



Sustainable Supercomputing: an overview of activities at EPCC

Professor Michèle Weiland
Met Office Joint Chair
m.weiland@epcc.ed.ac.uk



About EPCC

- Part of the University of Edinburgh
- Established in 1990, now with 140 staff
- UK National HPC Service provider
 - Hosting site for UK Exascale
- Research activities range from Supercomputing to AI to Data Science
 - Reflected by wide range of systems – from HPE Cray EX to Cerebras CS-3
- MSc & PhD programme in HPC & HPC with Data Science





MACHINE HISTORY

EPCC hardware timeline

2019 Fulhame, HPE
Apollo 70 (4,096 Arm
ThunderX2 cores)



2021 DiRAC ATOS
Sequana XH2000
(4,416 cores/456
GPUs)



2021 ARCHER2
HPE Cray Ex
(750,080 cores)



2019 NEXTGenIO,
Custom Fujitsu
PRIMERGY design
(1,632 cores, 102TB
persistent memory)



2018 DiRAC
HPE SGI 8600
(35,424 cores/
32 GPUs)



2017 Cirrus SGI
ICE XA Cluster
(13,248
cores/
152 GPUs)



2014 ARCHER
Phase 2: Cray XC30
(118,080 cores)



2013 ARCHER
Phase 1: Cray XC30
(72,192 cores)



2012 UK-RDF
(23PB)



2011 DiRAC IBM
BlueGene/Q (98,304
cores)



2011 EDIM1
(240
cores,
750 TB
disk)



2005 IBM
BlueGene/L
(2,048 cores)



2005 HPCx
Phase 2a: IBM p5-575
(1,536 processors)



2006 HPCx
Phase 3: IBM p5-575
(2,560 processors)



2007 FHPCA
Maxwell (64 FPGAs)



2007 HECToR
Phase 1: Cray XT4
(11,328 cores)



2009 HECToR
Phase 2a: Cray XT4
(22,656 cores)



2010 HECToR
Phase 2b: Cray XE6
(45,544 cores)



2011 HECToR
Phase 3: Cray XE6
(90,112 cores)



2004 QCDOC
(14,464 processors)



2004 HPCx
Phase 2: IBM p690+
(1,600 processors)



2002 HPCx
Phase 1: IBM p690
(1,280 processors)



2002 Sun Fire
E15K (52
processors)



2002 Sun Fire
6800
Cluster (66
processors)



1997 Hitachi
SR2201
(8 processors)



1997 Cray T3E
(344 processors)



1996 Cray J90
(10 processors)



1982 ICL DAPs
(2 x 4,096 processors)



1986 Meiko T800
CS (400 processors)



1988 AMT
DAP608 (1,024
1-bit processors)



1990 Meiko i860 CS
(64 processors)



1991 TMC CM-200
(16k 1-bit processors)



1992 Meiko i860 CS
(16 processors)



1994 Cray T3D
(512 processors) +
CRAY Y-MP



1995 Meiko CS-2
(22 processors)



Pre-EPCC

EPCC

Sources of CO₂ emissions from supercomputing



Operation

- Power usage



Manufacturing

- Computer hardware
- Power & cooling infrastructure, e.g. transformers



Construction

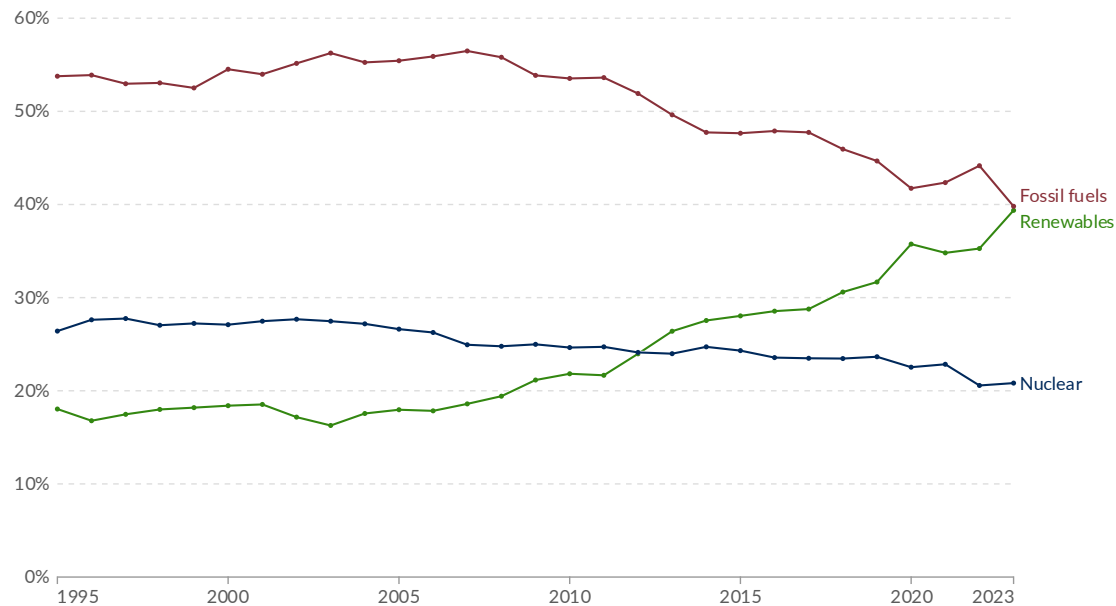
- Data centres
- Supporting infrastructure

Grid decarbonisation

Share of electricity generation from fossil fuels, renewables and nuclear, **Europe**

Our World in Data

Measured as a percentage of total electricity produced in the country or region. Fossil fuels include coal, oil, and gas. Renewables include solar, wind, hydropower, bioenergy, geothermal, wave, and tidal.



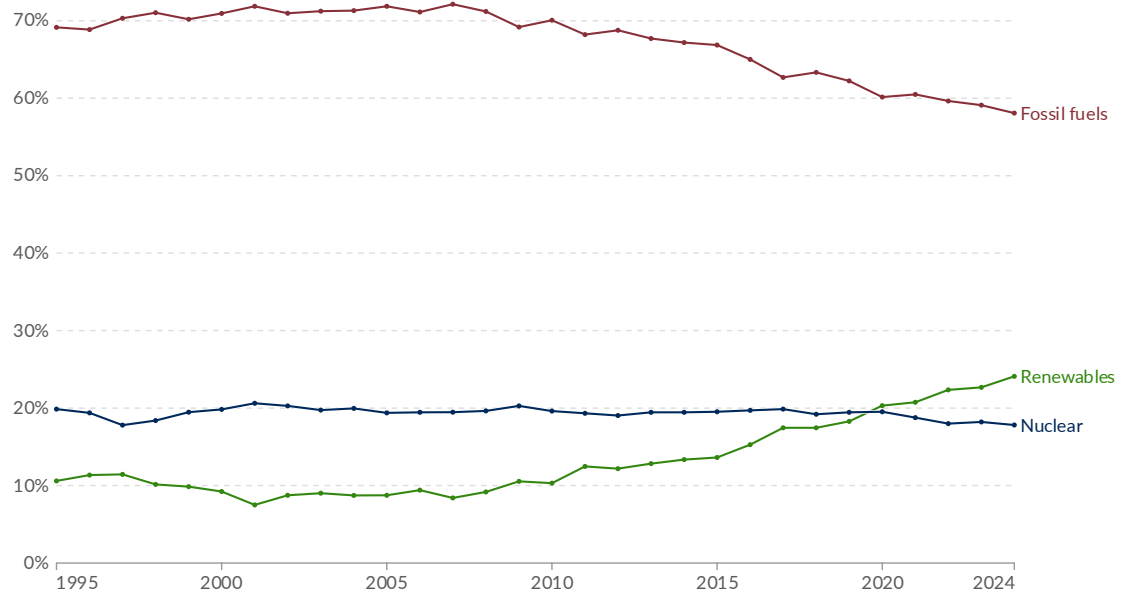
Data source: Ember (2025); Energy Institute - Statistical Review of World Energy (2024)

OurWorldinData.org/energy | CC BY

Share of electricity generation from fossil fuels, renewables and nuclear, **United States**

Our World in Data

Measured as a percentage of total electricity produced in the country or region. Fossil fuels include coal, oil, and gas. Renewables include solar, wind, hydropower, bioenergy, geothermal, wave, and tidal.



Data source: Ember (2025); Energy Institute - Statistical Review of World Energy (2024)

OurWorldinData.org/energy | CC BY

Hannah Ritchie (2017) - "Global renewables are growing, but have been partly offset by a decline in nuclear production"

Retrieved from: '<https://ourworldindata.org/global-renewables-are-growing-but-are-only-managing-to-offset-a-decline-in-nuclear-production>' [Online Resource]

What are we doing at EPCC?

- 1 Power usage reduction
- 2 Better cooling infrastructure & reuse of waste heat
- 3 Optimisation of system utilisation
- 4 Experimentation with novel/bespoke hardware
- 5 Educating users

POWER USAGE REDUCTION

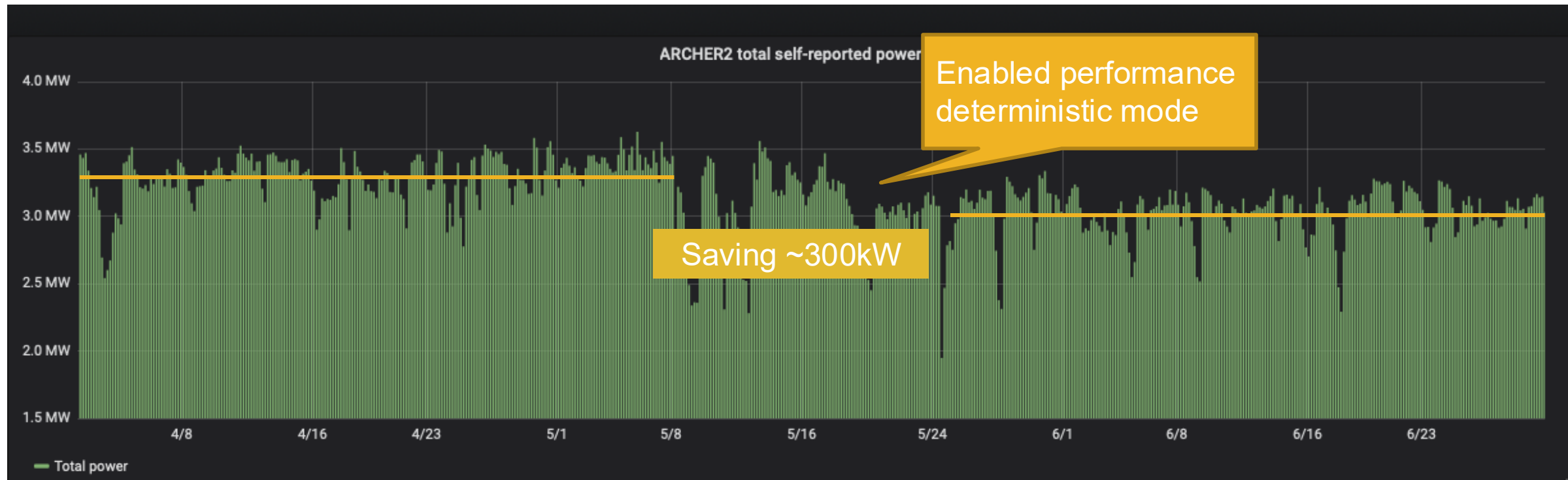
Energy efficiency

- Focus on **system level** and **performance** improvements
 - Biggest impact across large number of systems and applications
- Algorithmic/numerical improvements are also important
 - Mostly with a view to optimising performance (i.e. time to solution)

$$Energy (J) = Power (W) \times time(s)$$

AMD EPYC modes

- **Power** deterministic
 - CPU will run as fast as it can for given TDP (thermal design point) or power input – variable performance
 - Allows the highest possible performance
- **Performance** deterministic
 - Will deliver the same predictable performance across CPUs
 - Might result in slightly different power consumption across CPUs



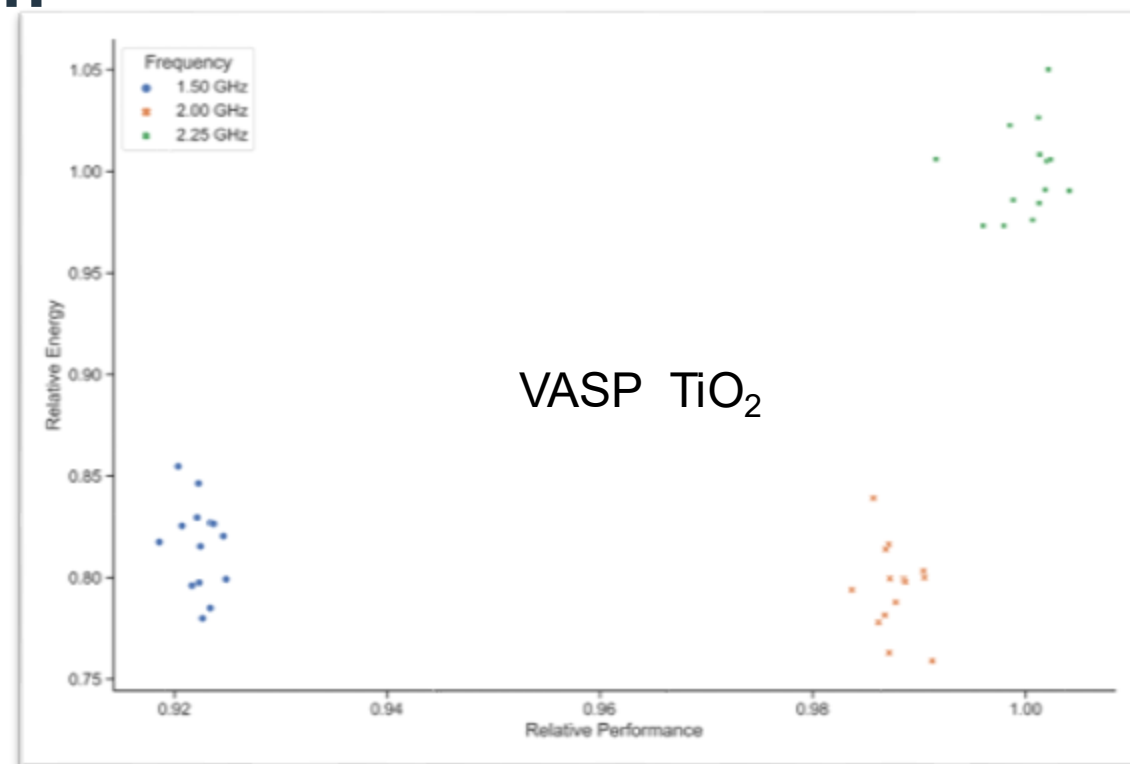
ARCHER2 CPU frequency reduction

Summary of relative energy and performance at 2.00 GHz, compared to 2.25 GHz

Benchmark (single node)	Energy	Performance
VASP (TiO ₂)	-20%	-1%
CASTEP (Al Slab)	-13%	-1%
GROMACS (1400k atoms)*	-5%	-15%
OpenSBLI (TGV 512ss)	-20%	-5%
LAMMPS (LJ 8M atoms)**	-4%	-21%
NAMD (STMV 1M atoms)**	-5%	-33%

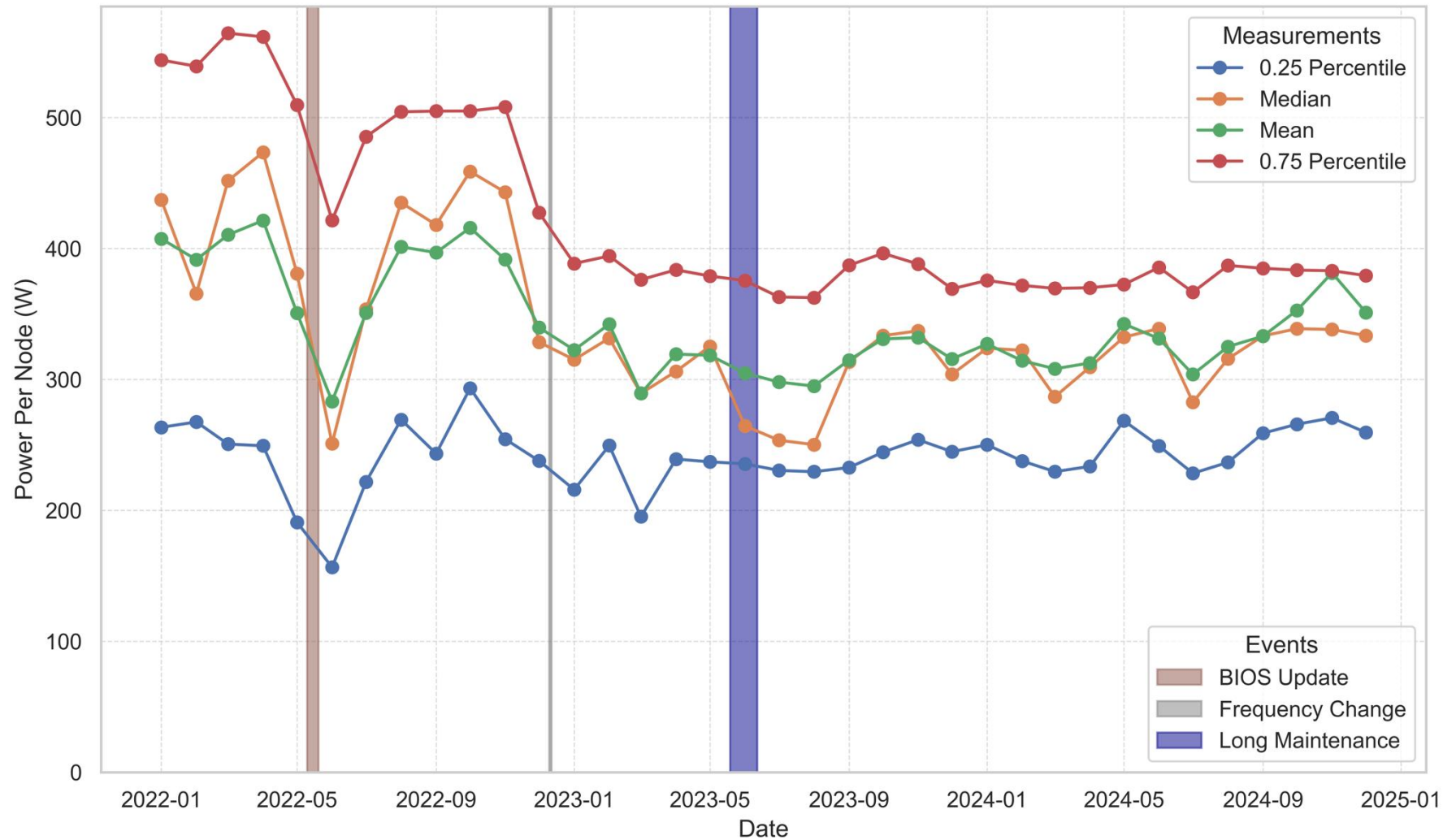
* Data from Laura Moran, EPCC

** Data from Douglas Shanks, HPE



- Default CPU frequency reduced from 2.25GHz to 2.0GHz
- User can override this default
 - Higher frequency defaults for some codes

Impact of changes over time



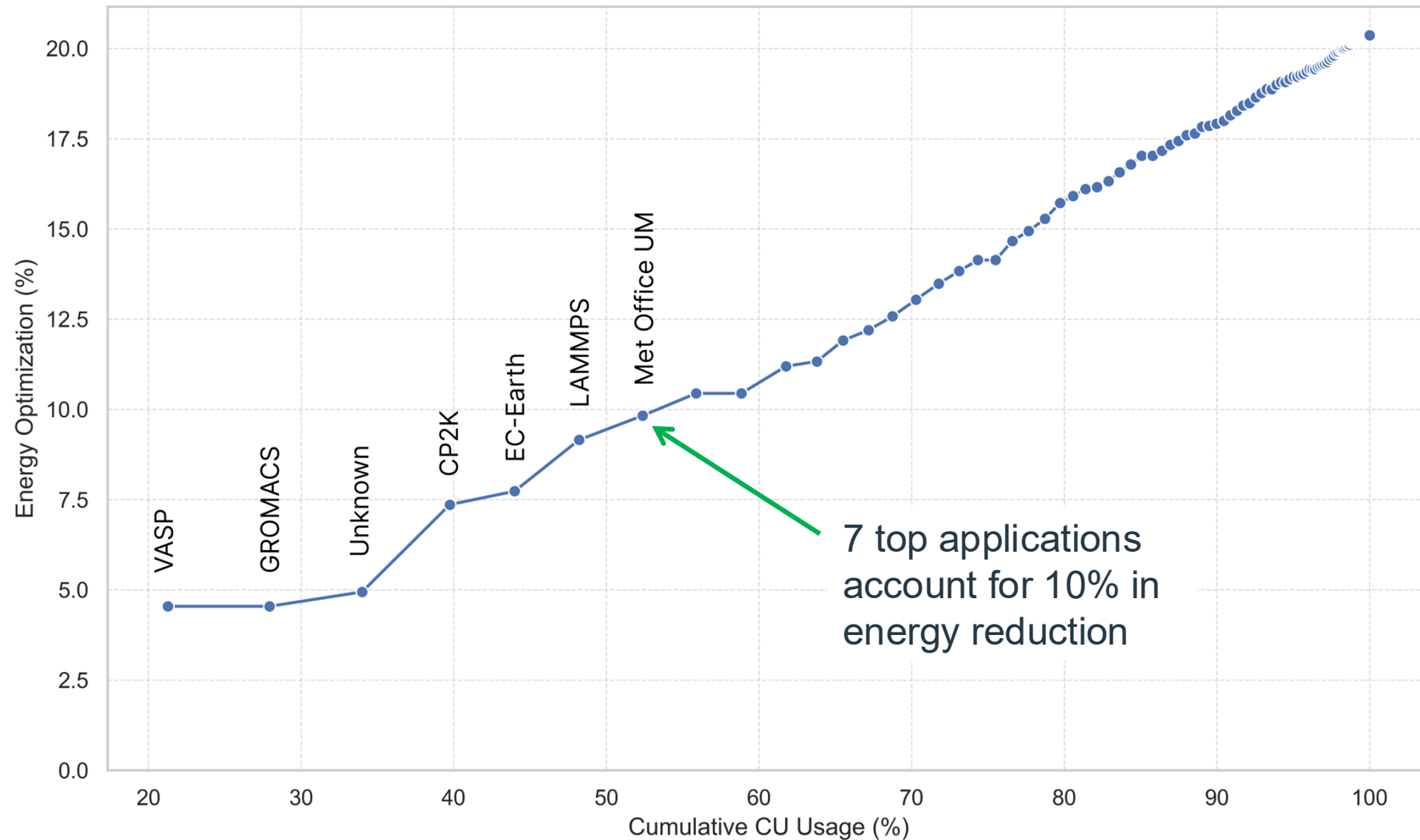
ARCHER2

5,860 nodes

2 x AMD EPYC™ 7742
64-core CPUs

750,080 cores

Impact of changes on application energy usage

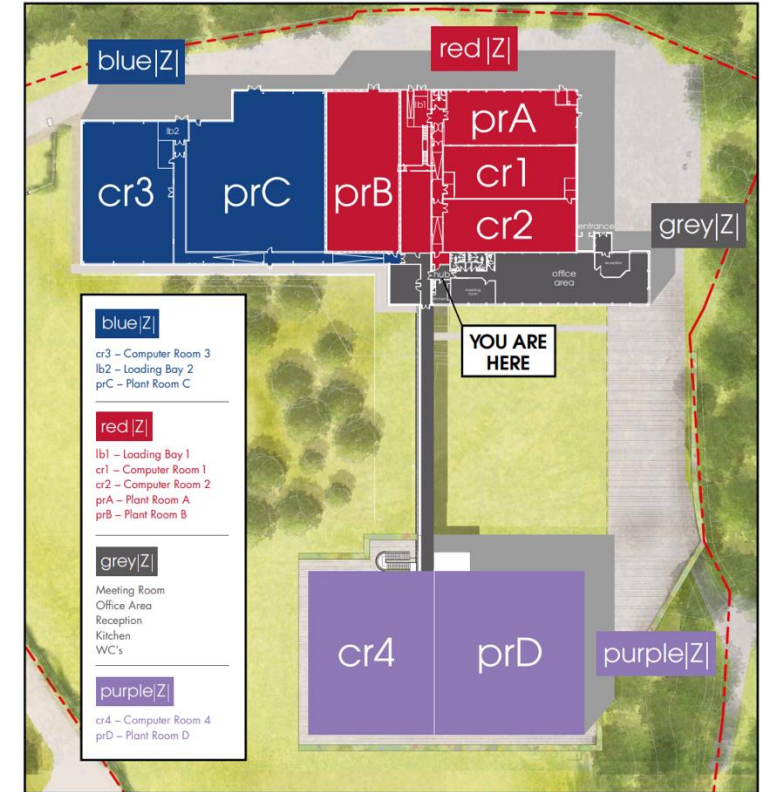


CU = Compute Unit = 1 node hour

COOLING & WASTE HEAT

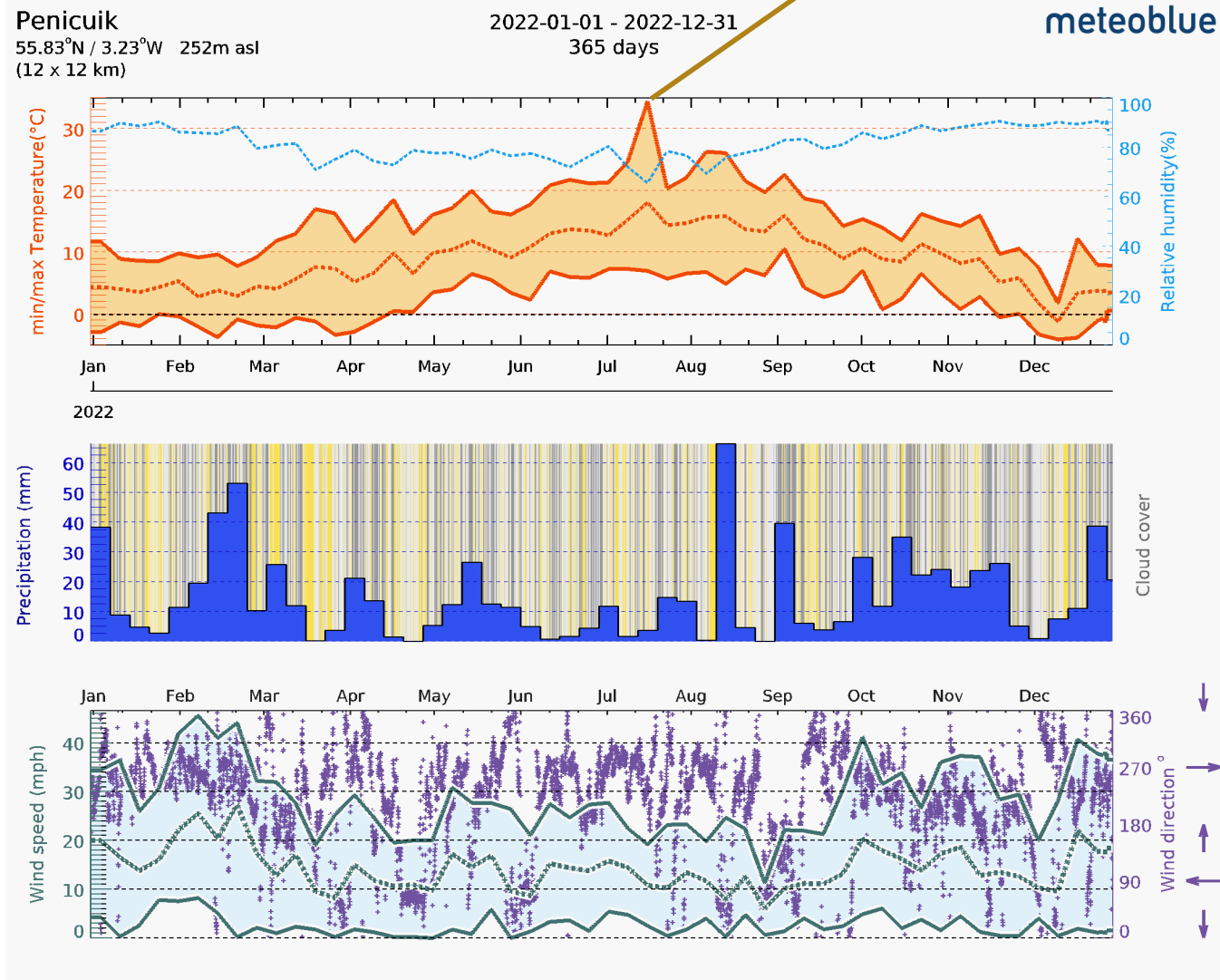
Long term investment

- Data centre efficiency requires **long term strategic** investment
 - There is an (inevitable) upfront cost in emissions
- At EPCC, oldest machine room from 1970s
- Infrastructure must support new developments in power and cooling
- Certified renewable energy



Climate

First time over 30C

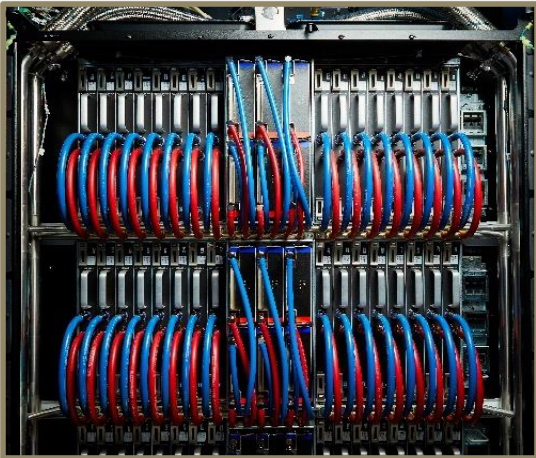


Free cooling!

Warm water is pumped to the roof, outside air & fans chill it



Other forms of cooling



Direct liquid
cooling



Adiabatic
cooling

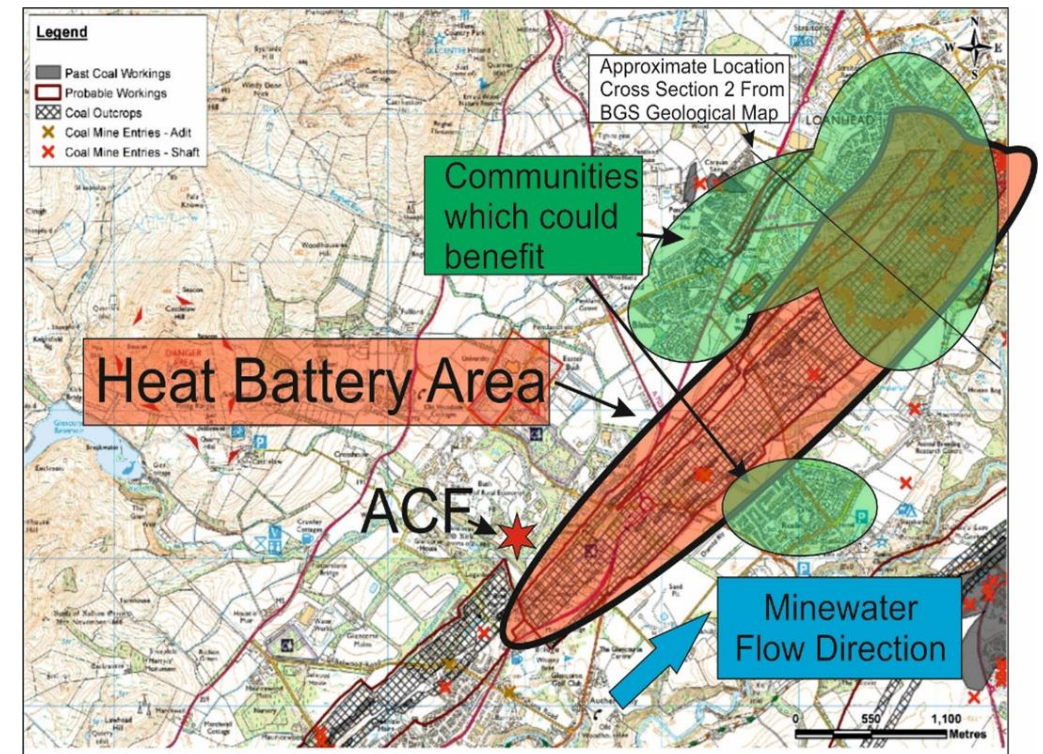
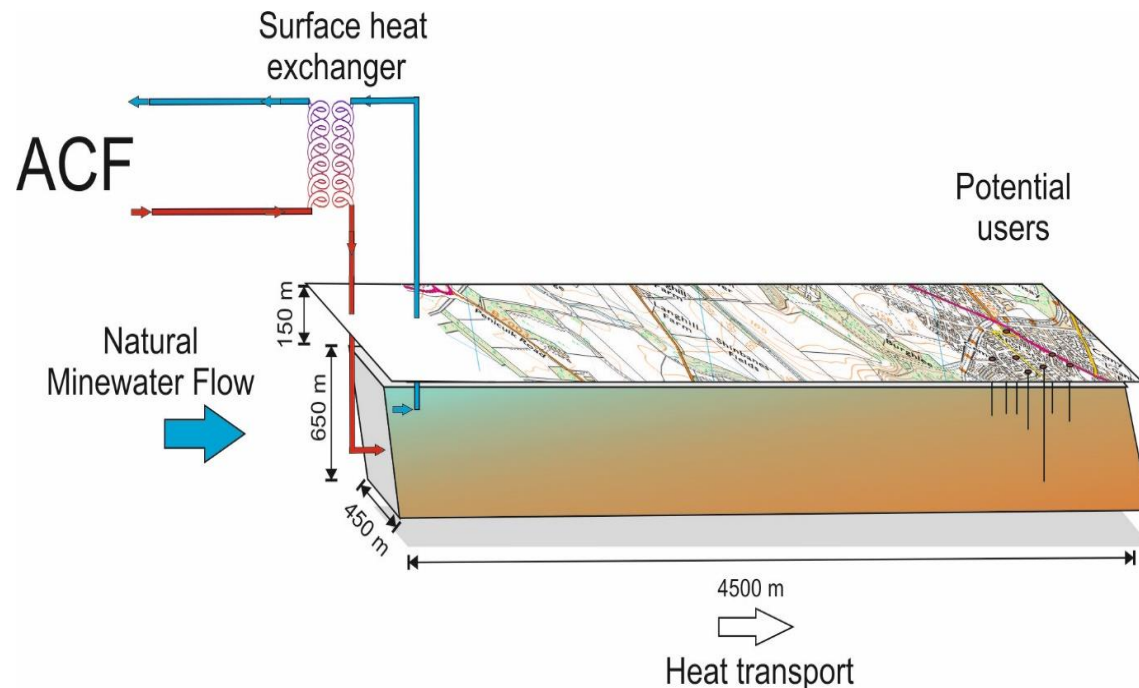


Temperature
controlled racks

Geothermal battery feasibility project

Problem: We want to be able to reuse our excess heat, but nowhere nearby can use it

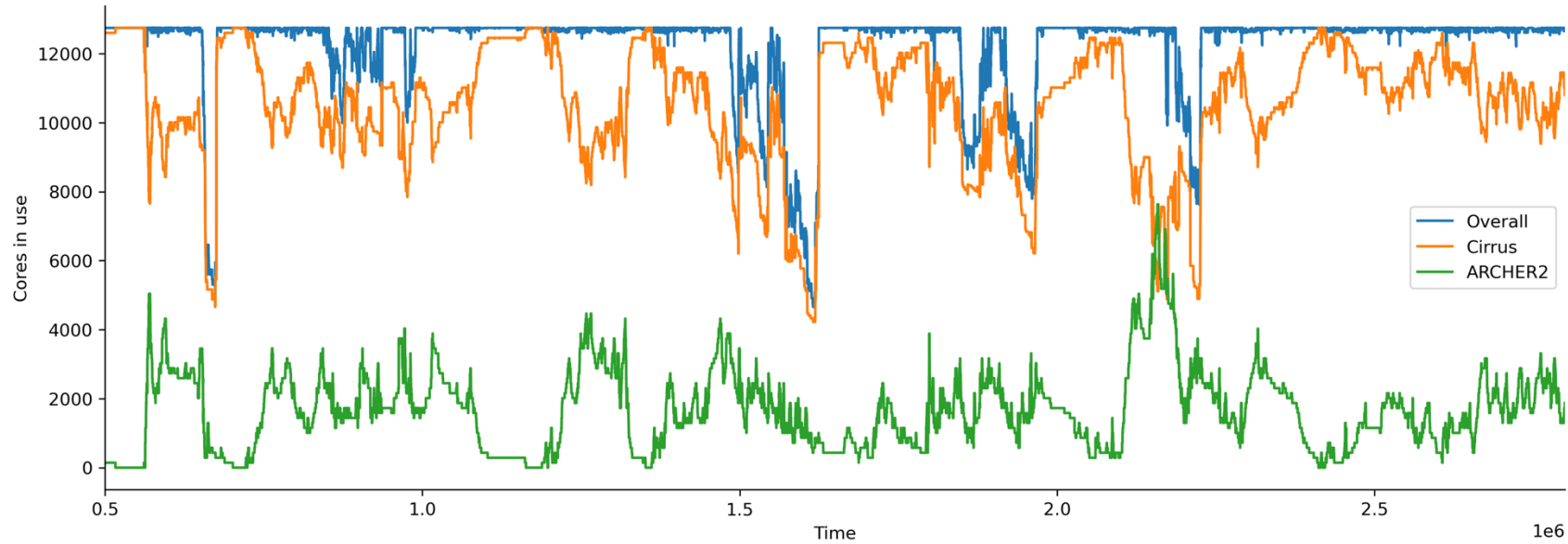
Solution: Move the heat to where it is useful



IMPROVING SYSTEM UTILISATION

Load balancing jobs across supercomputers

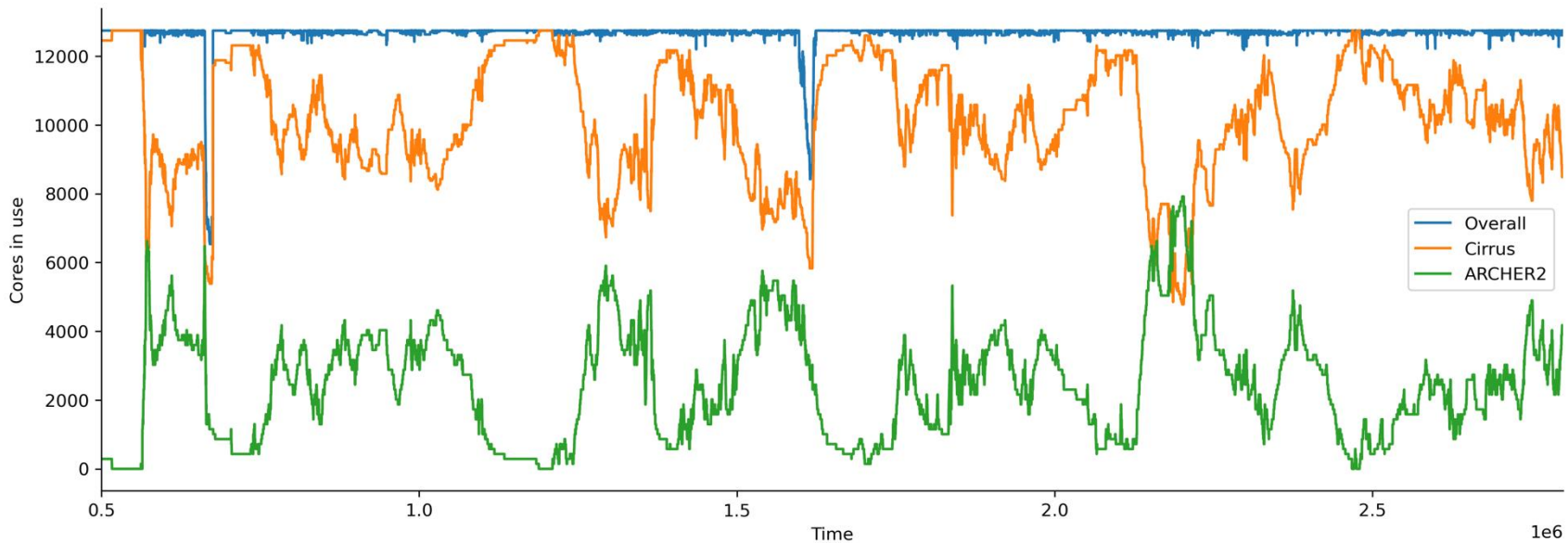
- Problem: Multiple systems, utilisation varies
 - Steady 95% for **ARCHER2** (Tier1 national facility)
 - Highly variable 50-90% for **Cirrus** (Tier2 regional facility)
- Basic premise: move jobs *from* busy system *to* less busy one
 - Should result in faster turnaround for users, better utilisation
 - Better utilisation means improved use of investment
- Methodology:
 - Use ElastiSim simulator tool
 - Move single node jobs from **ARCHER2** → **Cirrus** (“mobile” jobs)
 - Make Cirrus jobs “moldable” (using SLURM)



Top: Moldable Cirrus jobs plus
20% of eligible ARCHER2 jobs

January 2024 - Cirrus
base load 80%

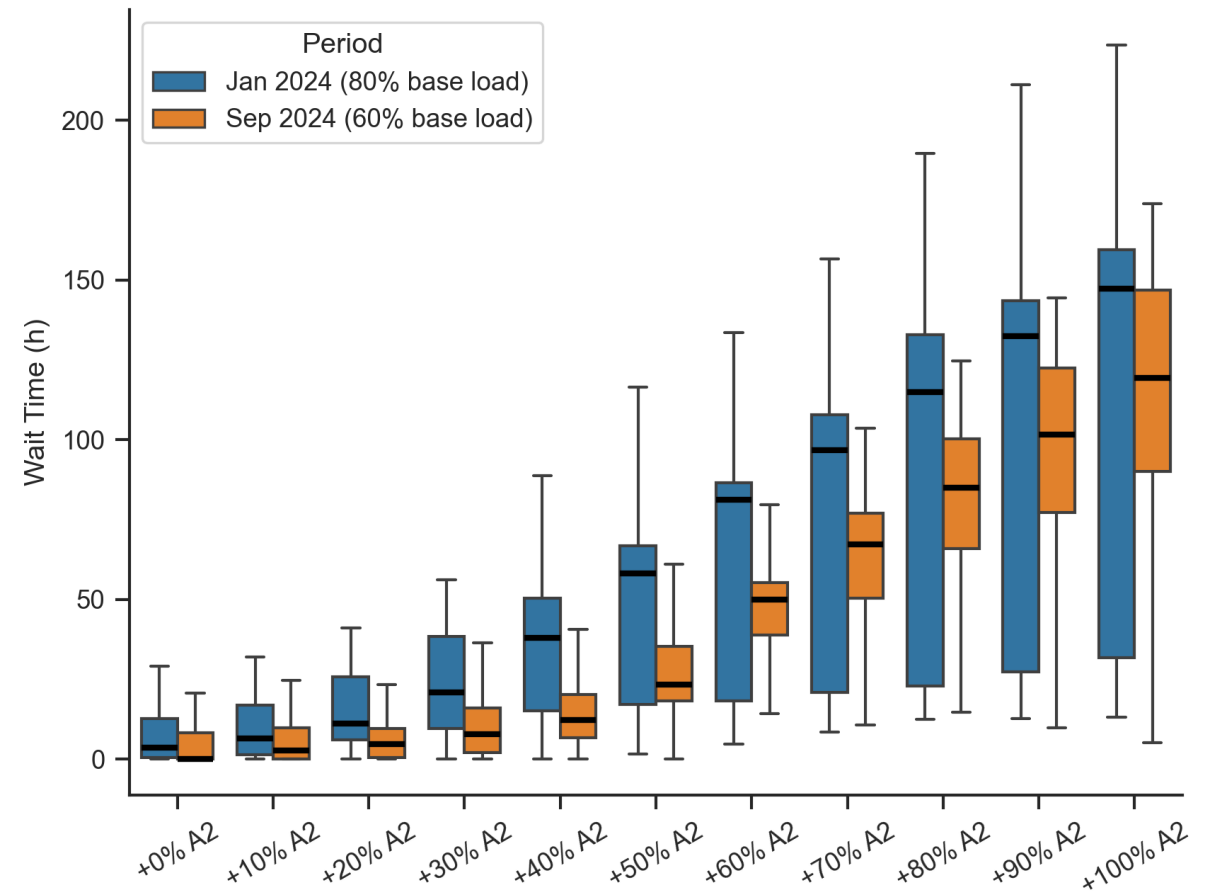
Orange: Cirrus
Green: ARCHER2
Blue: Combined



Bottom: Moldable Cirrus jobs
plus 30% of eligible ARCHER2
jobs

Simulation of impact of moldable & mobile jobs

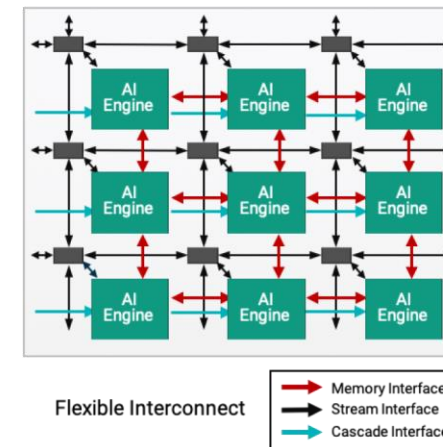
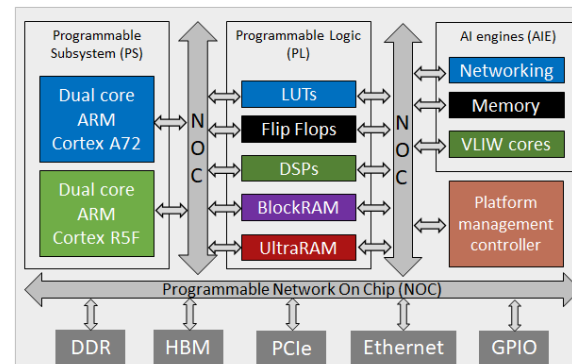
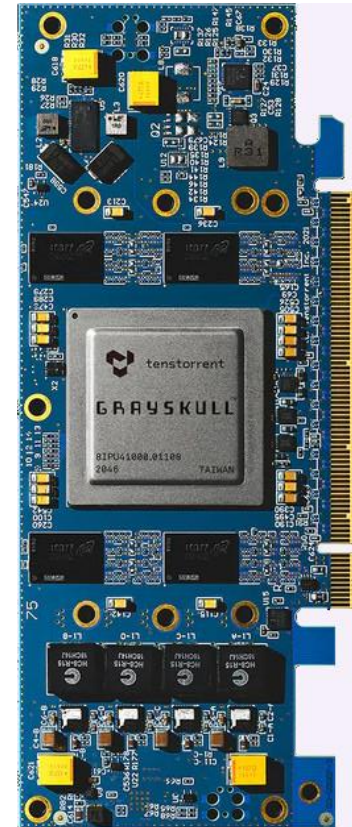
- Increased utilisation can result in prohibitively long wait times for users
 - Sweet spot roughly at base load + mobile jobs $\cong 100\%$
 - Assumptions
 - Perfect scaling
 - All single node jobs can be mobile
 - All jobs can be moldable
- ➔ Many more impact/feasibility analyses required before we can implement a proof-of-concept



EXPERIMENTATION WITH NOVEL/BESPOKE HARDWARE

Efficient and specialised hardware

- New hardware solutions that promise improved energy to solution
 - Through better performance and/or reduced power draw
- Cerebras Wafer Scale Engine
 - AI-focussed, but with potential for HPC workloads
- RISC-V
 - Tenstorrent Grayskull can run stencil code at similar performance to Xeon Platinum, 5 times less energy
- AMD Xilinx FPGAs and AI engines
- AMD AI engines



EDUCATION

Education

Efficient software is important → the **developers'** responsibility

Efficient *use* of software is equally important → the **users'** responsibility

Deployment of software is important → the **system providers'** responsibility

Education is key – enable developers/users/system providers to understand implications of their choice

“Green software use on HPC”

https://epcced.github.io/2025-04-01_GreenHPC_Online

Final thoughts

Supercomputers are **scientific instruments** that are used to find solutions to many of the problems humanity faces

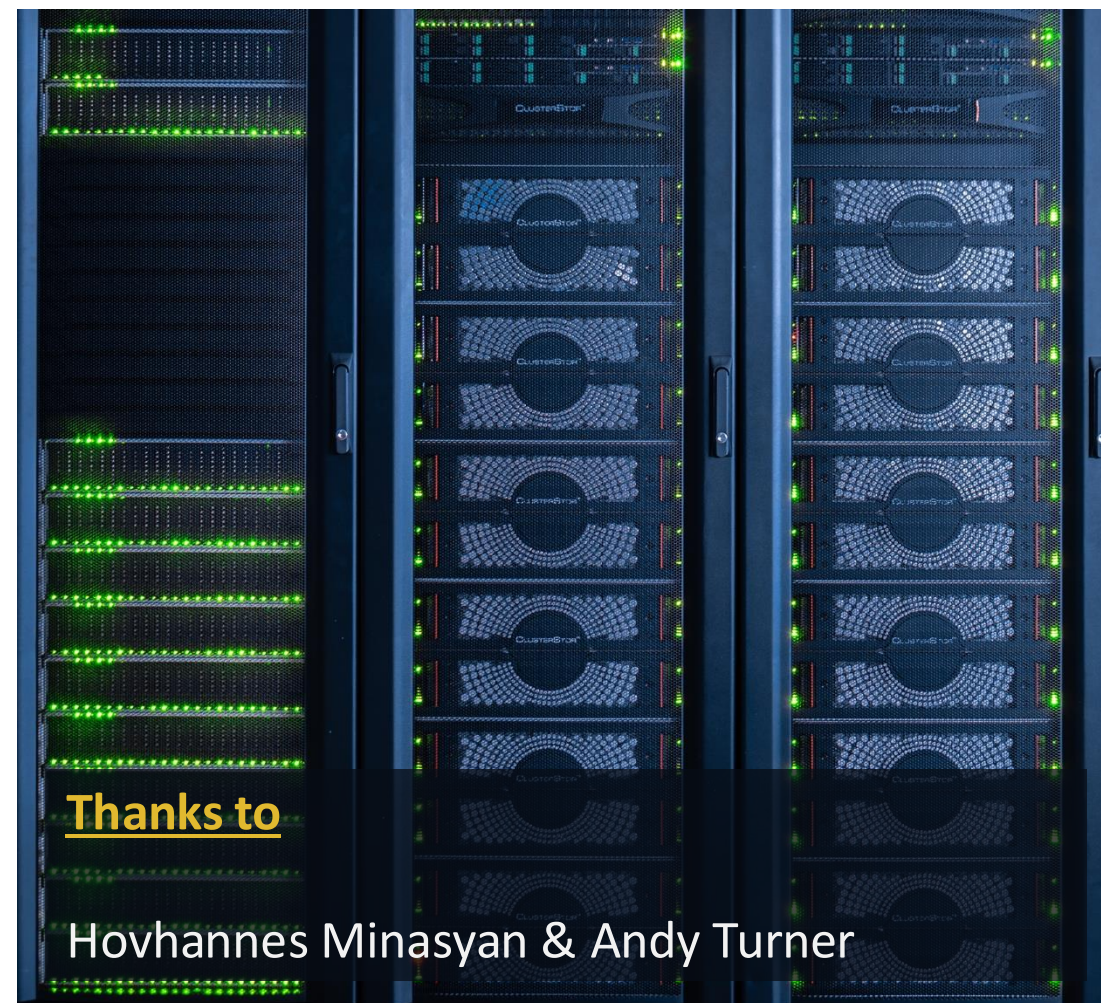
- to discover new vaccines
- to design new renewable energy solutions
- and even to model the climate, in order to more accurately predict climate change and its impact

Significantly reducing scientific throughput is a false economy

Net Zero HPC must be achieved while maintaining, or indeed increasing, the amount of science we do

Conclusions

- Sustainable supercomputing is about **more than just energy efficiency**
- Energy efficiency remains important even as national grids decarbonise - keep demand under control
- Other important factors are **infrastructure** optimisation, improved resource **utilisation**, exploring **alternative hardware, education**
- Many open research questions remain!



Thanks to

Hovhannes Minasyan & Andy Turner

Funding acknowledgements

EP/Z531170/1 International Collaboration Towards Net Zero Computational Modelling and Simulation (**CONTINENTS**)

EP/Y53061X/1 Malleability in resource allocation for improved system efficiency in high-performance computing (**MIRA**)