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Why do they flock together? Analysing role of behavioural and socio-demographic factors in electricity consumption profiles of Norwegian households

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Residential energy consumption has a significant share in the overall peak demand and energy related carbon emissions footprint of European nations (Torriti, 2014; Dubois, et al., 2019; Eurostat, 2024). Energy demand management within the avoid, shift and improve framework are considered as high potential climate change mitigation actions (Creutzig, et al., 2022; Jarre, Noussan, & Campisi, 2024). Digital innovations combined with occupant behaviours are believed to play important role in residential energy demand management and integration of variable renewables (Diao, Sun, Chen, & Chen, 2017; Schuitema, Ryan, & Aravena, 2017). Smart energy meters that measure, record and communicate energy consumption at frequent time intervals are being deployed at unprecedented scale and speed in many countries around the world with China, EU member states, USA and New Zealand as leading examples (ASSET Study, 2021; Sovacool, Hook, Sareen, & Geels, 2021). Availability of large scale granular electricity data for residential households has prompted a growing volume of empirical studies and renewed interests in residential profiles among researchers, industries and policymakers (Ramírez-Mendiola, Grünewald, & Eyre, 2017; Glasgo, Hendrickson, & Azevedo, 2017; Gellings, 1985). Further, it is expected that residential electricity profiles are likely to change in future due to enhanced use of solar photovoltaic cells, electrification, use of electric vehicles and demographic changes (Powells & Fell, 2019; Proedrou, 2021). A better and nuanced understanding of profile indicators is not only important in improving economic efficiency of energy systems but also vital for evidence-based climate change mitigation policies (Satre-Meloy, Diakonova, & Grünewald, 2020). However, in comparison to numerous studies based on aggregated monthly or annual residential energy consumption, empirical analysis of temporal dimensions of residential electricity demand remains limited, less understood and under researched (Ruokamo, Kopsakangas-Savolainen, Meriläinen, & Svento, 2019; Baker & Blundell, 1991; Grunewald & Diakonova, 2018).

In this study, we draw from and add to the growing volume of literature on residential energy profiles using a mix of survey responses and hourly electricity data from Norwegian households. In our two-part study, we first seek to identify subgroups that exhibit similar consumption profiles using cluster analysis while controlling for the price and weather effects. Next, we compare those identified residential subgroups based on their stated survey responses to behavioural, socio-economic and demographic attributes using multinomial logit regression. Our study makes many novel contributions to the contemporary residential electricity profiles literature. Our analysis is based on longitudinal smart meter data explores temporal dimensions of residential energy consumption profile indicators that are different and cannot be captured using aggregated consumption volumes. By combining the hourly metered electricity data with survey responses on behavioural and socio-demographic attributes, we take forward the existing empirical literature on residential profiles that either use smart meter data alone or use it in combination with time of use activities. In line with our research objectives intended to explore the heterogeneity in household energy profiles, we control for the weather and price effects by choosing to use differences from average values of electricity consumption as the objective function in cluster analysis. By using cluster analysis, we reduce the dimensionality of high frequency data suitable for merging with one time survey responses on behavioural and socio-demographic attributes. Our choice of k-means clustering technique is guided by the objective to find explanatory factors that influence membership of households with similar energy consumption profiles at unique time intervals rather than the shape of the profiles or for projecting future demand. Finally, we are able to validate our analytical ap-

proach by predicting correctly more than two-thirds of cluster memberships based on our regression model and chosen variables.

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