EDRC
Energy Demand Research Centre

Data Centre: An Emerging Source of Flexibility for Power System

Meysam Qadrdan, Jamie Day and Mehmet Takci

Cardiff University

Qadrdanm@Cardiff.ac.uk

Photo by Geoffroy Hauwen on Unsplash

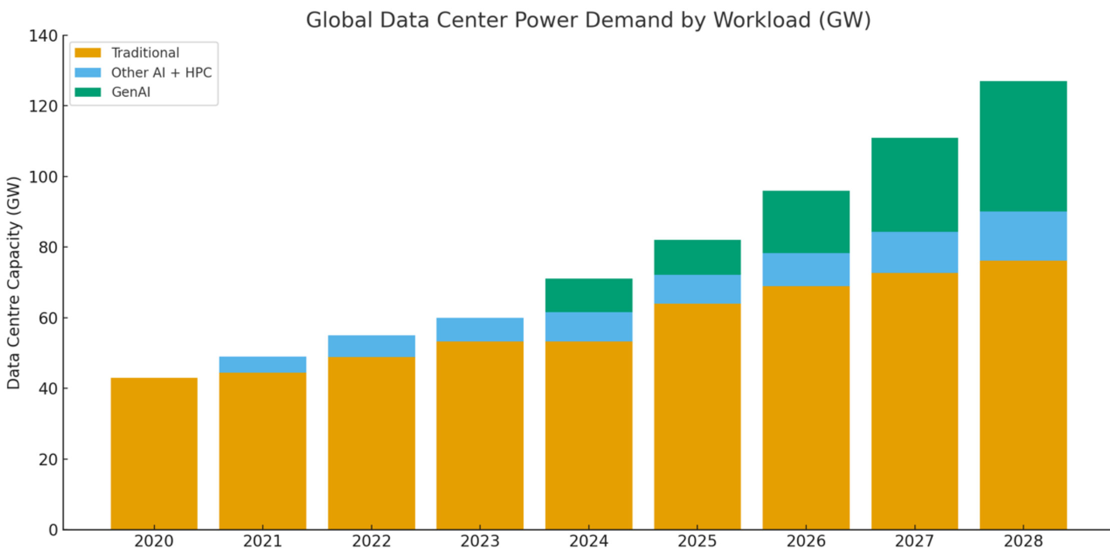
09 September 2025

International Workshop on Managing Global Energy Demand of AI Data Centres, London

UK Research and Innovation
Economic and Social Research Council
Engineering and Physical Sciences Research Council
Cardiff University
Prifysgol Caerdydd

Background

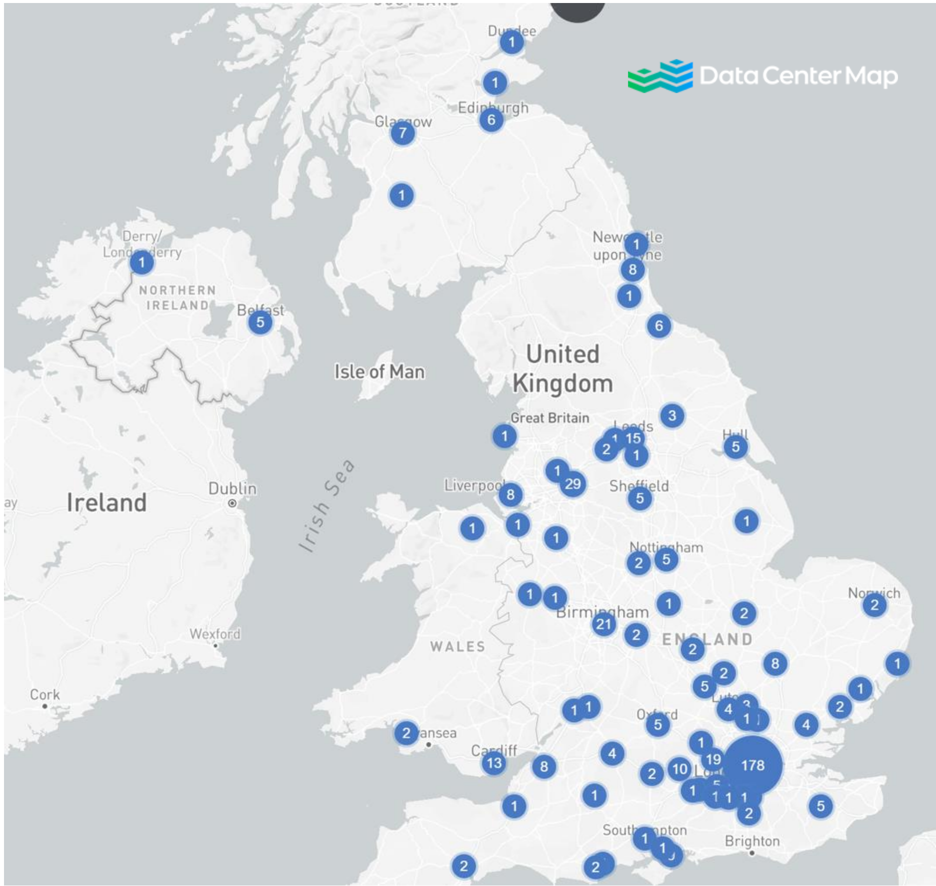
- Global data centre capacity is projected to increase from 82 to 127 GW over the next 3 years [1].
- By 2030, global electricity demand from data centres set to more than double to 945 TWh [2].
- The expansion is being driven by traditional enterprise workloads as well as from generative AI.



[1] Boston Consulting Group: Breaking barriers to Data Center Growth
[2] IEA: AI is set to drive surging electricity demand from data centres while offering the potential to transform how the energy sector works

UK Data Centres

- In the UK there are around 500 data centres [4] with estimated capacity of 2 GW [3].
- UK will need at least 6 GW of AI-capable data centre capacity by 2030 [4].
- The government is creating AI Growth Zones in regions across the UK to accelerate the development of AI-enabled data centres.

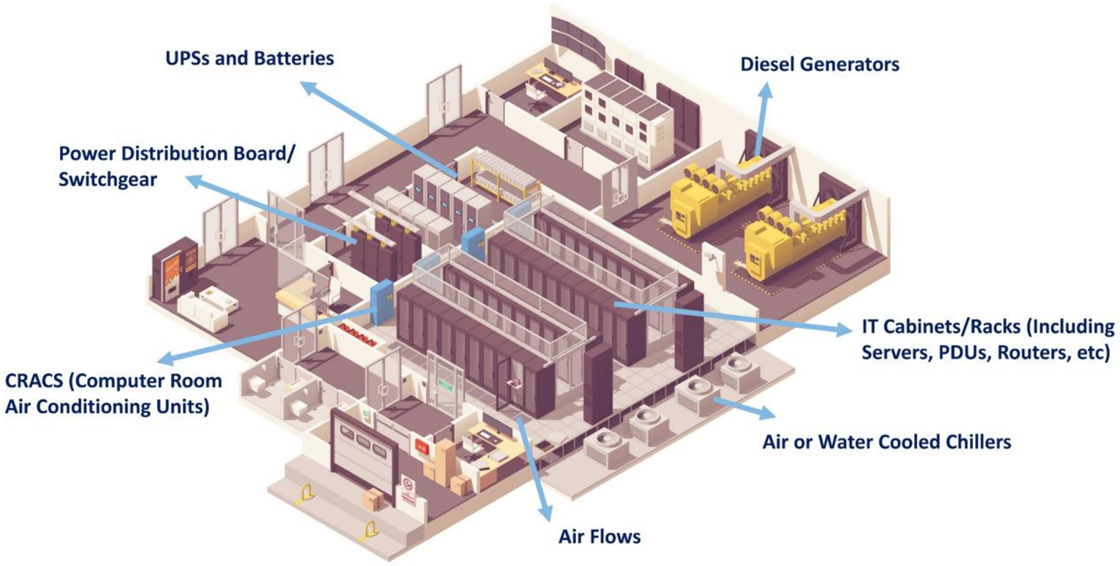


[3] GOV.UK Estimate of Data Centre Capacity: Great Britain 2024
[4] GOV.UK UK Compute Roadmap

Flexibility from Data Centres

EDRC Energy Demand Research Centre

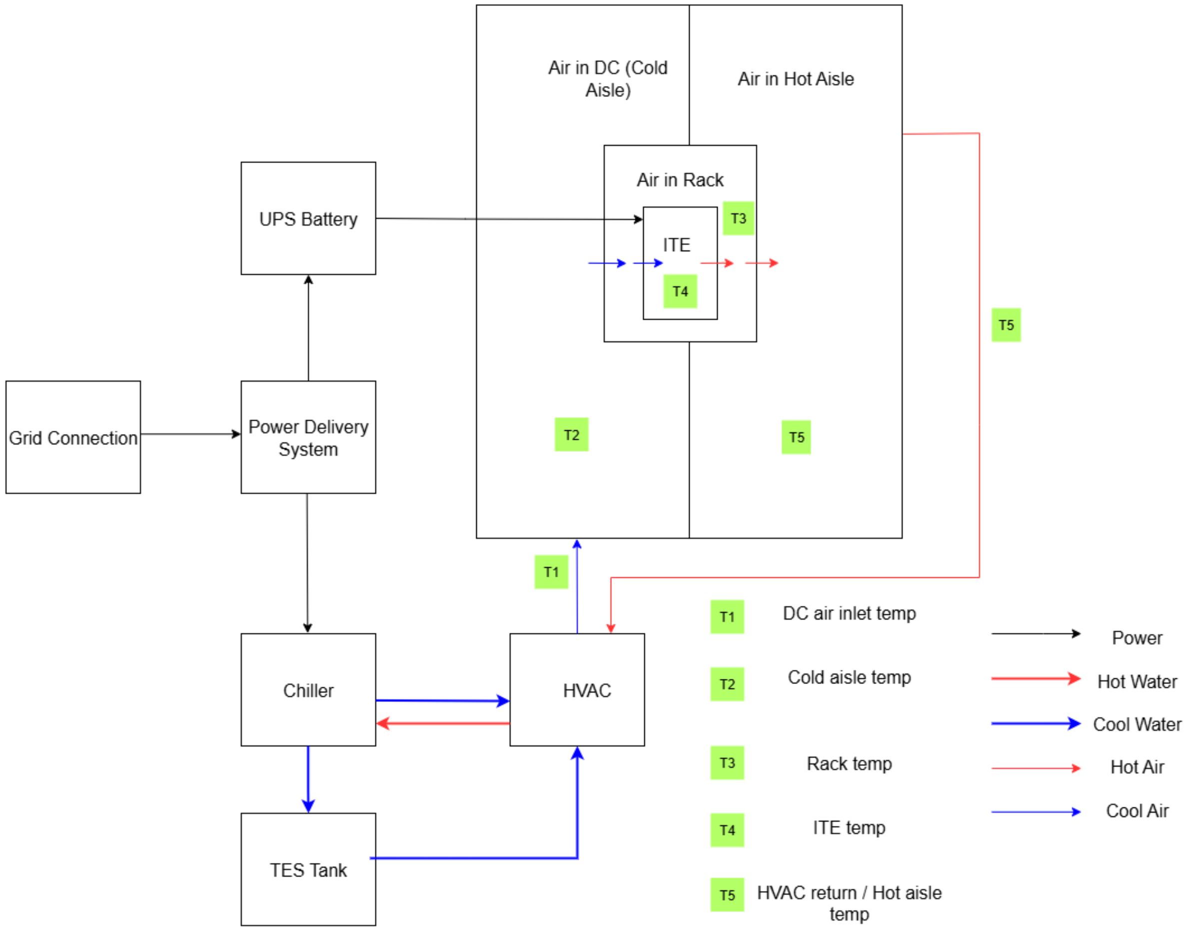
- **IT Workload:** IT workloads, less sensitive to delay, are re-scheduled to adjust processing power and its associated electricity consumption of a DC.
- **UPS Battery:** The UPS battery is a key DC asset whose core responsibility is providing back up power to the IT servers, in case of a grid outage, before the diesel generators have powered up.
- **Cooling System:** This comprises of chiller, HVAC system and TES tank. The TES tank, as well as the thermal mass of the components in the DC, are used to provide flexibility in the cooling system.



Research Objectives & Case Study

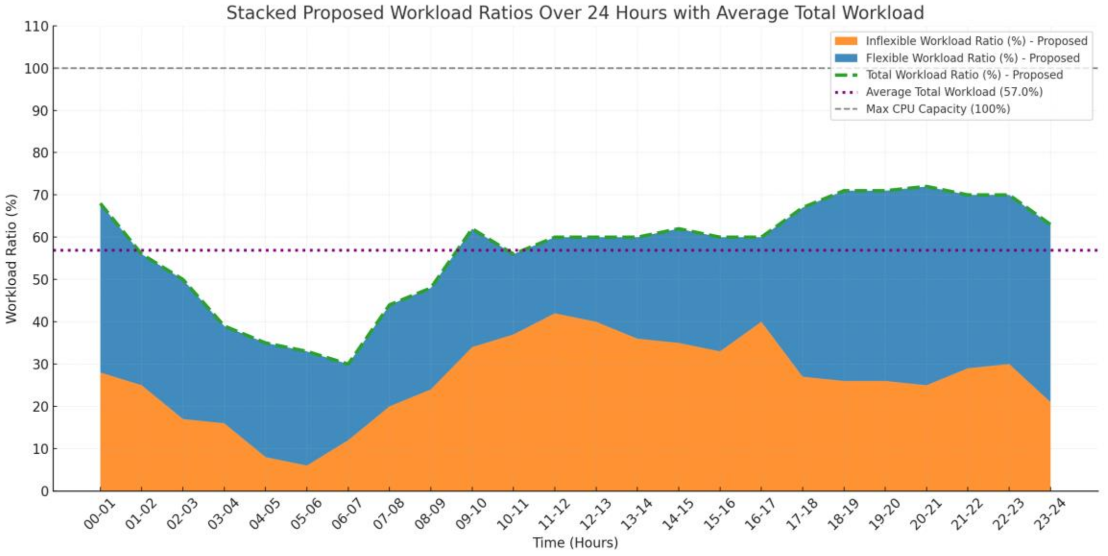
EDRC Energy Demand Research Centre

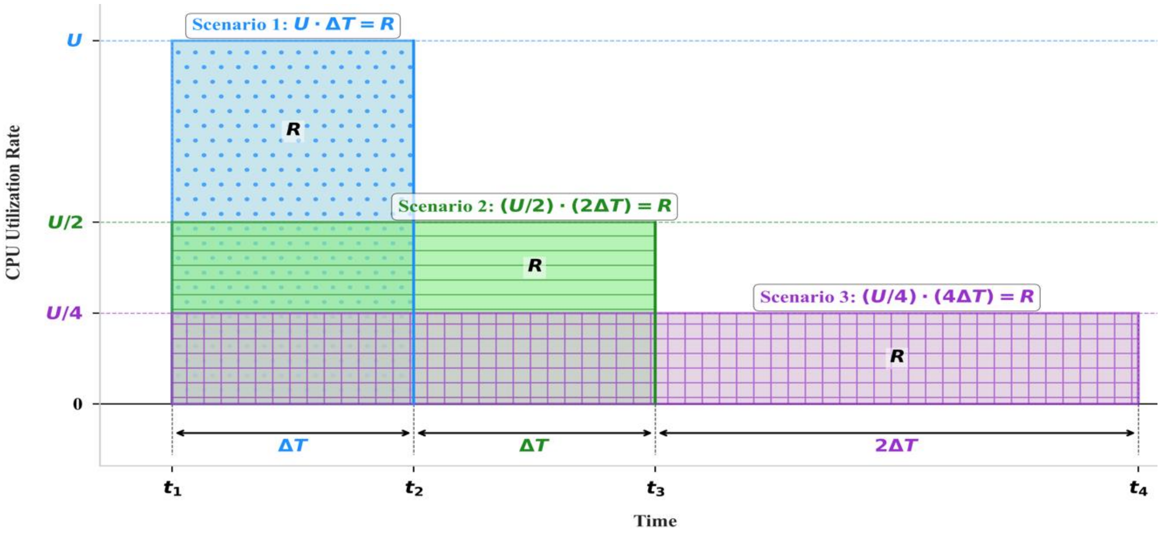
- The research objectives were:
  - Investigating the optimal operation of a DC in day-ahead electricity market
  - Characterising aggregated flexibility from a DC
- A hypothetical 1 MW DC including IT workload, UPS battery and cooling system was studied.



IT Workload Assumptions

- IT workload profile was synthesised with certain share of flexible and inflexible loads.
- Flexible load can be distributed to reduce the utilisation of IT equipment.

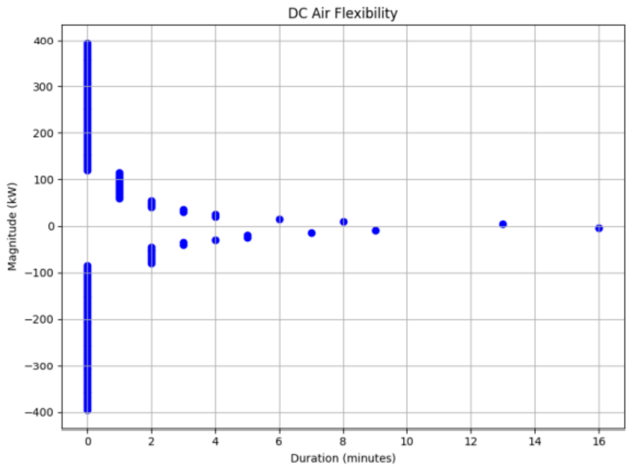


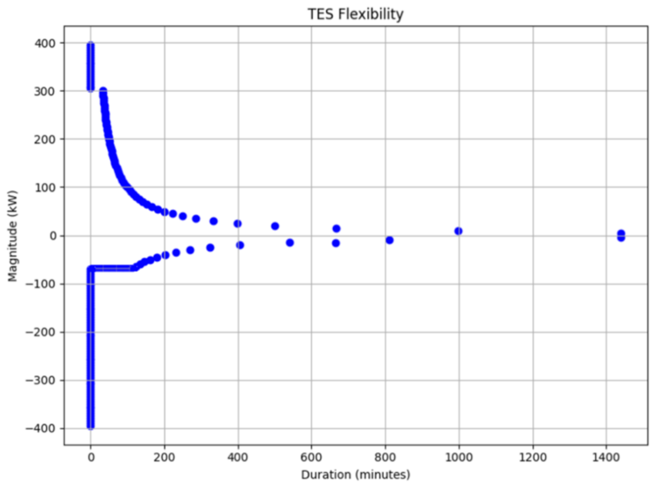


Deferral	Time																							
	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
$0 \leq 30$ min	25	25	35	25	25	25	23	20	25	25	35	32	45	50	40	45	50	50	10	15	18	22	20	15
$0 \leq 60$ min	25	25	17	15	20	15	28	20	15	17	22	20	25	20	20	25	15	20	20	20	12	18	16	20
$0 \leq 2$ h	20	15	18	20	15	15	15	15	13	16	13	15	15	15	25	15	20	15	30	25	25	25	24	20
$0 \leq 3$ h	30	35	30	40	40	45	34	45	47	42	30	33	15	15	15	15	15	15	40	40	45	35	40	45

UPS Battery & Cooling System

- The UPS battery can be charged and discharged in such a way to minimise energy costs further.
- The cooling system output is optimised and varies with the IT workload such that the heat generated by the servers and the cooling power provided are sufficiently balanced to keep the temperature of the DC within 18 – 22 degC.
- The TES tank is charged and discharged where appropriate to further improve energy cost reduction.





Analysis

EDRC Energy Demand Research Centre

- **Baseline case:** The DC processes IT workloads as they were originally scheduled; the DC temperature is kept constant; DC does not utilise the UPS battery or TES tank.

- **Optimised case:** The DC uses it's flexibility to minimise electricity cost over a 24 hour period.

- **Flexibility characterisation:** Using the operation profile in the Optimised case, magnitude and duration of flexibility at each time step is determined.

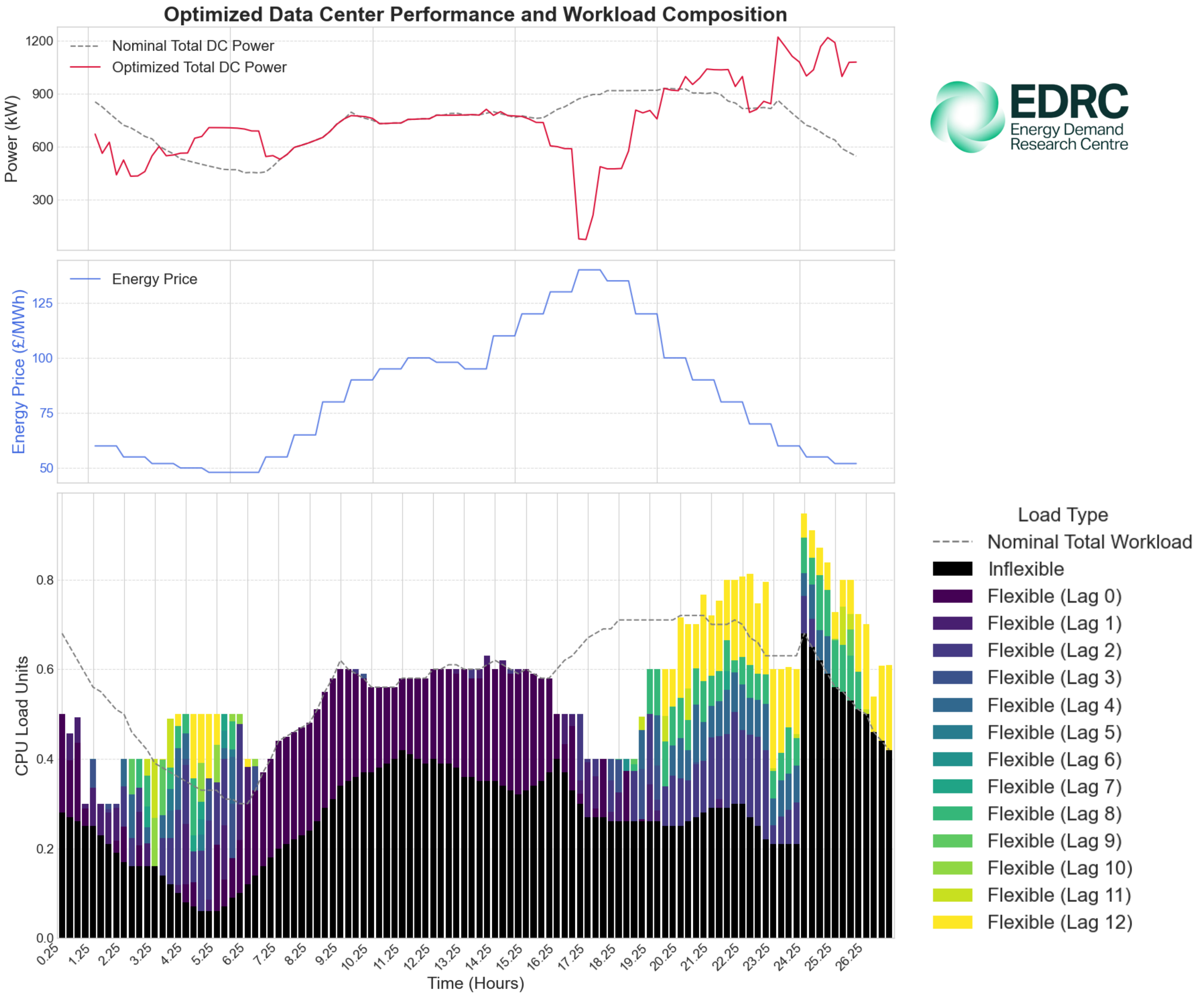
A linearised optimisation problem to **minimise the operating cost**

s.t.

Constraints of IT workload
Constraints of UPS
Constraints of cooling system

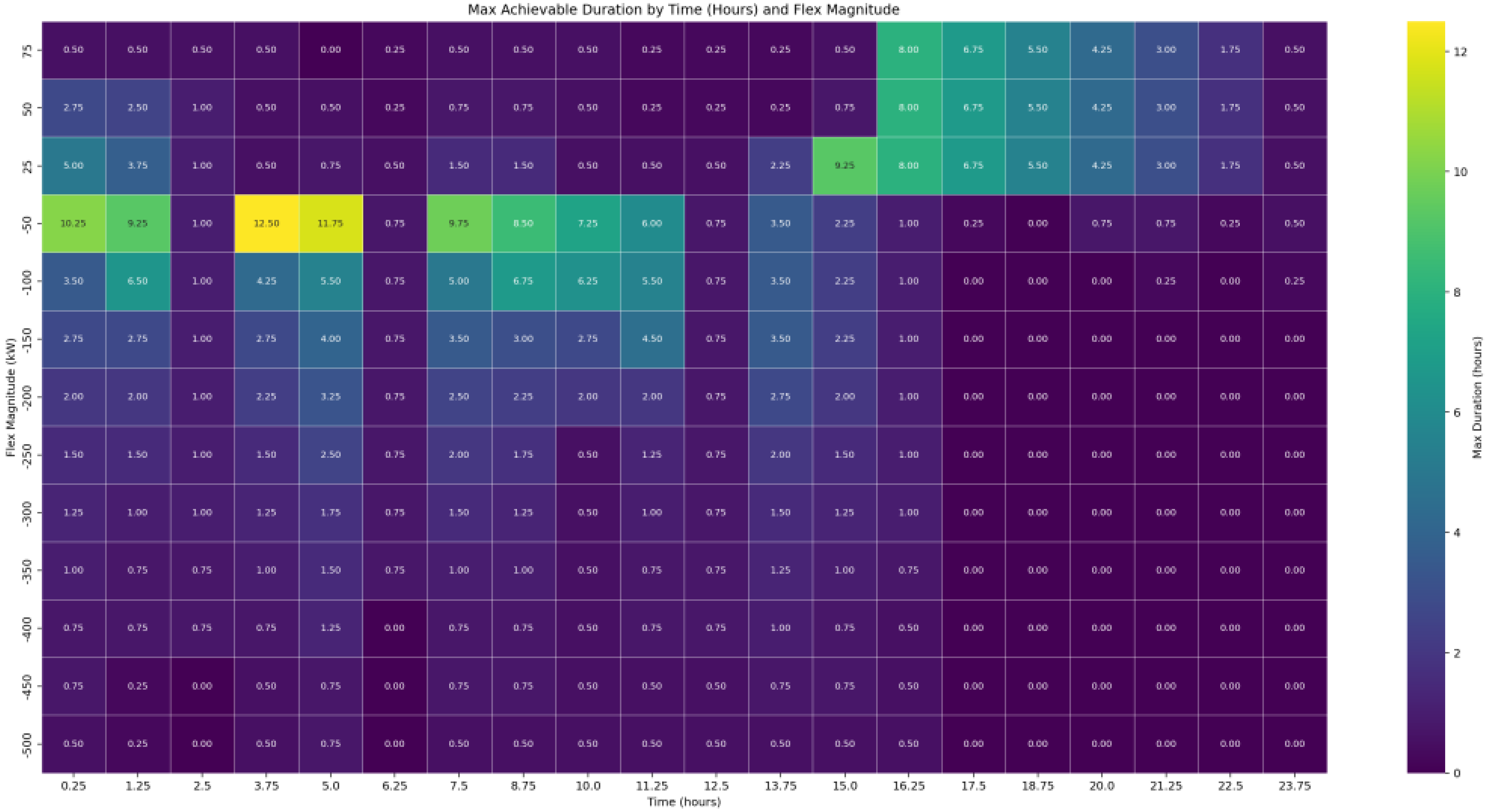
Baseline vs Optimised case

- IT workload can be shifted to take advantage of electricity price variations.
- IT workload was shifted away from the afternoon spike in energy price.
- The results from this run yield a 10% reduction in total energy costs over the day.



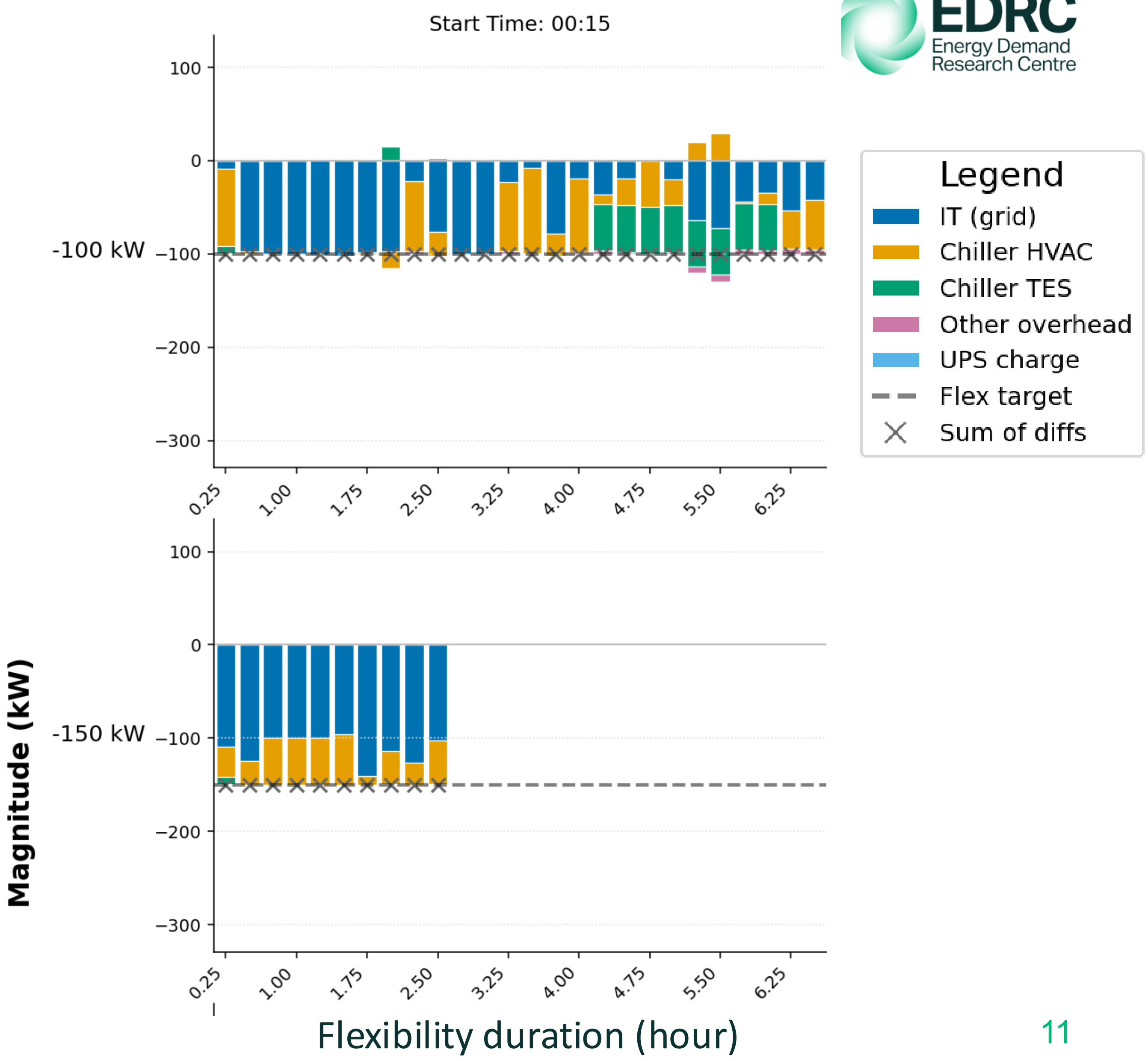
EDRC Energy Demand Research Centre

Magnitude vs. Duration of Flexibility



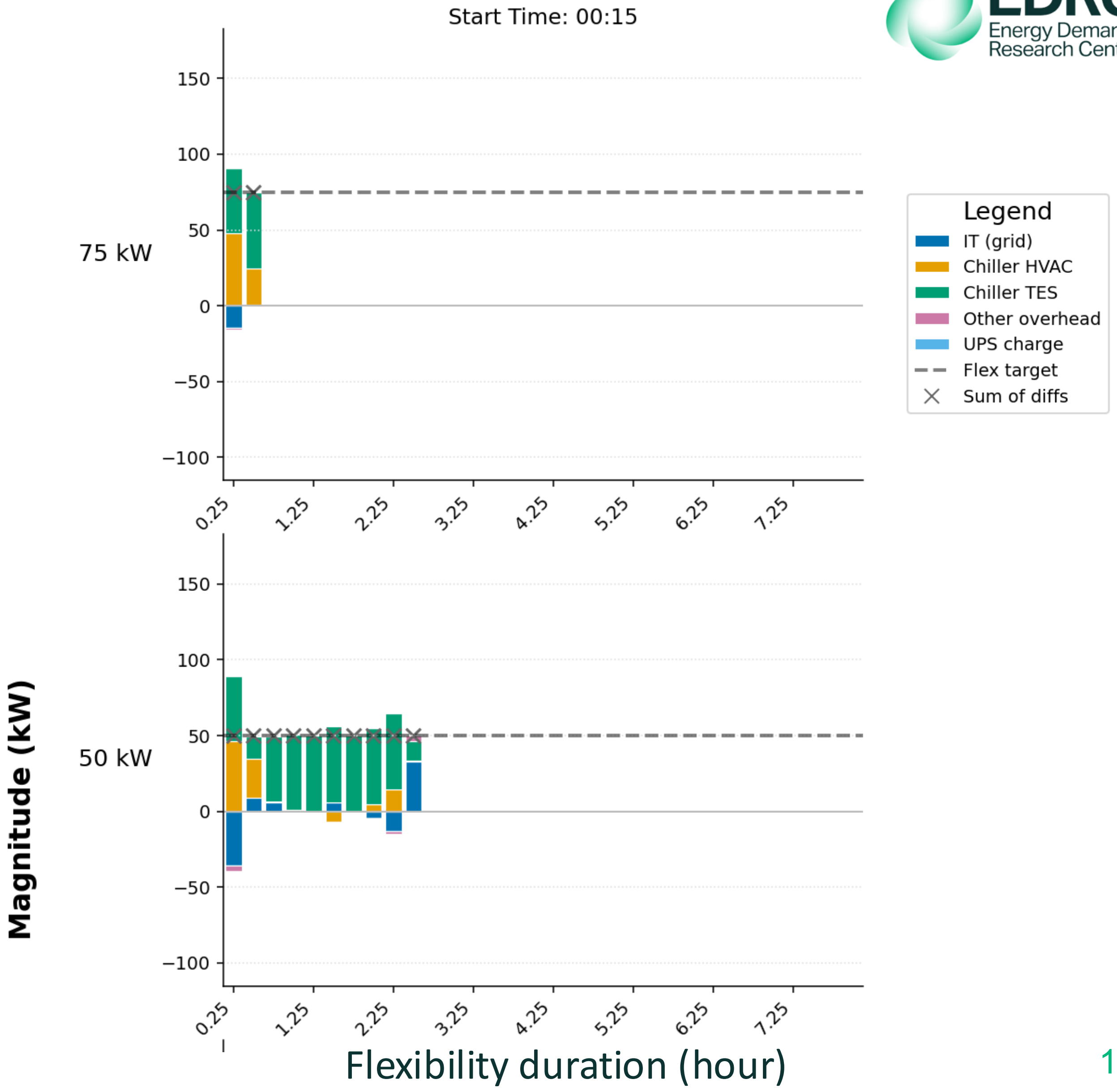
Upward Flexibility Quantification

- The rows in the figure show flexibility magnitude of -100 and -150 kW, corresponding to reducing DC power drawn from the grid (upward flexibility).
- In this case, most flexibility is provided by the IT workload and reducing the energy consumed by the chiller.



Downward Flexibility Quantification

- The rows in the figure show flexibility magnitude of 75 and 50 kW, corresponding to increasing DC power drawn from the grid (downward flexibility).
- In this case, most flexibility is provided by the increasing electricity consumption of the cooling system.



On-going and Future Works

EDRC Energy Demand Research Centre

- Developing a better understanding of the IT workload characteristics, i.e. temporal variations, data centre types – needs access to real data.

- Investigating practicality of and incentives for temporal and spatial load shifting/migration.

- Accounting for flexibility when designing DCs, i.e. size of energy storage devices.

- Assessing the system-value of flexibility from data centres.

EDRC Energy Demand Research Centre

Funded by:

UK Research and Innovation

Economic and Social Research Council

Engineering and Physical Sciences Research Council

In Partnership:

University of Sussex · Newcastle University · Cardiff University / Prifysgol Caerdydd · The University of Edinburgh · Imperial College London · Lancaster University · UCL · University of Exeter · University of Leeds · Manchester 1824 The University of Manchester · University of Reading · University of Strathclyde Glasgow · University of Surrey · University of Birmingham