BUILDINGS & CITIES

Survey study on energy use in UK homes during Covid-19

RESEARCH

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ABSTRACT

To contain the spread of Covid-19, governments across the world imposed partial or complete lockdowns. National energy demand decreased in periods of lockdowns; however, as people spent more time at home, residential energy use likely increased. This paper reports the results of a UK survey study (N = 1016 participants) about their energy-use practices during the first lockdown in March 2020. The results indicated that self-reported heating behaviours did not substantially change during lockdown. Regarding appliance use, in particular the duration of usage for televisions and computing equipment has increased and has spread more over the day. Being less able to manage financially was correlated with a greater usage of the smart meter in-home display and a greater attempt to save energy was positively correlated with greater usage of the in-home display, though correlations were small. In summary, the results indicate that home energy-use behaviours, in particular around heating, did not change as much as might have been expected, which might at least partly be explained by the comparatively warm weather during the first lockdown. Corroborating the survey findings with actual energy data is the next essential step to understand findings in more detail.

POLICY RELEVANCE

Governments are developing policies to support the transition to net zero. Covid-19 has accelerated the transition in behaviours such as home working which may result in a 'new normal' energy behaviour and will need to be taken account when planning for net zero. Insights into the changes in behaviour during lockdown indicate it would be oversimplified to assume that electricity and gas use have increased in all homes because of a stay-at-home order. Self-reported heating did not change, whereas electrical appliance usage increased. The sample composition of the household is important for understanding

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the energy implications. In this study, about half the households did not spend more time at home during lockdown as judged on their work status. In-home displays may support energy saving behaviour, particularly for those doing less well financially. Hence, promoting their use should be a key consideration when installing smart meters.

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1. INTRODUCTION

Covid-19 has profoundly changed the way we live our lives. To contain the spread of the virus, governments across the world have imposed partial or complete lockdowns at various time points, including the closing of non-essential businesses and childcare settings, banning of public and private meetings, and mandating working from home wherever possible. Because of the pandemic, many people started to spend substantially more time at home.

In the UK, in the first lockdown starting in March 2020, everybody but keyworkers (ONS 2020d) had to work from home, non-essential shops were closed, a stay-at-home order was imposed, and schools and nurseries were shut to all children but those from keyworkers. Hence, a likely expectation would be an increased usage of energy in the home and a decrease in national demand. Indeed, national electricity demand dropped quickly when confinement measures were introduced (IEA 2020). For example, electricity demand in China dropped by 13% in February 2020, in Italy by about 28% in March–April 2020 and in the UK by 12–13% during the same period. Focusing on the UK and controlling for general trends in the consumption of electricity, an overall reduction in electricity was estimated, with reductions of up to 20% in the morning peak period, 11% in the daytime and 9% in the evening peak period in April (Anderson & James 2021).

In Europe, from January to May 2020, demand for natural gas reduced by about 8%; likely due to a mixture of factors, *e.g.* comparatively warm weather, lots of renewables in power generation and Covid-19 (Honoré 2020). Gas use showed a reduction of about 15% during the first two weeks of lockdown in Ireland compared with the same period in 2019; however, this was not weather corrected (SEAI 2020). For the UK, annual demand for gas in 2020 fell by 6.2% compared with 2019 (BEIS 2021a).

Hence, on national levels both electricity and gas demand were lower during the pandemic. Focusing on the residential sector, a different picture emerges: Residential electricity consumption increased by about 30% during lockdown in the US (Krarti & Aldubyan 2021). Data from Spain indicate energy increases of 15% (García *et al.* 2021) and 7% (Santiago *et al.* 2021), together with a more even distribution of consumption over the day. The UK reported an increase of 2.1% in total domestic energy consumption and of 0.8% in domestic demand for gas in 2020 compared with 2019, even though 2020 was warmer on average (BEIS 2021a). Focusing on the second quartile (April–June), *i.e.* the period that contained most of the first lockdown, total domestic energy consumption in the UK increased by 6.5% on a seasonally and temperature-adjusted basis (BEIS 2020c). Using per circuit monitoring revealed an increase in cooking and digital device use in Australia; however, total energy use reduced during lockdown because of lower air-conditioning use as external temperatures decreased (Snow *et al.* 2020).

An online survey amongst respondents in New York, US, showed that almost 50% of respondents reported higher electricity use during the pandemic, whilst about 40% reported no change (Chen *et al.* 2020). As per self-report, there were no longer morning or evening usage peaks on weekdays in lockdown.

Taken together, national energy demand decreased during lockdown, but residential demand increased; however, correcting for weather and seasonality is crucial. Little is known about how exactly energy use in the home changed during lockdown. It is expected that working from home will remain more widespread even after the pandemic (Hern 2020); hence, understanding the implications for energy use of an increased time spent at home are important.

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1.1 UK CONTEXTUAL INFORMATION ON THE FIRST COVID-19 LOCKDOWN

The UK government started the first Covid-19 lockdown on 23 March 2020. All non-essential businesses were closed or operated in a delivery mode only; schools and nurseries were only open to children of keyworkers; and people were ordered to stay at home, but permitted to leave for essential purposes only. First easing of lockdown restrictions occurred on 11 May 2020.

Park mobility as a proxy for outdoor recreational activity decreased significantly during the initial phase of lockdown (Burdett *et al.* 2021), and traffic counts in April 2020 were 69% lower than in April 2019 (Jephcote *et al.* 2021). In April 2020, 46.6% of people in employment conducted some work at home, and the majority of those (86.0%) because of the pandemic (ONS 2020a). About one-third of those employed are key worker occupations and industries (ONS 2020c). Hence, a substantial number of employees continued to work outside the home. Also, those of working age classified as economically inactive (about 20%) or unemployed (about 4%) (ONS 2020b) would not have changed their place of work. About 18% of the population is aged 65 and above (ONS 2019). This is very close to the average exit age from the job market for both women (64.3 years) and men (65.3 years) (ONS 2021). Hence, whilst many people will have spent more time at home because of the pandemic, this is not the same across the population.

A second important contextual factor is the weather during lockdown. ***Figure 1*** shows average daily temperature and average daily solar radiation for the location of the dwellings in this sample, with the green vertical lines indicating the lockdown period. Data were taken from the Copernicus/ECMWF ERA5 hourly re-analysis data, using the *2m_temperature_K* and *surface_solar_radiation_downwards* variables (Copernicus Climate Change 2020).

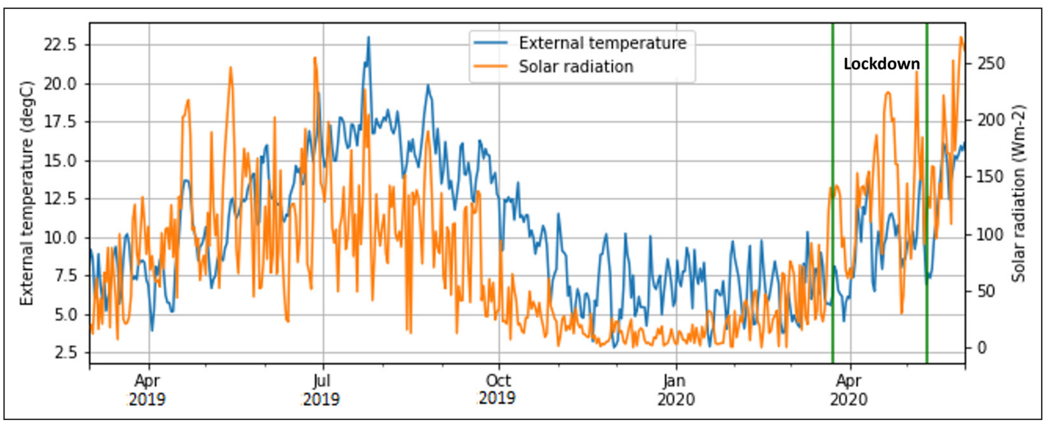

Figure 1: Average daily external temperature and horizontal solar radiation for the dwelling locations in the sample.

Note: The vertical green lines indicate the period of the first lockdown in the UK.

Conditions during the first lockdown were both warmer and sunnier than on the same dates the previous year. Average temperature in lockdown was 9.4°C (SD = 2.34) compared with 8.6°C (SD = 2.29) the year before; solar radiation was 133.7 Wm^{-2} (SD = 50.6) in lockdown compared with 105.1 Wm^{-2} (SD= 43.5) the year before. Both external temperature and solar radiation can impact the energy use for space heating in a building (Kreider *et al.* 2010; Mihalakakou *et al.* 2002; Uglow 1981), so the comparatively higher ambient temperatures and higher solar radiation might have decreased the need for space heating during lockdown.

1.2 AIM OF THE PAPER

This paper explores how self-reported energy-use behaviours changed in UK homes during the first lockdown of the pandemic, from 23 March to 11 May 2020, with a survey administered after the end of the first lockdown. The survey focuses on heating-related questions and self-reported changes in the frequency and timing of appliance-use data and explores changes in other energy-related practices such as the usage of in-home displays (IHDs). All hypotheses were prespecified in advance of analysing the data (Huebner *et al.* 2020) to avoid selective reporting and cherry-picking of results. Data-cleaning procedures are also described in the preregistration. A reporting guideline is used for this paper to ensure that all relevant details are reported to increase the transparency of the work conducted.

2. METHODS

This study made use of the natural experiment created by Covid-19. The SERL project[1] has been recruiting participants with smart meters in their homes, and is accessing and collating their smart meter data in a secure data environment continuously since initial sign-up. As part of the pilot sample recruitment, SERL has enlisted 1711 homes in England and conducted a survey with them in September 2019 (called background survey subsequently). These participants were recontacted during the UK's first lockdown in April–May 2020 and asked to fill in an additional survey related to their household and energy use during Covid-19 (called the 'Covid survey'). Both postal and online surveys were used to contact participants. The initial postal survey was sent out on 22 May 2020, with a reminder mailed on 8 June; the initial email survey was sent on 27 May 2020, with reminders emailed to unfinished responders on 3 and 10 June 2020.

2.1 SAMPLE SIZE AND PARTICIPANTS

Surveys were sent to 1711 households, *i.e.* the number of households who had signed up to SERL by September 2019. They received a postal survey or an online survey (depending on household preference); those who received a postal survey based on their previously stated preferences were also given the option to answer online (called 'push to web'). Of these households, 1084 filled in the Covid survey. Only one person from each household was instructed to fill in the survey on behalf of the household. After removing duplicates, households who were no longer living at the same address during lockdown and households who had not filled in the background survey, a final sample size of N = 1016 households remained.[2] Respondents were able to skip questions, hence the number of respondents can be < 1016; the valid N for each question are stated.

Participants were located in England and Wales. The sample was biased towards areas of low deprivation, detached homes and owner-occupied dwellings. Two-person households were most common, followed by single-person households. ***Table 1*** shows a comparison with national statistics based on the 2011 Census (ONS 2011), the English Housing Survey (EHS) 2019/20 (MHCLG 2021), and the Ordnance Survey's (OS) Address Base (OS n.d.). For how these were derived in detail, see Webborn *et al.* (2021).

VARIABLE	SAMPLE (COUNT)	SAMPLE (%)	POPULATION (%)
Accommodation type			*Source:* Census 2011
No answer/other	12	1.2	1.4[a]
Detached	393	38.7	24.3
Semi-detached	271	26.7	29.0
Terraced	224	22.0	23.0
Purpose-built flats	99	9.7	17.6
Converted/shared house	17	1.7	4.6
Tenure			*Source:* EHS 2019/20
No answer/other	24	2.4	n.a.
Own	848	83.5	64.6
Privately rented	52	5.1	18.7
Social housing	92	9.1	16.7
Household size (persons)			*Source:* EHS 2019/20
1	278	27.4	27.9
2	453	44.6	36.6
3	114	11.2	15.6

(Contd.)

Table 1: Basic information about the sample and comparison with population estimates.

Note: [a] In the census category, this category consists of flats in commercial units, whereas this sample also includes no response; hence, the data are not comparable for this category, but are given to show the prevalence of other types.

[b] Comparability of the 5+ category limited because the sample includes those not providing an answer.

EHS = English Housing Survey; OS = Ordnance Survey.

VARIABLE	SAMPLE (COUNT)	SAMPLE (%)	POPULATION (%)
4	82	8.1	12.9
5	21	2.1	4.8
Other (> 5/missing)	68	6.7	2.3[b]
Index of multiple deprivation (quintile)			*Source:* OS Address Base
1 (most deprived)	94	9.3	20.5
2	160	15.7	21.0
3	202	19.9	20.6
4	268	26.4	19.7
5 (least deprived)	292	28.7	18.2
Response method			
Email	421	41.4	n.a.
Post	467	46.0	n.a.
Push to web	128	12.6	n.a.

2.2 SURVEY QUESTIONS

Both surveys are shown in full in Appendices 1a, 1b and 2 in the supplemental data online. The Covid survey asked in particular about how heating and other energy-use behaviour had changed given that residential energy use is dominated by heating in the UK. It also covered questions around household composition, financial satisfaction, work status, window-opening, the attempt to save energy and usage of IHDs, which provide easy access to smart meter data for the occupants and, in Great Britain, are offered to all homes receiving a smart meter (BEIS 2021b). The background survey was much broader, covering dwelling characteristics, appliance ownership, tenure and other variables. Some questions were identical across both surveys, allowing the direct comparison of responses pre- and during lockdown.

2.3 DATA AVAILABILITY

All data collected as part of the SERL project are accessible to all accredited UK academic researchers with access to pseudo-anonymised data via a Secure Lab environment (for details, see SERL 2021). The background survey is already available; the Covid survey will be released in the first quarter of 2022, as will the code underlying the analysis.

Note that for statistical disclosure control reasons, this paper can only show data with a frequency of at least 10 cases for each value.

2.4 HYPOTHESES AND STATISTICAL ANALYSIS

The analysis was mainly focused on descriptive statistics. However, the following five hypotheses were also tested:[3]

> *Hypothesis 1. Thermostat settings have increased during lockdown: Assessed through a paired sample* t*-test.*
>
> *Hypothesis 2. The attempt to save energy has increased during lockdown: Assessed through a Wilcoxon signed-rank test.*
>
> *Hypothesis 3. Those who report using an IHD more are more likely to say they attempt to save energy: Assessed through a Spearman-rank correlation coefficient.*

Hypothesis 4. Those who indicate less satisfaction with their financial situation are more likely to say they attempt to save energy: Assessed through a Spearman-rank correlation coefficient.

Hypothesis 5. Window-opening has increased during lockdown: Assessed through a Wilcoxon signed-rank test.

All hypotheses were prespecified in advance of analysing the data (Huebner *et al.* 2020); data-cleaning procedures were also described in the preregistration. Any deviations from the preregistration are noted in Appendix 3 in the supplemental data online. Data were analysed in R (Core R Team 2019) using the base stats package ggplot2 (Wickham 2016) and tidyverse (Wickham *et al.* 2019). The STROBE reporting guideline were used to ensure necessary details are reported (see Appendix 4 in the supplemental data online). Appendix 5 online contains a summary of the pre-specification, data and code availability, reporting guidelines and preprints (Huebner *et al.* 2021).

2.5 BIAS ASSESSMENT

Risk of bias describes whether the results are affected by flaws in the design, conduct or analysis of a study. This study is observational and largely descriptive; however, it does aim at linking findings to the first Covid-19 lockdown. It is possible that in some households other events happened that might have impacted the answers, such as the birth of a child, or the death of a household member or a loss of income due to factors other than the Covid lockdown. This was not explicitly measured. However, given the low likelihood of these events—*e.g.* 153,464 live births occurred in England and Wales in the second quarter of 2020 across about 24.5 million households (ONS 2020f)—and the fact there is no clear evidence how those events might impact the replies, this was not considered a crucial bias. The sample was biased in its selection. However, this was beyond the control of the researchers and care was taken to limit statements about the generalisability of findings. To overcome selective reporting, the analysis and data cleaning were prespecified in advance.

3. RESULTS

3.1 WORKING FROM HOME

The respondent of each household had to indicate for each adult in the house (N_{valid} = 869) whether they always worked from home, never worked from home, sometimes worked from home, or did not work before lockdown (N_{adults} = 1426) and during lockdown (N_{adults} = 1472). The proportion of adults working from home more than tripled during lockdown, and the proportion of those never working from home halved during lockdown; however, both before and during lockdown about half of the adults in the sample did not work (***Figure 2***).

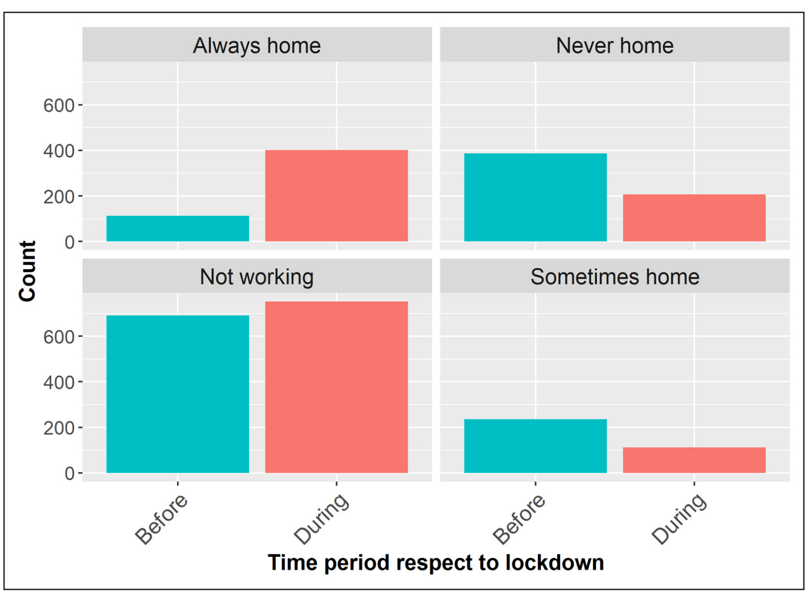

Figure 2: Work status of adults before and during lockdown.

What ***Figure 2*** does not reveal are within-household changes. In order to account for those, a point system was developed. Always working from home and not working were given 2 points for each adult; sometimes working from home 1 point per adult, and never working from home 0 points. For each household the sum of points was calculated for before and during lockdown, and the difference between before lockdown and during lockdown was calculated. A positive difference indicated more time at home during lockdown, a negative difference less time, and no difference the same. The largest group was no change (61.4%), followed by more time at home (30.9%); 7.7% spent less time at home.

3.2 HEATING BEHAVIOURS

Participants were asked for how many hours they heated their home during lockdown on a cold day (N_{valid} = 842). If a household gave a non-integer answer (possible in the postal survey and decimals were allowed in the online survey), values were rounded to the nearest half-hour. If minutes were given (*e.g.* 9 h, 20 min; 9h20), anything < 30 min was rounded down and anything ≥ 30 min rounded up. For decimals, 0.3 was considered to indicate 30 min, as was 0.5. If anyone gave a fraction, the respective minutes were calculated and rounded to the nearest half-hour. If a respondent gave a range, *e.g.* 2–3 h, the midpoint was calculated and rounded if needed. If a household gave an answer > 24 h or < 0 h, the data would be flagged as an error; however, no household did this.

Mean (SD) hours were 7.46 (5.66); median hours were 6 (interquartile range (IQR) = 7). As becomes clear from the measures of dispersion and as visualised in ***Figure 3***, responses were widely spread out.

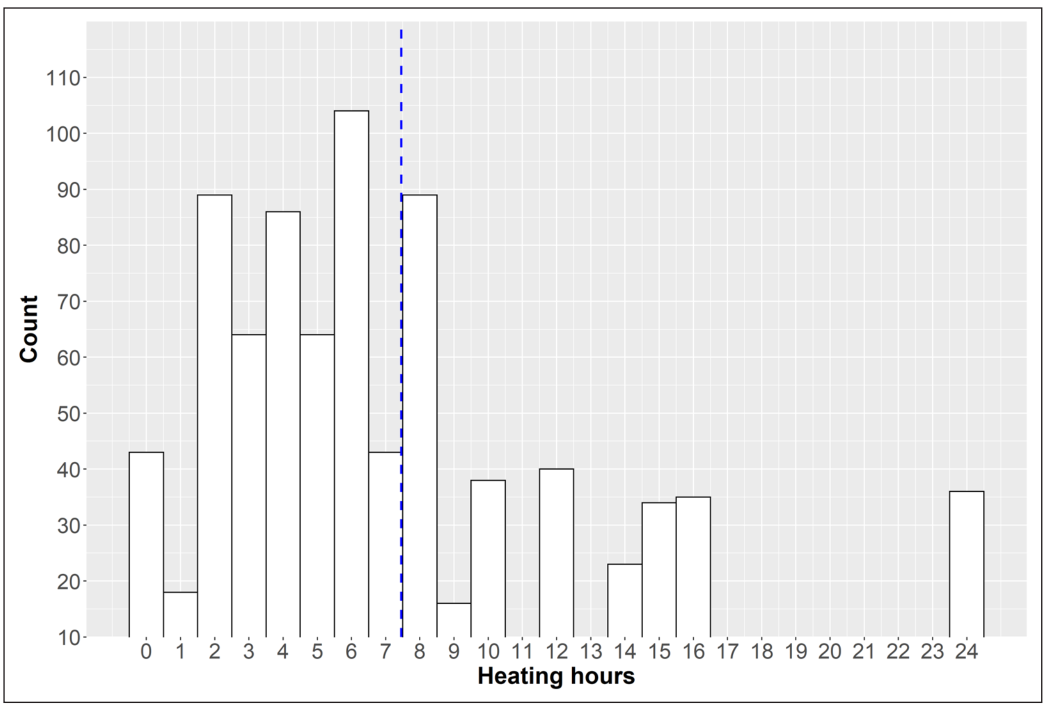

Figure 3: Heating hours during lockdown.

Respondents then indicated whether this was more or fewer hours than before lockdown (N_{valid} = 839). The vast majority reported no change (59.5%), with 13.6% indicating an increase and 7.6% a decrease. A total of 19.9% did not remember or indicated the question as not applicable.

However, those who spent more time at home indicated an increase in heating-hours (***Figure 4***).

Participants were also asked to state to what temperature they set their thermostat on a cold day during lockdown. This same question had also been asked in the background survey. Values < 5 and > 40°C were considered as outliers and excluded. Mean thermostat settings were very similar

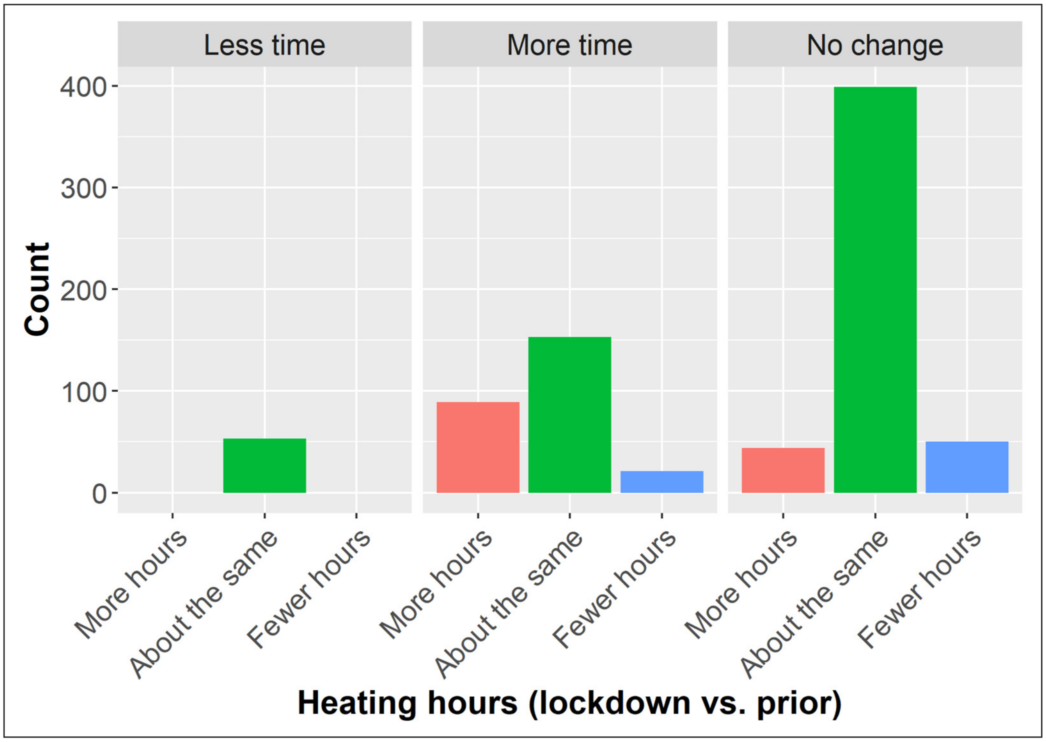

Figure 4: Change in heating-hours during lockdown compared with pre-lockdown.

Note: Based on whether respondents spent less time, more time or the same time at home during lockdown.

in both surveys, with mean (SD) = 20.05°C (2.13; N_{valid} = 809) in lockdown and mean (SD) = 20.40°C (2.14; N_{valid} = 799) pre-lockdown. Contrary to Hypothesis 1, thermostat settings were slightly lower before lockdown than during lockdown, paired sample *t*-test, $t(710) = -5.55$, $p < 0.001$; mean difference = –0.336 (95% confidence interval (CI) for the mean difference: –0.454 to –0.217). However, the effect was small (Cohen's $d = 0.2$). When repeating the results only for those who stayed at home more, the finding was the same, *i.e.* thermostat settings were slightly lower during lockdown than before, $t(229) = -4.33$, $p < 0.001$; mean difference M_{diff} = –0.495°C (95% CI: –0.720 to –0.270).

A third heating related question asked about the number of rooms heated during lockdown on a cold day (N_{valid} = 990). The vast majority indicated no change in the number of rooms heated (86.9%), with about 3% each indicating more and fewer rooms (the remaining answers fell into categories of not applicable or did not remember). There was no difference depending on whether the respondent spent more time at home during lockdown.

3.3 APPLIANCE USAGE AND TIMING OF ACTIVITIES

Participants had to indicate how often (***Table 2***) or for how long (***Table 3***) they used certain appliances. For any answer with a range (*e.g.* once or twice) the midpoint was calculated. Negative numbers were coded as an error. Note that the spread of answers was very wide, and data were non-normally distributed, hence the median and IQR are used to describe the data. N = 961 respondents provided at least one answer.

ACTIVITY	MEDIAN (IQR)
Bath	1 (3)
Shower	7 (10)
Washing machine	3 (2)
Tumble-dryer	1 (2)
Dishwasher	4 (6)
Cooker, oven, grill	7 (5)

Table 2: Weekly frequency of household activities.

Note: IQR = interquartile range.

ACTIVITY	MEDIAN (IQR)
Television	6 (6)
Laptop, computer, tablet	5 (10)
Electric gym equipment	0 (0)

Table 3: Weekly duration of household activities (h).
Note: IQR = interquartile range.

They were then asked to indicate if this was more or less than before lockdown (***Figure 5***).

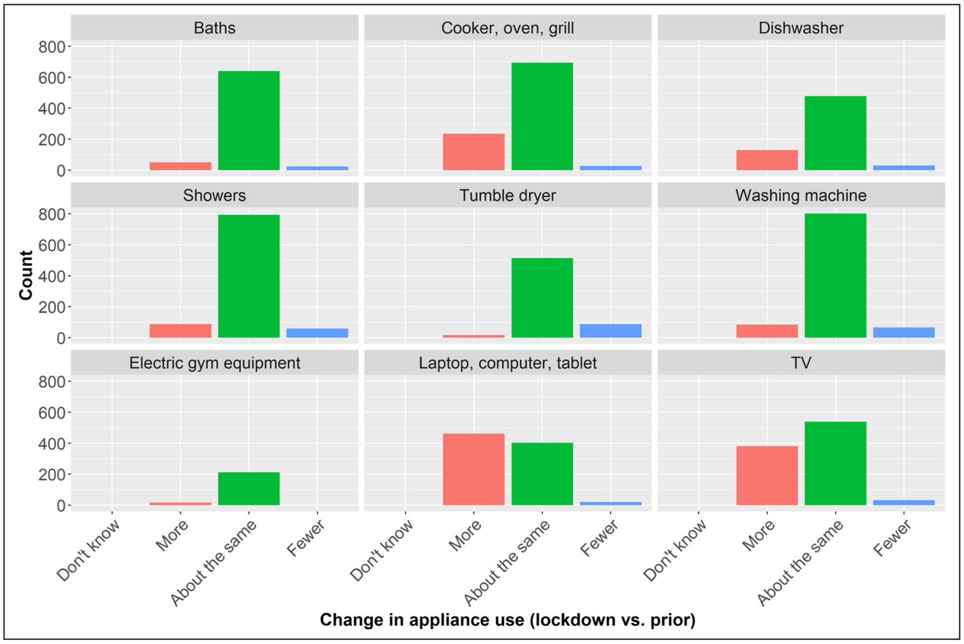

Figure 5: Changes in appliance use in lockdown compared with before lockdown.

For all activities, doing it for the same amount or with the same frequency in lockdown compared with pre-lockdown was the most common answer, except for using laptops, computers and tablets. Here, most respondents indicated using it more often in lockdown than beforehand. The only activity that respondents indicated doing less in lockdown was the use of the tumble-dryer. Pronounced increases in lockdown were seen in television, cooking and dishwasher use.

A second block of questions, only present in the online survey version, asked about the timing of activities (***Figure 6***). Respondents indicated both pre-lockdown (N_{valid} = 509) and during lockdown (N_{valid} = 522) when they carried out the activities from the previous question.

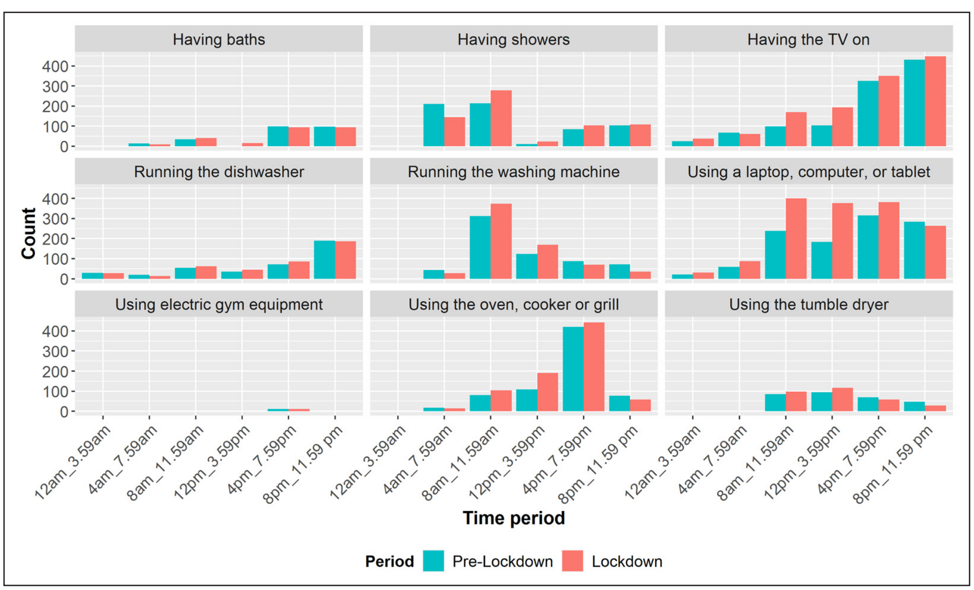

Figure 6: Timing of activities before and during lockdown.

No changes occurred in the timing of having baths, and using both the dishwasher and tumble-dryer. For cooking, about 80 additional responses were given for cooking around midday. Changes were most pronounced for watching television and using laptops, computers and tablets. These activities increased in frequency and were spread out across the day during lockdown.

3.4 USAGE OF IN-HOME DISPLAY, MANAGING FINANCIALLY AND EFFORT IN SAVING ENERGY

Respondents were asked how often they use the IHD that shows their energy consumption (an exact valid *N* cannot be released for statistical disclosure control, but was between 980 and 1016). The most common answer was 'Never' (30.3%), followed by 'Most days' (22.8%) (***Figure 7***); '*DK_NA*' stands for 'don't know' or not applicable as answers.

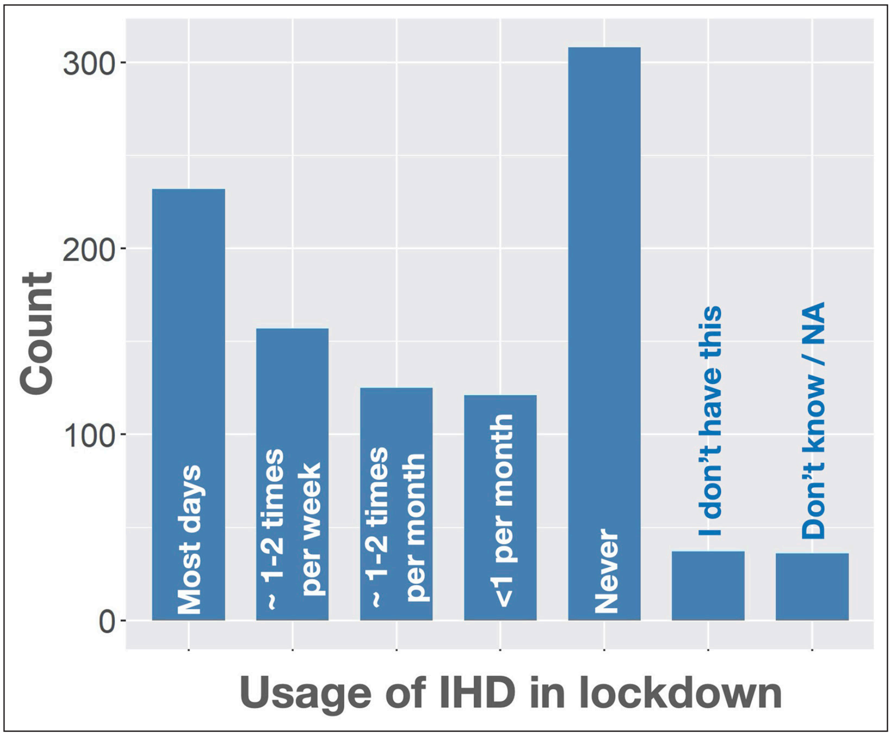

Figure 7: Frequency of in-home display (IHD) usage in lockdown.

Most respondents indicated that their usage of the IHD had not changed during lockdown (80.3%), with 8.8% indicating using it more often, and 10.9% less often (N_{valid} = 852).

Respondents indicated how much effort they made to save energy during lockdown (N_{valid} = 989). This question had also been asked in the background survey (N_{valid} = 1004), and it was hypothesised that the effort to save energy would have increased in lockdown. As already clearly visible in ***Figure 8***, this was not the case: the majority indicated having made no effort at all during lockdown, whereas pre-lockdown that answer was hardly chosen, and most respondents chose 'some effort' or a 'great deal of effort'.

A Wilcoxon signed-rank test confirmed that the difference was significant, V = 288,885, p < 0.001, samples estimates: (pseudo-) median = 1.500 (95% CI 1.499–1.500), based on 980 cases. Hence, Hypothesis 2 of greater usage of the IHD during lockdown compared with pre-lockdown was not supported.

To understand if those who reported using the IHD more were more likely to say they attempted to save energy, the Spearman rank-correlation coefficient (N_{valid} = 934) was calculated. Anyone who had stated 'don't know' to either question or reported not having an IHD was excluded. There was a significant positive correlation between the effort to save energy and the usage of the IHD, r = 0.244, p < 0.001, supporting Hypothesis 3. However, the correlation coefficient is small.

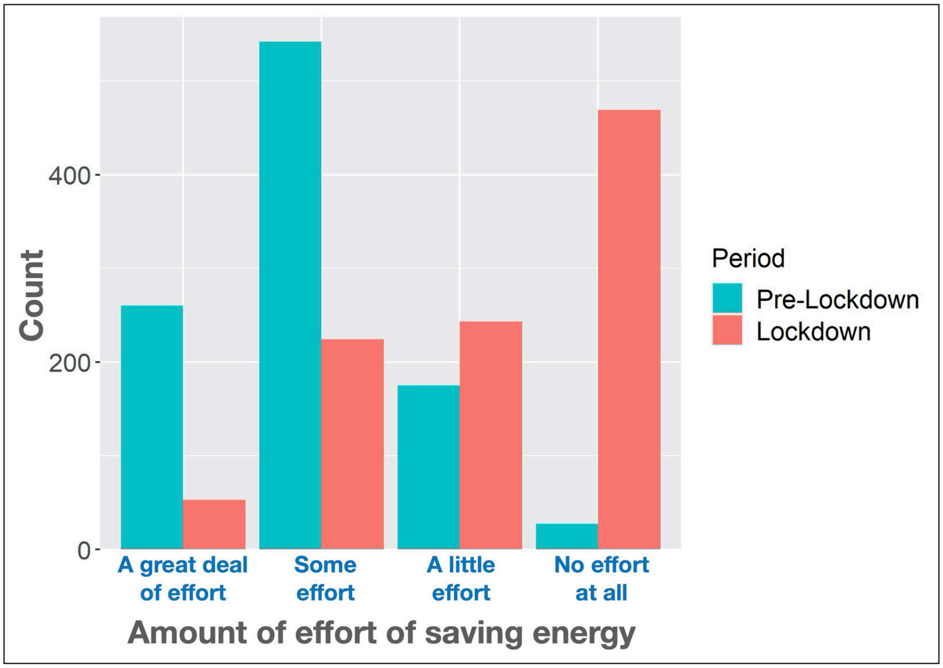

Figure 8: Effort to save energy pre- and during lockdown.

Respondents also indicated how well they were managing financially during lockdown (for statistical disclosure control reasons, the exact valid *N* cannot be released, but it was between 975 and 1016). The answer categories 'finding it very difficult' and 'finding it quite difficult' were combined into 'difficult' for statistical disclosure reasons. ***Figure 9*** shows that about 80% of the sample were 'living comfortably' or 'doing alright'.

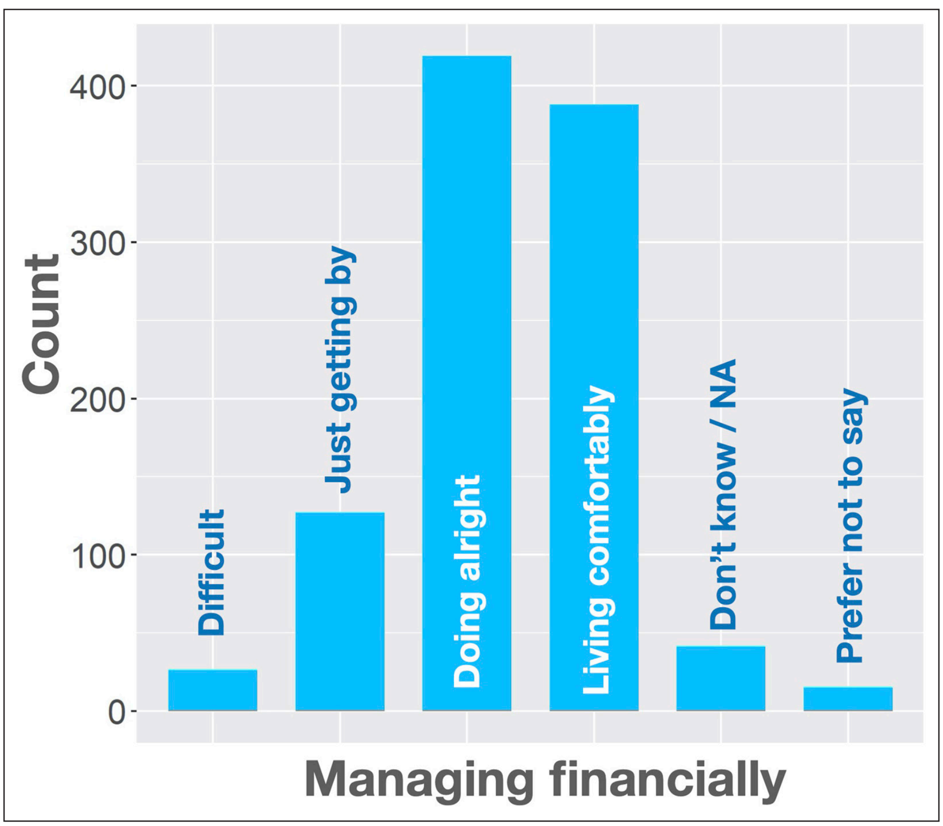

Figure 9: Managing financially during lockdown.

To understand if those who indicate doing less well financially were more likely to say they attempted to save energy, the Spearman rank-correlation coefficient (N_{valid} = 948) was calculated. Anyone who had stated 'don't know' to either question, did not provide an answer or chose the option of 'prefer not to say' for the question on financial status were excluded. There was a significant negative correlation between the effort to save energy and managing financially, $r = -0.196$, $p < 0.001$; hence, Hypothesis 4 was supported. However, the correlation coefficient was small.

3.5 WINDOW-OPENING

In both the Covid-survey and the background survey, respondents indicated how often they opened windows on a cold and on a warm day (***Figure 10***).

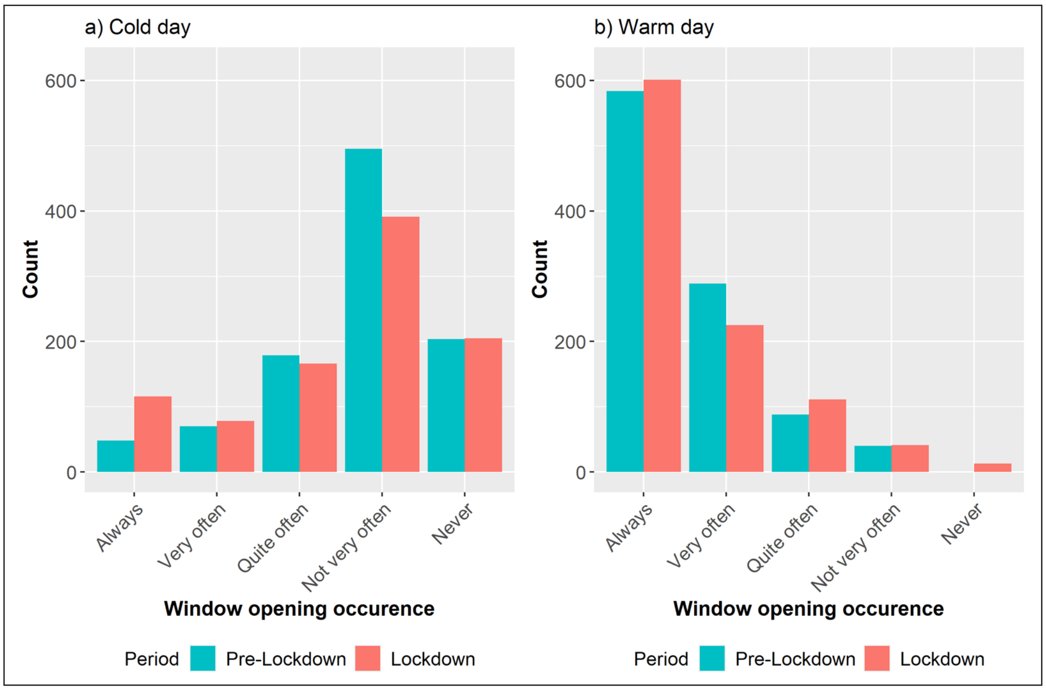

Figure 10: Frequency of window-opening pre- and during lockdown for **(a)** a cold and **(b)** a warm day.

Complete cases across both surveys were N = 938 (cold days) and N = 980 (warm days); exact valid N for the individual surveys cannot be released for statistical disclosure control reasons, but were above the numbers of complete cases across survey and < 1016. A Wilcoxon signed-rank test was used to test Hypothesis 5 that window-opening increased during lockdown. It was supported for cold days, V = 77,757, $p < 0.001$, sample estimates: pseudo-median = 0.4999, 95% CI = 0.00–0.500. The hypothesis was not supported for warm days.

4. DISCUSSION

The survey carried out with N = 1016 respondents about their energy use during the first Covid-19 lockdown showed comparatively few changes in energy-use practices. Contrary to expectations, for heating behaviour, neither an increase in heating-hours, in the number of rooms heated nor in thermostat settings was reported. Some changes in appliance use were reported, such as increased usage of cooking appliances, televisions and laptops/computers/tablets, and their usage was spread out more over the course of the day. Those who were doing less well financially reported using their IHD more often, as shown by a significant negative correlation between the two variables and a greater attempt to save energy correlated with greater usage of the IHD; overall usage of the IHD did not change. Given that national statistics implied an increase in residential energy use, these results are somewhat surprising.

One possible explanation is that although respondents spent more time at home, they did not increase their heating-hours, number of rooms heated and demand temperature. For gas (which is predominantly used for heating in the UK), only weather and seasonality-adjusted data showed an increase during the quartile that contains all but one week of the initial lockdown (BEIS 2020c). However, the quartile covered in those data (April–June) also went beyond the period of the strict lockdown that ended on 11 May, providing only limited comparability. In any case, an absolute increase in those heating behaviours is not necessary to be congruent with these data, only a lesser decrease than expected based on weather and season.

About half the sample was not working before or during lockdown, *i.e.* lockdown might have had a lesser impact on how much time this cohort spent at home and hence their heating behaviour. For those who stayed home more during lockdown than before, there was a likely increase in heating-hours. Hence, studying changes in subgroups will be important in understanding the implications of increased working from home.

In general, home occupants might not be particularly willing to change heating patterns. One study among 52 social housing tenants showed that the majority of participants did not change the settings of the thermostatic radiator valves during the heating season (Huebner *et al.* 2013).

A second explanation is that self-reported changes in space heating are not a very reliable indicator of people's actual energy behaviour. Given that there was a time lag of at least two months between the lockdown's start (March 2020) and the survey (May–June 2020), self-reporting might not have been very accurate, in particular for heating behaviours for which respondents were asked to think back about cold days during lockdown. If this explanation is true, it brings into question the value of self-reported data on energy use which are widely used in domestic energy research.

Data on an increased frequency and duration of the use of certain appliances (*e.g.* television, computing equipment and cooking) and a wider spread over the course of the day are in line with other findings on electricity use during lockdown (Chen *et al.* 2020; García *et al.* 2021; Santiago *et al.* 2021; Snow *et al.* 2020). For both heating behaviour and electrical appliances use, survey findings ought to be linked to actual energy consumption to understand their actual effect on energy used during lockdown. For all households in this survey, smart meter data pre- and during lockdown are available.

Overall IHD usage had not increased in lockdown. Snow *et al.* (2020) reported that respondents indicated using it even less during lockdown, given the stressful situation the pandemic posed. Usage of the IHD correlated negatively with being able to manage financially and positively with the effort to save energy. Receiving real-time feedback on energy consumption can lead to significant energy savings (Delmas *et al.* 2013). Indeed, the UK government has adopted smart meters and IHDs at least in part to 'help give consumers more control over energy use and spending' (Navigator 2012: 4), and consumers are expected to realise financial savings from smart meters and IHDs (DECC 2013). The correlations around IHDs found in this study support such aims, though it needs to be emphasised that correlations are small, do not imply causality and some findings support scepticism around the ability of current IHDs to deliver a decrease in domestic energy use (Buchanan *et al.* 2015).

The results around the effort to save energy are puzzling. The effort to save energy was substantially lower in lockdown compared with pre-lockdown. A new wave of recruitments for the SERL project in September 2020 showed replies to the question on the effort to save energy very similar to the baseline survey (Elam *et al.* 2021), *i.e.* both before and after lockdown the effort to save energy was comparable and much higher than during lockdown. One possible explanation is that respondents misunderstood the question as to whether lockdown caused them to make an extra effort to save energy beyond what they were already doing anyway. The second explanation is that the responses to the question on the effort to save energy in the background survey were preceded by other questions on energy-saving behaviours which might have influenced the answer on the effort to save energy. Those questions were not used in the Covid survey. However, nationally representative surveys show that overall climate change concern was high in March and June 2020 with about 80% of respondents concerned about climate change (BEIS 2020a), and over half of respondents indicated in March 2020 that they tried to minimise the amount of energy they use in the home (BEIS 2020b); hence, it seems more likely that respondents misinterpreted the question. Finally, similar to the usage of the IHD (Snow *et al.* 2020), it could be that participants were simply too preoccupied with the pandemic to give energy saving any particular attention.

The hypothesis that window-opening had increased during lockdown was supported for cold days, though the effect was small. The main rationale for including this hypothesis was that increased occupancy of a home will lead to the greater production of moisture and hence mandates the need for more ventilation, *i.e.* window-opening. Dampness leads to increased mould growth and dust mites, which might have implications for building and occupant health (Clark 2004; Koskinen *et al.* 1999). The results imply that occupants only increased window-opening by a very small amount, which might increase the chance of issues around damp in the homes. The longitudinal element of the SERL project will allow tracking this over time.

In general, it needs to be kept in mind that the sample consisted of participants who had opted in to a study on smart meters and the sample was biased towards those who are better off, living in non-deprived areas and in detached homes. Hence, the generalisability of the findings to other parts of the UK population is limited. Especially, financial dissatisfaction might have been more pronounced in a more representative sample (ONS 2020e). Also, as the data were solely based on retrospective self-report, it is not possible to estimate how accurate the answers were. Any future study with a similar aim, *i.e.* understanding changes in a crisis situation, should collect data whilst the particular crisis situation is still ongoing. This was not possible for this study given the need for survey development, the ethical approval process and the partly postal roll-out but would likely increase fidelity of results.

5. CONCLUSIONS

Self-reported energy-use showed comparatively little change in heating behaviour during the first Covid-19 lockdown in England and Wales; appliance-use data showed that the demand was spread out more over the day and also showed an increased usage of cooking, television and computers. This study also supports the notion that in-home displays (IHDs) may support energy-saving behaviour and might be of particular importance to those doing less well financially. Hence, promoting their use should be a key consideration at point of smart meter installation.

Only a subgroup of the sample studied spent more time at home during lockdown than before, as judged on their work status, *e.g.* because they were retired, continued to go to work or already worked from home. To understand the implications of homeworking explicitly, it will be important to focus on subgroup analysis. The findings suggest it would be oversimplified to assume that electricity and gas use have increased in all homes because of a stay-at-home order. The crucial next step is to compare actual energy consumption normalised for weather with self-reported energy behaviours, which is the next planned analysis of the SERL Covid-19 data.

NOTES

1 See *https://serl.ac.uk/*.

2 For statistical disclosure reasons, how many surveys were duplicates from households that had moved or which had not filled in the background survey cannot be revealed.

3 The numbers of the hypotheses have changed in relation to pre-registration to allow a better flow of results, but they have stayed unchanged in what they test.

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COMPETING INTERESTS

The authors have no competing interests to declare.

DATA AVAILABILITY

All data collected as part of the SERL project are accessible to all accredited UK academic researchers with access to pseudo-anonymised data via a Secure Lab environment (for details, see SERL 2021).

ETHICAL APPROVAL

The study was approved by the departmental ethics committee at the Bartlett School of Energy, Environment and Resources (BSEER), University College London, which has the authority to approve low-risk studies such as this one.

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SUPPLEMENTAL DATA

Supplemental data for this article can be accessed at:

- **Appendix 1a.** SERL Covid-19 survey (email respondents). DOI: *https://doi.org/10.5334/bc.162.s1*
- **Appendix 1b.** SERL Covid-19 survey (paper respondents). DOI: *https://doi.org/10.5334/bc.162.s2*
- **Appendix 2.** SERL Consent form. DOI: *https://doi.org/10.5334/bc.162.s3*
- **Appendix 3.** Deviations from the pre-specification. DOI: *https://doi.org/10.5334/bc.162.s4*
- **Appendix 4.** STROBE statement. Checklist of items that should be included in reports of cross-sectional studies. DOI: *https://doi.org/10.5334/bc.162.s5*
- **Appendix 5.** The TReQlist: a checklist for reporting of tools that promote transparency, reproducibility and quality of research. DOI: *https://doi.org/10.5334/bc.162.s6*

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