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Integrating Data Centers into Energy Systems: Load Characteristics and Waste Heat Potential

Daniel Brunsch, Tobias Ader, Christoph Weber
Universität Duisburg-Essen, Essen, Germany

Extended Abstract

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Abstract Summary

Electricity demand from data centers (DCs) is projected to grow rapidly across Europe, driven by ongoing digitalization and large-scale capacity expansions. While DCs are essential for digital infrastructure and economic development, their increasing energy demand raises concerns regarding grid stability, peak loads, and infrastructure investments. At the same time, they may offer system integration opportunities, particularly through waste heat utilization and interactions with renewable generation. This paper investigates whether the temporal characteristics of DC electricity demand enable such synergies.

The analysis combines empirical modeling of high-resolution load profiles with a system integration perspective. Using data from UK Power Networks, we estimate regression models that integrate ordinary least squares with autoregressive components to identify intra-day, intra-week, and seasonal patterns, as well as temperature dependencies. Based on this, load profiles are decomposed into deterministic temporal structures and stochastic residual components. The derived profiles are then used in a case study framework to assess the temporal alignment of waste heat availability with district heating demand and to analyze interactions with photovoltaic generation.

Preliminary results show that DC electricity demand exhibits highly stable intra-week patterns with low variability, indicating limited temporal flexibility but high predictability. A structural mismatch emerges between waste heat availability and heat demand, constraining direct utilization. However, potential synergies with photovoltaic generation are identified, particularly due to cooling-driven demand patterns.

Overall, DCs can be characterized as predictable base-load consumers, which simplifies system planning but may exacerbate peak load challenges. Their integration into energy systems depends strongly on local conditions, highlighting the importance of coordinated electricity and heat infrastructure planning.

Presenting Author Biography