

Harnessing Demand-Side Flexibility Analysing the Resource Adequacy Potential of Electrified Heating

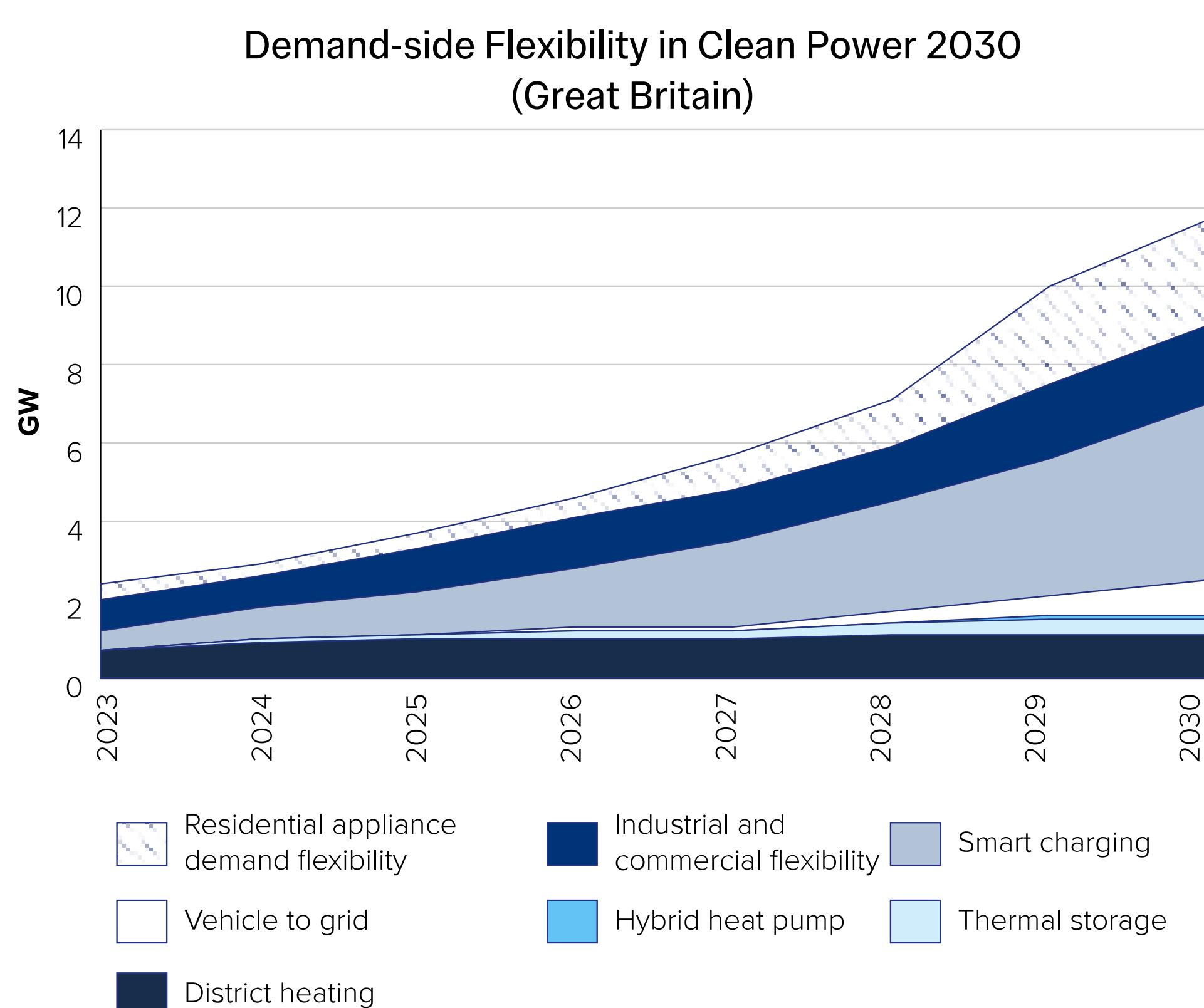
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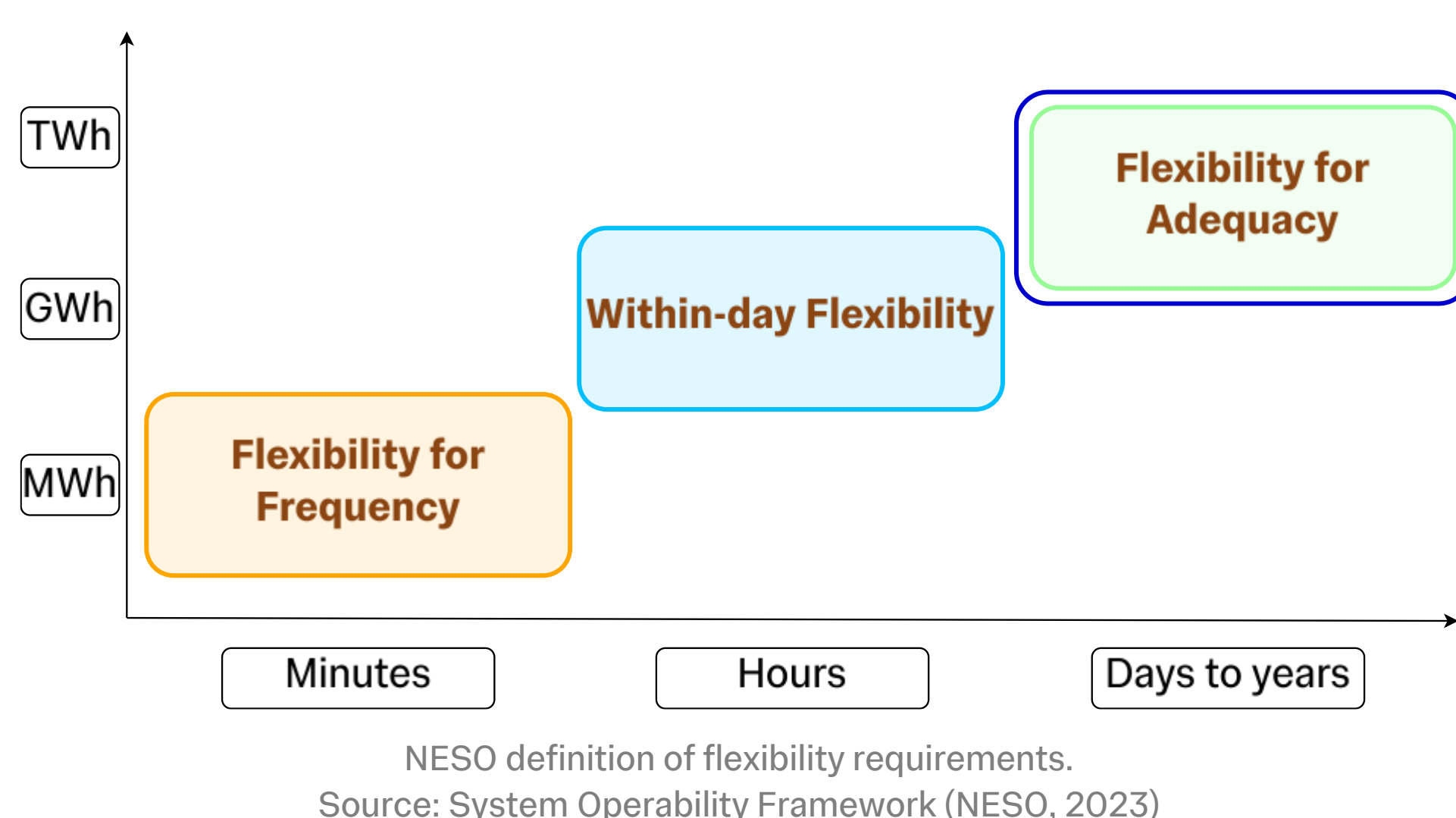
Context and motivation

- In decarbonised power systems, **flexible alternatives** will help manage the variability and uncertainty, partly caused by Variable Renewable Energy (VRE) resources.
- New electric appliances such as heat pumps and electric vehicles (EVs) can become new sources of flexibility, increasing the potential of **demand-side flexibility (DSF)** as a **low-regret, cost-effective alternative**.



Demand-side flexibility potential at peak, in GW, between 2023 and 2030, according to Great Britain's Clean Power 2030 Action Plan. There is a sustained growth in demand-side flexibility potential, increasing from 2.4GW in 2023 to 12GW in 2030. Largest growth is expected from residential appliances and smart charging capabilities.
Source: Department for Energy Security and Net Zero [1]

- Demand-side flexibility contributes to Flexibility for Frequency and Within-day Flexibility, with potential to explore Flexibility for Adequacy



Resource Adequacy Contribution of DSF

DSF can participate in Capacity Markets with capacity credits in the 79-92% range. In GB, capacity credit calculation is:

- Based on the historical performance of behind-the-meter onsite generation
- Not resource-adequacy-based, unlike other resources (i.e. wind, solar and storage)

Research questions

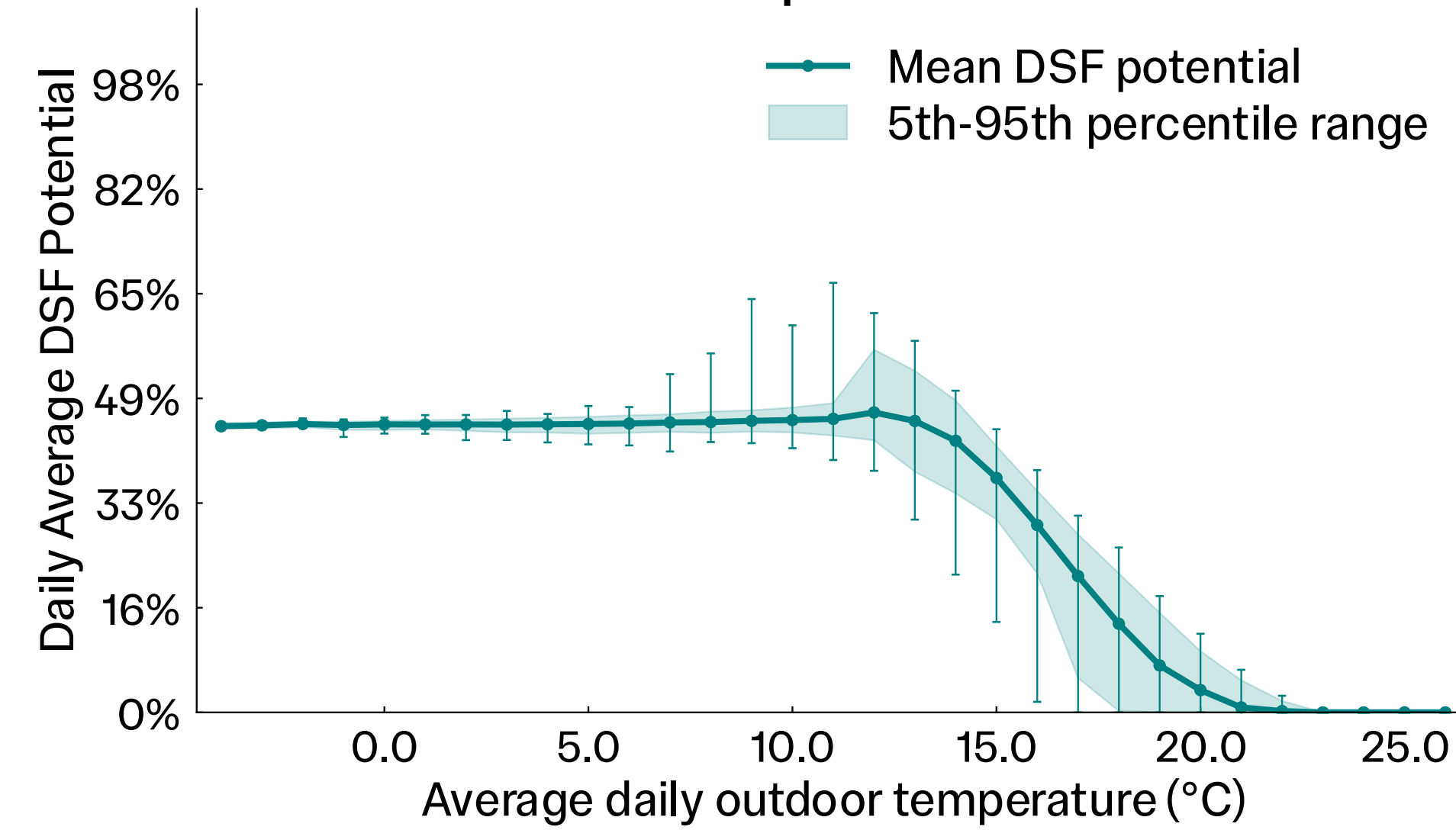
What is the capacity credit of electrified heating flexibility?

How does the temperature-dependency of electrified heating affect its capacity credit?

How sensitive is the capacity credit to alternative dispatch assumptions?

Electrified heating DSF potential

- Heating demand modelling of a GB household using a RC thermal model [3].
- DSF potential defined as the difference between the heat pump consumption for maintaining a comfortable vs. safe temperature.



Average demand-side flexibility potential for a single household, considering 20 weather years. DSF potential is dependent on the outdoor temperature, with low variability and stable potential during colder periods, and higher variability and lower potential during warmer periods.

The DSF potential is:

- relatively stable and with low variability on days with low ambient temperature.

- reduced as ambient temperature increases, with higher variability at the mid-temperature range.

Methodology

Marginal accreditation: relative to contribution of a reference perfect unit [1,2]

$$CC = \frac{EUE_0 - EUE_{dsf}}{EUE_0 - EUE_{ref}}$$

Dispatch assumptions:

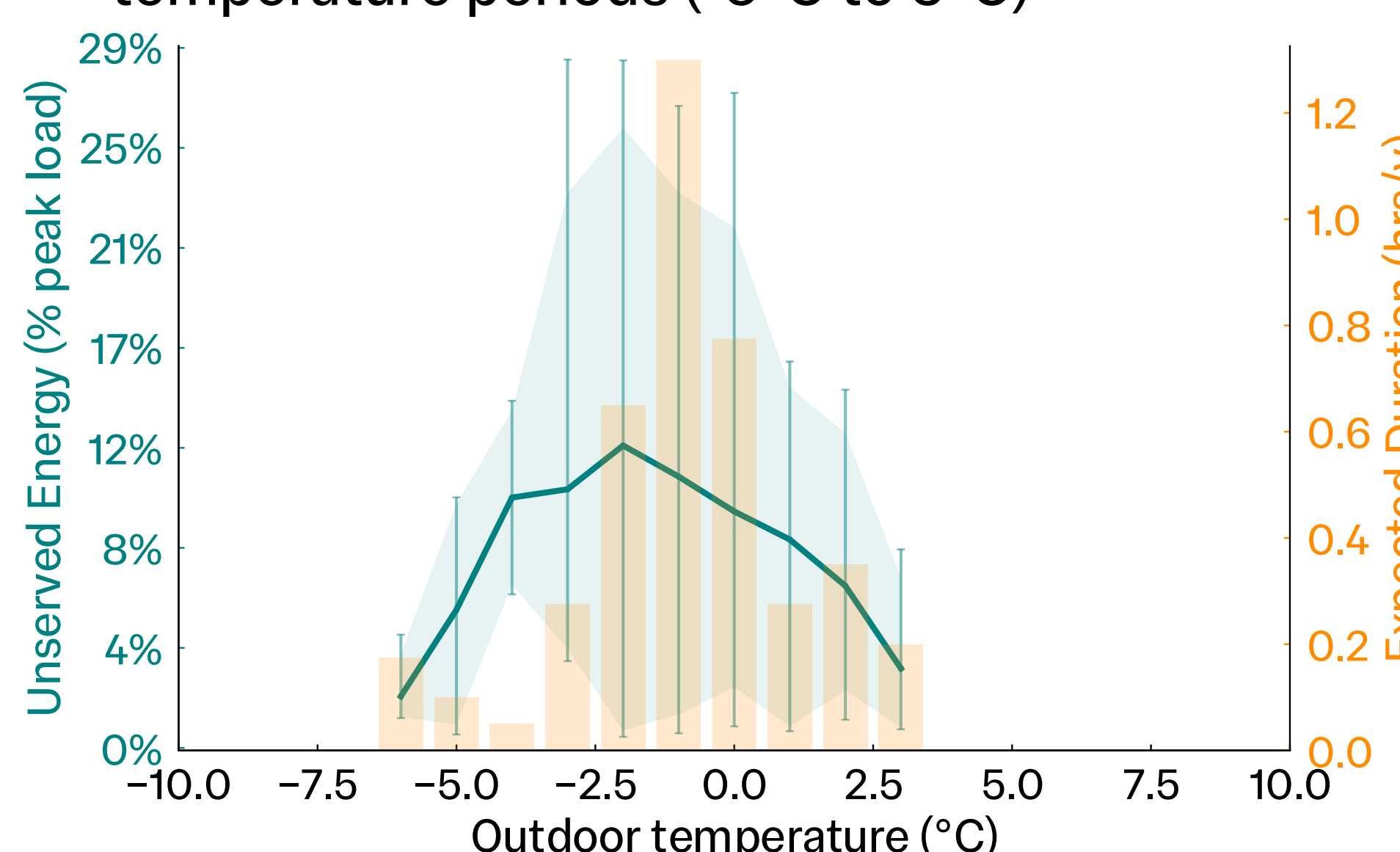
- Integrated dispatch: generation and storage co-optimised with DSF
- Sequential dispatch: DSF dispatched after generation and storage

24/7 Availability: DSF available all year round, benchmark scenario

Time-Limited: DSF available during specific times, based on GB evidence [4]

Case Study

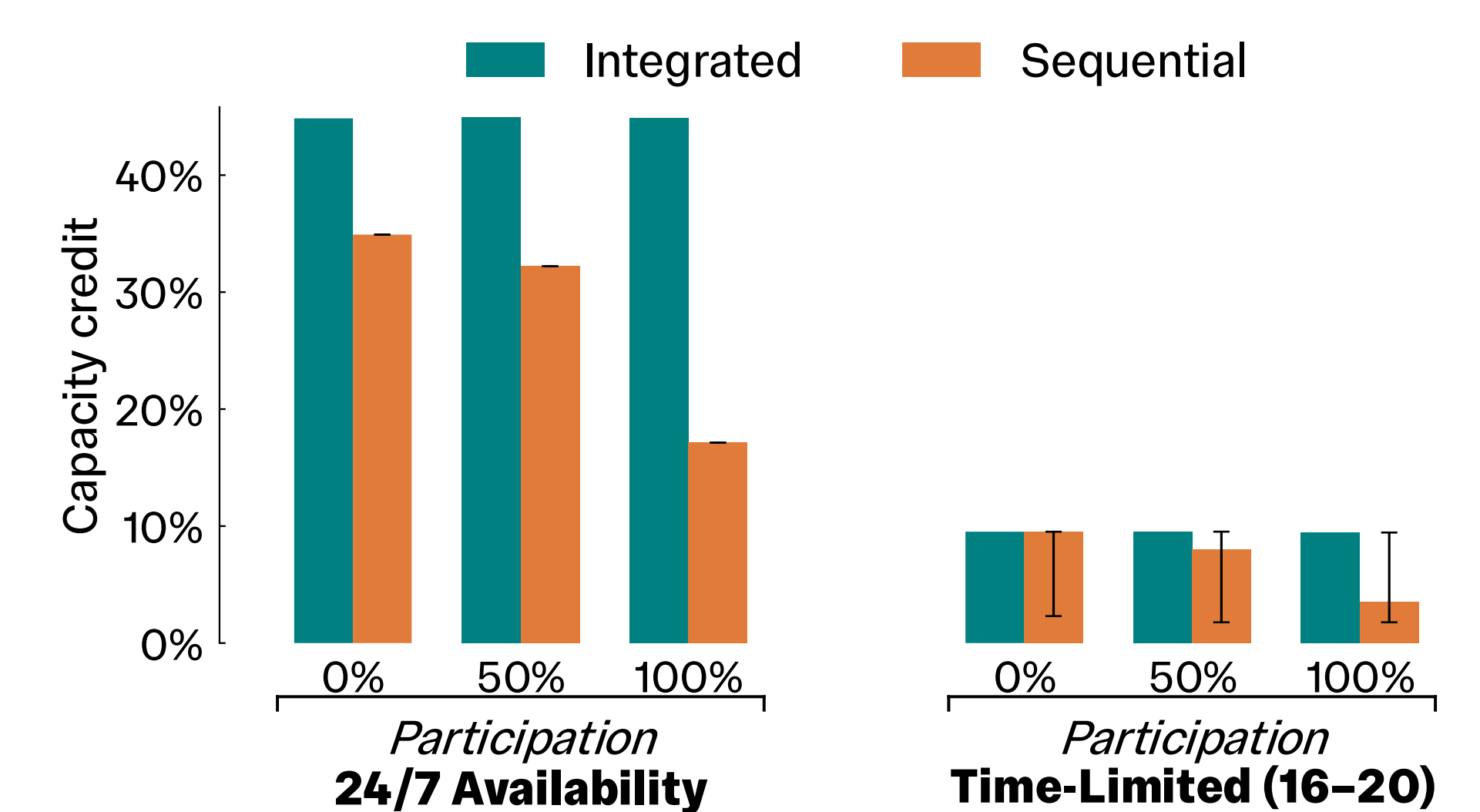
- GB-based study, single node system aligned with CP2030 Action Plan. LOLE of 4.15hrs and NEUE of 0.0075%
- 20 scenarios of VRE and heating demand.
- Unserved energy events occur during low temperature periods (-6°C to 3°C)



Unserved energy event distribution by outdoor temperature. No flexibility deployed. Events occur during peak cold periods, consistent with a winter peaking system.

Results

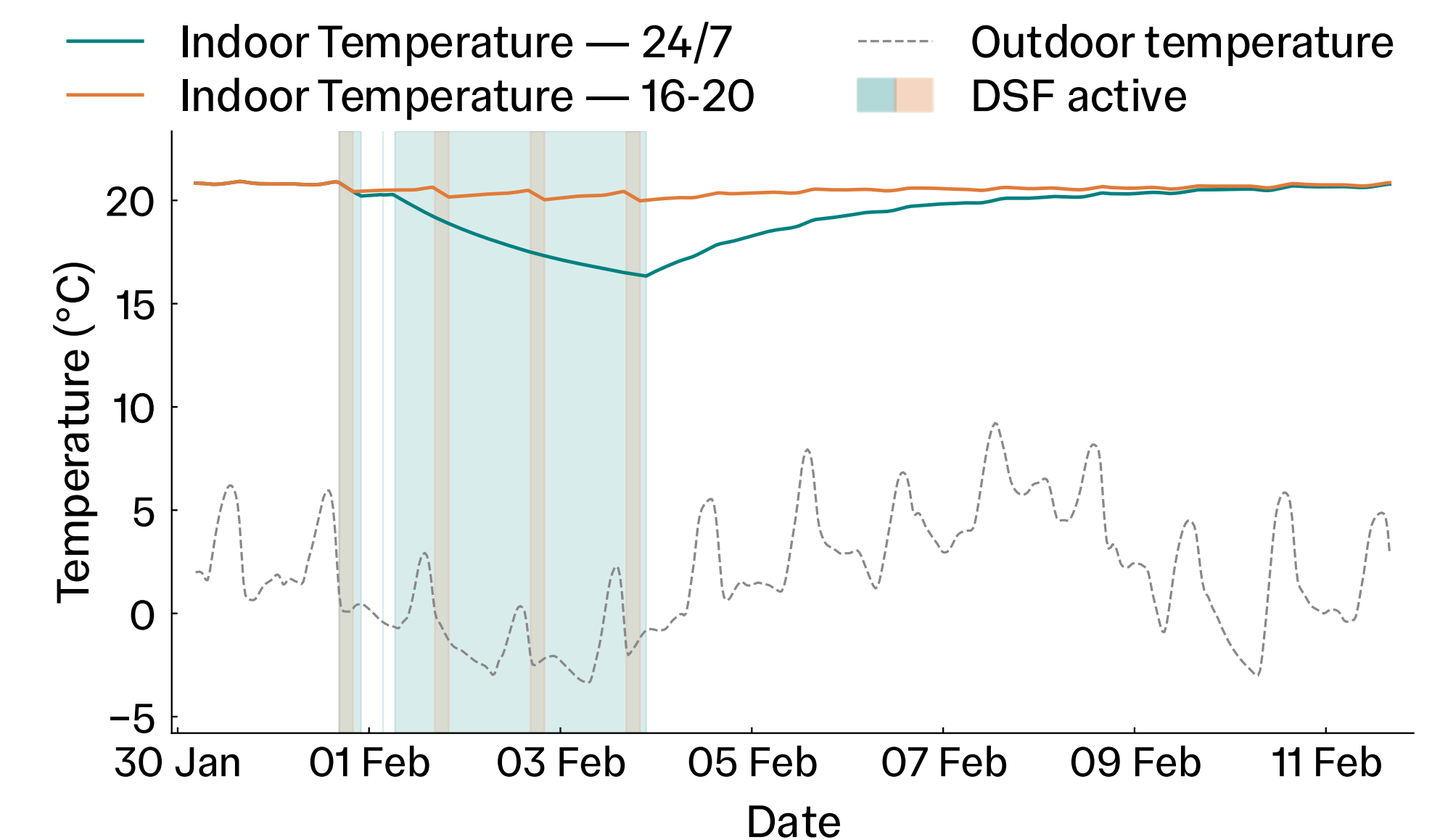
- Heating-based DSF contributed to resource adequacy, reducing unserved energy.
- Coordinated dispatch of assets increase capacity credits, yielding a stable value across participation levels.
- Limiting dispatch to specific windows reduced capacity credits, as unserved energy is still observed outside activation windows.



Capacity credits for 24/7 available DSF and time-constrained DSF. Integrated dispatch shows stable credits as participation increases. Sequential dispatch shows diminishing credits.

- For longer activation windows, indoor temperatures reached a lower minimum when providing DSF.

- Trade-off between system-wide benefits and consumer comfort



Indoor temperature for a household providing integrated Demand-side Flexibility (weather year 2006). 24/7 Availability dispatch increases consumer discomfort due to reduced indoor temperature. Time-constrained DSF has lower contribution to adequacy but does not considerably affect consumer comfort.

Conclusions and Next Steps

- Capacity credit of heating-based DSF ranged between 4% and 45%.
- Requirement for capacity and DSF potential aligned at cold temperatures.
- Capacity credits considerably increased with longer activation windows and asset coordination.
- Next steps: endogenous activation windows (duration and timing), capacity market integration.

References

- National Grid ESO. (2024). Storage de-rating factors methodology review.
- S. Wang, N. Zheng, C. D. Bothwell, Q. Xu, S. Kasina and B. F. Hobbs. (2022). "Crediting Variable Renewable Energy and Energy Storage in Capacity Markets: Effects of Unit Commitment and Storage Operation. IEEE Transactions on Power Systems.
- Wang, Z., Hong, T. & Li, H. (2021). Informing the planning of rotating power outages in heat waves through data analytics of connected smart thermostats for residential buildings. Environmental Research Letters.
- Centre for Net Zero. (2024). HeatFlex: the untapped potential of automated heat pump flexibility.

Acknowledgements

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