“Sustainability & HPC”

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Sustainable Supercomputing

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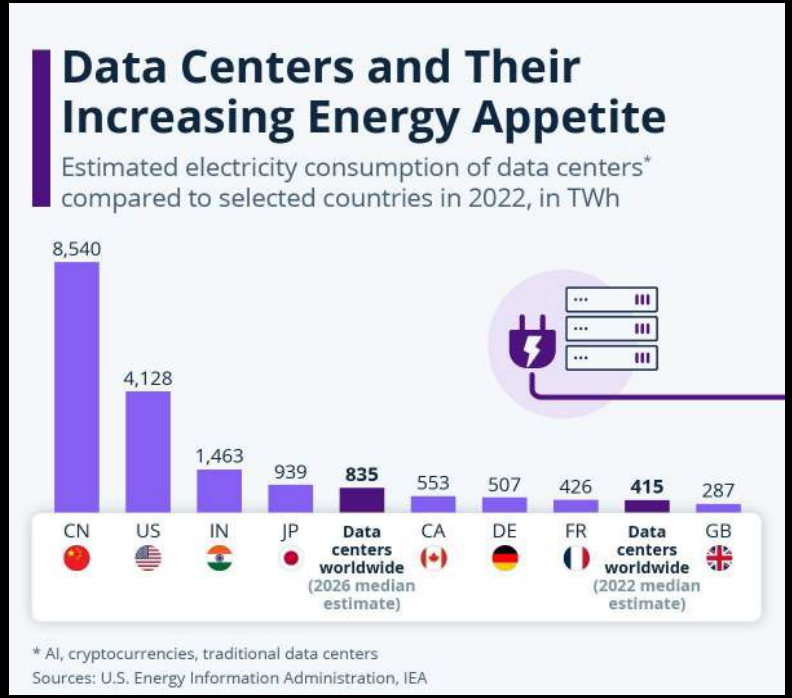
The Carbon Impact of (High Performance) Computing

- Datacentres currently use 1-2% of the world's energy
- "AI is poised to drive a 160% increase in data center power demand by 2030" (source: Goldman Sachs)*
  - A ChatGPT query requires 10 times as much electricity as a Google search....

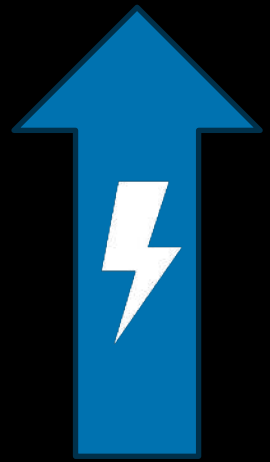
* Other estimates are significantly higher !



The Relentless Rise of Electricity Prices ?

- Although geo-political/economic factors can cause significant short-term variation in wholesale electricity markets, the real-term price to consumers and business has continued to increase

Source: gov.uk



Reducing our Carbon Footprint (& Cost ?)

- What and how do we try to optimize ?
- Can the choices we make result in ‘less-bad’ outcomes?
  - Is entering into a Power Purchasing Agreement for renewable energy enough?
  - Or can we make choices that:
    - encourage investment in future infrastructure for renewables
    - help rather than hinder the energy transition
    - help to minimize overall power demand

IT and Data Centre Efficiency

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Maximizing IT efficiency: ‘science per £ and gCO_2e’

- Maximize throughput at the platform level:
  - Maximize system reliability
  - Minimize idle cycles
  - Manage user adoption & minimize user errors
  - Ensure that applications can scale to the resources demanded

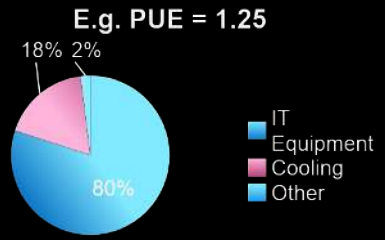
- Optimize throughput at the application level
  - Software optimization, scalability and I/O
  - Workflow optimization
  - Target applications for most suitable platforms

- Implies an increased focus on system management expertise and

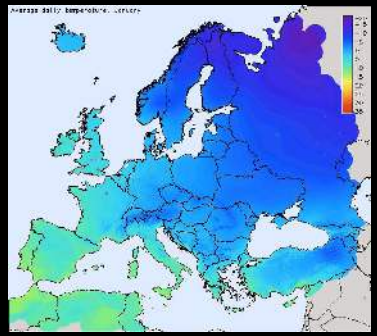
Data-centre efficiency: Power Usage Effectiveness

- Power-usage effectiveness is a measure of datacentre (in-)efficiency:

$$\text{PUE} = \frac{\text{Total power used by the Data Centre}}{\text{Power used by the IT Equipment alone}}$$



- A 'good' datacentre will have a PUE < 1.2 ; a 'bad' data-centre may have a PUE > 1.5
  - Lots of on-prem HPC datacentres are in the 'bad' category
  - Rear-door and immersive cooling technologies can drive PUEs closer to 1 (especially the latter)
  - Geographical location can also have significant impact on PUE



On-site (or near-site) generation and heat re-use

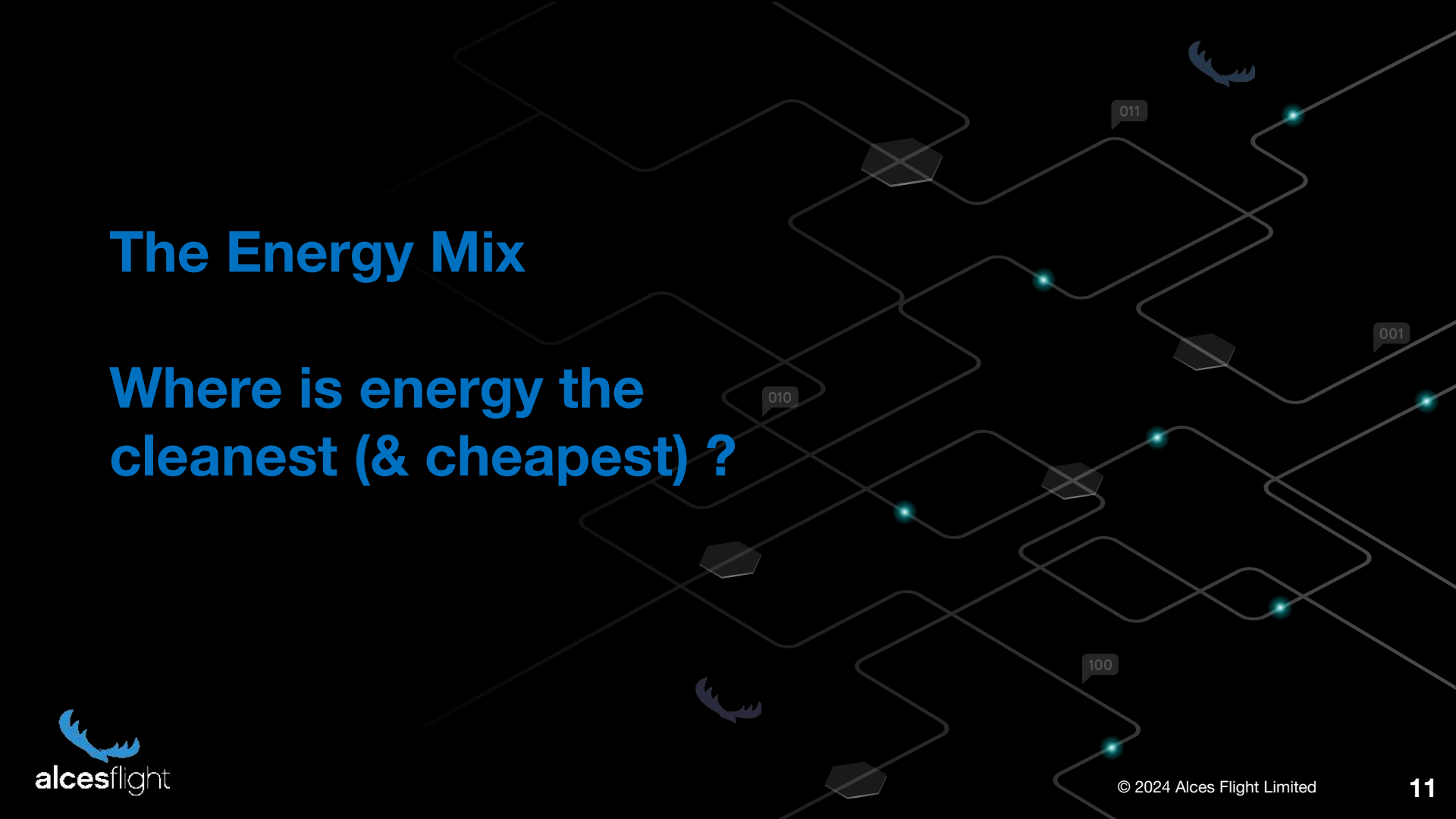
- The reduction in capital costs for renewables is starting to drive the adoption of on-site solar and/or wind generation (albeit insufficient to power large datacentres)

- Forward-thinking datacentres are also being designed for heat re-use, which can offset CO_2e and reduces contention for electricity
  - Waste heat can be used for district heating systems, swimming pools, greenhouses or industrial processes
  - Sadly, most existing datacentres have not been designed nor sited with this in mind…

- A new generation of smaller ‘edge’ datacentres, with on-site solar and heat re-use will help to offset both emissions and cost

The Energy Mix

Where is energy the cleanest (& cheapest) ?



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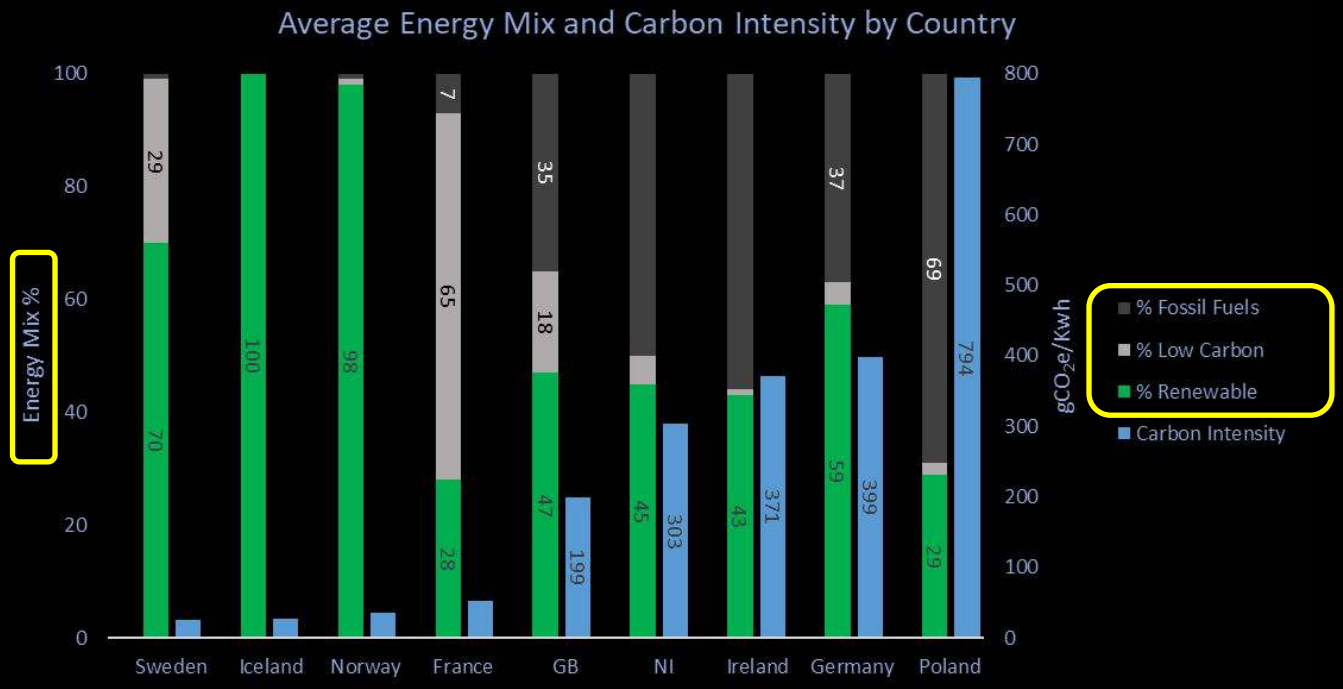
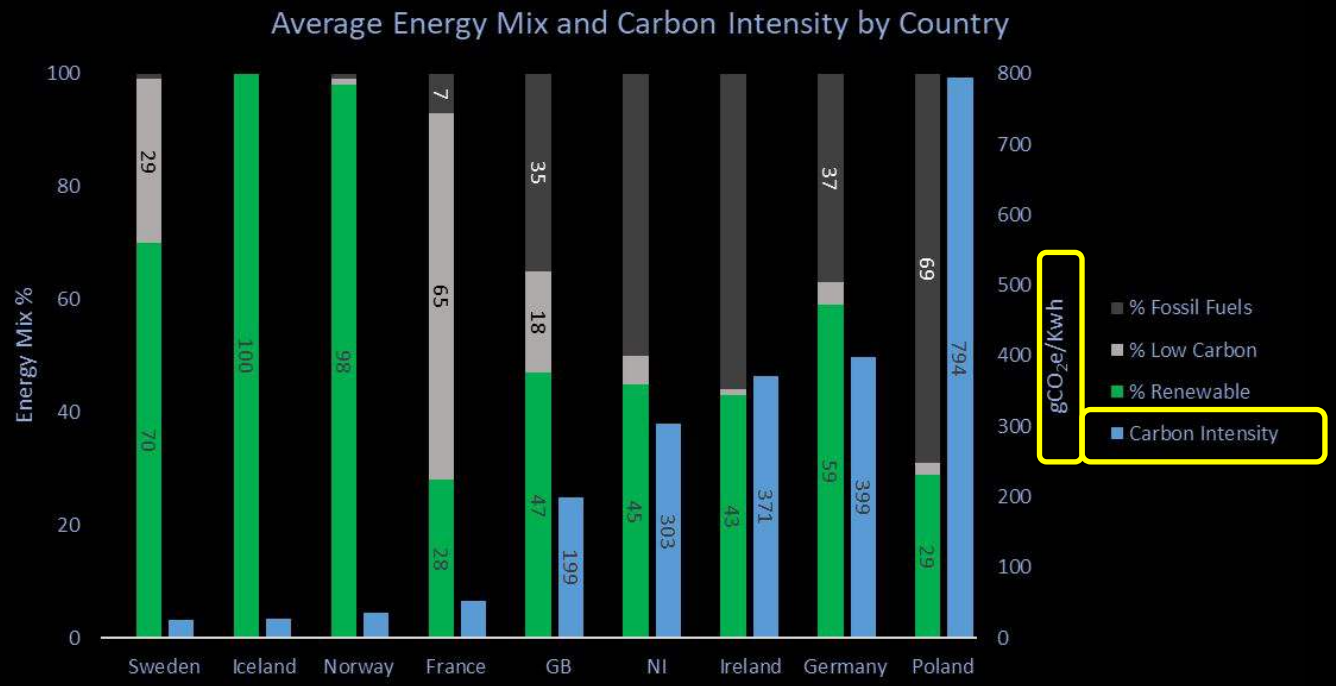
Electricity generation and renewables



2023 Data. Source: app.electricitymaps.com

Electricity generation and renewables



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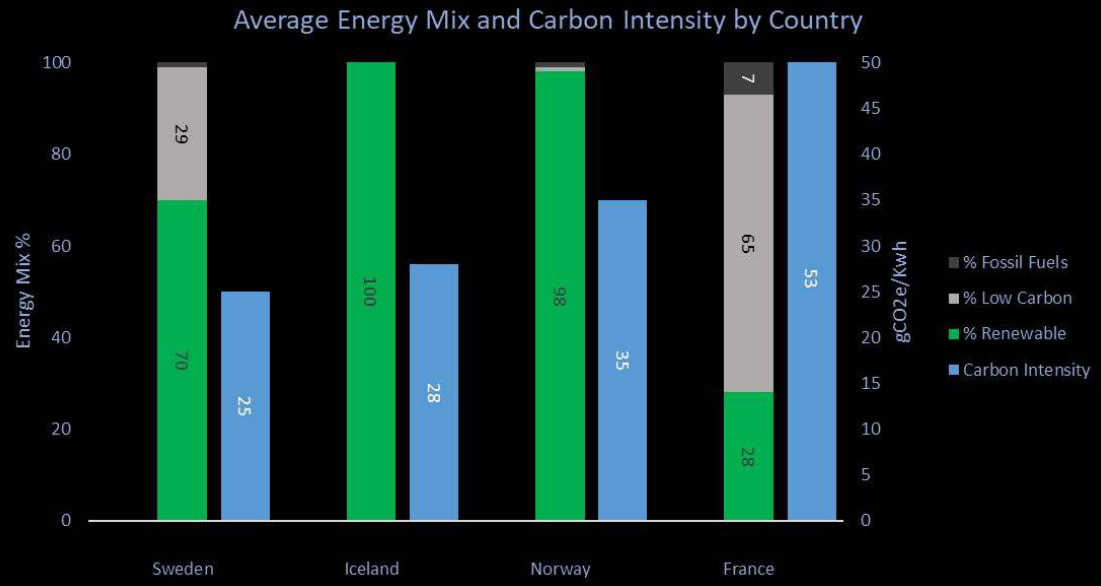
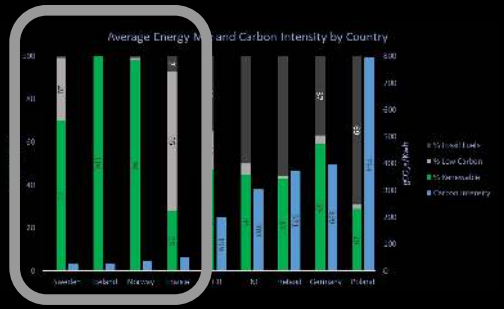
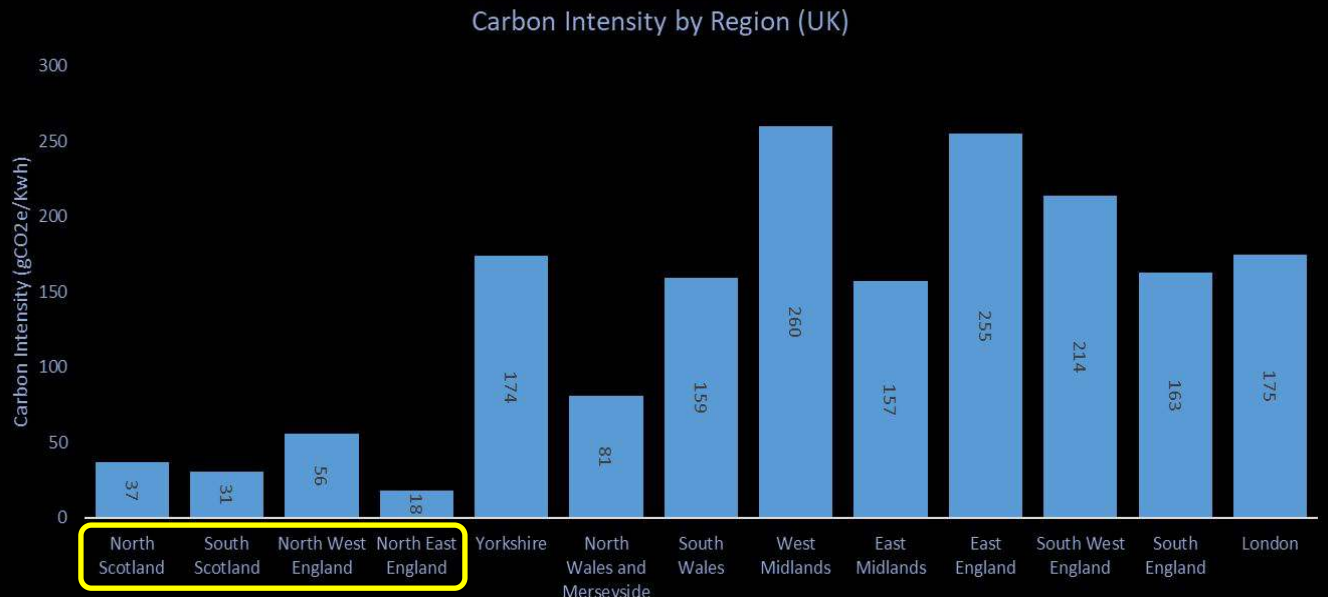
Electricity generation and renewables





Carbon intensity by region (UK)



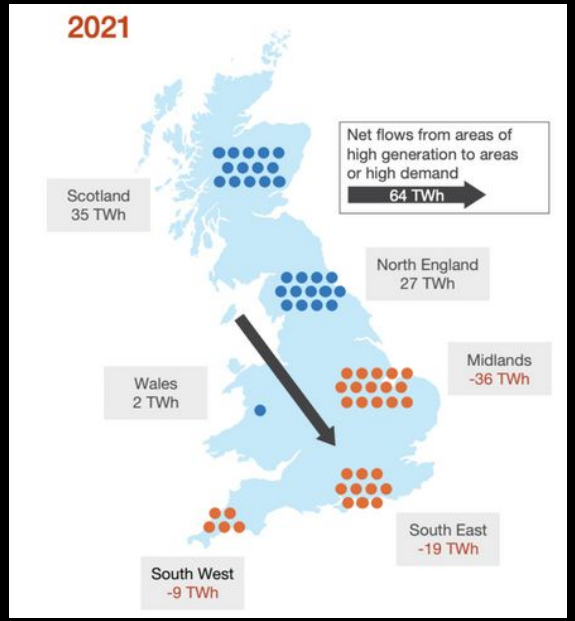
2023 Data. Source: nationalgrideso.com

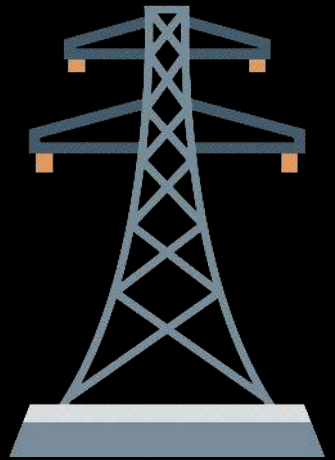
Location, location, location

Why does it matter for HPC in the UK ?

Transmission losses

- In 2022, 22Twh of electricity generation, or 8% of the total electricity generated, was lost in transmission and distribution (source: gov.uk)

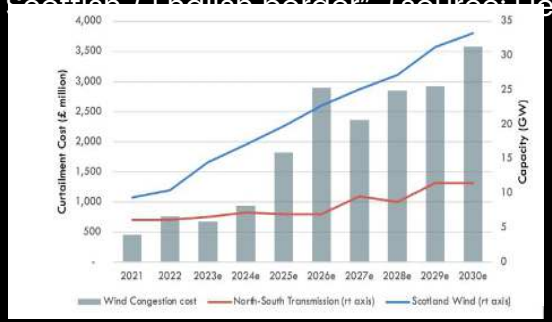




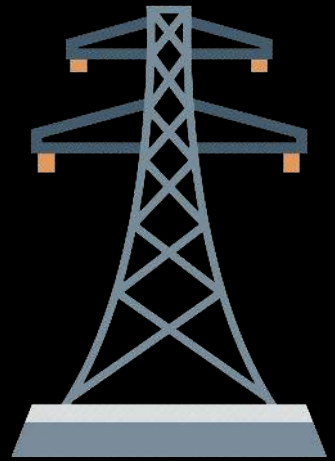
Energy Curtailment

- 3.2TWh of wind energy was curtailed in 2023, adding 1.4 $MtCO_2e$ and costing £570M on the wholesale market (Source: UK Wind Curtailment Monitor)

- "The practice of powering up gas power plants in England and Wales and switching off wind farms in Scotland cost bill-payers £920M in 2023. Approximately £670M was due to limited bandwidth of the UK's transmission network on the Scottish / English border" (source: Field Energy)



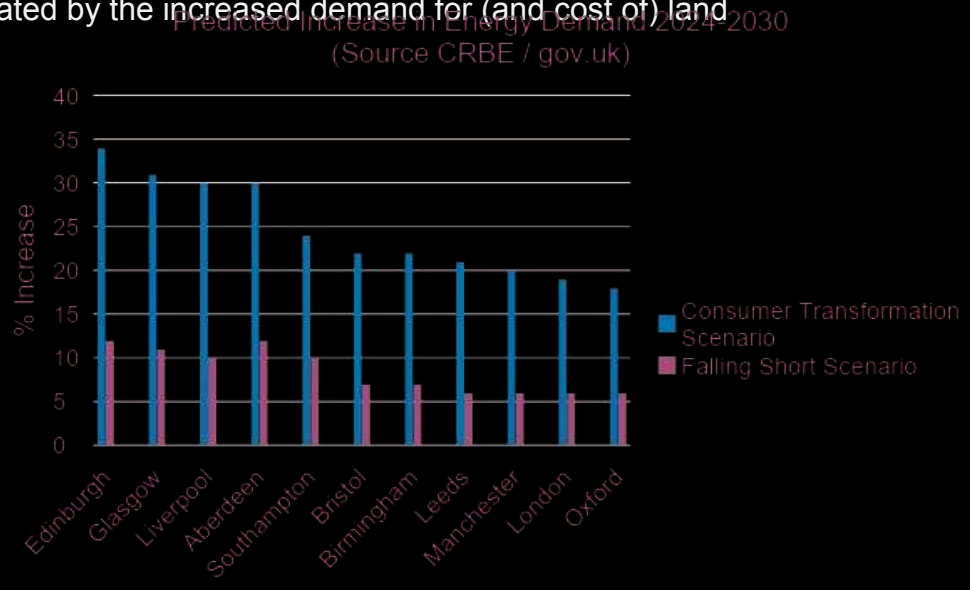
Carbon Tracker Initiative 2023



- PS. National Grid has recently announced a £30B investment from 2025-2030, including upgrading key bandwidth limitations.

Electricity Demand in Built-up Areas

- Meeting net-zero targets and associated regulation will lead to increased electricity demand (and cost?) within UK cities
- Exacerbated by the increased demand for (and cost of) land



*Excluding updated predictions on the effect of the growth in AI/ML

Embedded Carbon

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Embedded Carbon – Data Centres

- Understanding the Embedded Carbon footprint of a newly-built, existing or renovated datacentre is very difficult!

- Some new datacentres are designed with Scope 3 in mind. E.g.:
  - They may use existing buildings where feasible
  - They may be built by local tradesmen using locally-sourced wood instead of concrete…

Embedded Carbon – HPC hardware

- Companies (e.g. Dell and HPE) increasingly publish data on embedded carbon equivalents for their products, detailing:
  - Manufacturing: generally, well over 90%
  - Shipping to customer: often negligible
  - EOL: often a small (1-3%) positive or negative %
  - Significant variation in estimates !
- Note:
  - “SSDs dominate in terms of impact in manufacturing phase. They contribute between 48% and 62%, depending on the product” – Dell Factsheet

Understanding the Carbon footprint of an HPC system with very specific hardware configurations can be difficult, but things are improving

Conclusions...

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Our Conclusions

- Cost and sustainability are (increasingly) strongly correlated
- Users should carefully consider where compute takes place
  - It is easier (and cheaper) to move data to the power than power to the data
    (for applications for which bandwidth, latency or data sovereignty / security are not major issues)
  - Near-prem solutions, with heat re-use and some solar, are increasingly viable
    and may be technically and 'politically' preferable in some cases
  - A mix of near-prem, co-located and on-demand public cloud resource will make sense for larger HPC/AI users
    (NB. There is increasing choice of public cloud providers for HPC/AI !)
- Understanding and reporting on efficiency, cost and sustainability is not only increasingly important, but is a requirement for larger organisations