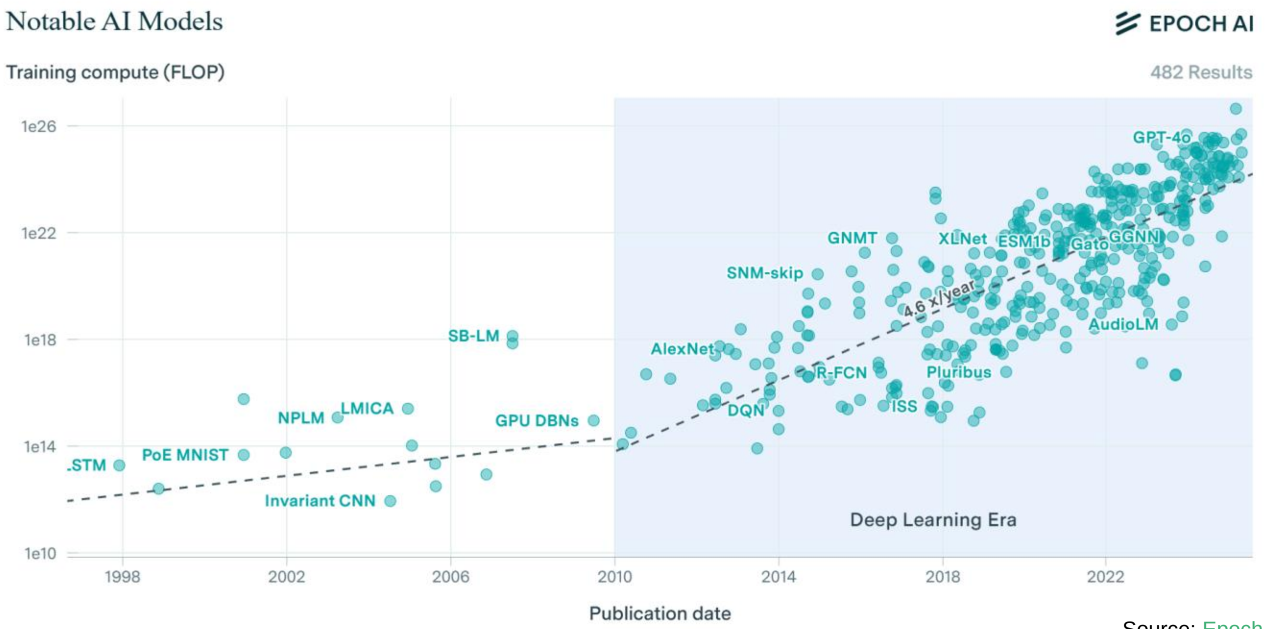
AI and Energy: A Mutually Beneficial Duo



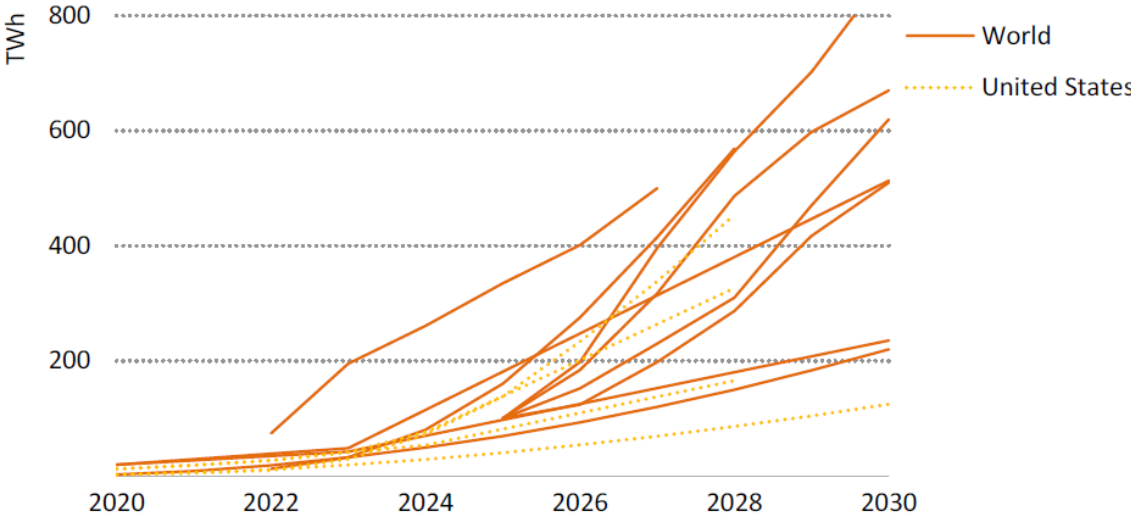
Source: EIA

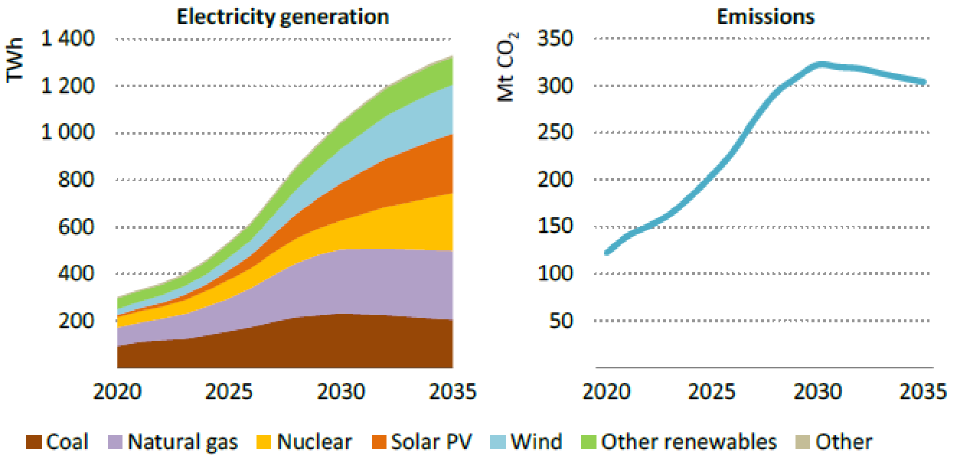
- AI benefits on CO2 emissions through efficiency gains in industry, transportation, and consumption is larger than its associated emissions
- It depends however on the use of solutions benefiting from efficiency gains

Energy for AI: Where are we going?



Source: EpochAI

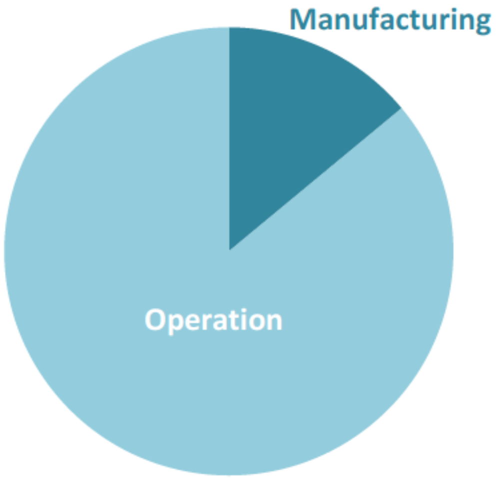




Source: EIA

- Strong gains on compute efficiency offset by significant rebound effect (model size, usage)
- Generative AI is a game changer
- Estimates vary considerably but all show energy demand growth accounting for a large part to the overall DC energy demand growth

Energy for Compute: Main Stakes



Source: EIA

Carbon Footprint
- Low Carbon Generation
- Carbon Capture & Compensation

DC Supply Security
- Grid Connection
- BTM Generation
- Flexibility

Cost of Energy:
- Reduce Consumption
- Secure Supply Price

More control →

← More integration effort needed

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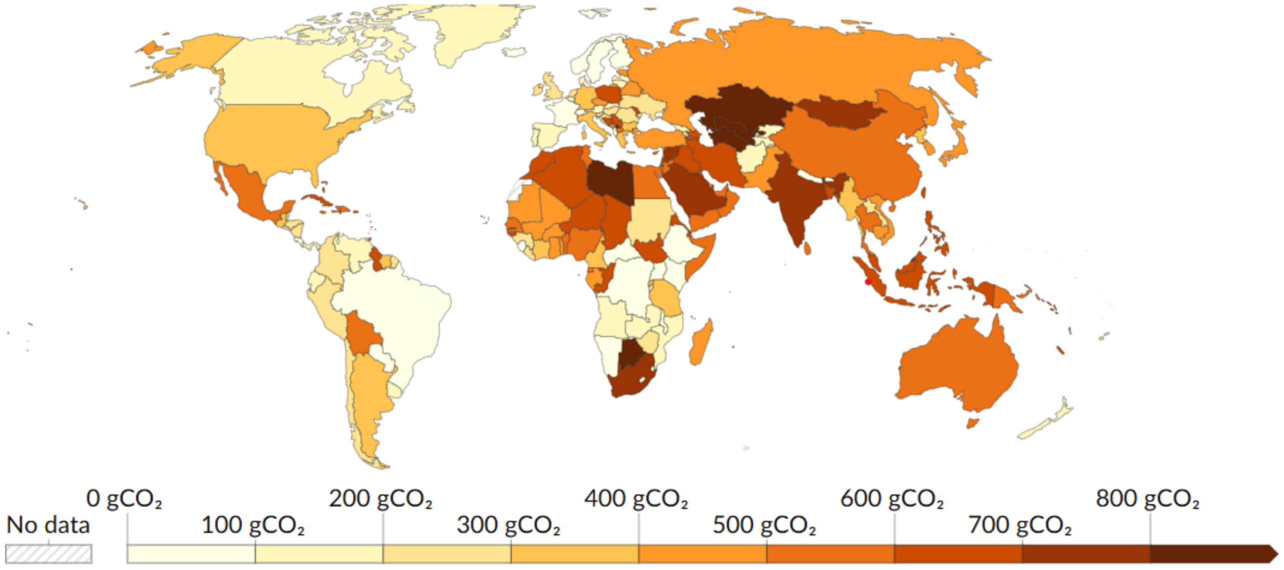
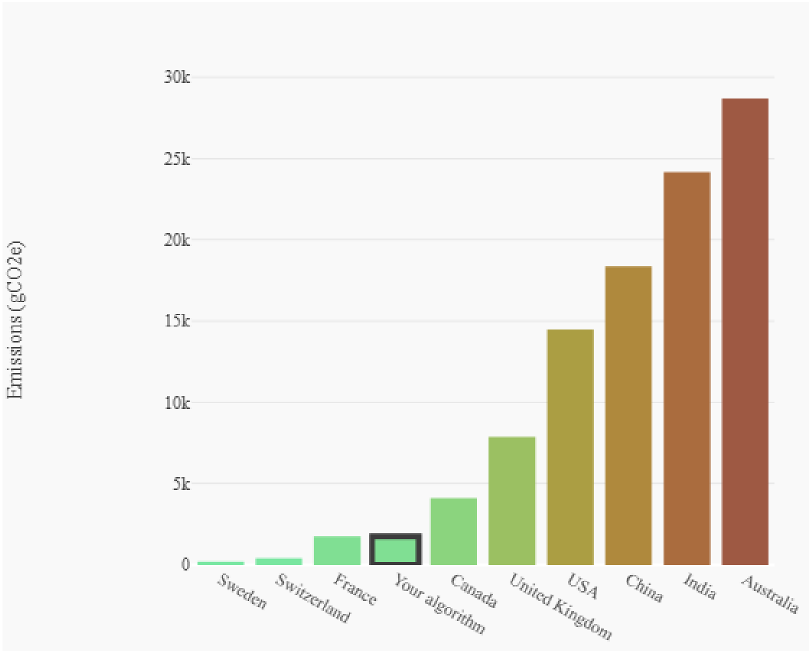
Carbon Footprint: Location Matters for Grid Power



Ember (2024); Energy Institute - Statistical Review of World Energy (2024)



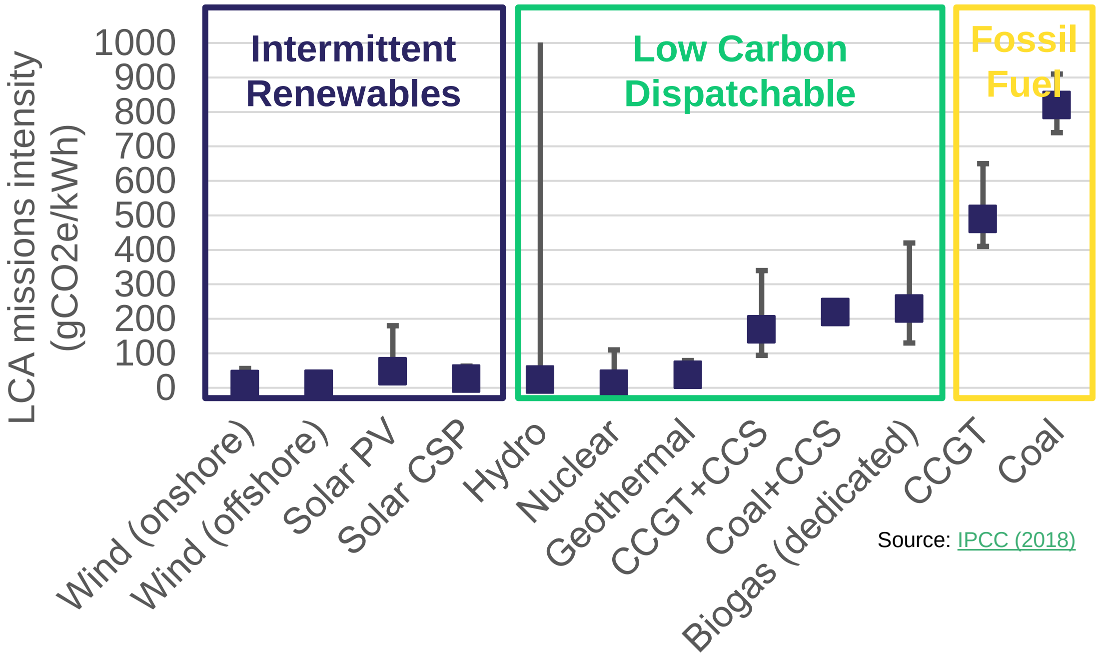
Ex: 12h training 6xV100

Source: Green Algorithm Calculator

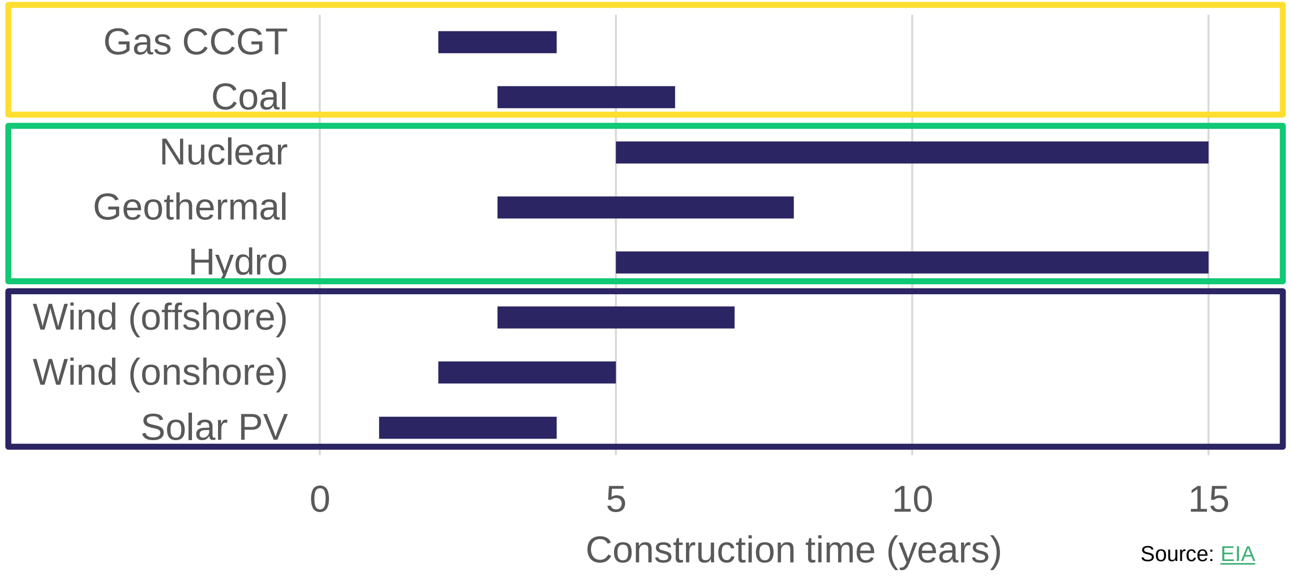
Grid power emissions intensity varies according to energy mix

For a same algorithm, emissions can vary up to 10-100x depending on location

Carbon Footprint: Low Carbon Dedicated Generation



Source: IPCC (2018)



Source: EIA

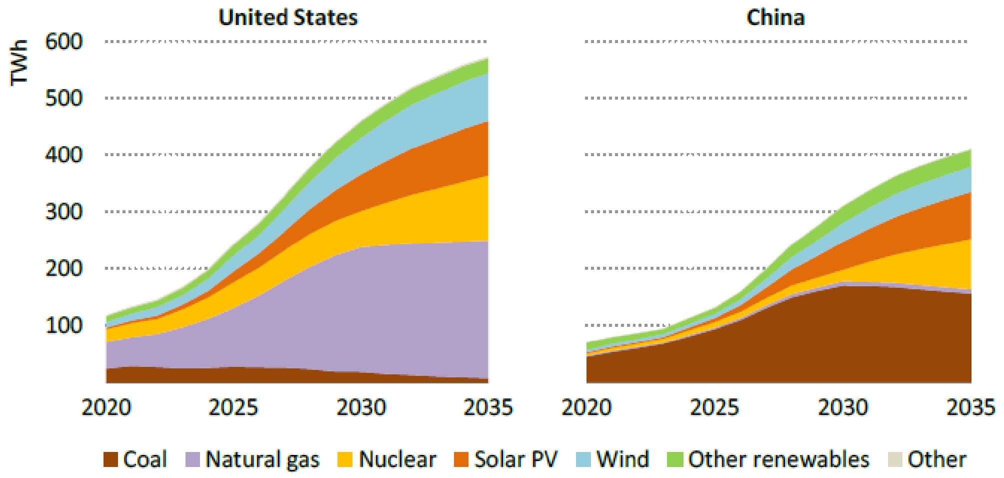
Fossil-based is today the quickest way to develop new capacity (note: tension on gas turbines and transformers)

Renewables also quick to develop but intermittent – still needs coupling with fossil or battery storage

Low-carbon dispatchable:

- Nuclear, CCS much longer (CCS early stage so cost still high)
- Geothermal only interesting in select areas (high geothermal gradient)
- Hydro already near max capacity in many markets

Carbon Footprint vs Cost



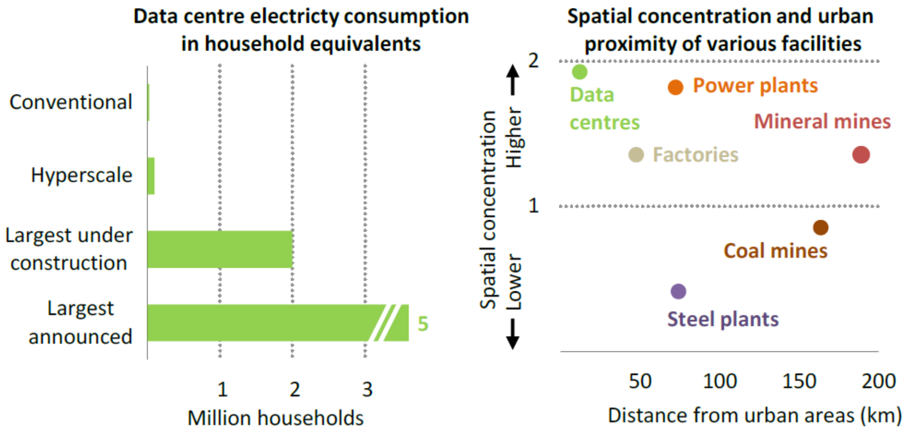
Source: EIA

Costwise most competitive option at scale (short-term):

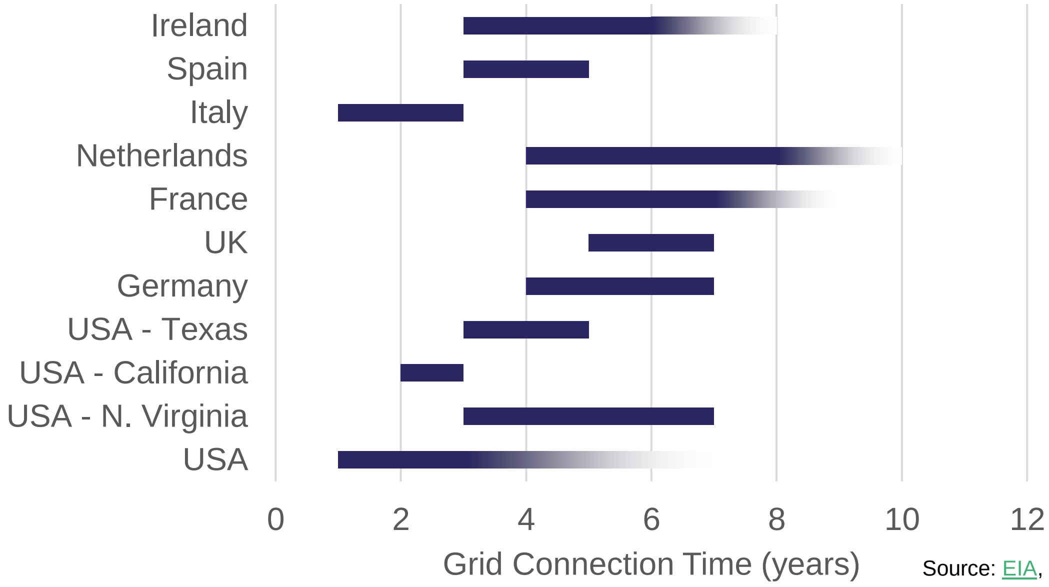
- Europe: Renewables (onshore)
- USA: Gas (cheap fuel), Solar PV
- China: Coal, Onshore Wind

Longer term (2035+): Nuclear and Dispatchable Low Carbon will become more competitive (scale effect for renewables esp. In China, US: Tax credits on renewables, CCS and nuclear)

Supply Security: Connection to Grid



Source: EIA



Source: EIA, press

Lead time for connection becoming more and more critical

Various strategies according to DC developers’ priorities, local policies and access to land

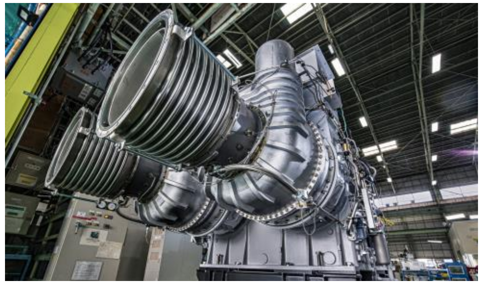
- DC developers: multiple applications, BTM generation, flexibility
- TSO: pre-connected (former) industrial sites (e.g. 35 sites in France – EDF AMI) – but some will still require adaptation + accelerated procedures
- Energy producers: dedicated generation offers
- Regulators: TSO mandate to study all applications (e.g. France, Texas), tariffs regulation

Supply Security: BTM Generation and Flexibility

Goal: accelerate connections by relaxing grid constraints

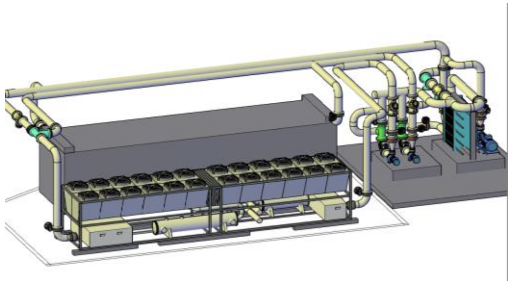
Battery storage

- Transient energy to enable safe shut-down of genset start-up
- More significant storage to offset peak-demand periods (+perform grid services)



Behind-the-meter generation

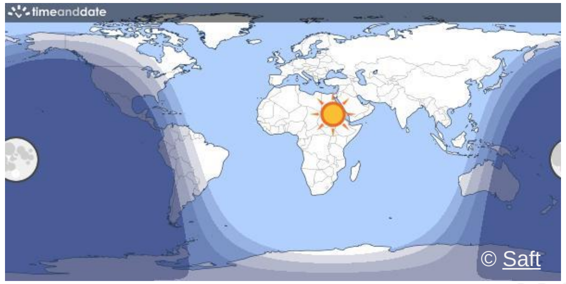
- Genset or turbine, depending on usage
- Back-up or peak-demand offset
- Can run on biogas/HVO to reduce carbon footprint



Cooling storage

(for cooling systems only)

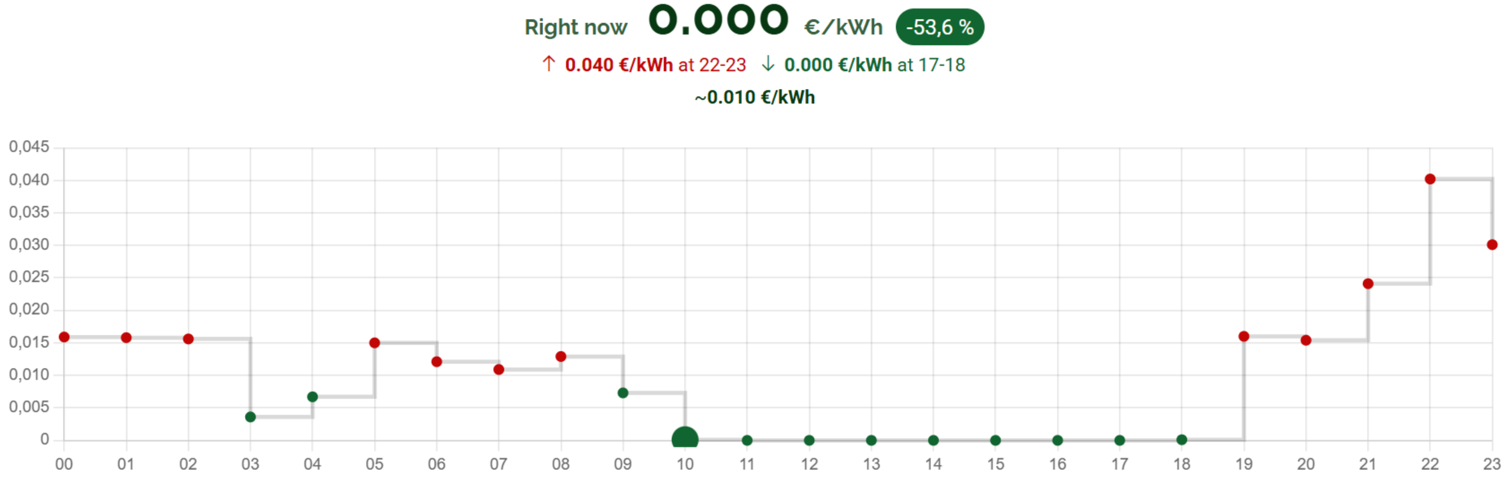
- Failsafe for backup systems
- Cold storage to reduce peak-demand

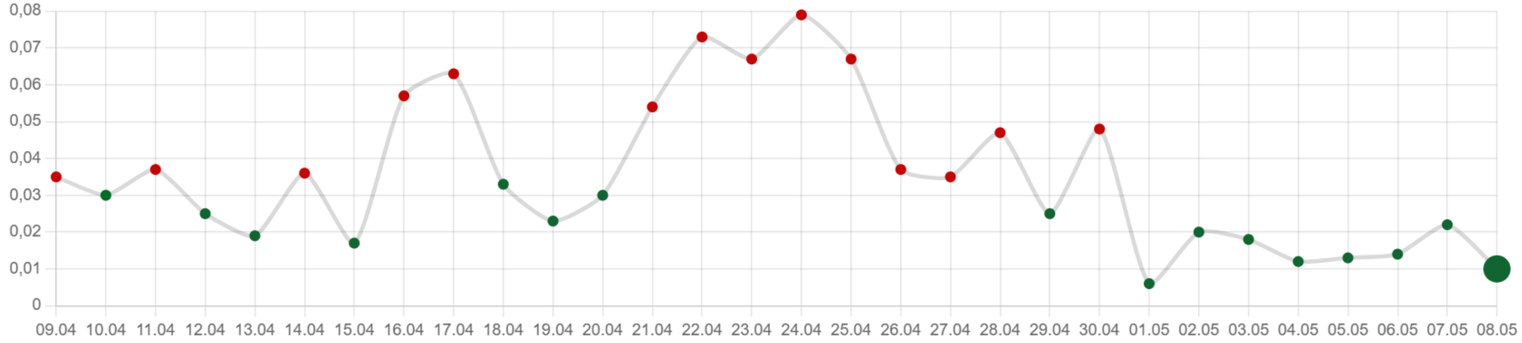


Temporal/Geographic Load management

- Move workload to off-peak of lesser CO2-intensive times or to other DC

Cost of Energy: Secure Pricing





Electricity price in France last 30 days

Source www.energyprices.eu retrieved on May 8th 2025

Electricity spot price highly volatile

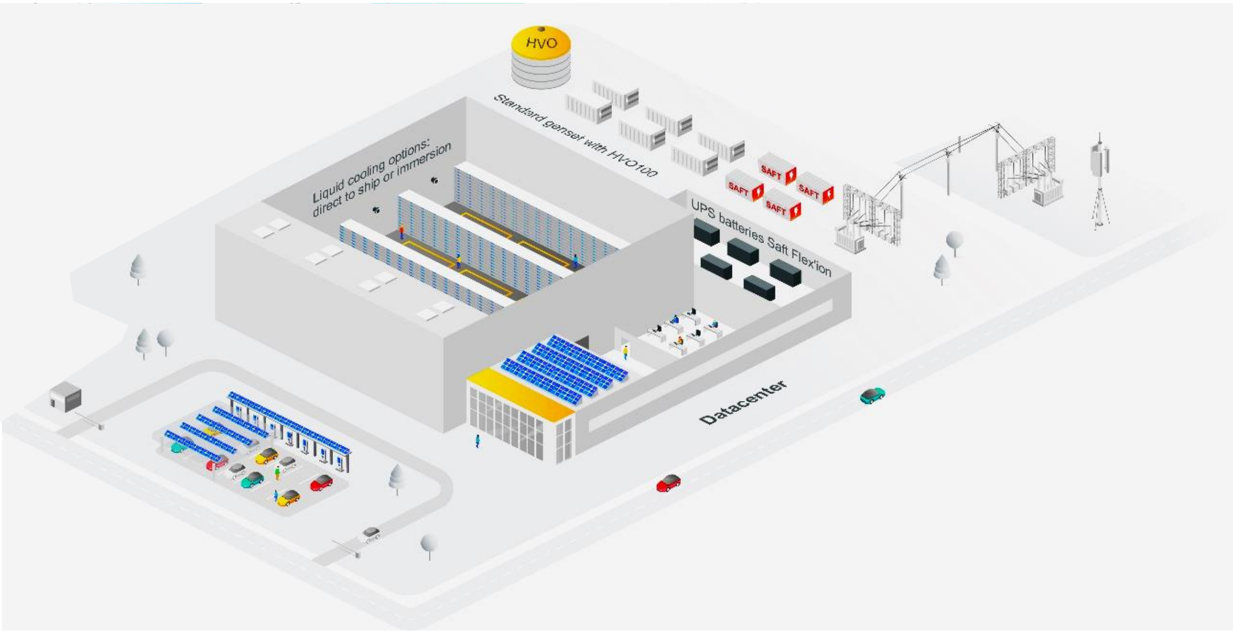
- Difficult to predict on long term
- Uncertainty source for buyer

Generally overcome with Power Purchasing Agreements (PPA)

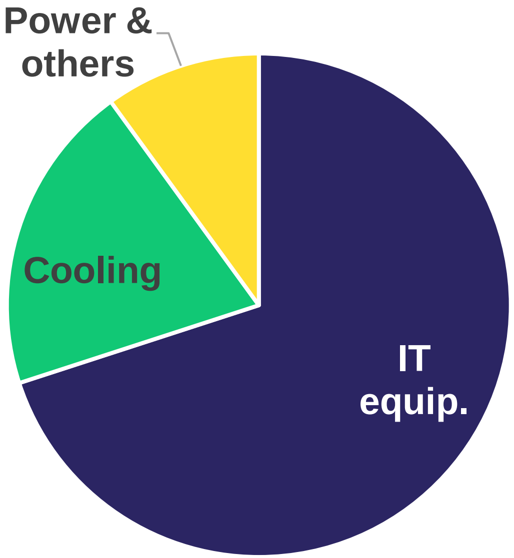
- 25-30% of renewables PPAs from Data Centers[1,2]
- Could grow to 40% by 2030[2]

[1] European Data Center Association, 2024
[2] EIA, 2025

Cost of Energy of HPC: A Race for Efficiency



Share of energy use



Note: typical values vary from a datacenter to another

Make data centers more energy-efficient (lower Wh per usage)

Low-power processors
Efficient memory/storage
Innovative cooling
Heat reuse

Energy-efficient algos
Specialized models

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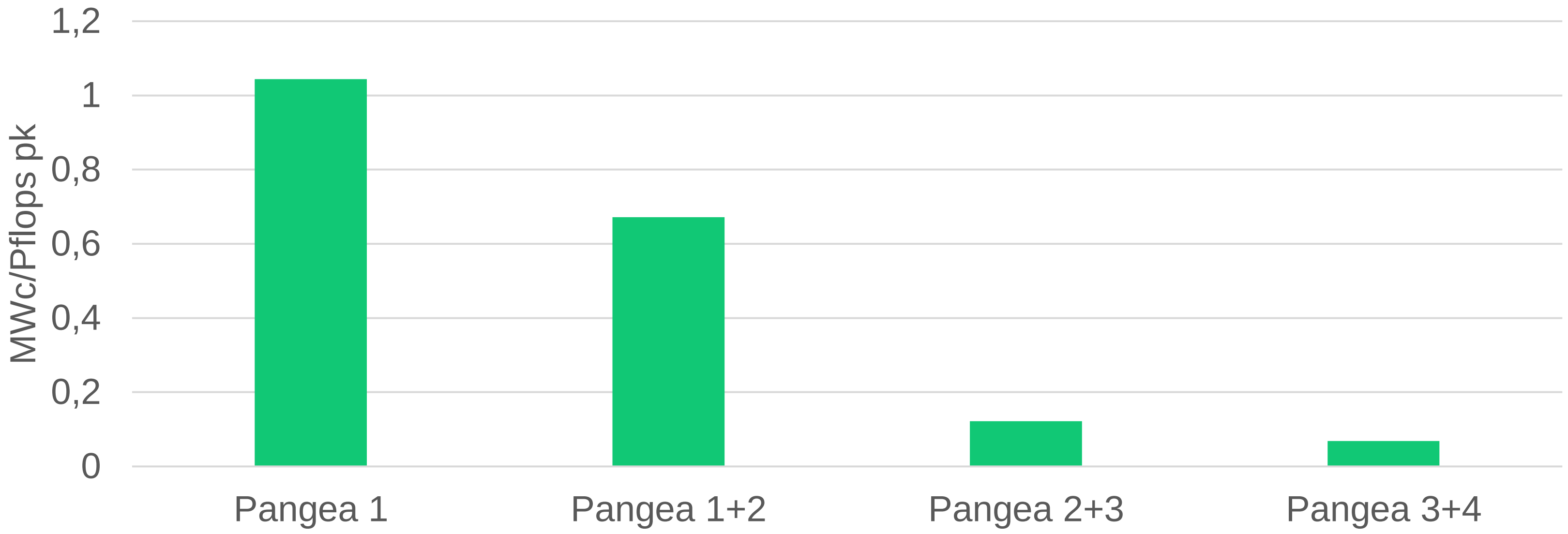
Example in TotalEnergies' Pangea HPC

A decade of innovations to make our HPC more energy efficient



Pangea 1&2 (2013, 2016)
Ice inertia cooling backup & peak-shaving (up to 4h)
Cold Plate Cooling (15°C)
Heat reuse on campus (2015)

Pangea 3 (2019)
Hybrid CPU-GPU architecture (2 main codes ported on GPU)
Cold Plate Cooling (25°C)
Li-ion backup battery

Pangea 4 (2023)
Hybrid cloud/on-prem CPU
Cold plate cooling (32°C)

Software (started 2024)
Coalition for Sustainable AI (Paris AI summit 2025)
Code energetic profiling
DCIM: power vs use (R&D servers)

Conclusion: Sustainability of AI, Compute

AI shows promises for progress but also decarbonation, but faces different types of challenges

Several elements are 'easy' to control by DC developer & operator

- Power efficiency, BTM capacity, Low-carbon PPAs

Can be deployed today by DC developer and operator

Other elements are difficult to control and strongly depend on location

- Grid carbon footprint, supply lead times

Need for energy ecosystem integration (DC-grid-producer)

Some others still early stage:

- Carbon Capture and Storage, Nuclear (Small Modular Reactors)

Early stage, needs more developments and cost efficiency

Efficiency trends: Significant focus on hardware (not over), software more recent, usage education still nascent
→ *The most certain way to access affordable compute*

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