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The effects of LED light bulb installation on electricity demand in UK households: results of a large n randomised control trial

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EXTENDED ABSTRACT

Energy efficiency is a critical component in any strategy to reduce the need for expensive GHG-intensive peak demand generation and reduce the need for capital intensive local distribution network reinforcement. Lighting currently consumes approximately 15% of total electricity consumption in the UK ranging from 6 to 15% for electrically heated and non-electrically heated households respectively and 14% of peak winter load[1]. Increasing lighting efficiency could therefore offer substantial sustained residential demand reduction coinciding with known patterns of (especially) winter peak demand. In this paper we report analysis of a large-scale UK randomised-controlled trial which tested the effect of LED lightbulb installation on temporal electricity consumption in winter and estimated the consumer and network benefits of doing so.

Introduction / background

The transition to a low emissions energy system via increased electrification coupled to non-dispatchable renewable electricity generation is likely to increase the challenge of demand peaks. This could force investment in carbon-intensive peaking generation and/or capital-intensive storage capacity as well as additional transmission and distribution network capacity which may then be substantially under-utilised. Whilst testing a range of demand response interventions to reduce or shift consumption is underway, less attention has been given to the ability of certain appliances to permanently reduce demand at peak through energy efficiency[2].

One obvious driver of winter evening peak demand is lighting. While LED bulbs have been available in the UK for some time, uptake has been slow. Reducing peak load through energy efficient lighting could therefore offer permanent reductions in demand. However, there is little evidence of the actual customer and network benefit of doing so and virtually none from a representative sample of customers. This paper reports the results of a trial to fill this gap for customers of a Distribution Network Operator (DNO) in the south of England, UK.

Approach

The study recruited a representative sample of over 4,000 households in the south of England. Households were selected using a stratified random sampling approach and recruited via a fieldwork agency. A small financial incentive (retail voucher) was offered to all participants. Each household completed a short survey covering appliance ownership and use as well as socio-economic attributes of the occupants. A power clamp was fitted to the incoming power cable which recorded (net) kWh import every 15 minutes and transmitted this in

[1] Owen, P. 2012. 'Powering the Nation: Household Electricity Habits Revealed'. London: Energy Saving Trust.; Zimmerman, Jean-Paul, Matt Evans, Jonathan Griggs, Nicole King, Les Harding, Penelope Roberts, and Chris Evans. 2012. 'Household Electricity Survey: A Study of Domestic Electrical Product Usage'. HES Study Final Report Issue 4. Milton Keynes: Intertek; Jason Palmer, Nicola Terry, and Tom Kane. 2013. 'Further Analysis of the Household Electricity Survey Early Findings: Demand Side Management'. Further Analysis of the Household Electricity Survey. Cambridge: Cambridge Architectural Research, Loughborough University and Element Energy.

[2] Dortans, Carsten, Michael W. Jack, Ben Anderson, and Janet Stephenson. 2020. 'Lightening the Load: Quantifying the Potential for Energy-Efficient Lighting to Reduce Peaks in Electricity Demand'. Energy Efficiency, May. https://doi.org/10.1007/s12053-020-09870-8.

real time to our analytics data cloud. Monitoring was continuous for up to 1 year before and six months after the trial intervention period[3]. Participants were randomly allocated to either a control (no intervention) or trial group of ~1000 households each. The latter received a field visit from the agency who offered to replace up to 10 existing non-LED light bulbs at no cost. 882 participants (76%) of the intervention group accepted the project's offer and these were installed across the Autumn and early Winter of 2017. Replaced bulbs were removed to prevent re-installation.

Results

Figure 1 shows that replaced bulbs were predominantly located in main living areas (Living room, kitchen stairs/corridors and bedrooms) although this may have been constrained by 60% of participants already having at least 1 LED bulb in their kitchens. Figure 2 shows the mean Wh reduction in the evening peak period during the winter of 2018 compared to the control using a difference-in-difference model. The maximum observed reduction in power demand (W) during the peak period (16:00 to 20:00 hours) was 8% (weeks 1 and 2 of January), or 47 Watts per household (significant at $p < 0.1$). Across all hours the reduction was ~31W or ~ 3.9 kWh per household per week. A larger treatment affect was found when the household response person was retired or unemployed suggesting there may be heterogeneity to the response.

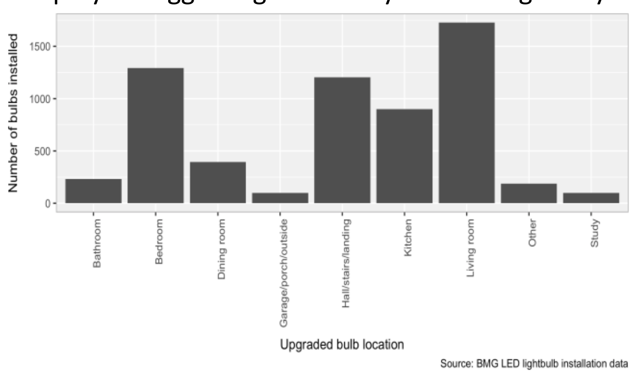

Figure 1: Location of installed lightbulbs. *Source: Authors' calculations*

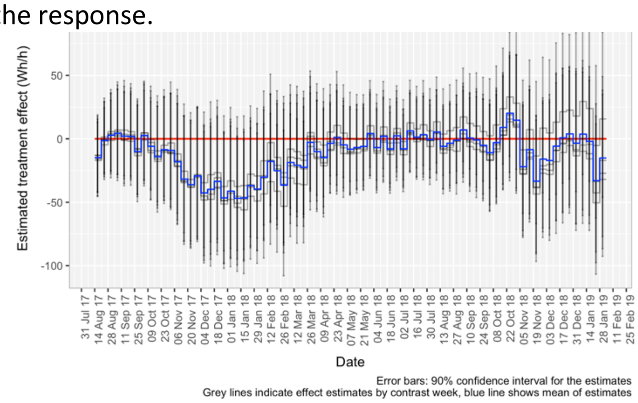

Figure 2: Impact of intervention (mean Wh 16:00 – 20:00, 90% CI). *Source: Authors' calculations*

Conclusion & discussion

The results suggest that across a 500-customer secondary substation, LED installation of this kind could provide approximately 24 kW of peak load reduction (~ 3.5 electric cars). We estimate that average annual savings per household would have been ~90 kWh, resulting in limited financial savings of approximately £16.00 per year. Clearly these savings are not substantial and the relative slow rate of LED uptake in the UK is a logical consequence

If the LED programme was extended to all 3.7 million of our DNO partner's customers, savings would be ~333 GWh and 127,000 metric tons of CO_2 a year. Further, we estimated that through the acceleration of the adoption of energy efficient light bulbs, approximately 1 additional 7kW EV charger could be added to the network per 212 households assuming charging is at peak times and that constraints are at the higher voltage level. Overall, the trial suggested that an LED programme of this kind may sometimes be as cost effective as network reinforcement but also offered non-financial advantages such as identifying Priority Services Register customers and directly engaging customers with a new understanding of the challenges of peak demand[4].

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[3] An anonymised version of this data is now available for re-use via http://doi.org/10.5255/UKDA-SN-8676-1

[4] For further implications see https://save-project.co.uk/energy-efficiency/