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The case of 100% electrification of domestic heat in Great Britain

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Decarbonising the domestic heat sector is one of the major hurdles to economy-wide decarbonisation and achieving net-zero for many countries such as Great Britain, Germany, Italy, the Netherlands and the United States among others. Particularly, the shift from the incumbent natural-gas dominated heat sector to low-carbon alternatives poses significant challenges for the design of the future electricity grid. The rapid decarbonisation of the power grid in many countries has led many governments to consider the electrification of the heat sector as one of the main pathways to reduce its emissions, as indicated as early as 2013 in the UK government publication "The future of heating: meeting the challenge".

However, to date, limited access to high resolution heat demand data have led to analysts questioning the feasibility of this pathway mostly driven by concerns over the volatility and the seasonality of the resulting load for the future grid. Most previous studies start from a small dataset of building-level data and attempt to scale up their findings to the national level. Motivated by the lack of a high-granularity systematic study on the impact of designing the future grid with the goal of 100% electrification of the domestic heat sector, in this study we employ modelling and optimisation to elucidate the implications for the case of Great Britain. We focus on the regional interaction of the power and heat sectors and adopt a spatially-explicit and multi-period perspective. A key contribution of our study is the derivation and modelling of region-specific domestic heat demand profiles across the 13 local distribution zones (LDZs) of the GB gas network. Our model is underpinned by hourly gas demand data collected by the gas distribution networks over 2015-2018.

Succinctly, the mathematical model (OPHELIA) we have developed simultaneously optimises decisions related to: (i) investment for generation and storage in the power and heat sectors, (ii) operational decisions for the power and heat sector on an hourly basis, (iii) short term operating reserve decisions, (iv) interconnection flows in future years based on market clearing rules and future price projections published by ENTSO-E and (v) investment and operational decisions related to the transmission of power. Building on actual historical regional gas demand data, we can offer some novel findings including: (i) domestic peak heat demand would be almost 50% lower than widely-cited values that do not take account of regional differences in peak levels; (ii) although domestic heat demand is linearly dependent on ambient temperature on a daily basis, highly nonlinear interactions were found when the analysis is performed on an hourly basis thus giving rise to impact of regional characteristic in housing stock, social behaviour among others; and (iii) during extreme weather events such as a severe cold snap (e.g., the so-called 'Beast from the East' plus Storm Emma in 2018), adopting regional grid-level storage technologies will be especially important for integration of renewables into the system.

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