Assessing the impact of lockdown due to COVID-19 on the electricity consumption of a housing development in the UK

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Abstract. In March 2020, the United Kingdom (UK) government ruled that householders must stay home as a response to the COVID-19 outbreak to help flatten the curve of the epidemic and reduce the exponential growth of the virus. Commercial activities, workplaces and schools were obliged to temporarily close in compliance with the government rules. This first and most restrictive lockdown took place from late March to early May 2020 when occupants had to stay in their homes except for very restricted essential activities. Two other lockdowns were introduced in November 2020 and January 2021, alongside with a range of restrictive measures during 2020. This offered an unprecedented opportunity to investigate the impact of a prolonged period of occupancy on household electricity consumption. In this work, the authors compared electricity consumption data collected from 21 energy-efficient houses in Nottingham, UK, during these lockdown periods to the same period in previous year. The findings indicated that the monthly electricity consumption in April 2020, during the strictest lockdown, increased approximately 5% in comparison to the same period in 2019. The daily electricity consumption profile during this lockdown showed earlier and longer peaks in the evenings with the emergence of a new midday peak in comparison to typical daily peaks prior to lockdown. The findings supported the idea that electricity consumption is increased as a result of the proportion of time residents spend in their homes and this corresponded to 17% more in 2020-2021, when restrictive measures were in place.

Keywords: Electrical Energy; Electricity; Consumption; Domestic consumption; Household consumption; Occupancy; Covid-19; lockdown.

1 Introduction

The domestic sector accounts for 30% of UK national electricity consumption [1]. The contribution of self-generation within the sector has increased considerably, corresponding to 1.6 TWh of electricity in 2018, but this still only represented 1.5% of the sector's electricity consumption [1].

Household electricity consumption has been slightly reduced over the years due to continued energy-efficiency improvements and renewable generation [1]. Even though most of the improvements in the households impact more directly on heating consumption (e.g., insulated and airtight building envelope), which is mostly provided by gas [2], these improvements also include optimisation on the housing size and shape, the design of well-sized windows for natural lighting and the use of energy efficient lighting and appliances.

Nonetheless, one of the most important factors in the household energy consumption still is the patterns of use and occupancy, attributed to occupant's behaviour [3-5]. The energy consumption due to occupancy is determined by a series of variables such as the number and age of occupiers, the proportion of time residents spend in their homes, the way that they inhabit the indoor spaces (e.g., lights on, multiple use of electrical appliances and equipment), activities conducted (e.g., cooking, sleeping) and the amount of electrical equipment and its usage.

Householders are typically in their homes for a significant amount of time, but changes in lifestyle have increased the number of hours that they are out. The increase of working hours and commuting times are some of the reasons that have contributed to less time at home [6]. The emergence of the COVID-19 pandemic in early 2020 forced the implementation of lockdown measures by the UK government in order to flatten the curve of the epidemic and reduce the exponential growth of the virus [7]. This maximised the time spent at home for the great majority of people, prompting a series of challenges within the built environment and a great opportunity for research into energy usage within fully occupied domestic buildings and the impact of this on their communities.

UK policy responses to COVID-19 were very distinct and rapidly evolved over the course of 2020 [8]. Establishing a timeline of these responses was an essential step to understand their impact on the domestic sector. For this study, the main interest is to understand the policies that focused on limiting people's movement in 2020 and 2021 to reduce the spread of COVID-19. These can be seen in **Fig. 1**.

In this paper, the authors looked at electricity consumption data of 21 dwellings to assess potential changes in their electricity demand due to the stay home measures in response to the COVID-19 pandemic. This situation offered a unique opportunity to investigate prolonged occupancy in housing and the overall impact on the built environment and energy systems. This work can contribute to increase preparedness to adapt homes and their energy systems, inform the optimisation of community energy schemes and help increase the resilience of urban infrastructure.

2 UK Domestic Electricity Consumption

Typical domestic consumption values (TDCV) are considered to be reasonably consistent in the country [9]. Data from Office of Gas and Electricity Markets (Ofgem), organisation that regulates electricity and natural gas in Great Britain, estimates an electricity consumption of 2,900 kWh/year in 2020 [10], a reduction from the previous years, estimated to be 3,100 kWh/year in 2017 [11] and 3200 kWh/year in 2013 [12, 13]. Using 2020 data, this represents approximately 8 kWh daily and 242 kWh monthly.

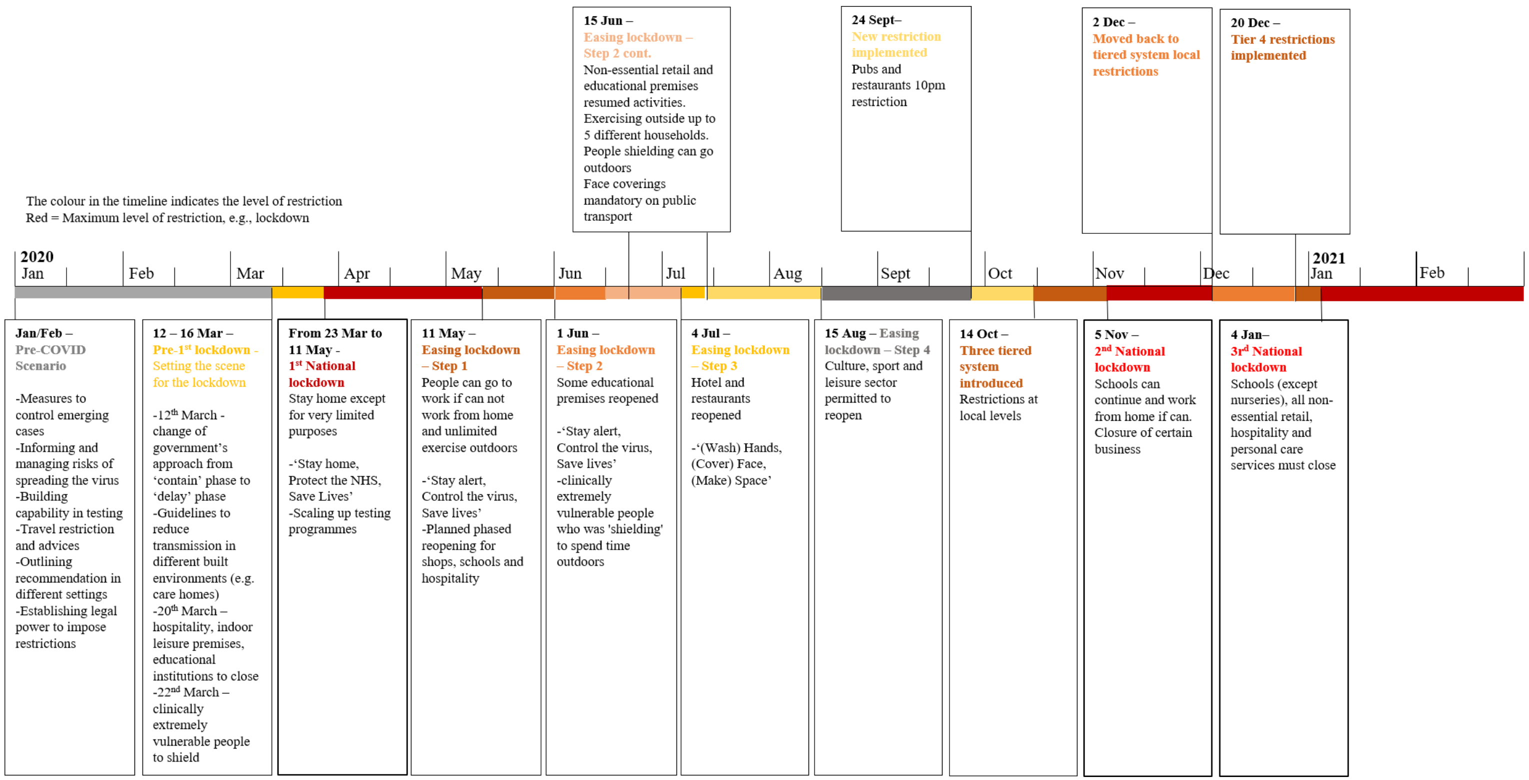

Fig. 1. Timeline of national restrictions to limit spread of COVID-19 as illustrated by the authors, based on Dunn, P., et al. [8]

These are median figures and exclude very high users of electricity, and hence can be thought of as being more representative of typical household consumption.

Nonetheless, a study conducted between 2010 and 2011 investigated 251 owner-occupier households and suggested a TDCV of nearly 3,700 kWh/year [14]. This is equivalent to over 10 kWh daily and nearly 310 kWh monthly. These figures exclude heating demand, which is mostly supplied by gas in the country.

Typical UK domestic electrical energy consumption profile consists of daily peaks that occur in early mornings and evenings [9]. Morning peaks have been reduced over the years associated to changes in lifestyle. Evening peaks have been delayed in time also due to changes in the routine. These are relatively consistent themselves throughout the year and are the highest levels of household electricity demand [6].

The magnitude of the peaks is not only determined by the time of the day, but also by the day of the week (weekday or weekend) and seasonality [6]. Whilst the daily demand in the week is bigger than in the weekend, it is estimated that the difference between weekdays and weekend days has diminished [6] given the range of activities the occupants do outside of their homes over the weekends. Also, seasonality effect should be accounted in the energy use. Whilst, cold appliances are responsible for higher energy usage in summer, lighting, wet appliances (washing/drying) and cooking (e.g., oven, hob, kettle, microwave) have higher usage in winter [15, 16].

A study that analysed households electricity consumption data between 1974 and 2014 demonstrated that one of the shifting patterns associated to the electricity consumption reduction over the years was food-related [6]. It consisted of the reduction of breakfast and lunch times and the push to a later evening peak, which was driven by social transitions such as patterns of employment, longer working hours, home-coming times, and commute hours. The study also suggested that the household's electrical energy consumption during the typical work hours was also reduced over the years as consequence of a social style, with few people working from home and most of households in a working-away system, that included not only males but females [6].

In the context of COVID-19 outbreak and the imposed Stay Home period, these changes in the household's electricity consumption were most attenuated as most meals were eaten at home, commuting was excluded from the daily routine and working hours were flexible. These applied for most of the householders that were not essential workers, such as health and delivery workers in the first national lockdown.

Whilst an overall decrease in the electricity consumption was observed during the first lockdown due to the reduction of certain activities such as commercial, educational, and institutional, the households had an increase of their demand. However, the domestic electricity demand was reported to be increased by only a few percentage points, rather than dramatically surging and this corresponded to 3-6% increase [17]. Considering UK average electricity prices of 0.144 GBP/kWh, this would correspond to an average annual electricity bill increase of 15-29 GBP, respectively [18].

3 Method

Electricity consumption data collected from 21 dwellings was used to analyse the impact of prolonged occupancy on domestic energy consumption. The investigation considered the period from the start of March 2020 to the end of February 2021, which corresponded to a year-period where a range of restrictive measures were in place. Electricity data from the same corresponding period in 2019 and early 2020 was used for comparison purposes.

3.1 Trent Basin Community Energy Scheme

Trent Basin is a housing development and community energy scheme built in Nottingham. It comprises low-energy houses and community assets, which include one of Europe's largest community energy batteries with a capacity of 2.1 MWh and a photovoltaic panel system rated at 200 kWp. The development is structured into different phases. The first phase is the object of this work, which consists of 35 semi-detached and terraced 3-storey houses (3-5 bedrooms) with areas of nearly 110 square metres, and an apartment tower with 10 housing units (2-3 bedrooms) of circa 60 square meters [19]. The project was chosen mostly because of the availability of robust datasets and access to buildings and their users.

3.2 Monitoring Households

A total of 21 participating households were considered in this study. Electricity data was collected over a period of two years using Class 1 energy sensors [20]. The sensors were installed in the consumer unit and connected to a cloud platform for data storage and analysis [21], which allowed the continuity of data collection during the pandemic. Motion count data was also used to provide occupancy information. Data was collected from a passive infrared motion sensor, installed in the main hallway of the property. A count was incremented whenever the sensor was triggered thus giving a measure of occupancy. The data collected was made available through an on-line data platform.

In the monitored houses, electricity is the energy source for lighting, appliances, and electrical equipment, while gas is the energy source for hot water and heating. Gas consumption is not analysed in this work due to lack of metering and little use of central heating due to an energy-efficient envelope, which reduces consumption in mid-season.

4 Results

Yearly average electricity consumption across the 21 monitored households corresponded to 3054.4 kWh in 2020-2021 during COVID-19 restrictions, this represented a consumption of approximately 17% more than in 2019-2020, prior to restrictions (**Table 1**). Considering UK average electricity price of 0.144 GBP/kWh [18], this corresponds to an increase of 65 GBP per year. Monthly consumption was consistently higher in 2020-2021 when compared to 2019-2020 (**Fig. 2**). The average daily electricity consumption was equivalent to 8.4 kWh, over 1kWh more than in 2019-2020.

Looking at the monitoring households individually and using data from April 2020, which corresponded to the period with the strictest lockdown and restriction measures, the findings suggested that most of houses showed an increase of their electrical energy consumption in comparison to the same period in 2019. This increment in the demand varied from 9% to up to 95% more in April 2020 than in 2019 (**Fig. 3**).

Table 1. Electricity consumption in 2019-2020 and 2020-2021, in kWh.

Period	2019 March - 2020 February	2020 March – 2021 February
Daily average	7.1	8.4
Monthly average	216.9	254.5
Yearly average	2603.4	3054.4

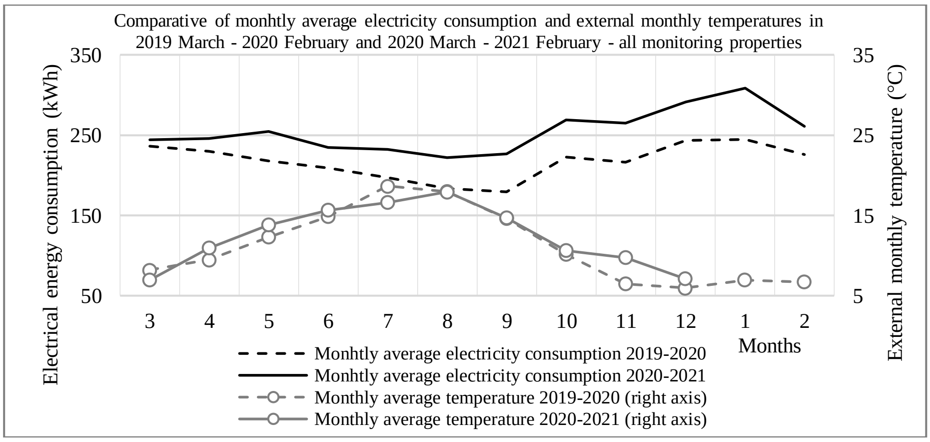

Fig. 2. Monthly average electricity consumption – all properties

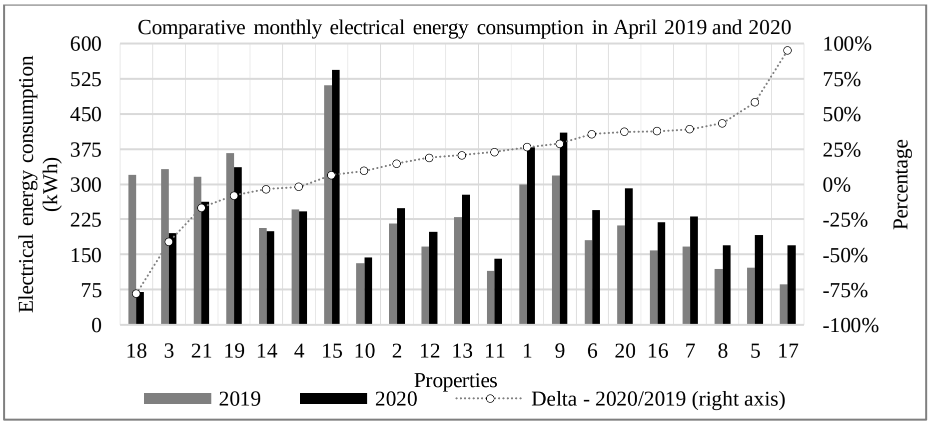

Fig. 3. Monthly electricity consumption in April 2019 and 2020 – per property

However, a total of 6 households (29% of the sample) showed higher demand prior to the restriction measures in 2019-2020 (these were properties number 3, 4, 14, 18, 19 and 21). In 2 out of these 6 houses (house number 4 and 14) this difference was very small and considered to be almost negligible. This might suggest that there were not significant changes in the household's lifestyle (e.g., working from home prior to lockdown, pensioners, key workers).

Property number 18 showed a considerable drop in the energy consumption in 2020, which when cross-compared with collected motion count data for the corresponding period, seems to suggest an unoccupied or partially occupied house in comparison to the same period in 2019. Motion count had readings equivalent to 20 in April, 601 in March 2020. This same property had readings of 4198 and 4812 in March and April 2019. It should be mentioned that the national restriction measures limited households to mix with each other. As consequence, some households opted to stay and self-isolate at other residencies with family members.

The week prior to the first and strictest lockdown (commencing on 16th March) was compared to the first week in lockdown (commencing on 23rd March). The findings indicated an increase in energy consumption in the majority of monitored houses. However, this increase showed a variation from approximately 1% (house number 11) to up to 132% (house number 12) (**Fig. 4**). Only three dwellings had a higher consumption in the week prior to lockdown in comparison to the first week in lockdown (house number 15, 18 and 21). This was more significant in property 18, which, as mentioned before, was associated to an unoccupied or partially occupied property.

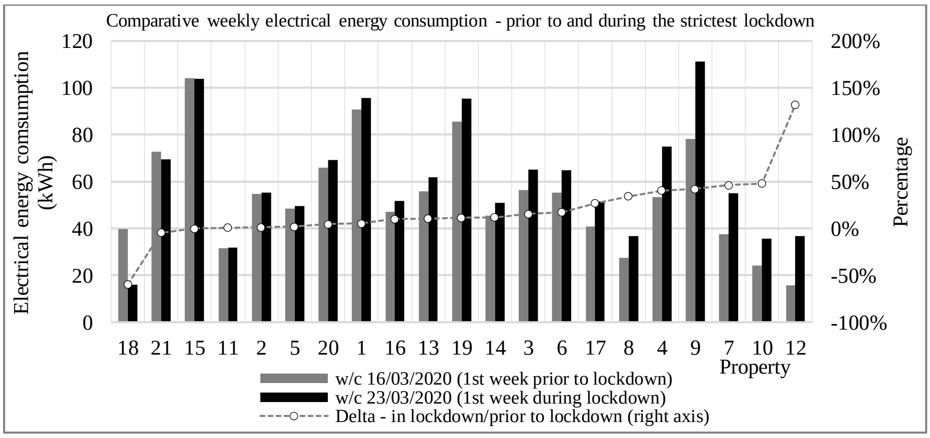

Fig. 4. Weekly electricity consumption per property – week prior to and first week in lockdown

Hourly profiles were investigated comparing the same corresponding day of the week before and during the lockdown for the dwellings that showed an increment in their consumption. The results demonstrated a peak around noon followed by a more distributed evening peak. Prior to lockdown period, evening peaks were higher and started later than during lockdown. An example of this can be seen in **Fig. 5**.

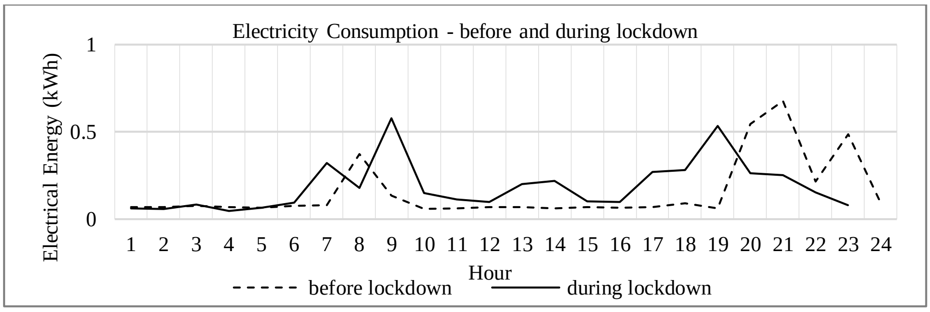

Fig. 5. Example of hourly profile of electricity prior to and in lockdown – single property

5 Discussion

Data from the Trent Basin monitored households was used to explore the impact of the Covid-19 pandemic on domestic electricity consumption. The results of the 21 monitoring households during a 2-year period revealed an overall increase in the consumption during the restriction period (2020 March-2021 February) in comparison to the same period prior to restrictions (2019 March-2020 February) of 17%, equivalent of an extra 65 GBP per year. These findings are higher than those suggested by the electricity providers, which state an electricity consumption increase of 3-6% within the UK domestic sector, as a consequence of the stay home measures. It should be noted that 2020-2021 included a range of different levels of restrictions and the period included in this investigation accounted for the three lockdowns in the UK (**Fig. 1**).

When cross-comparing **Fig. 1**, which illustrates the national policies to tackle COVID-19, and **Fig. 2**, which shows monthly average electricity consumption in 2020-2021, there is no direct correspondence. One of the lowest differences in the consumption between 2021-2020 and 2020-2021 occurred in April, the same period when the strictest lockdown was in force. The energy consumption increase corresponded to nearly 5% and showed to be within the expected national limits. It should also be mentioned that the monthly average temperature in April 2020 corresponded to 11°C, 1.5K higher than in 2019, and this might have helped reduce the difference in the consumption between 2020 and 2019. Cooking and laundry appliances as well as lighting are influenced by seasonality [16]. This suggests that stay at home is not the only determinant aspect to increase the energy consumption and other variables such as lifestyle and temperatures are other important factors in the demand, as suggested by the literature.

This intertwined relationship between prolonged occupancy and climate can also be observed when looking at September 2020, when monthly averages between 2019 and 2020 were practically the same (14.7°C) but the consumption in 2020 had one of the highest differences in comparison to the same period in 2019. In September, the measures were eased but staying home and social distancing were strongly advised.

Looking at households individually during the strictest period, 71% of the households had their demands increased and 29% had their consumption decreased related to the previous year. However, houses with lower demands in lockdown seemed to be associated to lack of occupancy. This shows the importance of combining energy consumption data with occupancy data (e.g., motion count, questionnaires) for better understanding of how residents have inhabited their homes and what changes were made.

Another relevant aspect to be considered within this context is the increased ownership of electrical vehicles (EV). The reduced need for EV charging when working from home tends to significantly decrease electricity consumption in comparison to when the period that EV charger is used on a regular basis.

Even though this work used motion count as occupancy data, one of the limitations is the lack of evidence gathered with the residents about how the houses were inhabited. This would help better understand the data collected and explain deviations on the data. For example, the reason why some households had no significant change in their lifestyle. This could be linked to householders that are pensioners or are working from home prior to lockdown or yet have left their homes unoccupied in lockdown.

6 Final Considerations

This work examined electrical energy data of energy-efficient homes, which are part of a community energy scheme, in Nottingham, UK. A total of 21 homes were monitored over a 2-year period. This research aimed to investigate whether there was an increase in the electricity demand in 2020-2021 when compared to 2019-2020, as a result of the UK measures restricting people's movement to reduce the spread of COVID-19.

Findings suggested that during 2020-2021 the households had an average increment in their annual average consumption of 17% when compared to 2019-2020, which corresponds to an additional cost of 65 GBP. At household levels, the analysis of the weekly data prior to and in lockdown mostly indicated an increase in their consumption due the restrictive measures and stay home rules, varying from nearly 1% to up 132% more, depending on the property. Few properties showed a reduction in the consumption of up to nearly 60% but the highest reduction was associated to an unoccupied or partially occupied property. The research also identified that seasonality may play an important role alongside with lifestyle and patterns of occupancy.

Cross-comparison between consumption and occupancy data (e.g., working patterns), showed to be relevant to provide detail on how the properties were occupied. Motion count was used to help identify if houses were inhabited or not.

Hourly analyses identified a new trend in the electricity consumption, with a new peak around noon when cooking was added to the baseline of daily consumption. Early morning electricity demands were delayed or reduced when compared to the previous pattern, while evening peaks were earlier than before and spread across the evening.

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