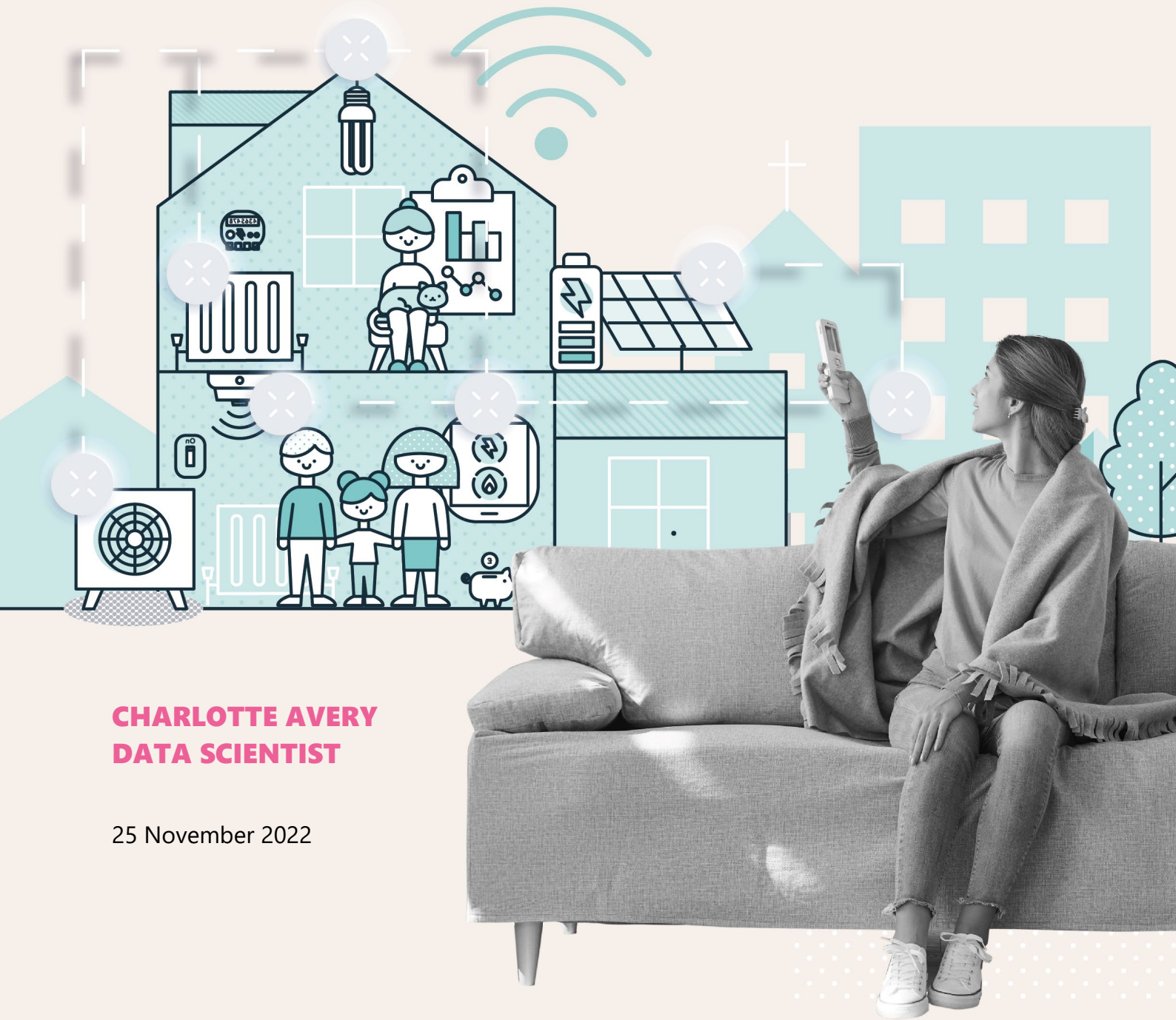
LIVING LAB

CATAPULT Energy Systems

MEASURING THE CONSUMER RESPONSE TO THE ENERGY CRISIS

Investigation into how people in the Living Lab have changed the way they use energy to heat their homes



CHARLOTTE AVERY
DATA SCIENTIST

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CONTENTS

1. EXECUTIVE SUMMARY

For a sample of 36 homes from the Living Lab, we compare the total gas consumption during the period of 1st September to 31st October in 2021 and 2022, where the impact of external temperature on household gas consumption has been removed. We find that homes have consumed approximately 30% less gas during this period this year compared to last year (when energy prices were substantially lower). We further find, by estimating the gas consumed for home heating, that Living Lab participants are using 40% less gas for heating this year compared to last year during these months. These results indicate that external weather cannot account for the decrease in gas consumption seen over the period when gas prices have more than doubled.

Further analysis of gas smart meter data suggests that a minority of participants have delayed turning their heating on this year, with the proportion of people heating their homes in October being lower this year compared to last year, despite the external temperature at the location of each home being similar during October of 2021 and 2022.

Data from Tado sensors monitoring the temperatures of rooms within 85 Living Lab homes is used to measure the average internal temperature of homes. We find that homes are being kept approximately 0.6ºC colder, on average, during September/October this year compared to last year.

These results combined show that consumer behaviour has changed significantly during the energy crisis where consumers are using less gas and are keeping their homes at lower temperatures compared to before the energy crisis.

Key points

- Living Lab homes used 40% less gas, on average, for heating during September/October this year compared to last year.
- Living Lab homes were being kept approximately 0.6ºC colder on average during October this year compared to last year.
- There is weak evidence for participants delaying turning their heating on this year, where their heating was already turned on by October last year.

By considering, and accounting for, the impact of external temperature on household gas consumption we show these results are not reflective of differences in external temperature between 2021 and 2022.

2. BACKGROUND

The cost of energy has changed dramatically over the course of the previous year, and there is no reassurance that the trend of increasing energy prices will plateau as we progress through 2023. It is likely that the way in which people are managing their energy usage has changed as a result, in particular extra considerations will be made when deciding to heat our homes as we enter winter. However, the proportion of people significantly changing their behaviour due to the energy crisis, and the amount by which they do, is uncertain and difficult to quantify.

Energy Systems Catapult's Living Lab offers a database comprising 1500 homes throughout the UK. Historic and present energy usage data is recorded for hundreds of these homes, including smart meter and Tado room-temperature monitoring data. This report is based on the gas smart meter data and the room-temperature data collected by the Living Lab over the previous year. By comparing the gas used by Living Lab participants in 2021, when the energy prices were substantially lower (see Table 1) to the present time of writing, we are able to (a) investigate whether there has been a change in the way participants are heating their homes by quantifying the amount of gas participants are using to heat their homes in October this year, compared to in October 2021, (b) investigate whether a proportion of participants have delayed turning their heating this year during the energy crisis by measuring the proportion of participants that turned their heating on before November last year compared to this year.

	2021	2022
Gas price (p/kWh)	4.1	10.3
Electricity price (p/kWh)	20.8	34.0

Table 1: average gas prices in the fourth quarter of 2021 and 2022 with the price cap[1].

This study comes with the caveat that our sample is small and non-representative of the UK population. We further point out that this analysis was performed in November 2022 so it cannot be used to make statements about the way people will use their heating over the winter during the energy crisis. We also point out that in this analysis, we have not considered the impact of consumer routine changing between 2021 and 2022 (participants returning to work, for example).

3. METHODOLOGY

3.1. DATA AND HOME SAMPLE SELECTION

For each home in the Living Lab, gas consumption readings from the smart meter are aggregated over each day and Tado room temperature readings are averaged over all rooms in the house each day.

To investigate the use of gas for heating, we compare the gas consumption throughout the period 1st September to 31st October 2022 to the same period of the year in 2021 when the energy prices were substantially lower. Therefore, to select a sample of homes for this analysis, their associated smart meter data must meet the following requirements: 1) smart meter data must date back to at least to October 2021; 2) homes must not have zero total gas consumption throughout the month of October in both 2021 and 2022. The motivation for (2) is that most homes selected from criteria (1) have hot water heating via gas boilers, so we expect the total gas consumption reading to be greater than zero if the boiler is switched on. Homes with heating via heat pumps are further excluded from our sample since this analysis relies on gas usage data to estimate energy used in heating. The final sample consists of 36 homes.

In this report, we further investigate the internal temperatures of homes throughout the period 1st September to 31st October. There are 85 homes with Tado data, 29 of which have sufficient gas smart meter data to fall within our sample of 36 homes.

3.2. COMPARING GAS CONSUMPTION WHILST REMOVING EFFECTS OF OUTSIDE TEMPERATURE

To make an appropriate comparison of the energy used before (September/October 2021) and during (September/October 2022) the energy crisis, we need to account for any external temperature difference which may influence when people turn their heating on, and the amount of energy they use for heating. This is achieved by calculating the Heating Degree Days (HDD)[2] at the location of each home, over the months considered. Heating Degree Days is a measure of how long the outside air temperature was below the 'base temperature', Δt (measured in days), and by how much it was below this temperature ΔT (measured in °C). The base temperature can be interpreted as the outside temperature below which homes require heating for them to be at a comfortable temperature. A base temperature of 15.5°C is assumed which is considered typical in the UK[3], however we point out that this base temperature can vary from home to home depending on many factors including the type of home and insulation quality, for example.

External temperature data is extracted at hourly intervals at the postcode location of each home in our sample using the Meteostat database[4]. From this, for each home, the HDD for each hour is given by

ΔT (°C) = 15.5 °C – hourly temperature reading

Δt (days) = 1 / 24

HDD = ΔT (°C) X Δt (days)

The total gas consumption used in the 1st September – 31st October period is then measured for each home and this value is normalised by the total number of HDD at the home location during this time period:

$$\text{Gas consumption corrected for external temperature (kWh per HDD)} = \frac{\text{Total gas consumption (kWh)}}{\text{HDD (°C days)}}$$

This gives a measure for the total gas usage in kWh per HDD for each home, thus correcting for the effects of the external temperature on the gas consumption and allowing us to mitigate the effects of external temperature when comparing of the gas consumption in September/October 2021 to September/October 2022.

3.3. ESTIMATING ENERGY USED FOR HEATING

To estimate the gas used for heating, normalised by HDD, we need to remove the energy used for processes other than heating (e.g., hot water, gas cookers). Given that it is unlikely that participants turn their heating on during the summer months (where for the purpose of this analysis we consider these months to be July and August), we assume a baseline gas consumption taken as the average gas consumption over the summer months. This is calculated independently for 2021 and 2022 and is subtracted from the September/October gas consumption of the respective year to estimate the amount of gas used for home heating. For homes where the gas consumption data does not date back to summer 2021, we use the 2022 summer baseline consumption as an estimate of the 2021 baseline consumption.

3.4. DELAYED HEATING ONSET

Using the following two methods, we identify homes which have delayed turning their heating on so far in 2022. These homes are identified as having turned their heating on by the end of October 2021 but did not switch on their heating by the end of October 2022 (since we expect homes generally turn their heating on in October):

1) For individual homes, we determine whether the heating has been switched on during October 2021 and/or October 2022 if the October gas consumption is significantly higher than the summer gas consumption of that year, according to at least two of the three statistical tests described in Section 3.5. This is motivated by the fact that it is unlikely that participants turn their heating on during the summer months (July/August).
   For this method we exclude homes where there is no summer gas consumption data dating back to 2021 since, for these homes, there is no summer data to compare the October gas consumption to. A sanity check is made on the homes selected by an eyeball inspection of the gas consumption profiles.

2) We quantify the correlation between daily HDD and daily gas consumption during September and October for each home in 2021 and 2022. If there is a significant correlation between gas consumption and HDD (according to a p-value less than 0.05), then we expect that the amount of gas used is weather dependent and is likely used for home heating (higher HDD means colder weather and more gas is expected to be used for home heating). If there is no significant correlation, then we suspect the gas is not being used for heating.
   The main caveat of this method is that any observed correlation between HDD and gas consumption is considered indicative of heating, however the use of gas for processes other than home heating (e.g. hot water) may also plausibly increase with HDD. Furthermore, this method will struggle to identify homes which have switch their heating on for only a single day, or homes which have switched their heating on 'random' days independent of the weather conditions (e.g., when working from home) and this may result in a significant correlation not being identified despite the heating being turned on.

3.5. TESTING FOR STATISTICAL SIGNIFICANCE

Throughout this report, the statistical significance of the results is tested using the three statistical tests: the T-test, Mann-Whitney U test and Kolmogorov-Smirnov test (K-S) test. These tests are used to determine whether two samples are significantly different from each other, and this would be considered the case if the p-value associated with a given test is less than 0.05. In other words, the null hypothesis (that the two samples are the same) is rejected at the level of 5%.

The T-test compares the means of the two samples, however assumes that the samples are approximately normally distributed. On the other hand, the Mann-Whitney U test does not require the samples to be normally distributed and looks more at the difference between the sample medians, rather than the sample means. The K-S test essentially compares the peaks of the distributions of the two samples (in practice is looks at the maximum distance between the cumulative distribution functions) and does not assume a normal distribution.

Throughout the report we consider two samples to be significantly different if, when comparing them, at least two of the tests show a p-value of less than 0.05.

Some part of this analysis involves comparing proportions to see if two proportions are significantly different from one another. For this, we use the two proportion Z-test test. Again, we assume two proportions are significantly different is the p-value is less than 0.05.

4. RESULTS

4.1. CHANGES IN ENERGY CONSUMPTION

Figure 1 shows the total energy consumption since 1st September during the period 1st September - 31st October in 2021 and 2022. From this figure, we see that in October 2022, less gas is consumed within Living Lab households.

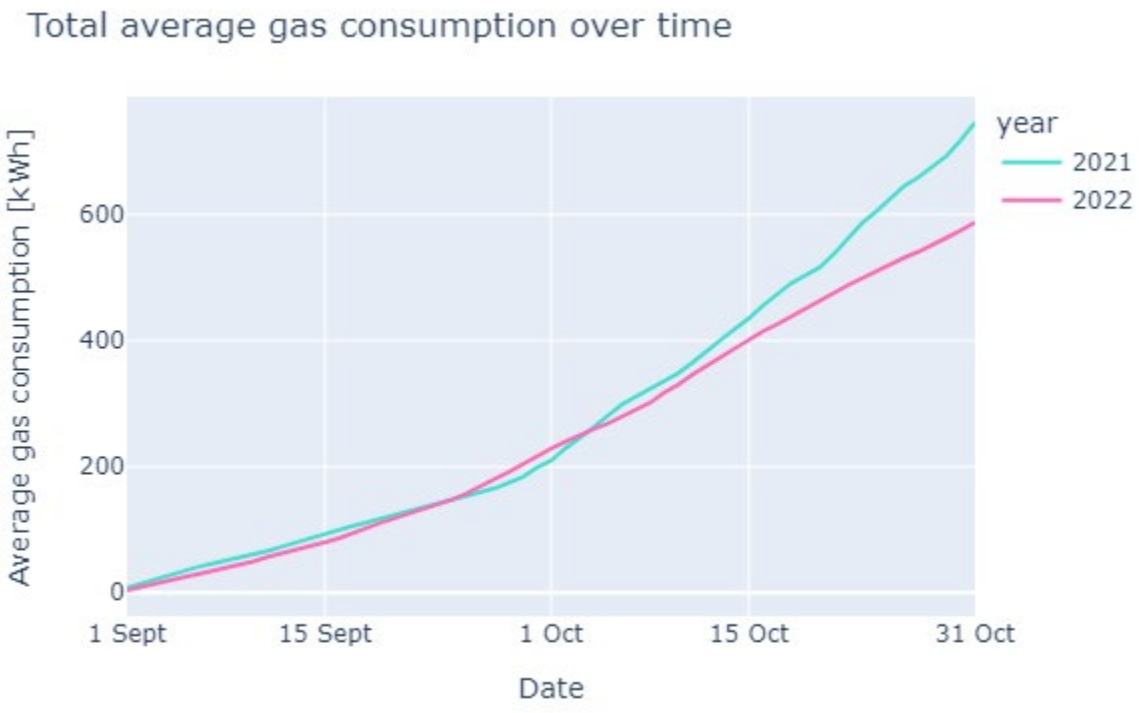

Figure 1: Cumulative gas consumption averaged over homes in the Living Lab sample for September/October 2021 and 2022.

To determine if this change is due to a change in consumer behaviour, and not simply reflective of warmer weather during 2022, we calculate the total gas consumption throughout September/October whilst accounting for external temperature using the method outlined in Section 3.2. From this, we find that the total amount of gas consumed in kWh per HDD during September and October 2022 is 28% less than during September/October 2021, on average across Living Lab households. This result is statistically significant according to two of the three statistical tests (the T-test and Mann-Whitney U test) outlined in Section 3.5.

Looking at the gas used for heating only (estimated by subtracting the baseline summer gas consumption from the total gas consumption as described in Section 3.3), the average household energy savings in gas used for heating during September/October is estimated to be 40% between 2021 and 2022. This result is presented in Figure 2 which shows the distribution of the total September/October gas consumption for heating corrected for external temperature in 2021 and 2022. This result is statistically significant according to all three statistical tests considered (see Section 3.5).

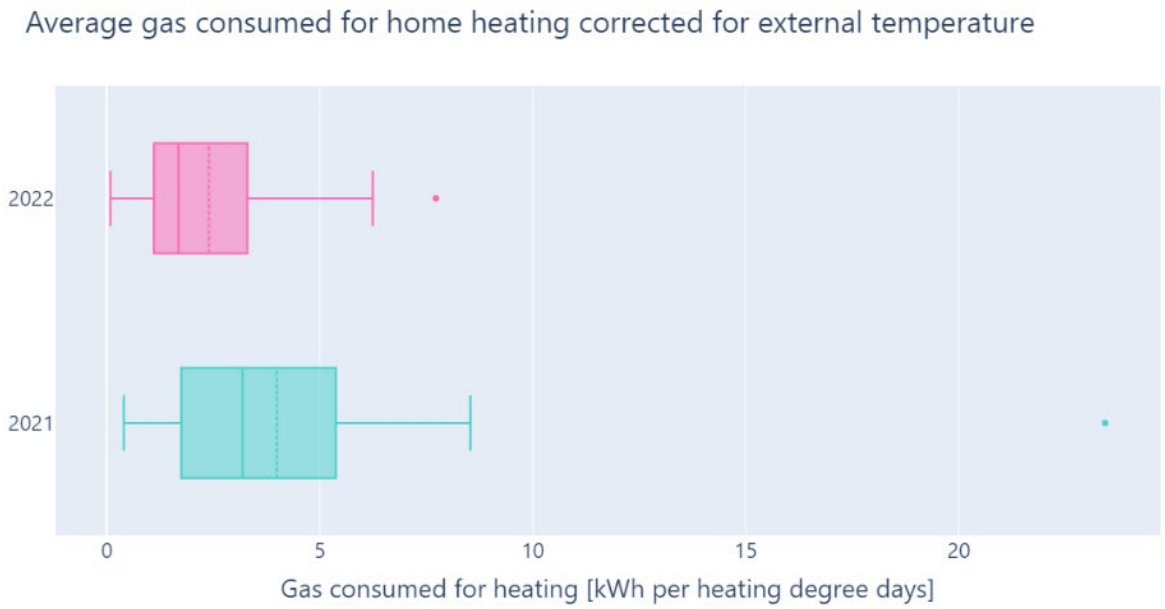

Figure 2: Distribution of gas consumption for home heating corrected for external temperature for 36 Living Lab homes. The median and mean of the distributions are indicated with solid and dashed lines respectively. 50% of the data lies within the box. Outliers are indicated as circular points.

This suggests that consumers have decreased the amount of energy used for heating during the energy crisis. This could potentially be a result of participants not yet turning on their heating this year, lowering their thermostat temperatures, or turning heating on intermittently for short periods of time, for example.

In Figure 3 we show for reference, the Heating Degree Days measured for homes in the Living Lab sample. Since the distributions overlap significantly, this indicates that the external temperature corrections to gas consumption in 2021 and 2022 are similar thus the gas savings of Living Lab participants are unlikely to be due to a difference in external temperature.

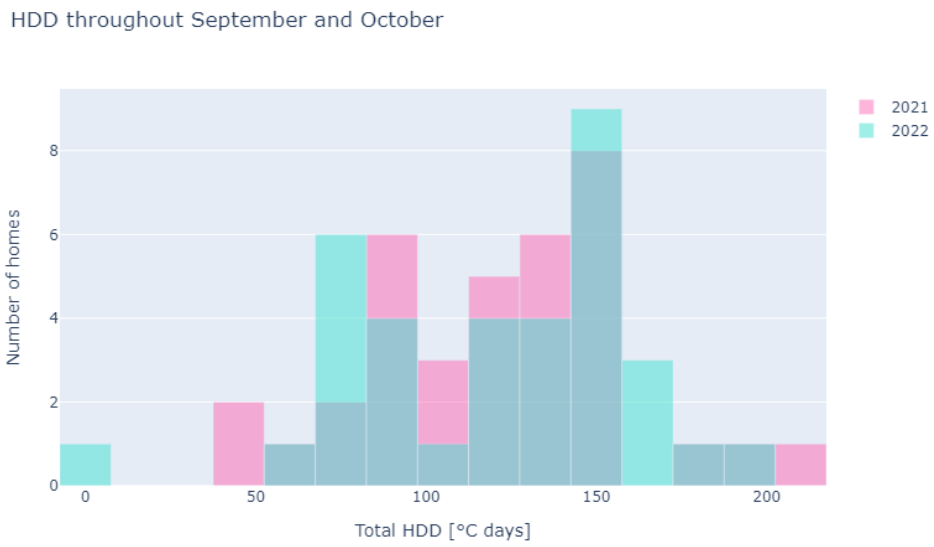

Figure 3: Total Heating degree days at the locations of homes in our sample during September and October 2021 and 2022.

4.2. INTERNAL TEMPERTURES FROM TADO DATA

For the 85 homes with Tado room temperature data, we compare the average household temperatures throughout September/October in 2021 and 2022. Figure 4 shows that during this period in 2021, homes had higher average internal temperatures compared to the same period in 2022. Specifically, homes are being kept 0.6ºC colder on average this year compared to last year. This result is statistically significant according to all statistical tests described in Section 3.5. We find that 65% of homes show a statistically significant lower average indoor temperature this year compared to the same time last year.

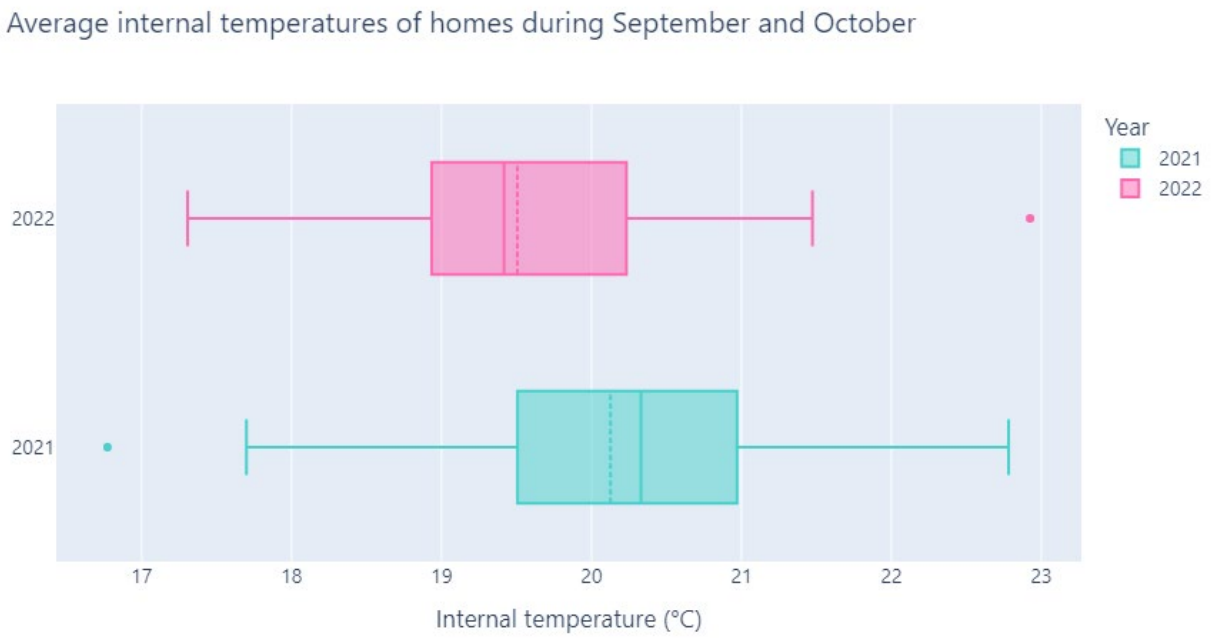

Figure 4: Distribution of the average internal temperatures of Living Lab homes during September October from Tado sensors. The median and mean of the distributions are indicated with solid and dashed lines respectively. 50% of the data lies within the box. Outliers are indicated as circular points.

4.3. DELAYED HEATING ONSET

This section investigates whether there is evidence of Living Lab homes which have a delayed heating onset in 2022 compared to in 2021, i.e., homes which turned their heating on before November in 2021 but did not turn their heating on before November 2022. There is weak evidence for this from our limited sample of homes.

Using method (1) outlined in Section 3.4, we find that 93% of homes in our sample were heated during October 2021 compared to the 81% of homes which have turned their heating on so far during October 2022, however this result is not statistically significant.

Applying method (2) in Section 3.4, we estimate that approximately 86% of homes were heated in September/October 2022 and 61% of homes were heated during the same time period in 2022. These two proportions are statistically different according to the z-proportions test, which supports the hypothesis that some people have delayed turning their heating on this year. However, the since number of homes involved is small and the conclusion is very sensitive to the specific methodology chosen, this should not be taken as definitive evidence of the effect.

5. CONCLUDING REMARKS

This analysis shows that the Living Lab data can be used to estimate the proportion of participants who are changing the way they consume energy, and by how much. Although we only have small sample size for this analysis, our results illustrate the capabilities of the historic Living Lab data in exploring impacts on consumer behaviour due to external changes. This may be of interest to innovators wanting to test their products on real users, policy makers wanting to understand consumer behaviour and the Living Lab participants themselves.

6. REFERENCES

[1] https://www.icaew.com/insights/viewpoints-on-the-news/2022/sept-2022/chart-of-the-week-energy-price-cap-update#:~:text=The%20average%20per%20kWh%20price,to%2051.9p%20in%20October.

[2] https://www.degreedays.net/calculation

[3] https://www.energylens.com/articles/degree-days

[4] Lamprecht, C. S. Meteostat Python [Computer software]

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7TH FLOOR, CANNON HOUSE,
18 PRIORY QUEENSWAY,
BIRMINGHAM, B4 6BS.

ES.CATAPULT.ORG.UK
@ENERGYSYSCAT