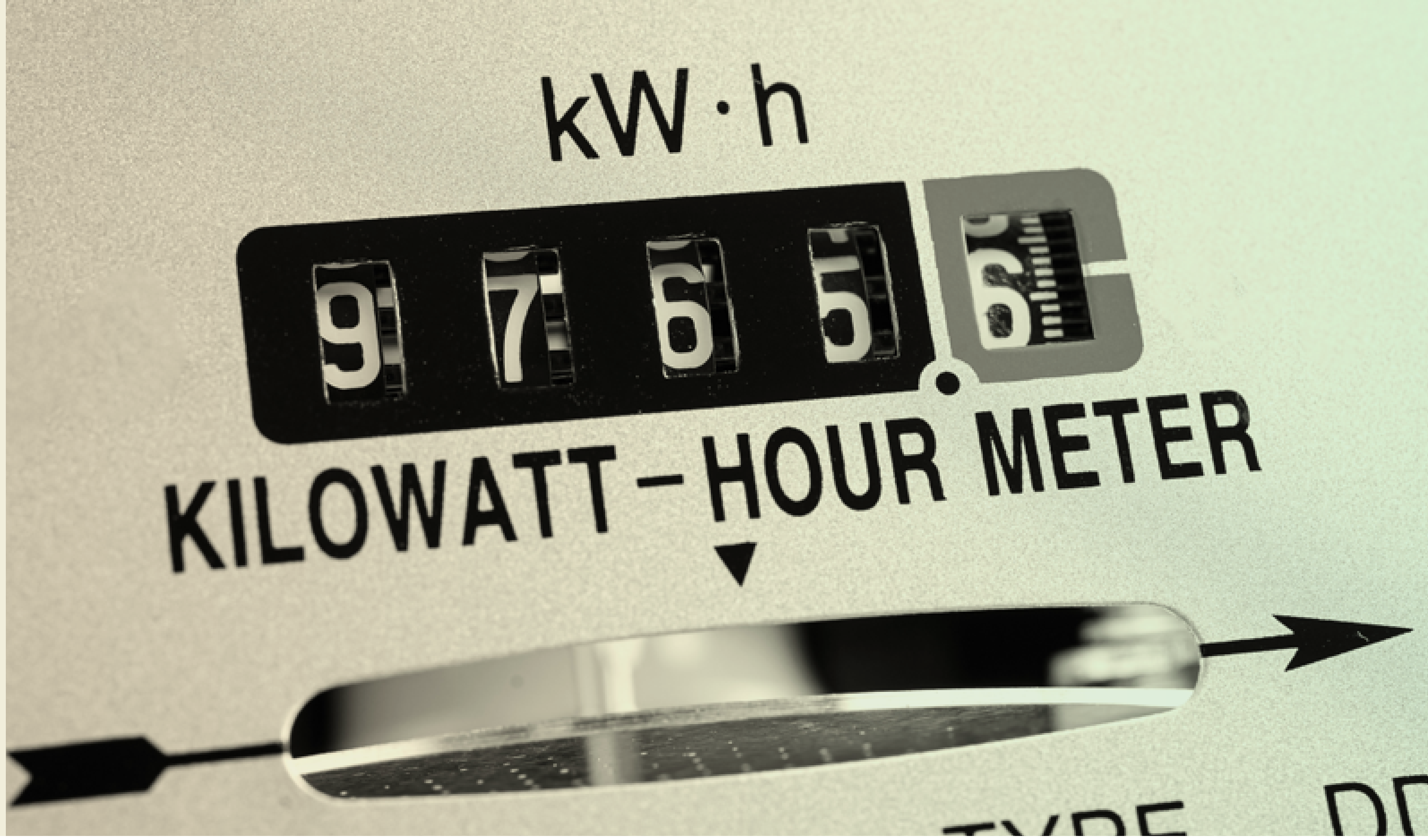
Demand Flexibility to Support the Electrification of Heat and Transport



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Challenge Statement

Heating the UK's homes accounts for approximately 18% of all UK greenhouse gas emissions, whilst domestic transport accounts for around 29%[1]. As such, decarbonisation of these sectors is a priority. Northern Powergrid expects the number of Electric Vehicles (EV) in the South Yorkshire region to increase from under 50,000 now to above 600,000 by 2050, with the number of residential heat pumps increasing from around 10,000 now to 360,000 by 2050[2].

Electrification will bring significant increases in peak electricity demands, presenting a challenge for the electricity system. Whilst a typical house currently contributes 1 - 2 kW to peak demands, a heat pump by itself contributes around 2 kW, and a residential EV charger contributes around 1 kW[3,4,5,6]. **Consequently, up to 42% of South Yorkshire's distribution substations may be overloaded by 2050 if not upgraded**, according to Northern Powergrid's distribution future energy scenarios[7].

To mitigate this challenge, EV and heat pump demand could be shifted away from peak times through incentives such as time-varying (time-of-use tariffs, TOUTs) that offer consumers cheaper unit rates outside of peak periods[8]. Smart EV chargers and heat pumps could also automatically adjust usage to alleviate stress to the grid[9].

1 Department for Energy Security and Net Zero (2025), Provisional UK greenhouse gas emissions statistics 2024.
2 Northern Powergrid (2025), Northern Powergrid DFES Local Authority Level.
3 UK Power Distribution (2017), Electrical Network Design Approval Application.
4 Customer-led Network Revolution (2015), After Diversity Maximum Demand (ADMD) Report.
5 Love, J., Smith, A.Z., Watson, S., Oikonomou, E. (2017), 'The addition of heat pump electricity load profiles to GB electricity demand: Evidence from a heat pump field trial'. Applied Energy, vol. 204, pp. 332-342.
6 UK Parliament, Scottish and Southern Electricity (2021), Written evidence from Scottish and Southern Electricity Networks.
7 Brown Group, The University of Sheffield, SYMCA, (2022), 'Hydrogen Conversion and Grid Capacity for South Yorkshire'.
8 Drax Electric Insights (2025) Electric vehicles and heat pumps are reshaping power demand.
9 Syla, A., Rinaldi, A., Parra, D., and Patel, M. K. (2024), 'Optimal capacity planning for the electrification of personal transport'. Renewable and Sustainable Energy Reviews , vol. 192, 2024.

Research Response

This research project aimed to address the following questions:

1. Can TOUTs in conjunction with smart controllers for heat pumps and EV chargers significantly defer the costs of upgrading South Yorkshire's distribution network?
2. Can TOUTs compete with direct control of appliances by the distribution network operator?
3. What is the role for EV charging at workplaces in facilitating the transition to EVs?

We modelled the demand for houses that would arise under three scenarios:

- Standard tariffs.
- TOUTs.
- Smart optimisation (with the DNO controlling devices to minimise peaks).

We used load profiles to model the anticipated demand for all South Yorkshire substations to understand if and when they would require an upgrade and the associated costs. Heat pump demand was modelled for buildings during a cold winter week. To predict the demand for charging EVs, we used real-world travel survey data and forecast EV uptake; we also explored a scenario where vehicles are incentivised to charge when parked at work.

Evidence and Outputs

Without flexibility measures, we find that circa 50% of both primary and secondary substations will require upgrade by 2050. The cost of carrying out these distribution grid upgrades is estimated at £940 per customer. 'Worst case' demand spikes are initially caused by EVs but will eventually be driven by heat pumps as heat electrification increases to 2050. It is worth noting that photo-voltaic (PV) solar has extremely limited impact on the highest demand peaks, as these occur in winter.

TOUTs by themselves are insufficient to alleviate distribution grid issues. Although they can accomplish savings to emissions and energy costs, large spikes in demand will still arise, and can

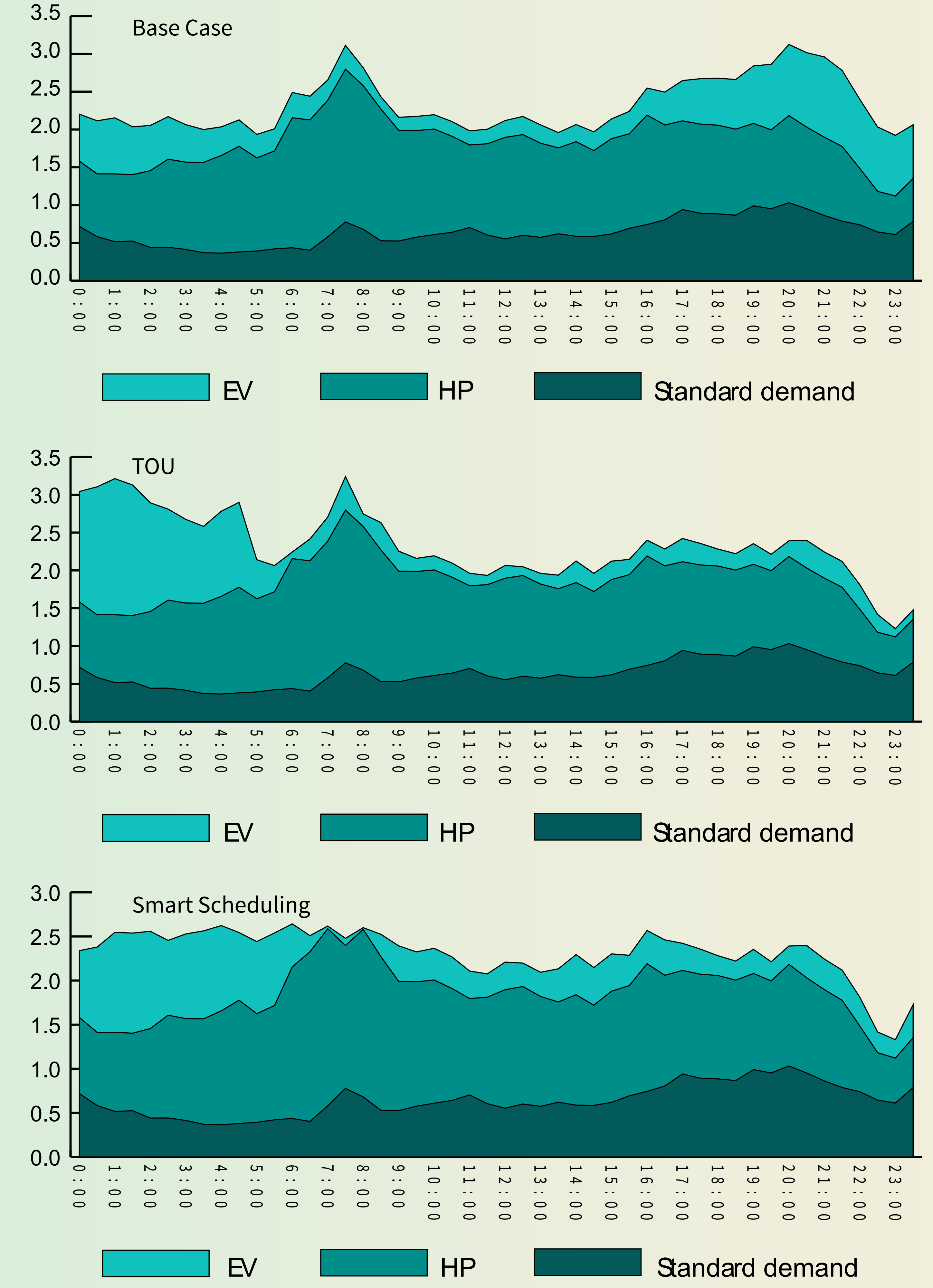

Figure 1: Electricity load on 'peakiest' simulated winter day; without flexibility measures; with TOU; and with smart scheduling.

actually increase in magnitude if consumers all respond simultaneously to lower prices. Smart controls which can coordinate all heat pumps and EV chargers on a network can reduce demand peaks for residential areas by around 21%. Implementing smart controls could reduce the proportion of overloaded substations by 2050 from 50% to 35%, and defer the requirement to upgrade in other cases. This would reduce the required investment in grid upgrades, by around £300 per household. Smart controls are most effective for EV chargers, which offer the greatest flexibility; heat pumps can be left under full user control whilst still retaining ~80% of the cost benefits, provided EV charging is under smart control.

Increased opportunity to charge EVs at work could further even out EV charging profiles, cutting peaks by an additional 5%, for an additional saving in grid upgrade costs of around £65 per household.

What does this mean for the region?

- Policy makers should seek to partner with the DNO to support trials of smart grid technologies for residential areas.
- Incentives for provision of workplace EV charging should be considered, especially where this can be coupled with PV and smart charging. Price incentives are required in tandem with this, as power is typically cheapest at night. Caveats: workplace charging has a possible tension with 'active travel'.

Next steps

The results of the study will be made available via the SYSC Residential Decarbonisation dashboard, enabling users to map results and compare different scenarios.

Peer-to-peer (P2P) trading of power can incentivise the adoption of EV chargers and heat pumps with PV generation. P2P could create microgrid communities that trade energy on a small scale, potentially saving households money and reducing the peak power requirement of the community. P2P was not covered in this case study; there is potential for trials and studies that combine smart controls with an element of P2P that could produce learnings on:

- The physical and digital infrastructure needed to support smart grid and P2P.
- The real-world effects on demand profiles (as opposed to modelled).
- The real-world human behaviour, including ease of recruitment.

This study focused on reduction of ***peak*** power demand in residential areas. There is a separate question around reduction of energy costs, which potentially unlocks more value for smart grid measures. Further research or trials should assess the impact of flexibility measures on energy costs and the energy market, as well as the network. Flexibility measures are also not without cost, so a full cost-benefit analysis is recommended.

Up to 42% of South Yorkshire's distribution substations **may be overloaded by 2050** if not upgraded