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IMPERIAL

Harnessing Demand-Side Flexibility
Assessing reliability value of heating DSF

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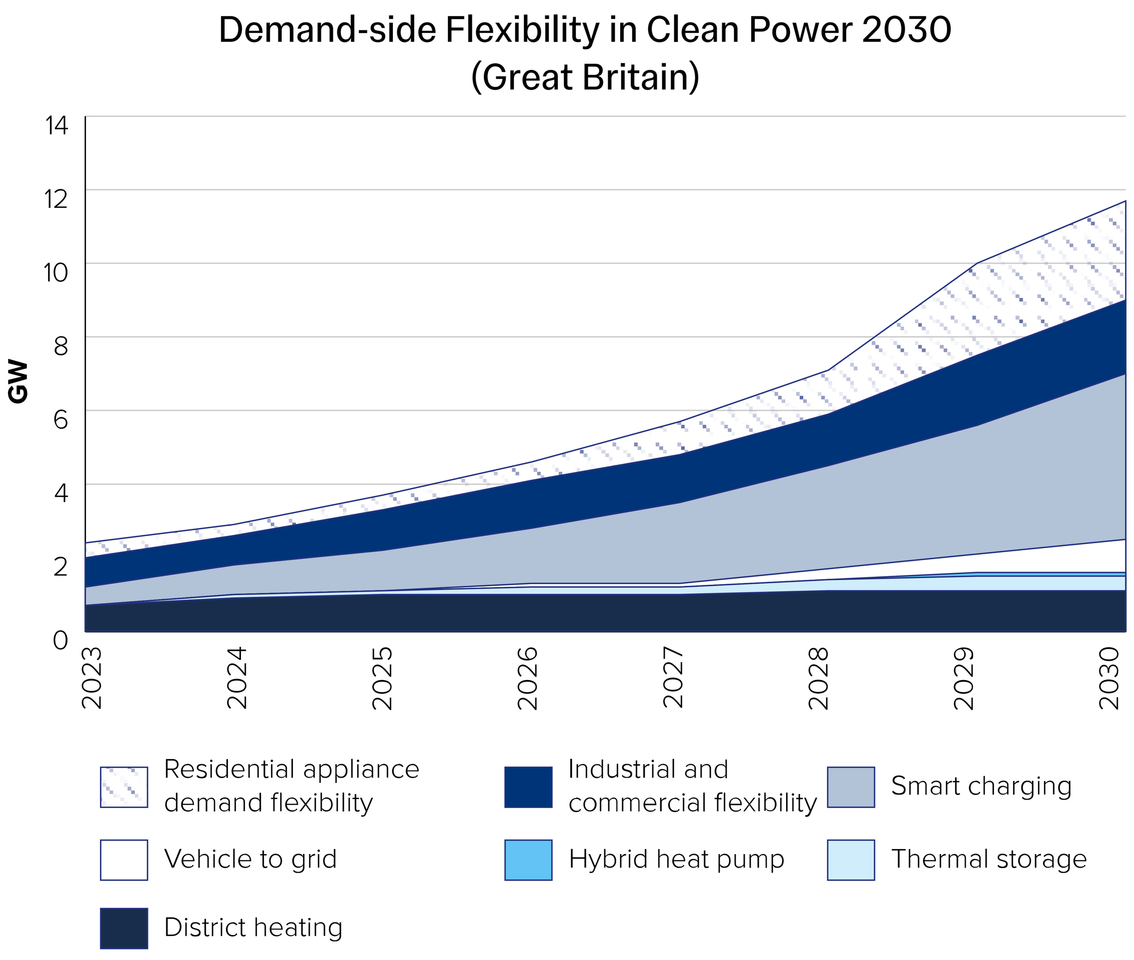
Context and motivation

- 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 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]

Challenges

Technical: metering and control of assets, **uncertainty and variability of flexibility potential**.

Economic: coordination of participation across markets, entry barriers for DSF in various markets

Regulatory: enabling frameworks, jurisdictional inconsistencies, privacy concerns.

Social: consumer engagement with (un)clear and (non-)transparent energy tariffs, equity concerns regarding affordability and accessibility to flexible assets.

Main research topics

- Connection: impact of new load connection agreements on DSF requirements, potential and performance.
- Accreditation: resource adequacy contribution of residential DSF (current work).
- Delivery: integration of DSF in real-time and day–ahead wholesale and flexibility markets.

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, like for other resources such as wind and storage.

In systems like PJM which follow resource-adequacy based methods for DSF, the calculation is typically optimistic regarding availability of DSF, overlooking historical evidence and product definitions.

Research question

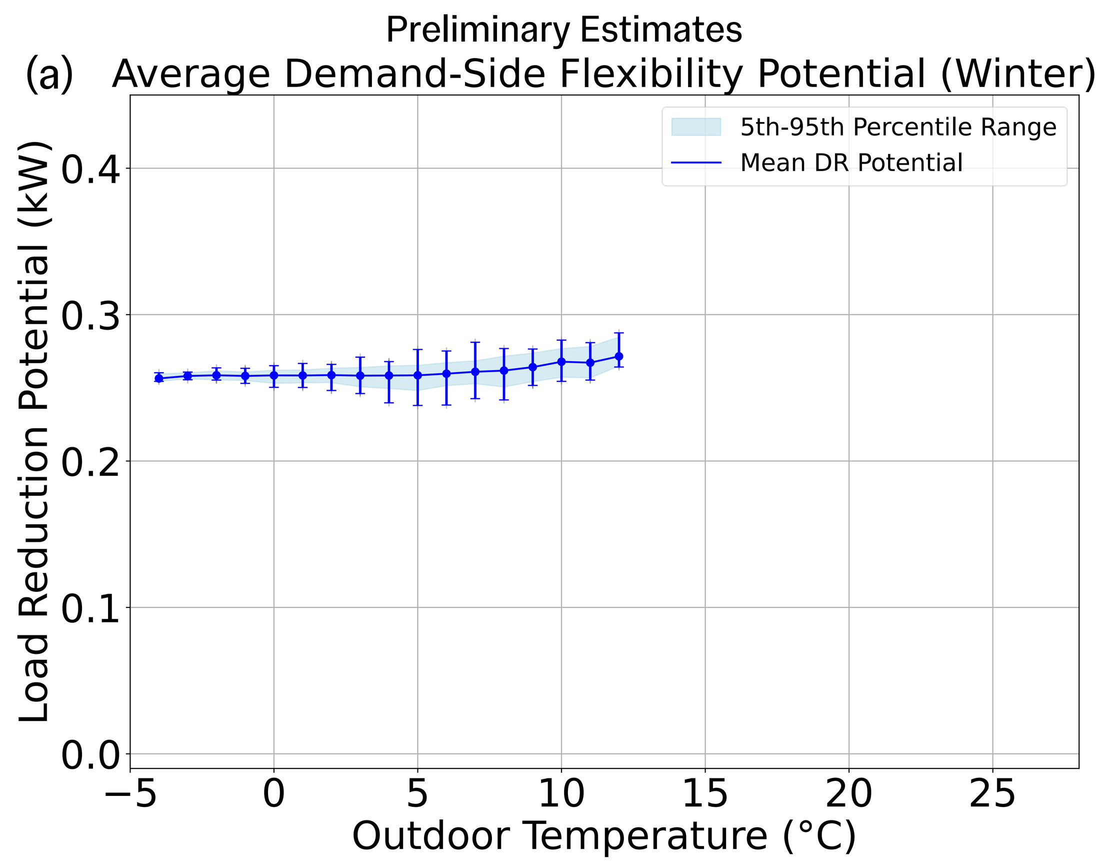
How different DSF product definitions affect the capacity credits?

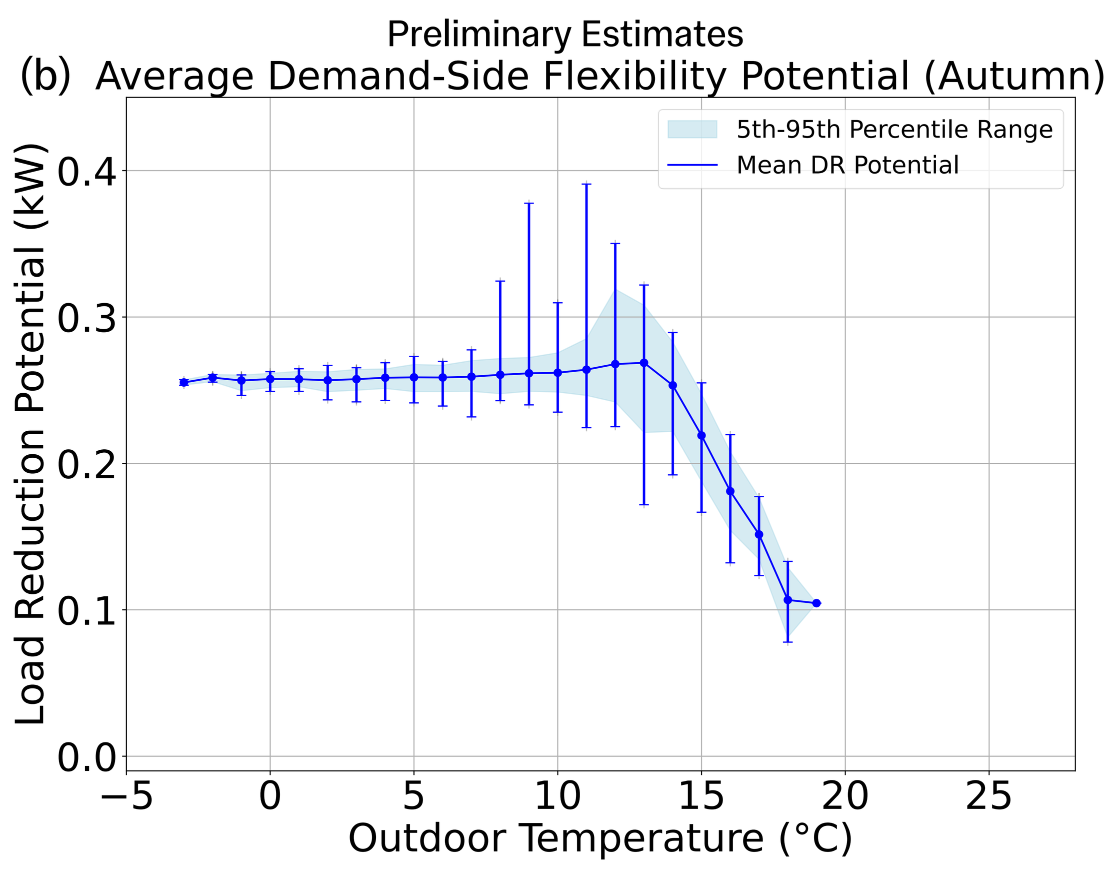
Demand-side characterisation

- Heating demand modelling of a GB household using a RC thermal model [4].
- DSF potential defined as the difference between the heat pump consumption for maintaining a comfortable vs. safe temperature:

The DSF potential is:

- relatively stable and with low variability in winter and on days with low ambient temperature.
- reduced as ambient temperature increases, with higher variability at the mid-temperature range.





Average demand-side flexibility potential during (a) Winter and (b) Autumn 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.

Methodology

Economic dispatch: generation and storage, fixed heating demand, price cap lower than VoLL

DSF redispatch: EUE-minimising dispatch of DSF, willingness-to-pay (WTP) greater than price cap (PC).

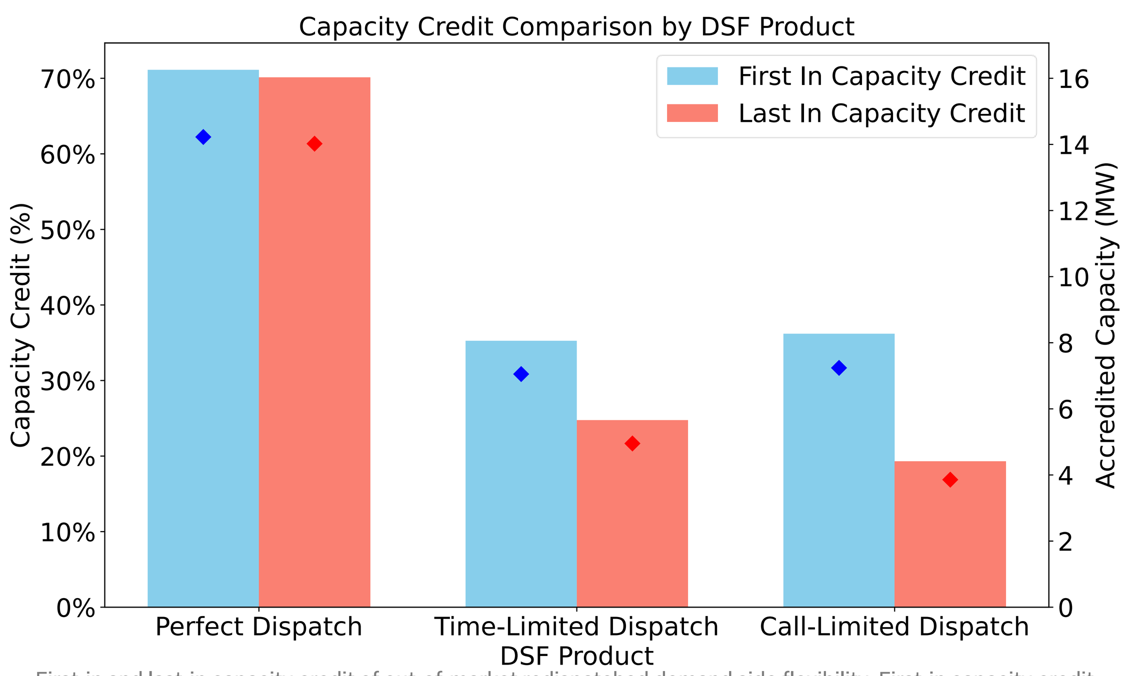
Marginal accreditation: comparison between DSF redispatch and a perfect unit dispatch [2,3]

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

Case Study

- GB-based study, single node system aligned with CP2030 Action Plan [1]. LOLE of 6.6hrs and NEUE of 0.0122%
- 20 scenarios of VRE and heating demand.
- Three DSF products: always available, 5-hour evening available, 5-hour evening available with two calls per day.

Preliminary Results



First-in and last-in capacity credit of out-of-market redispatched demand side flexibility. First-in capacity credit represents the marginal contribution of the first 20MW of DSF. Last-in capacity credit represents the marginal contribution of additional 20MW of DSF when 2.8GW were already dispatched.

- Capacity credit ranges from 19.3% for last-in Call-Limited Dispatch to 71.2% for first-in Perfect Dispatch.
- Activation period of DSF considerably affects CC, as it limits the delivery.
- Higher RA contribution in less constrained products, trade-off between system benefit and consumer comfort.

Current and future work

- Effectiveness of CM in integrating DSF curtailment potential with WTP greater than PC.
- Simulations with alternative measurement methods (drop-by vs drop-to; baseline methods).
- Sensitivity analyses: availability window shifting, increasing and reducing call recurrence.

References

[1] Department for Energy Security and Net-Zero.. Clean Power 2030 Action Plan. 2025.
[2] National Grid ESO.. Storage de-rating factors methodology review.2024.
[3] S. Wang, N. Zheng, C. D. Bothwell, Q. Xu, S. Kasina and B. F. Hobbs, "Crediting Variable Renewable Energy and Energy Storage in Capacity Markets: Effects of Unit Commitment and Storage Operation," in IEEE Transactions on Power Systems, vol. 37, no. 1, pp. 617-628,
[4] 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. 16 (7).

Acknowledgements

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