Food Standards Scotland

For safe food and healthy eating

FROST: Fridge Recording Over Set Time

A citizen science project

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Version control

Version	Date	Last review carried out	Next review date	Comments
v1	June 2025			

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At Food Standards Scotland we have a unique role, working independently of Ministers and industry to provide advice which is impartial, and based on robust science and data.

Our remit covers all aspects of the food chain which can impact on public health – aiming to protect consumers from food safety risks and promote healthy eating.

Contents

Abbreviations

LA	Local Authority
FROST	Fridge Recording Over Set Time
FSS	Food Standards Scotland
RTE	Ready to eat
SIMD	Scottish Index of Multiple Deprivation

Executive summary

A citizen science survey was carried out from August 2023 to May 2024 to measure the temperature of consumer fridges in Scotland. A total of 361 fridges in consumer's homes across Scotland were monitored in the Fridge Recording Over Set Time (FROST) trial, with the average temperature found to be 5.17°C overall, although individual average fridge temperatures ranged from -0.39°C up to 10.94°C.

Despite the recommend operating temperature for a fridge being 0-5°C, the majority of fridges monitored in FROST (55.4%) had an average temperature of greater than 5°C. The temperature was measured every 10 minutes for 10 days using two temperature loggers: one stored on the bottom shelf of the fridge and one on the top shelf.

The top areas of the fridges were found to be hotter, averaging 5.89°C overall for the trial, compared to the bottom of the fridges, averaging 4.45°C. However, there were a wide range of average individual fridge temperatures recorded, ranging from -2.52°C to 10.34°C for the bottom of the fridge and -3.83°C to 14.48°C for the top of the fridge, nearly 9.5°C over the recommended maximum temperature range for a fridge. There were 27 fridges (7.5% of the trial) monitored in FROST that never recorded a single measurement in the recommended temperature range during the trial, with all observations greater than 5°C.

The age of the fridge did not impact the temperature; however, the type of fridge did, with American-style fridges and free-standing fridges giving significantly lower temperatures overall compared to other types. No significant difference in average fridge temperatures were seen between households of different sizes, between different Scottish Index of Multiple Deprivation (SIMD) zones or between households with young children, older adults or those who are immunocompromised.

Although knowledge of the correct temperature range for a fridge was high with consumers, this did not translate to behaviour with low numbers of consumers manually checking their fridge temperatures. There was a significant difference in fridge temperatures between those who were alerted by their fridge when the temperature deviated outside the recommended zone and those who did not check, showing the potential for these features in helping consumers to ensure their fridge is operating at the correct temperature range.

Additional work is needed on improving fridge design, raising awareness of the importance of checking fridge temperatures with consumers, as well as the development of advice on the placement of food products within a fridge, such as storing of low-risk food products (e.g. chilled beverages) in the warmer areas of the fridge, rather than those of high-risk such as leftovers or chilled ready-to-eat foods to help minimise food safety risks.

1. Introduction

Every year there are approximately 43,000 cases of foodborne illness in Scotland, with 5,800 GP presentations and 500 hospital admissions [1, 2]. The correct domestic fridge temperature is an important factor in reducing foodborne illness since lower temperature limits bacterial growth rate. Psychotrophic bacteria such as Listeria monocytogenes are a particular concern for food safety, as they can be found in chilled ready to eat (RTE) food products that would be stored in the fridge and can grow at a faster rate at colder temperatures more so than the other foodborne pathogens [3].

The optimum operating temperature for domestic fridges is 0–5°C to ensure the shelf life of food by limiting growth of food spoilage bacteria and foodborne pathogens. Temperatures between 8–63°C are known as the “danger zone” for bacterial growth, where bacteria can proliferate at a faster rate if kept at this temperature for long periods of time [4]; hence it is essential that domestic fridge temperatures are kept between 0-5°C. However, data from the Food and You 2 Survey found that only 62% of consumers surveyed in Scotland identified this correct temperature range for a fridge, with more than 1 in 10 (16%) of respondents reporting that the temperature should be greater than 5°C [5]. A previous consumer survey by Food Standards Scotland (FSS) also found that although the majority of consumers stated that they check their fridge temperature (79%), the majority checked by using the built-in temperature displays on the fridge (which can state the desired temperature, not the actual temperature of the fridge) rather than manually checking with a free-standing thermometer [6]. There was also a strong emphasis on unreliable methods, such as checking the dial/gauge in the fridge, which indicates the fridge settings rather than temperature, touching food to see if it was cold or looking for ice and condensation [6].

Based on these findings, FSS developed the study “Fridge Recording Over Set Time” (FROST) to determine what the average fridge temperature of domestic fridges in Scotland is and how many consumer fridges are operating at the correct temperature range of 0-5°C. A citizen science approach was taken, where citizens throughout Scotland were able to take part, monitor the temperature of their fridge using calibrated temperature loggers provided by FSS and submit the data for analysis. In return, citizens would receive information on the temperature of their fridge, a graph showing how the temperature fluctuated over the monitoring period, as well as food safety advice regarding optimal fridge use (Appendix 7.1). By using a citizen science approach, FSS was able to collect data from a high volume of fridges across Scotland being used normally and typically by consumers. This approach also allowed us to explore any factors that may influence the working temperature of domestic fridges, whether this be down to the fridge itself due to type or age, or down to household demographics.

2. Methods

2.1 Citizen recruitment

A pilot study involving 30 Food Standards Scotland (FSS) employees took place in May 2023 to trial the recruitment process, logistics of distributing the loggers, gain feedback on clarity of information provided to participants and undertake data extraction. No issues were identified during the pilot phase so recruitment of citizens across Scotland commenced in August 2023.

Citizens were recruited by advertising online through the FSS website, FSS social media platforms and press releases. An advertisement was run for five days on Facebook to promote the project and was boosted to all users in Scotland (to allow visibility also to citizens that would not be following Food Standards Scotland social media pages). To be eligible to take part in the project, citizens were required to be resident in Scotland, over the age of 18 and own a fridge in their home. To sign-up, citizens completed a short questionnaire online collecting information on the type of fridge they owned, the age of their fridge and the number of individuals within their household (Section 3.2). A six-digit citizen code was assigned to each citizen that signed up, to ensure all personal details were anonymised during the study and data analysis.

Due to limitations in the number of data loggers available for distribution, recruitment was undertaken in five phases, with citizens being recruited to the main study between August 2023 and February 2024, and the final packs returned from citizens in May 2024.

A total of 408 households were recruited for the project across the pilot and main phases, with 368 study packs (90.2%) successfully returned to FSS. Due to recording failures or errors in the placement of the temperature loggers (e.g. not stored in the fridge for a significant duration of the trial), seven households had to be excluded from the study. Therefore, the number of fridges in the final dataset for analysis was 361, with two temperature loggers for each fridge (722 temperature loggers) (Figure 1). Households from all 32 local authorities (LA) in Scotland signed-up to take part in FROST but only households from 31 out of 32 local authorities were included in the final dataset (Figure 2).

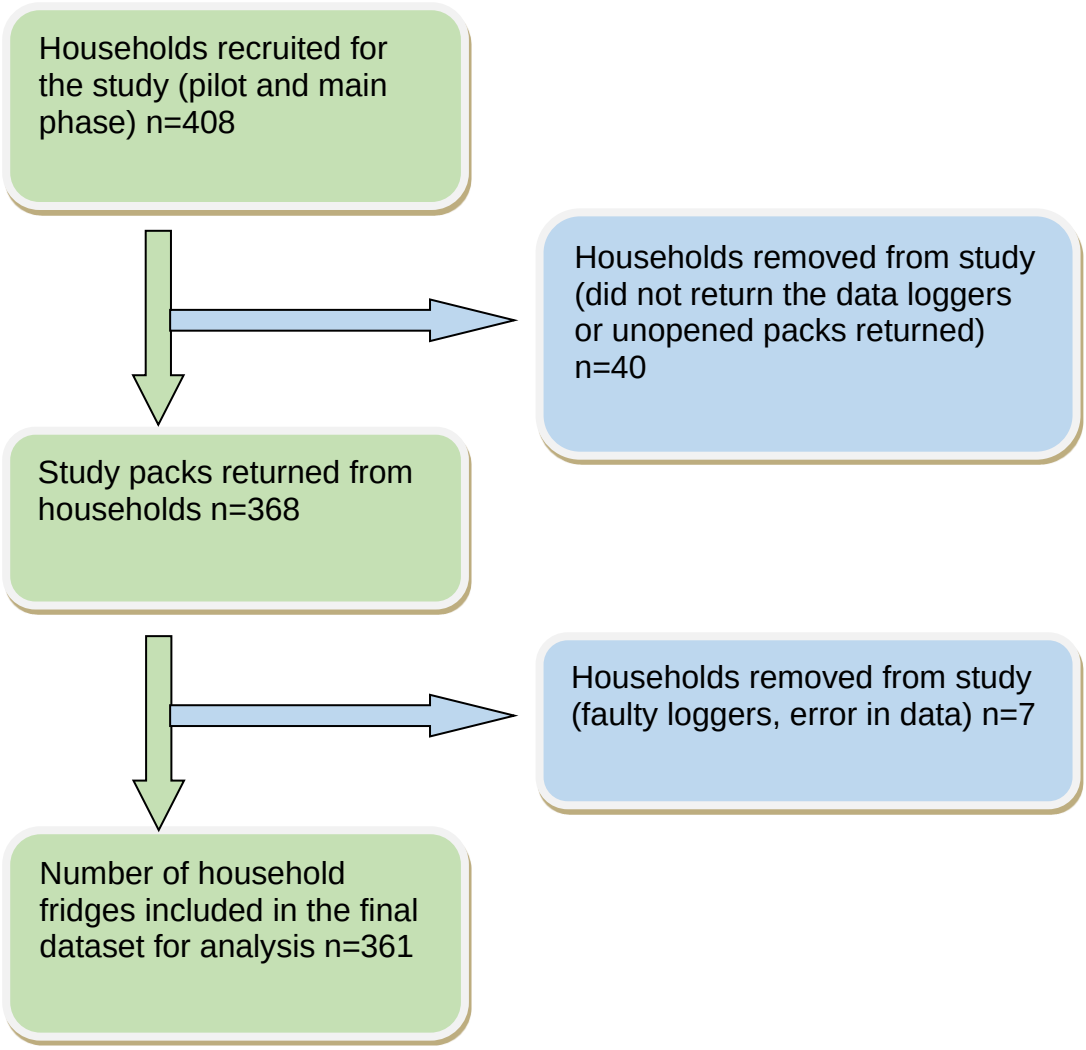

Figure 1. Recruitment of households into the final FROST dataset for analysis.

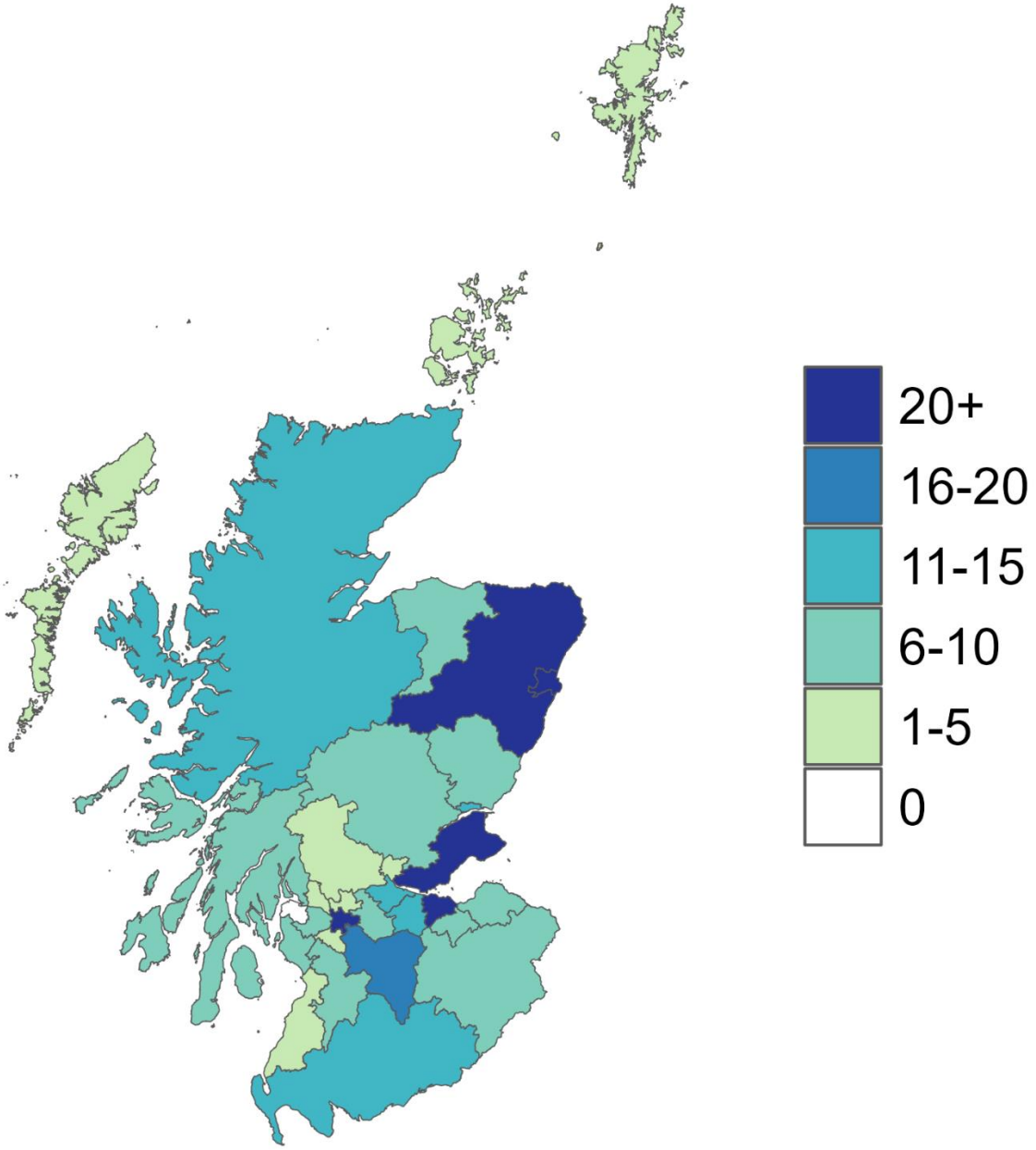

Figure 2. Breakdown of the number of households within each local authority (LA) in the final FROST dataset.

2.2 Citizen household metadata

To take part in the trial, citizens completed an initial questionnaire when they signed up (Appendix 1) and a second questionnaire during the trial (Appendix 3), to allow us to segment the data. The information provided consisted of:

Fridge details

- The age of their fridge (>5 years, 5-10 years, 10+ years or unknown);
- The type of fridge they have (classic fridge/freezer; full-size fridge; half-size/undercounter fridge; American-style fridge/fridge-freezer; unknown/other);
- Whether the fridge was free-standing or integrated;
- The temperature displayed on their fridge during the trial (if applicable);
- Whether they did any main/large food shops during the trial;
- And if they encountered any issues during the trial that may impact their fridge temperature (e.g. a power cut or were away from home for a significant period of time (>48 hours).

Household details

- The number of people in the household;
- The age groups of those in the household (0-4 years; 5-16 years; 17-30 years; 31-50 years; 51-64 years; 65-74 years; 75+ years);
- Whether someone was at home typically during the week;
- Whether anyone in the household had a weakened immune system (e.g. due to medication, illness or treatment) or were pregnant;
- Whether citizens would typically check their fridge temperature, and if so, using what method (e.g. checking the built-in display, putting a freestanding thermometer into the fridge);
- And whether citizens would typically adjust their fridge temperature, and if so, in what circumstances (e.g. after a main/large food shop, if the thermometer showed a temperature outside of the 0-5°C range, if they saw ice/condensation or if the food felt too warm/cold).

2.3 Temperature data collection

After sign-up, each citizen would receive a trial pack posted to their home address containing two Elitech RC-5+ calibrated temperature loggers (RC-5+USB Temperature Data Logger - Elitech (elitechlog.com)), an instruction leaflet containing a second questionnaire (Appendix 3) and a pre-paid return envelope. Prior to posting, the temperature loggers were started by FSS and set to record the ambient temperature every ten minutes. The temperature display on the loggers was concealed to prevent citizens' normal behaviours being influenced by the readings.

Citizens would place the temperature logger marked "TOP" on the top shelf of their fridge and the temperature logger marked "BOTTOM" on the bottom shelf of their fridge (above any salad/vegetable drawers) and leave them to record for two weeks.

The citizens were instructed to try and not move them during the trial, to place them on the shelf in a similar place for both temperature loggers (e.g. on the left of the shelf, near the back) not on food products and to use their fridge as they normally would to get as accurate data as possible. The start and end dates of the trial were noted on the returned questionnaire by citizens.

After the two-week trial was over, citizens would post the temperature loggers back to FSS for the data to be downloaded. Temperature data was downloaded using the Elitech software v6.4.3 (Softwares - Elitech (elitechlog.com)) and exported to excel format for analysis. A 10-day period was selected during the trial for analysis, with typically two days removed at the start and end of the trial to allow for any acclimatisation of the loggers to occur.

2.4 Fridge photographs

As an optional requirement for the trial, citizens could submit a photograph of the inside of their fridge at any point during the trial, either via e-mail or by uploading the photograph to the FROST Typeform page (https://www.typeform.com/). The submission of a photograph was completely anonymous; therefore, they were not able to be linked to specific citizens or to any of the fridge temperature data collected. These represented a single point during the trial and helped to determine what type of food products people were typically storing in different locations in their fridge.

2.5 Data analysis

R studio (v4.2.2) was used to combine the temperature logger data with the questionnaire data and conduct all analysis and statistical tests. Paired observations for each citizen's fridge were created, which is the temperature recorded by the loggers placed on the top and bottom shelves within five minutes of each other within the same fridge. This time difference is due to the amount of time taken to press the start button on the two loggers during the trial set-up at FSS. Ninety percent of all paired observations included in this were for records taken within 2.43 minutes of each other.

The mean, median, range and percentage of correct observations (i.e. percentage of datapoints that fell in the correct temperature range of 0-5°C) of each temperature logger was calculated for the selected 10-day period. The data from the top and bottom temperature loggers for each fridge were combined and averaged to calculate the overall fridge temperature results.

3. Results

3.1 Temperature of fridges surveyed in FROST

The average temperature for the 361 fridges monitored in the FROST trial was 5.17°C, averaged from data collected from 722 temperature loggers. Of the 361 fridges surveyed, 200 (55.4%) had an average temperature greater than 5°C (higher than the recommend temperature range of 0-5°C).
The temperature loggers stored at the bottom of the fridge recorded lower average temperatures, averaging 4.45°C, whereas the average temperature for the top logger was 5.89°C overall.

The temperature was recorded every 10 minutes for 10 days from two locations within each fridge (top shelf and bottom shelf), resulting in the collection of 1,040,922 data points (observations). Only 44% of these observations were in the correct temperature range for a fridge (0-5°C) during the trial, with the majority of observations found to be greater than 5°C.

Overall, the temperature loggers recorded temperatures ranging from -11.9°C to 19.1°C during the FROST trial, whilst the average operating temperatures of fridges ranged from -0.39°C to 10.94°C (Figure 3). Temperatures recorded from the temperature loggers stored at the bottom of the fridge ranged on average from -2.52°C to 10.34°C, whereas the top loggers ranged from -3.83°C to 14.48°C (Figure 4), with the latter being nearly 9.5°C higher than the recommended temperature range.

Sixteen fridges (4.4%) had at least one time point during the trial where one of the loggers recorded a temperature of 15°C or more. There were 27 fridges (7.5% of the trial) that never had a single observation in the correct temperature range (0-5°C) during the trial period, with all of the observations greater than 5°C. The average temperature for this group of fridges was 8.43°C. There was no common factor measured (e.g. fridge type, fridge age, number of residents in the household) between these 27 fridges, therefore the reason for these high temperatures is unknown.

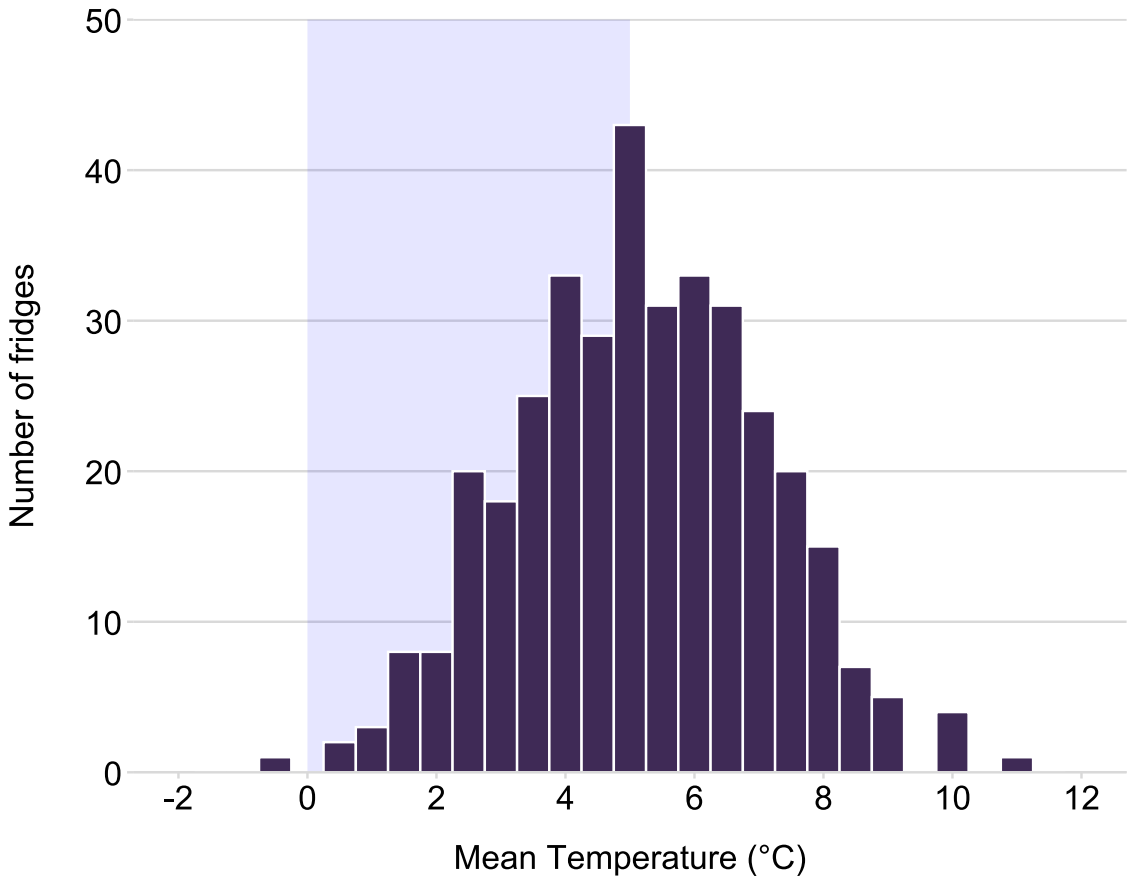

Figure 3. The average temperature of the 361 fridges monitored in the FROST trial. The shaded area of the graph denotes the correct temperature range for a fridge (0-5°C).

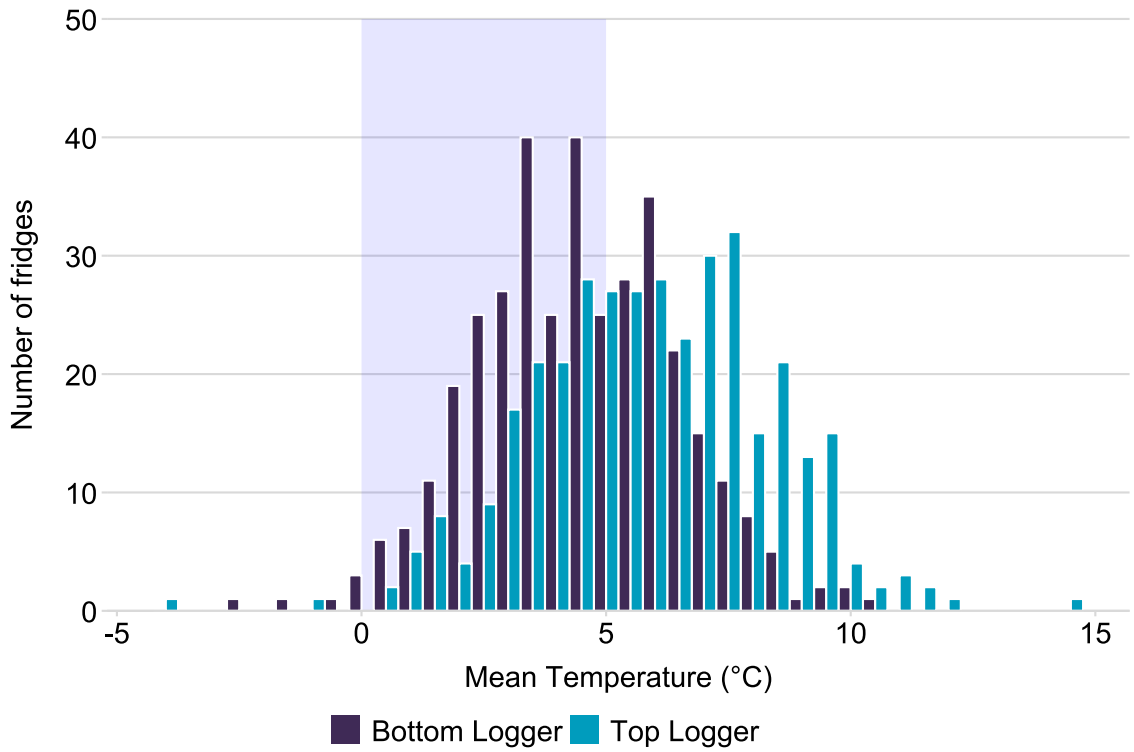

Figure 4. The average temperatures of the top and bottom loggers monitored in the FROST trial. The shaded area of the graph denotes the correct temperature range for a fridge (0-5°C).

3.2 Temperature range across the fridge

Temperature fluctuation varied from one appliance to another, and the temperature ranged up to 16.2°C between the temperature recorded on the bottom logger and that taken by the top logger at a single paired observation, within 3 minutes of each other (Figure 5). The majority (71% of observations) showed a temperature difference of between 0 and 2 degrees between the paired top and bottom logger observations. This shows just how much variation can exist between shelves in a single fridge at a single point in time.

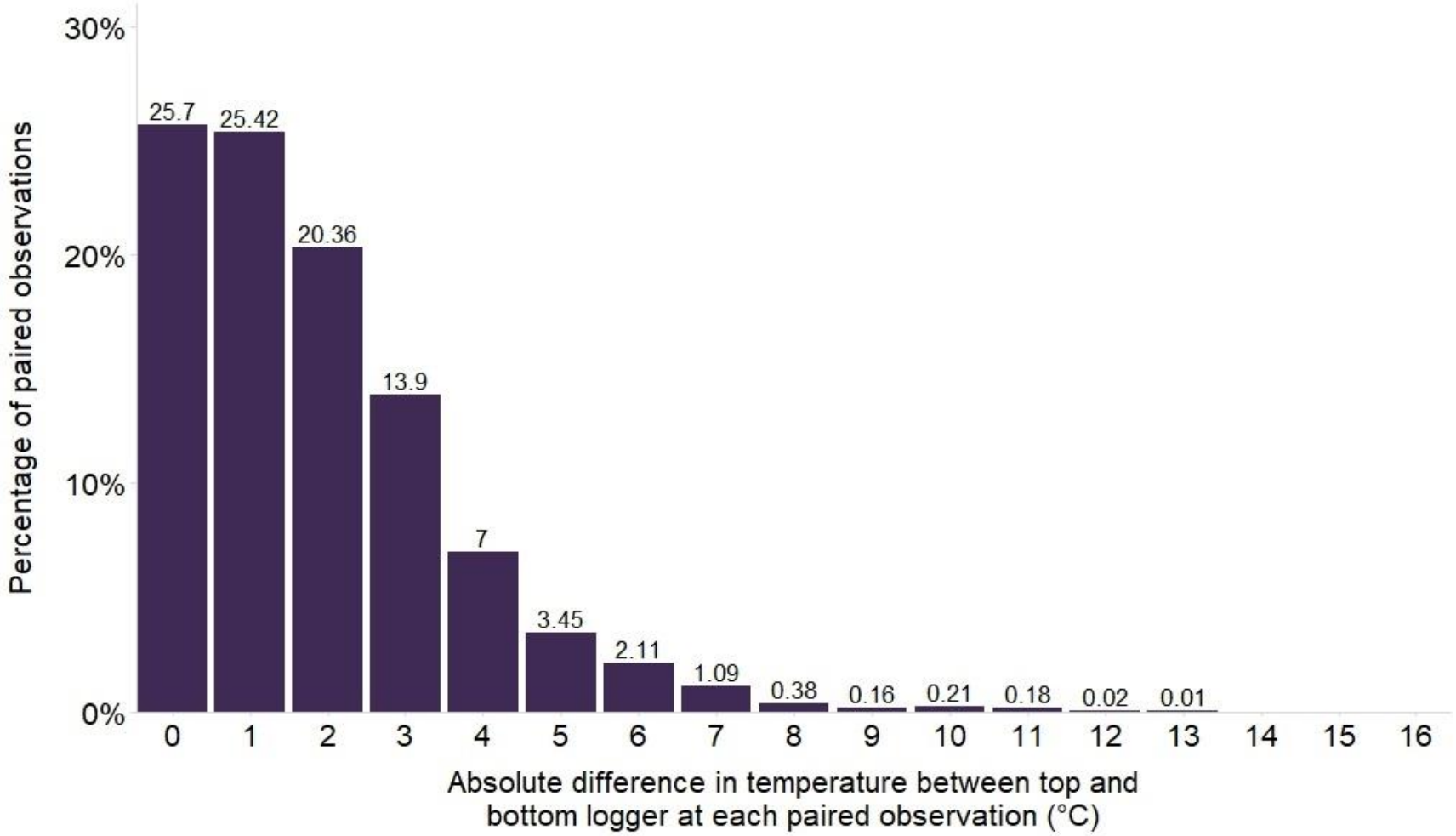

Figure 5. The absolute difference in temperature between the top and bottom logger within a fridge at each paired observation. Data labels for 14 for 16 are 0.0004 (n = 2) and 0.0002 (n = 1), respectively.

3.3 Impact of the fridge age and type on temperature

3.3.1 Fridge age

The most common age of fridges studied in the FROST trial was under 5 years old (n=142), followed by 5-10 years old (n=123). The average operating temperature was 5.24°C for fridges under 5 years old, 4.99°C for fridges aged 5-10 years, 5.58°C for fridges more than 10 years old and 4.84°C for those fridges for which the age was unknown (Figure 6). There was no significant difference in the average operating temperature among the fridge age groups (determined by one-way ANOVA, p=0.172).

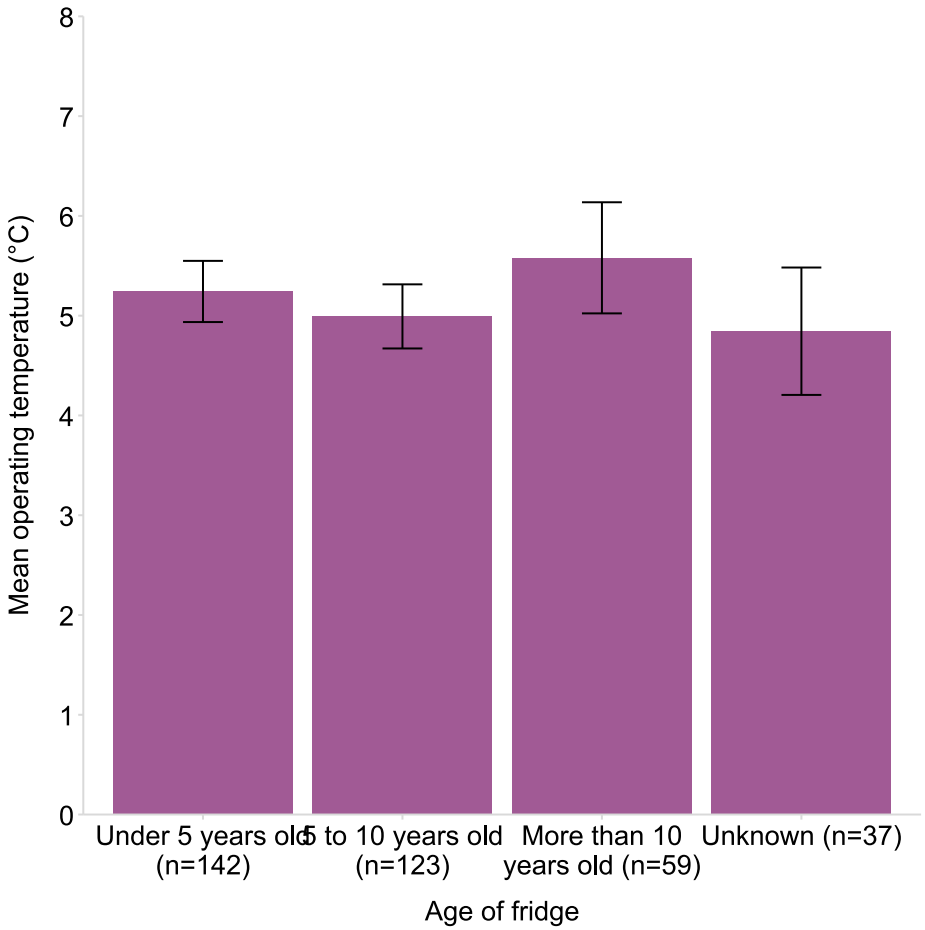

Figure 6. The mean operating temperature of the fridges by age of fridge. Error bars represent the mean +/- 95% confidence interval. No significant difference in temperature was seen between the different fridge ages.

3.3.2 Fridge type

On recruitment, citizens were asked which type of fridge they had in their home which was going to be measured in the FROST trial. They could choose from one of four options: 1) an undercounter or half-size fridge; 2) a full-size fridge; 3) a classic fridge-freezer; or 4) an American-style fridge. The most common type of fridge found in this study was a classic fridge freezer, with 54% (n=195) of citizens owning this type of fridge (Figure 7). Fifty-eight citizens had an American-style fridge, 54 had a full-size fridge and 49 had an undercounter/half-size fridge. There were five citizens that reported their fridge type as “unknown/other”.

A breakdown of the specific fridge types with reference to the freezer location within each category is seen in Table 1. There were very few fridges that contained a built-in freezer compartment in the fridge across the categories. For American-style fridges (option 4), the most common style had the fridge on one side and the freezer on the other, whereas for classic fridge-freezer (option 3) the most common style had the freezer on the bottom. The most common full-size (option 2) and half-size fridge (option 1) types were fridges only, with no freezer at all.

Due to the small numbers in the different specific fridge types, analysis was carried out on the four fridge options (classic fridge-freezer, American-style, full-size and undercounter) overall instead. A significant difference in the mean operating temperature between different fridge types was seen (determined by one way ANOVA, $p<0.001$) (Figure 8). Post-hoc Tukey multiple comparisons of means test revealed that American fridges have statistically lower mean operating temperatures (4.09°C) than classic fridge-freezers (5.31°C; $p<0.001$), full-size fridges (5.71°C; $p<0.001$) and under counter or half-size fridges (5.34°C; $p=0.003$).

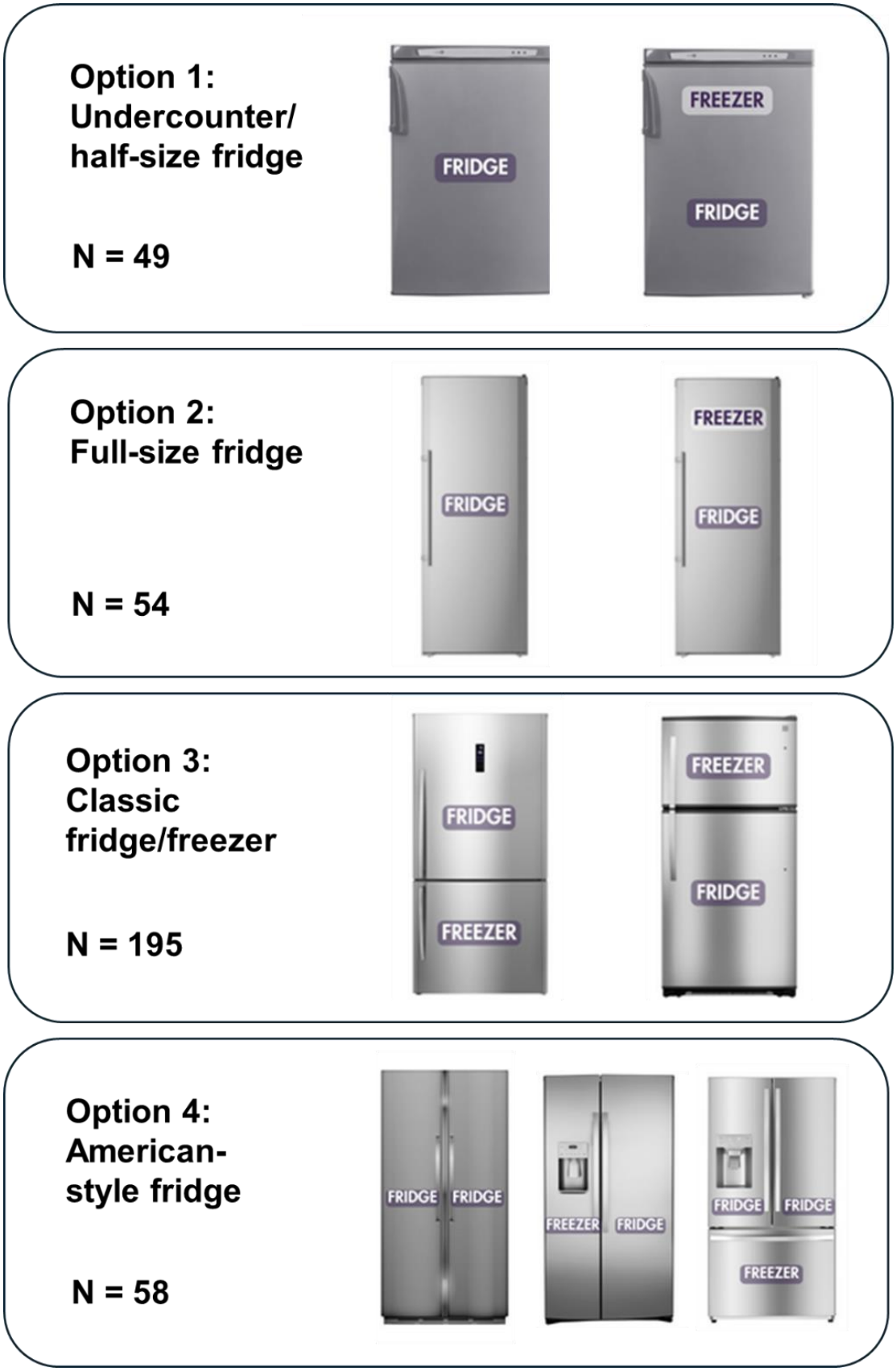

Figure 7. The four categories of fridges used by citizens in FROST.

Table 1. Breakdown of the number of fridge types within each category, detailing freezer presence or location.

Fridge type	Number of fridges
American-style: fridge on one half and freezer on the other	47
American-style: fridge on top and freezer on the bottom	6
American-style: fridge only	5
Classic fridge-freezer: freezer on the bottom	188
Classic fridge-freezer: freezer on top	7
Full-size fridge: fridge only	46
Full-size fridge: fridge with freezer compartment	8
Undercounter/half-size fridge: fridge only	42
Undercounter/half-size fridge: fridge with freezer compartment	7

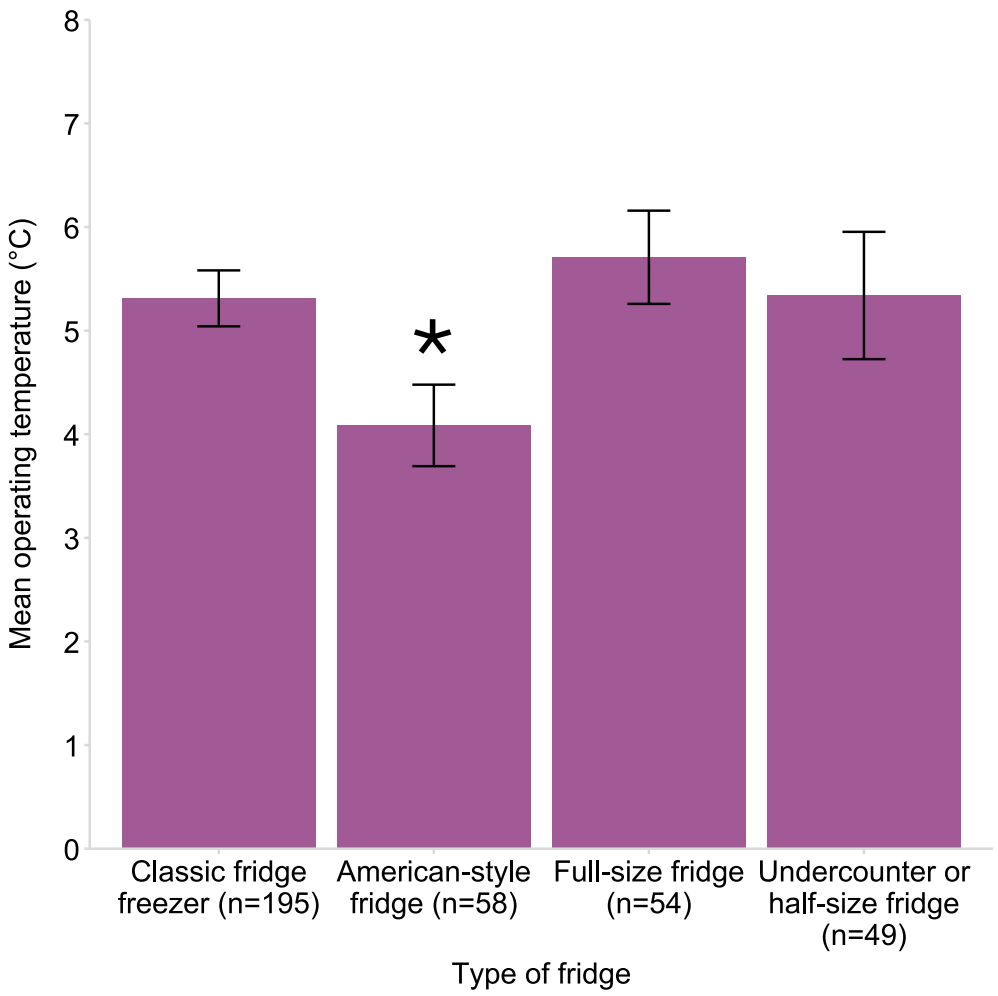

*Figure 8. The mean operating temperatures of fridges by type of fridge. Error bars represent the mean +/- 95% confidence interval. * denotes significant difference (p>0.001).*

3.3.3 Free-standing versus integrated

Citizens were asked whether their fridge was free-standing (not built-in and can be easily moved to a different plug socket if required) or integrated (fitted into the kitchen, typically behind a cupboard door as a more permanent fixture and hence cannot be moved as easily).

There was a significant difference in the average temperature for free-standing fridges (4.95°C) and integrated fridges (5.64°C) over the trial (Welch's t-test; p=0.002), with integrated fridges running slightly hotter (Figure 9).

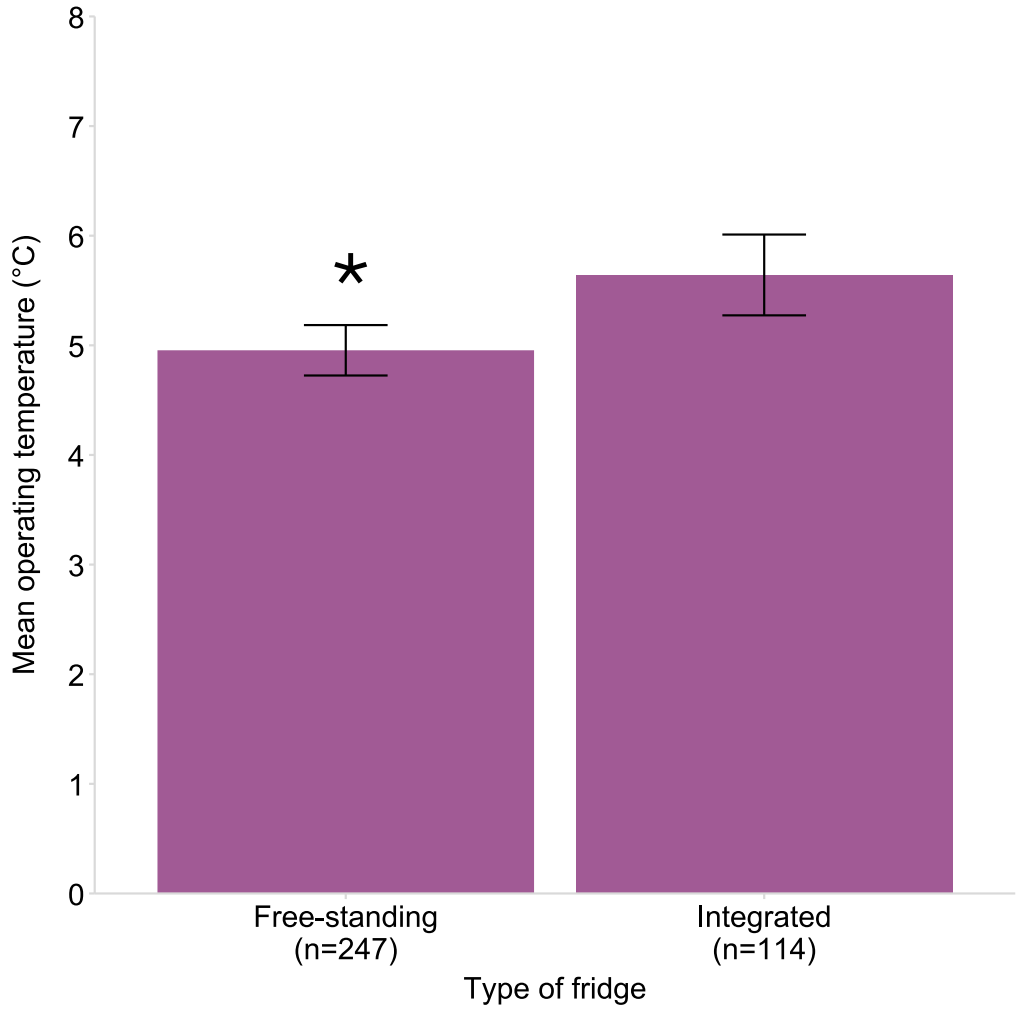

*Figure 9. Mean operating temperature of fridge by free-standing or integrated. Error bars represent the mean +/- 95% confidence interval. * denotes significant difference (p=0.002).*

3.3.4 Further analysis on fridge type and free-standing/integrated

Since 98% of the American-style fridges were free-standing (Table 2), it was possible that the American-style fridge was driving the significant difference seen

between free-standing and integrated fridges in Figure 9 (due to the significance of this fridge type, as shown in Figure 8).
To test this, a further analysis was carried out to determine if the free-standing versus integrated element was truly significant by testing for a difference within the classic fridge-freezers group only, since this was the fridge type with the highest sample numbers. A similar result was seen, with a significant difference seen between the mean temperature of fridges in integrated classic fridge freezers (5.92°C) than free-standing classic fridge freezers (4.99°C; $p \leq 0.002$; Figure 10).

Therefore, free-standing fridges were significantly colder than integrated fridges, as tested overall for the trial (Figure 9) and specifically for the classic fridge-freezer type (Figure 10).

Table 2. Breakdown of free-standing and integrated by fridge type.

Type of refrigerator	Free-standing	Integrated	Total
Classic fridge freezer	127 (65%)	68 (35%)	195
American-style fridge	57 (98%)	1 (2%)	58
Full-size fridge	32 (59%)	22 (41%)	54
Undercounter or half-size fridge	29 (59%)	20 (41%)	49
Unknown	2 (40%)	3 (60%)	5
Total	247 (68%)	114 (32%)	361

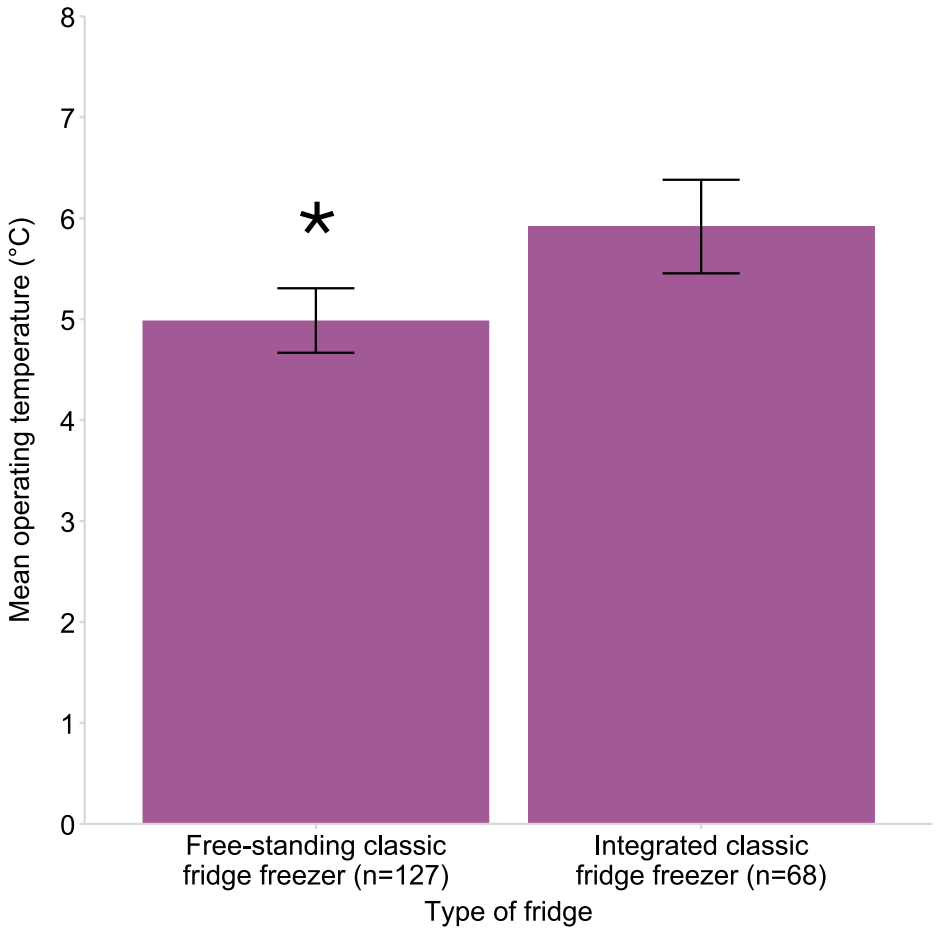

*Figure 10. Mean operating temperature of classic fridge freezers (free-standing or integrated). Error bars represent the mean +/- 95% confidence interval. * denotes significant difference (p>0.002).*

However, as the free-standing element was found to be significant, it was also possible that this was responsible for the significant result seen in Figure 8, rather than the fridge type (American-style).A further analysis to determine the significance of the American-style fridge type was carried out. In this analysis, temperatures were compared from all fridge types (classic fridge-freezer, American-style fridges, full-size fridges and undercounter/half-size fridges), but only for those that were free-standing. Unknown fridge types were removed from the analysis due to low numbers.

A significant difference in the mean operating temperature between the different free-standing fridge types was seen (determined by one way ANOVA, $p<0.001$; Figure 11) . Post-hoc Tukey multiple comparisons of means test revealed that free-standing American fridges (4.13°C) have lower mean operating temperatures than free-standing classic fridge-freezers (4.99°C; $p<0.001$), free-standing full-size fridges (5.98°C; $p\leq0.01$) and free-standing undercounter or half-size fridges (5.38°C; $p\leq0.01$).

Therefore, American-style fridges had significantly colder temperatures recorded than other fridge types.

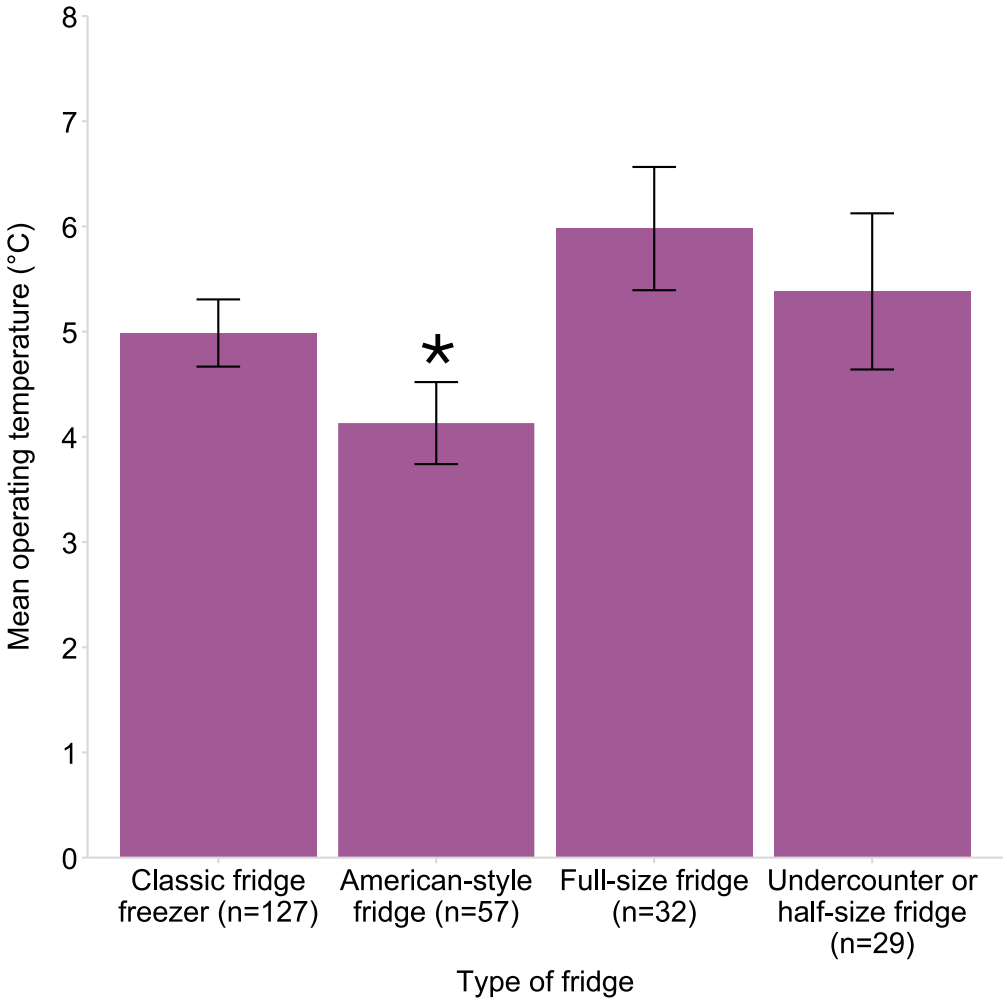

*Figure 11. Mean operating temperature of fridge by type (free-standing fridges only). Error bars represent the mean +/- 95% confidence interval. * denotes significant difference (p>0.01).*

3.3.5 Built-in temperature display on the fridge

Citizens were asked to note the built-in temperature display on their fridges (if available) during the trial. Eighty-five citizens submitted the built-in temperature displayed on the fridge; it is unclear whether this is an actual temperature reading from the fridge itself or whether this is the temperature that the fridge is set to operate at. Out of these 85 fridges, 32 were American-style fridges, 35 were classic fridge/freezers, 17 were full-size fridges and 1 was an undercounter fridge. The noted temperature on the built-temperature display on these fridges ranged from 1 – 8°C and the average temperature for these fridges recorded on the temperature loggers ranged from 1.21 – 7.94°C.

Seven of these fridges showed a reading higher than 5°C (6 – 8°C) on their built-in temperature display. The temperature loggers recorded on average 4.64°C for the bottom areas of these seven fridges (ranging from 2.14°C to 6.42°C) and averaging 6.48°C for the top of these fridges (ranging from 4.57°C to 7.93°C).

3.3.6 Oscillations in fridge temperatures

Fridge temperatures varied over the course of the 10-day trial due to the nature of cooling that fridges perform to maintain temperature. Several different patterns of temperature profiles were seen, which could be loosely grouped into four categories: 1) fridges had low temperature oscillation, with temperatures remaining fairly stable over the course of the trial (aside from citizen usage), with temperature typically staying within 2°C; 2) fridges had high temperature oscillation as they went through the cooling cycle, with the temperature range within each oscillation typically greater than 2°C; 3) fridges followed a consistent temperature oscillation pattern over the 10 days of cooling and 4) fridges did not show any clear cooling pattern (Figure 12).

Each fridge was manually assigned to the low (up to 2°C each oscillation) or high (>2°C oscillation) oscillation category, and whether a pattern of temperature fluctuation was seen or not. There was no correlation seen between oscillation category and the type of the fridge, the age of the fridge, or whether it was free-standing or integrated (Table 3). The vast majority of fridges studied in FROST had a low oscillation type and typically displayed no obvious pattern to their temperature fluctuations across the trial. Those with a high oscillation or pattern could not be linked to the type or age of fridge, or any other factor captured in this trial. These oscillations are expected to be related to the temperature setting and design of the fridge, e.g., defrost cycles. This was not monitored in FROST; however, this data has been shown to show the extent that the temperature of a fridge can vary over a 10-day period.

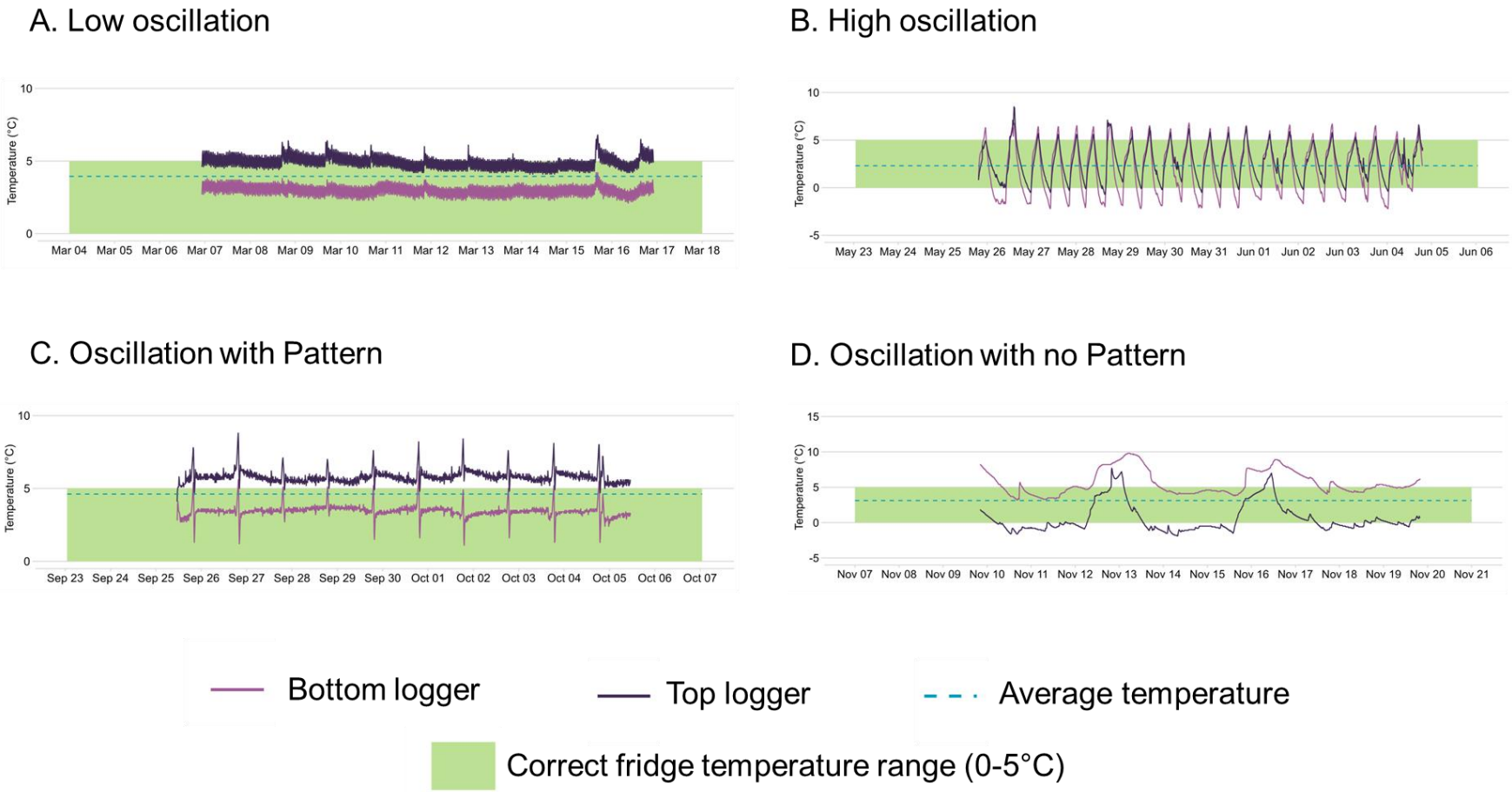

Figure 12. Examples of different oscillation patterns seen in temperature profiles of domestic fridges in the FROST trial. A) Low oscillation, temperature fluctuations oscillating within 2°C in a 24 hour period; B) High oscillation, a high temperature range is seen within each oscillation within a 24 hour period, typically greater than 2°C; C) Oscillation with a pattern, temperatures typically follow a pattern of cooling and heating over a 24 hour period that is repeated across the trial; and D) oscillation with no pattern, temperatures vary over the course of the trial but no clear cooling/heating pattern can be seen during the trial, with rises in temperature potentially due to fridge use.

Table 3. Oscillation type seen for each category of fridge, age of fridge and whether the fridge was free-standing or integrated. The percentage of fridges with the oscillation type (low/high) or pattern profile (pattern/no pattern) is noted in brackets.

Fridge category	Most common oscillation type seen	Most common pattern profile seen
Undercounter/half-size fridge	Low (54%)	No pattern (86%)
Full-size fridge	Low (67%)	No pattern (78%)
Classic fridge/freezer	Low (60%)	No pattern (84%)
American-style fridge	Low (62%)	No pattern (81%)
0 – 5 years old	Low (66%)	No pattern (85%)
5 – 10 years old	Low (63%)	No pattern (83%)
10+ years old	Low (53%)	No pattern (75%)
Unknown	Low (53%)	No pattern (82%)
Free-standing	Low (61%)	No pattern (84%)
Integrated	Low (68%)	No pattern (78%)

3.4 Impact of the household on fridge temperature

3.4.1 Demographic breakdown of the households that took part in FROST

Of the 361 households that took part in the FROST study, the majority (215 households; 59.6%) were those with 1-2 residents in the household, with 38.8% (140) households having 3-5 people and only 1.7% (6) having more than 6 residents (Table 4 and Figure 13). Although there was a trend in decreasing fridge temperature with the more people resident within the home (Table 4), there was no significant difference seen in the mean operating temperature among household size (determined by one-way ANOVA, $F(2,358)=1.94$, $p=0.145$).

Sixty-two percent and 31.5% of households had someone that would usually be at home all week or some of the week during the day, respectively. Only 6.3% of households did not have anyone usually at home during the day. It was hypothesised that those with someone at home during the day would be using their fridge more often and therefore may result in higher fridge temperatures. The majority of participants in FROST had someone home part or all of the week, with only 23 households recorded that nobody was typically home during the week. The average temperature for households with nobody home during the day was on average lower (4.64°C) compared to those who had someone home (5.18°C, part of the week; 5.22°C, all of the week) (Figure 14), however there was no significant difference found (determined by one way ANOVA, $F(2,258)=0.949$, $p=0.388$), although this could potentially be due to the small sample size of the “no residents home during the week” group.

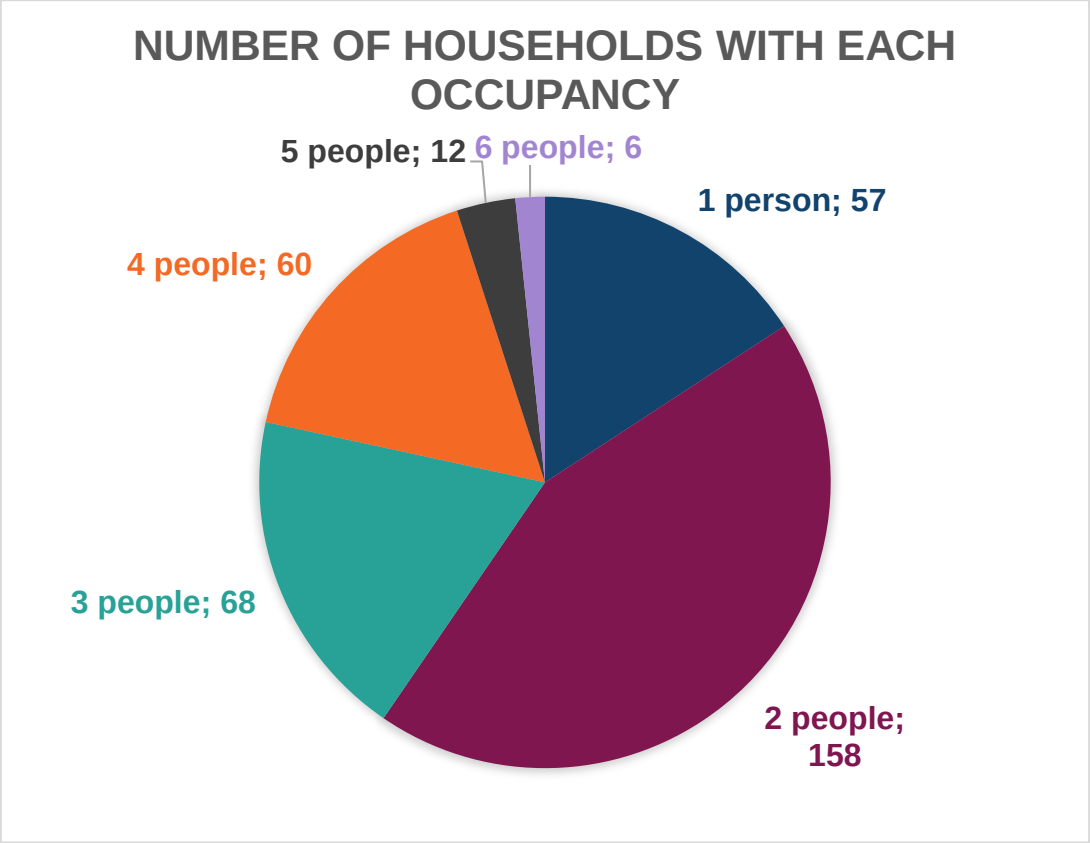

Figure 13. Number of occupants per household that took part in FROST.

Table 4. Summary of household demographics who took part in the FROST study. Categories are broken down into the number of residents, those who reported they were at home during the week or not and households where one of the residents was classed as a vulnerable group to foodborne illness (children under 5, older adults aged over 65, pregnant and immunocompromised individuals).

Household Group	**Number of households**	**Average Fridge Temperature (°C)**
Number of residents - 1 person	57	5.46
Number of residents - 2 people	158	5.29
Number of residents - 3 people	68	5.11
Number of residents - 4 people	60	4.88
Number of residents - 5+ people	18	4.44
At home during the day – all week	224	5.22
At home during the day – part of the week	114	5.18
Not at home during the day	23	4.64
No vulnerable group present	202	5.08
Children aged 0-4 resident in the house	22	5.08
Adults aged 65+ resident in the house	68	5.29
Someone with a weakened immune system (due to pregnancy/medication/ illness/other) resident in the house	65	5.36
Unsure/prefer not to say (regarding weakened immune system)	23	5.23

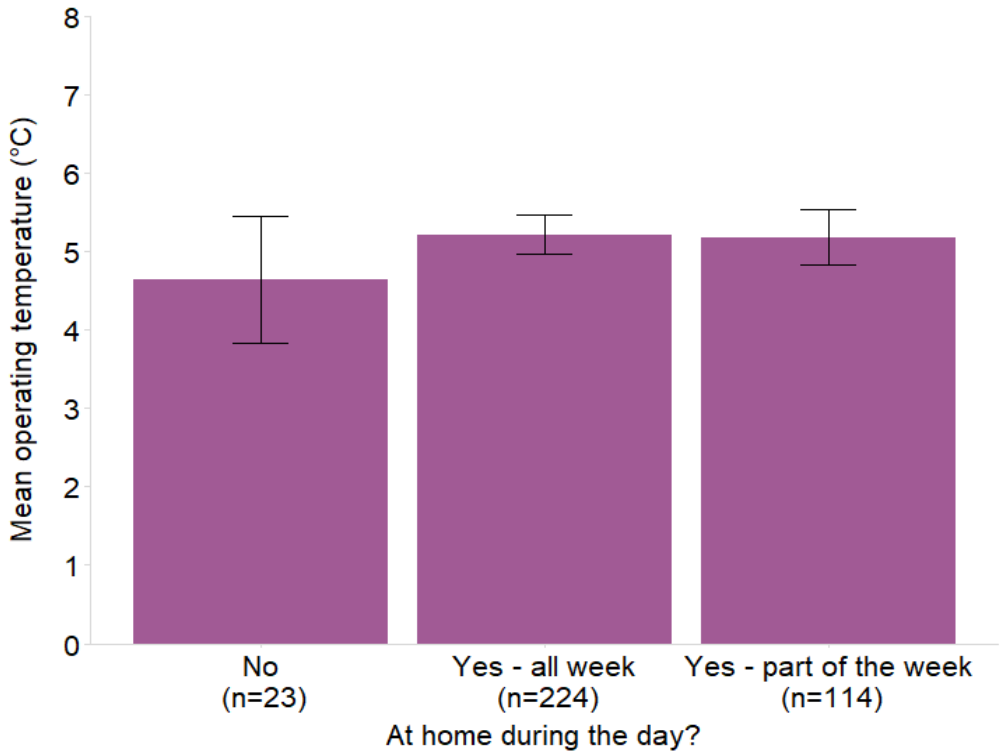

Figure 14. Mean operating temperature of the fridge for households that had someone typically home all week or not. Error bars represent the mean +/- 95% confidence interval.

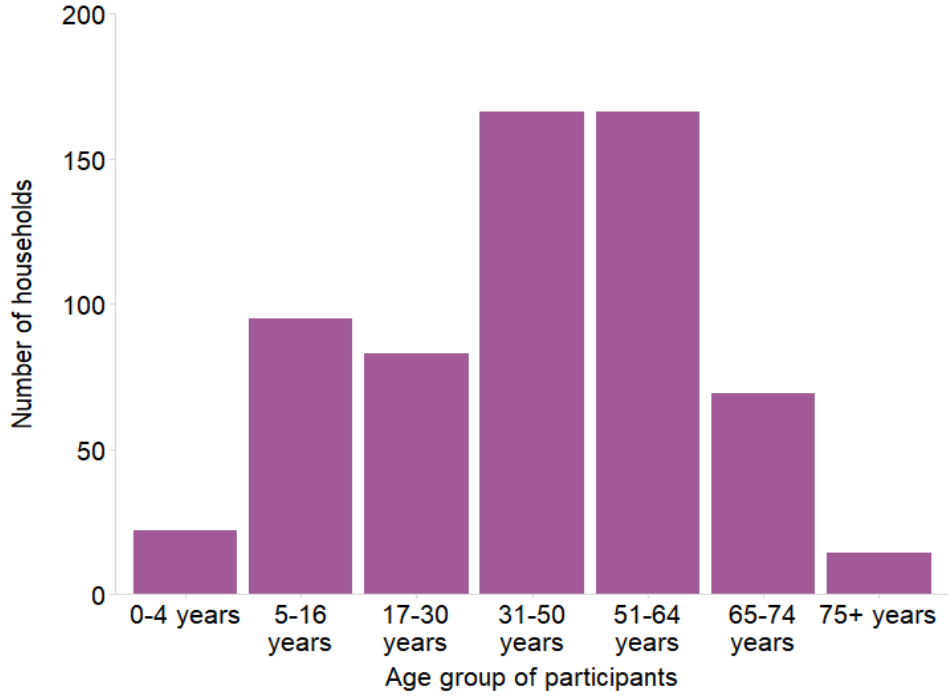

Figure 15. Age bands present in the households that took part in FROST. Note that due to multiple occupancy of some households, the total of citizens (913) exceeds the total households (361).

The most common age groups of citizens (931 citizens in total across 361 households) from the households that took part in FROST were 31 – 64 years old (332 citizens) (Figure 15). Citizens from each age group were present in households in the FROST study, allowing us to segment the data further to look at households with children or households with older adults present to determine if there were any differences in average fridge temperatures.

Those at highest risk of foodborne illness are referred to “vulnerable groups”. Vulnerable groups to foodborne illness are young children (less than 5 years old), older adults (65+) pregnant individuals or those with a weakened immune system (whether due to medication, illness or treatment). During the sign-up, citizens were asked the age bands of those resident within the household to determine the presence of vulnerable groups due to age: 22 households (6.1%) had a child under 4 and 75 households (20.8%) had resident(s) over 65 years old (Table 4). There was no significant difference in the fridge temperature of households with young children (aged 0-4 years; $p=0.854$) or in households with residents aged 65 and older ($p=0.482$) compared to households without these age groups.

A further question was asked during sign-up on whether a pregnant individual resided in the household or someone with a weakened immune system. Citizens could choose “prefer not to say” for both of these questions if they wished. Only one household had a pregnant individual. Sixty-four households had someone with a weakened immune system and a further 18 households stated they were unsure/preferred not to say whether someone resident in the home had a weakened immune system (Table 4). For the purposes of analysis, households with a weakened immune system are defined here as any household in which the citizen reported there was someone with a weakened immune system or a pregnant person in their household. No significant difference was seen between immunocompromised and non-immunocompromised households for fridge temperatures ($p=0.56$).

Finally, an overall analysis of the average fridge temperatures for households with a vulnerable group resident (someone aged under 5, someone aged over 65+, someone with a weakened immune system) compared to those without was carried out. There was no significant difference between the average fridge temperature for households with a vulnerable group to foodborne illness present (average temperature 5.26°C) compared to those without (average temperature 5.08°C; $p=0.438$; Figure 16).

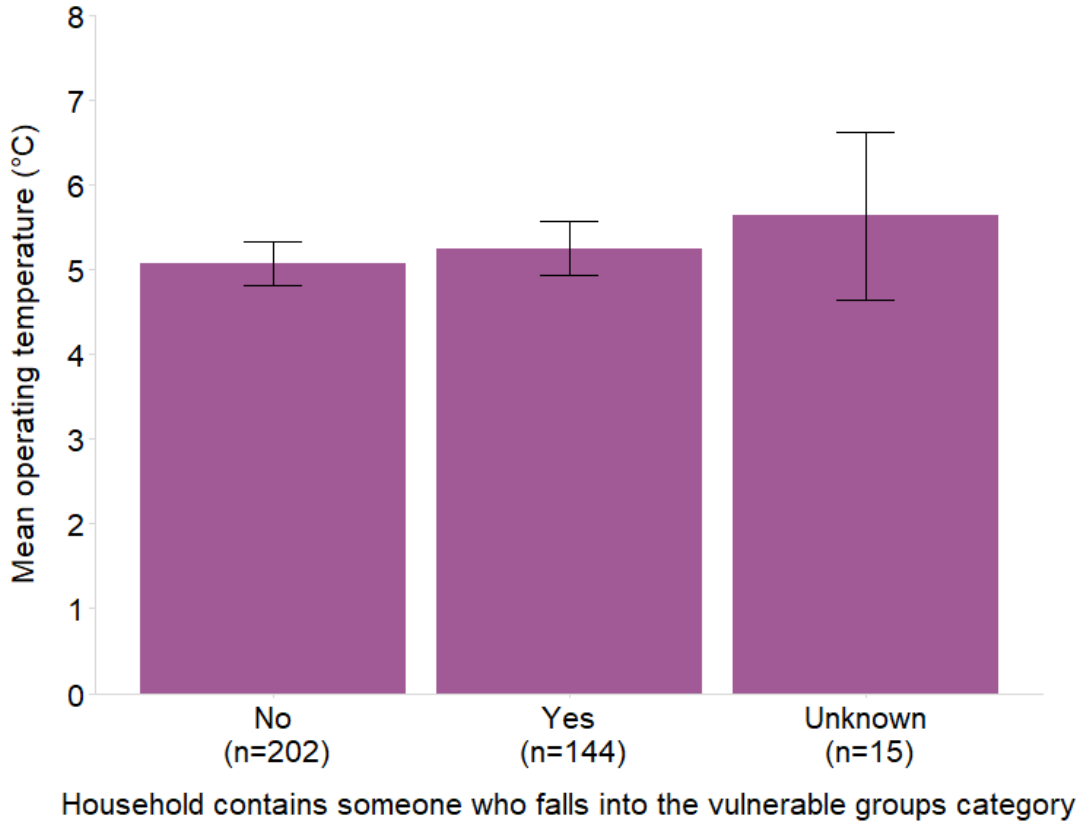

Figure 16. Mean operating temperature of the fridge for households with vulnerable groups to foodborne illness (young children, older adults, pregnant or those with a weakened immune system) residents present compared to those without. Error bars represent the mean +/- 95% confidence interval.

3.4.2 Citizen behaviours – checking and adjusting temperature

As part of the sign-up process, citizens were asked to report whether they typically would check the temperature of their fridge and if so, how they would do this. The majority of citizens (81.9%) reported that they do not check the temperature of their fridge (Figure 17), with 9.9% of this group reporting that they didn't need to check them because their fridge would alert them if it got too hot or cold. For those that reported that they do check the temperature of their fridge, 40 citizens reported that they would put a thermometer in to check the fridge temperature, with the remainder relying on fridge alarms, built-in fridge displays or dials to inform them of the temperature.

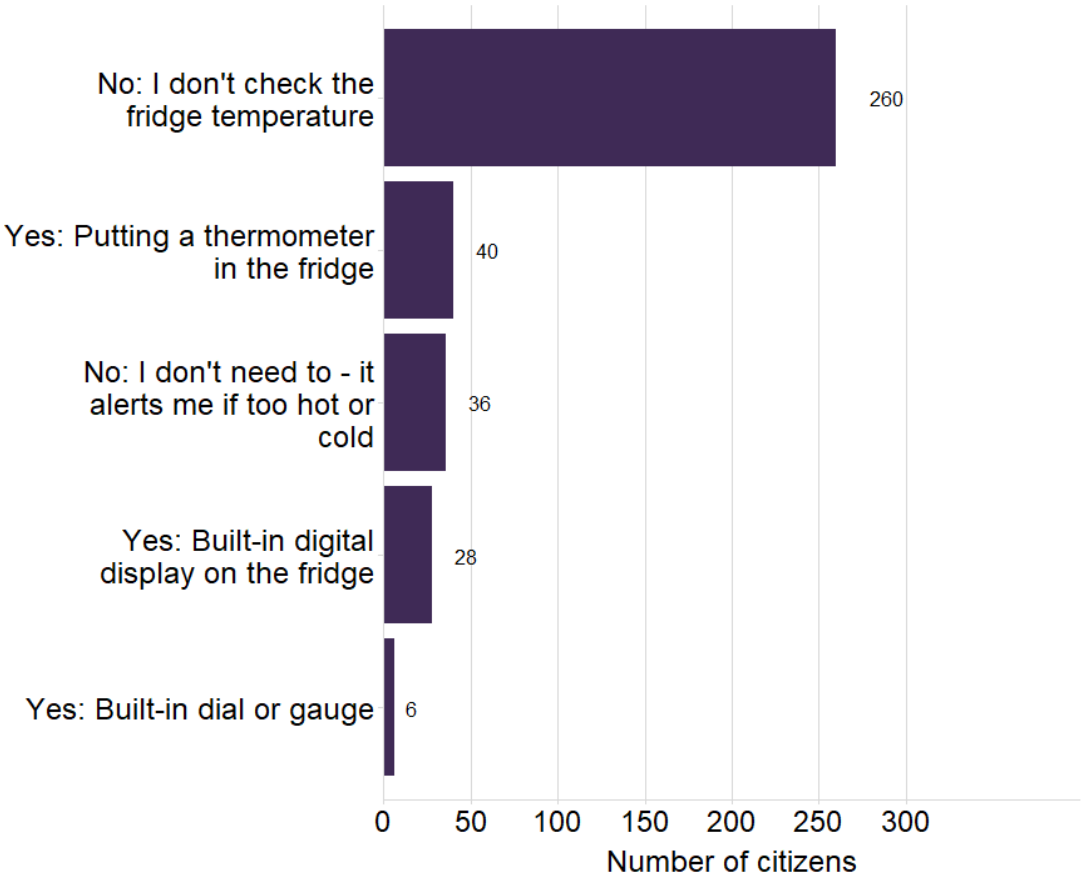

Figure 17. Methods used by citizens to check the temperature of their fridge. Note, some citizens use more than one method to check the fridge temperature, hence the total number of citizens exceeds 361.

There was no significant difference in fridge temperature between those that reported they checked the temperature of their fridge (5.20°C) and those who did not (5.27°C); however, a slight significant difference was seen between those who reported they don't need to check the temperature of their fridge (due to built-in alerts/alarms on the fridge; average temperature 4.37°C) and those who did not check the temperature (post-Hoc Tukey multiple comparison of means, p=0.02; Figure 18).

Citizens were also asked if they typically adjusted the temperature of their fridge, and if so, when they would do this. The majority of citizens (71.7%) reported that they do not typically adjust the temperature of their fridge (Figure 19). For those that do adjust the temperature of their fridge, reasons for this were typically due to sensory perceptions, such as the food feeling too hot/cold or noticing ice, rather than in response to a thermometer temperature reading. Those who adjusted their fridge temperatures had a higher average fridge temperature (5.39°C) compared to those who did not (5.09°C) (Figure 20) but this difference was not significant (p=0.162).

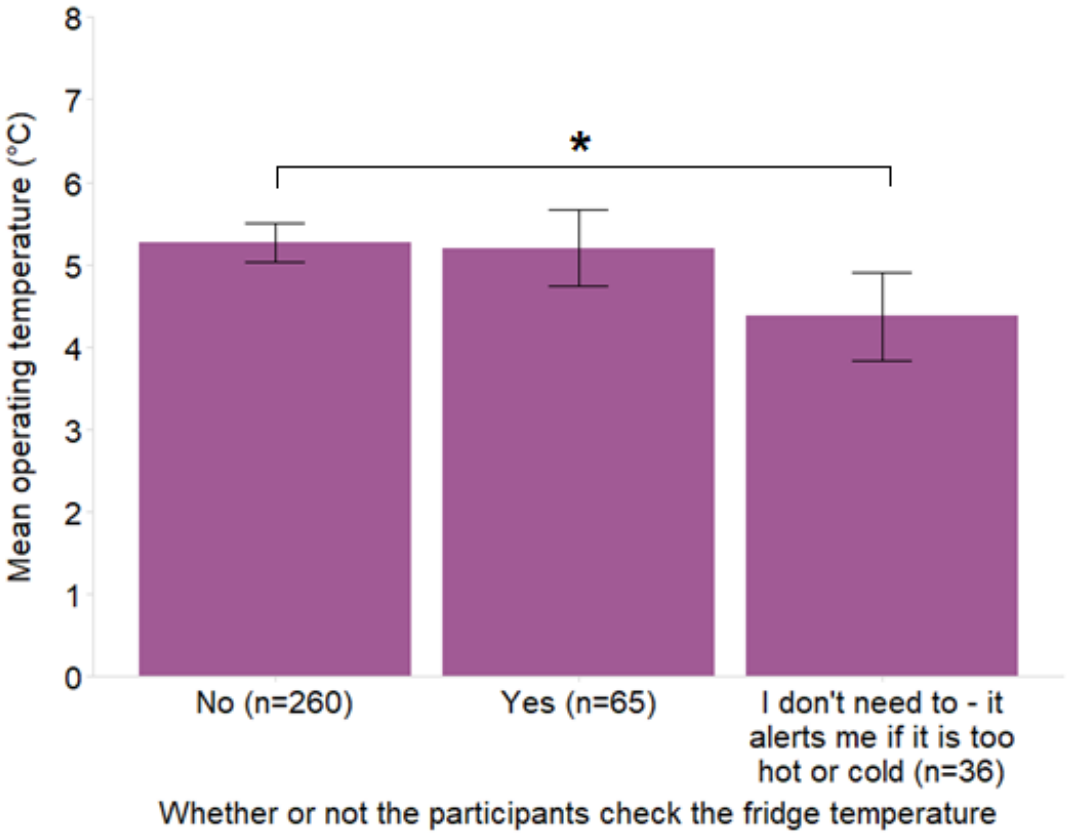

*Figure 18. Mean operating temperature of the fridge by whether or not the participants check their fridge temperature. Error bars represent the mean +/- 95% confidence interval. * denotes significant difference (p=0.02).*

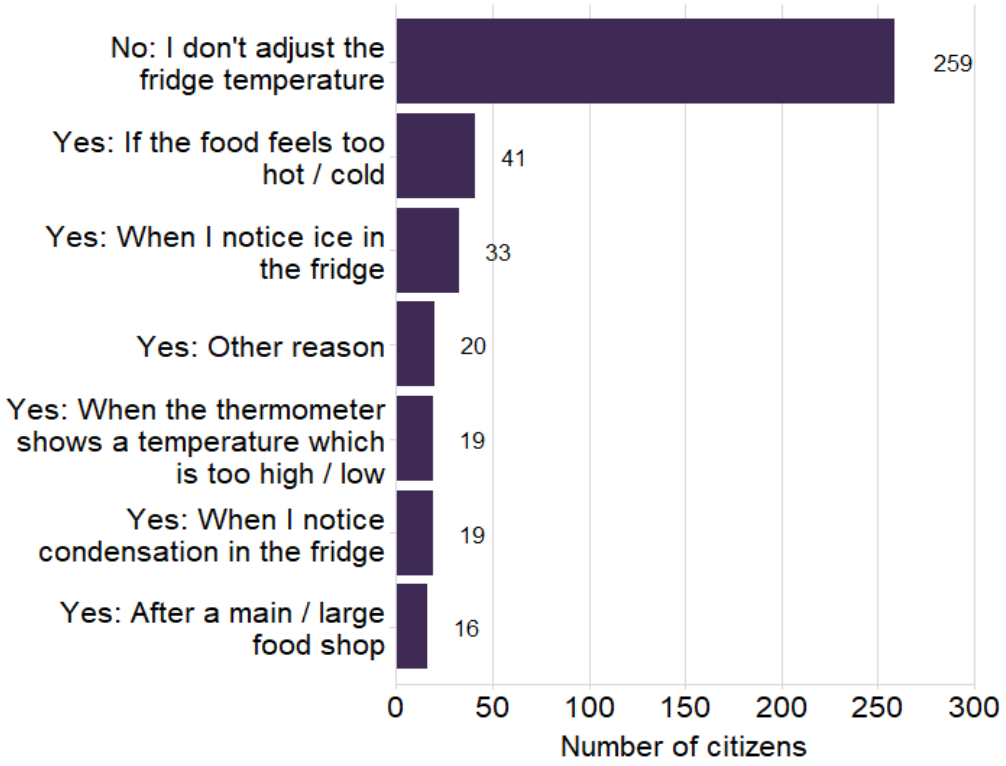

Figure 19. Citizen responses to the question "do you typically adjust the temperature of your fridge". Note that for those that said yes, multiple reasons could be selected so the total exceeds 361.

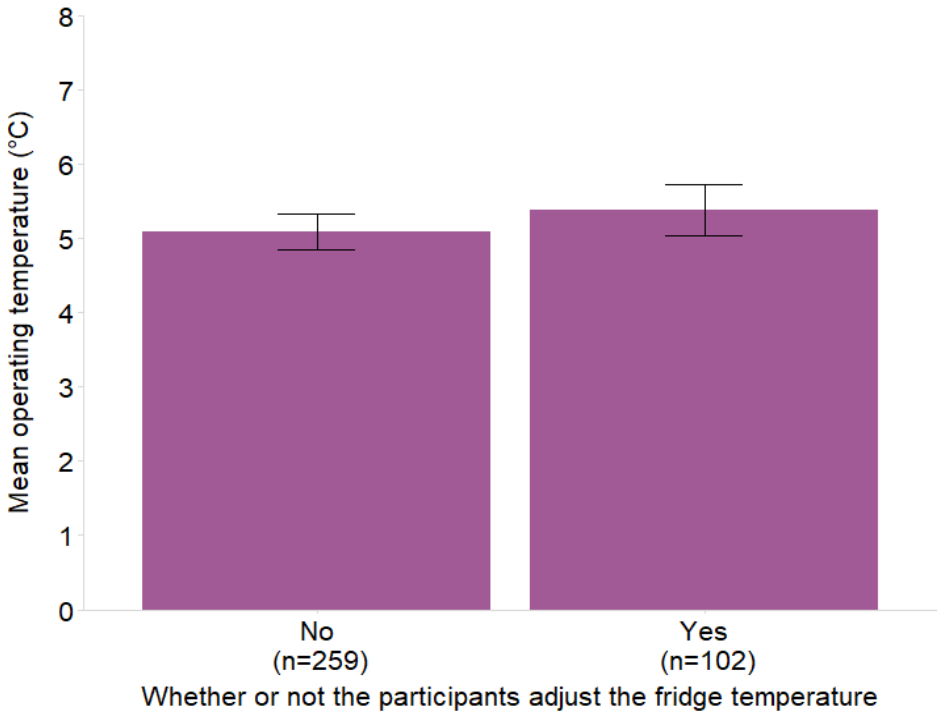

Figure 20. Mean operating temperature of the fridge by whether or not citizens typically adjusted their fridge temperature. Error bars represent the mean +/- 95% confidence interval.

3.4.3 SIMD and temperature

The Scottish Index of Multiple Deprivation (SIMD) is a tool for measuring deprivation across zones in Scotland calculated from seven categories (income, employment, education, health, access to services, crime and housing) (Scottish Index of Multiple Deprivation 2020 - gov.scot). Each data zone is scored an overall SIMD score from 1 to 5, with 1 indicating high deprivation and 5 indicating low deprivation across the categories.

Of the 361 households that took part in the FROST study, the majority (58.7%) of household postcodes were from the least deprived SIMD areas (SIMD 4 and SIMD 5). The average temperature of the fridges in households residing in SIMD 1 was 5.66°C, whereas the average temperature of the fridges in SIMD 5 was 4.96°C (Figure 21), however this difference was not significant (determined by one-way ANOVA, $F(4,326)=0.951$, $p=0.435$).

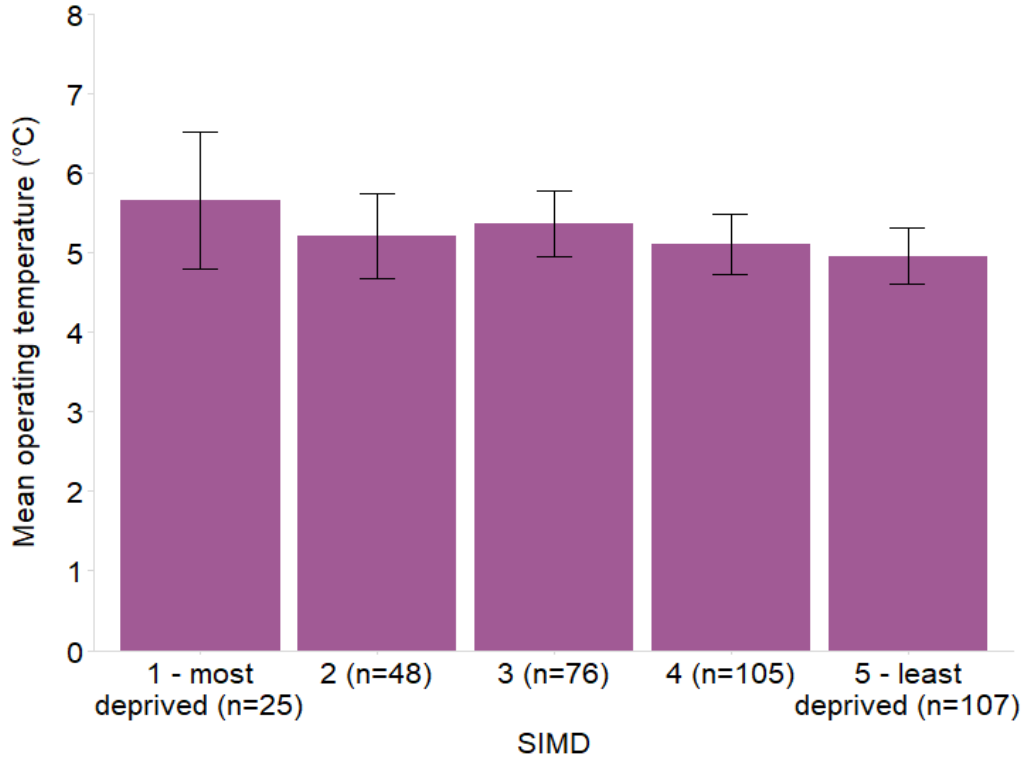

Figure 21. The average operating temperature of fridges by SIMD ranking. Error bars represent the mean +/- 95% confidence interval.

3.5 Impact of food shops

During the trial, citizens were asked to note the dates when they carried out a main food shop (if at all) to assess the impact of filling the fridge on the average temperature. No information on the amount of food stocked in the fridge was provided, therefore a mix of results were seen. In some cases, an obvious temperature increase was noted on the date of the main food shop (Figure 22A), with a temperature spike which gradually decreased back to the normal range for that fridge. However, in many instances, no impact was seen, with no significant change in temperature noted on dates of main food shops (Figure 22B).

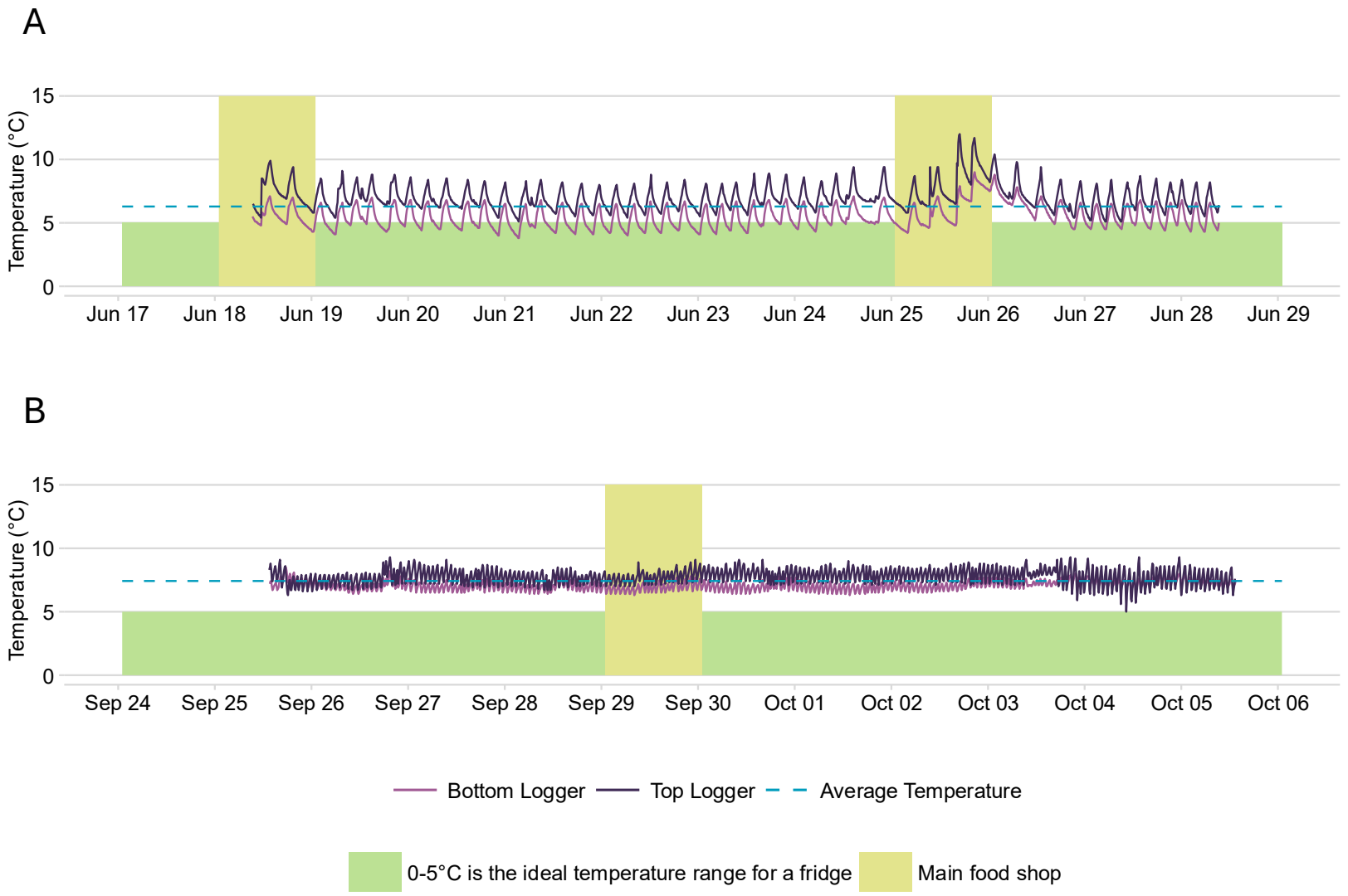

Figure 22. Temperature profiles of fridges in FROST with recorded main food shops (shaded yellow box).

3.6 Fridge photographs

As an optional ask as part of the trial, citizens could submit a photograph of the inside of their fridge. This was completely anonymous, not linked to their citizen code and therefore not linked to the temperature data. These photographs were instead used for qualitative analysis to understand how people were using their fridges, the typical food products that were stored in different locations in the fridge and whether risky food safety behaviours were observed, such as improper food storage. It should be noted that these photographs could be taken at any point during the trial and therefore only represent a single point in time, with some submitting photographs after food shops and some when their fridge was quite empty.

In total, 146 citizens submitted a photograph of their fridge for analysis. Within this group, 76% had some form of ready to eat (RTE) food on the top shelf of their fridge, but this was largely driven by products with a best-before date, such as yoghurts, hard cheeses or condiments.

Seventy-four fridges contained some form of raw meat and though the majority stored this on the bottom shelf of the fridge (the recommended place for storing raw meat) 28% of the photographs submitted containing raw meat stored them elsewhere in the fridge (Figure 23). There were also examples submitted of raw meat being defrosted on the middle shelves of the fridge rather than the bottom, above fruits and vegetables (Figure 24).

There were a few examples seen of over-packed fridges (Figure 25), which would impact the ability of the fridge to maintain temperature and/or could result in improper food storage, with raw meat products stored in close proximity to RTE products.

It should be noted however that the vast majority of photographs submitted showed proper food storage, with raw meat typically stored on the bottom shelf of the fridge. There were examples submitted of different methods citizens used to ensure good food safety within the fridge, such as in Figure 26, where a separate container was specifically used for raw meat only.

One of the aims of asking for photographs was to determine the type of food products that were stored on the top shelves and bottom shelves of the fridge. Typically, dairy products (butter, creams, yoghurts), cheese (hard/soft), leftovers and drinks (fruit juice, alcohol and soft drinks) were commonly seen on both top and bottom shelves (Table 5). Top shelves were also likely to contain condiments (jars/sauces), whereas the bottom shelves were likely to contain fruit, vegetables and meat products. Finally, there were also examples of fruit and vegetables being stored in close proximity to meat products on the bottom shelves, presumed due to a lack of space in the vegetable drawer underneath (Figure 27).

Table 5. Most common food categories seen in the top and bottom shelves from the photographs submitted to FROST.

Most common food category observed	Top Shelf	Bottom Shelf
1	Condiments/jars/sauces	Fruit & vegetables
2	Butter, yoghurt, cream	Butter, yoghurt, cream
3	Drinks (juice, soft drink, alcohol)	Meat products
4	Cheese (hard/soft)	Drinks (juice, soft drink, alcohol)
5	Leftovers	Leftovers/cheese

Figure 23. Example photographs of meat stored elsewhere than the bottom shelf, with meat stored in the vegetable drawer with RTE salads or near the top of the fridge.

Figure 24. Example photographs of defrosting and storing raw meat/poultry on the middle shelves of the fridge, above fruit and vegetables. Food safety advice is to store these in sealed containers on the bottom shelf to stop any juices from leaking onto RTE products.

Figure 25. Example photograph submitted of an over-packed fridge.

Figure 26. Example photograph of different storage methods used by citizens, such as a specific container in the fridge for raw meat only.

Figure 27. Examples of RTE salad vegetables stored in close proximity to meat/seafood products and packaging.

4. Discussion

The average temperature for fridges surveyed in FROST in Scotland fell just above the recommended temperature range of 0-5°C at 5.17°C. These numbers represent an average of the temperatures recorded over a ten-day period while the fridges were being typically used, so temperatures naturally fluctuated with the cooling cycles of the fridge itself, as well as increasing due to citizen use. This is similar to previous findings in other studies [7-16], and the estimated average fridge temperature worldwide (measuring air temperature within the fridge) at 6.1°C [17]. James and others (2017) estimated that 54% of fridges worldwide have average temperatures above 5°C [17]. In FROST, we found that 55% of the fridges surveyed were at this temperature on average over a 10-day period.

A wide range of temperatures were captured on the temperature loggers, with individual readings ranging from -11.9°C to 19.1°C overall and the average temperatures recorded ranging from 0.39°C to 10.94°C. In some instances, the temperature spikes could be attributed to citizen usage, with a main food shop (as recorded by the citizen) correlating with an increase in the temperature overall (e.g. Figure 23A), however this was not always the case so no direct correlation was able to made. It is hypothesised that the high temperature spikes seen are potentially due to the fridge door being opened for long periods of time, an over-stocked fridge and/or room temperature foods (e.g. fruit and vegetables) being added to the fridge. Additional work on citizen use of the fridge would be needed to understand this further.

For those lower temperature readings below zero, these were typically seen in fridges with a high oscillation profile. It is presumed that lower temperature spikes were possibly more noticeable to the consumer, due to food potentially freezing. For the high temperature spikes, these often did not correlate to any known cause measured in FROST; citizens were asked to note during FROST any issues/important information about their fridge that they felt we should know during the trial, therefore issues due to power cuts were logged. As such, it is presumed that citizens were unaware at times of the high temperature readings within their fridge.

Each fridge was measured with a temperature logger stored on the top shelf and a temperature logger on the bottom shelf. The top shelves of fridges were found to be hotter overall (average temperature of 5.89°C, with average temperatures ranging from -3.38°C to 14.48°C) than the bottom shelves (average temperature of 4.45°C, with average temperatures ranging from -2.52°C to 10.34°C). Typically, the warmest areas of the fridge are the tops of the fridge and the fridge door [10, 18, 19], with the bottom areas of the fridge being the coldest. As cold air is more dense than warm air, it is expected that the temperature loggers stored on the bottom shelves would record colder temperatures than those stored on the top shelves.

Our study found that the age of the fridge did not have an impact on the operating temperature of the fridge. This is in line with other studies analysing fridge temperatures in other countries [12, 19], although there have been published reports of older fridges resulting in higher temperatures [20]. However, while the age of the fridge didn’t impact the average temperature of fridges surveyed in FROST, the type

of fridge did. Free-standing fridges operated at lower temperatures than integrated fridges, and American-style fridges had the lowest average temperature over other fridge styles. The reason for free-standing fridges giving colder temperatures overall is unknown and could be down to variety of factors, such as better airflow, fridge design and the ability of these fridges to reject heat. American-style fridges also performed better at maintaining a lower temperature, although this could be down to consumer use: as these fridges are typically larger than other styles, they may be less likely to become overfilled as a result. Overfilling a fridge restricts the air flow throughout the fridge and can impact the operation of the fridge, potentially resulting in higher temperatures. Another potential option is the majority of American-style fridges had a fridge compartment on one side and a freezer on the other, therefore close proximity to a freezer could impact the temperature of the fridge. These refrigerators may also be more likely to have smart features, such as the temperature display or a built-in alarm, which was shown to in this study to significantly be associated with lower fridge temperatures.

Although the recent Food and You 2 survey [5] found that 62% of people surveyed knew the correct fridge temperature range of 0-5°C, this study found that the majority (55.4%) of fridges surveyed were averaging temperatures above 5°C. Although citizens may know the correct temperature range their fridge should be at, this knowledge did not translate into behaviour, with only 18% of those taking part in FROST regularly checking their fridge temperature. Food and You 2 reported that 55% of people surveyed in Scotland monitored the temperature of their fridge monthly (47% manually, 8% internal alarm) [5], however the method of monitoring was unknown. Previous surveys have found temperature monitoring is typically carried out using unreliable methods, such as using sensory cues (looking for ice/condensation) or the power dial within the fridge [6], which denotes the fridge setting rather than temperature. Only 11% of citizens in the FROST survey reported using an external fridge thermometer for manually checking the temperature of their fridge. However, a significantly lower average fridge temperature was seen in FROST for those who had a built-in alarm within the fridge that monitored the temperature and indicated if the temperature had exceeded the specific temperature range, compared to those without. Therefore, the use of built-in fridge alarms may be an effective tool where possible to help maintain temperature within the correct range, especially for those that do not manually check the temperatures themselves.

Worryingly, recent surveys by FSS have found that people in Scotland are adjusting their fridges as a method to save money on energy bills. In the latest Food in Scotland consumer tracker (FSS Wave 19), 12% of people surveyed stated they had changed the settings in their fridge so that the food was being kept at a warmer temperature [21]. Eight percent of those surveyed stated they had switched off a fridge and/or freezer that contained food to save on energy bills within the last month [21]. The importance of maintaining the temperature within 0-5°C within a fridge needs to be emphasised with consumers in Scotland to help address these behaviours, as an important method of not only reducing food waste [22] but for minimizing the risk of growth of foodborne bacteria.

Those potentially more likely of these high-risk behaviours are those most impacted by cost-of-living pressures, such as those residing in areas of high deprivation (SIMD 1). This study analysed whether deprivation may have an impact on fridge

temperature and while those residing in SIMD 1 had the highest average fridge temperature, this was not found to be significant. The household demographics were also analysed to determine if this impacted fridge temperature, looking at the number of people in the household, whether someone was typically at home during the day and whether residents were present in the household who may be classed as more vulnerable to foodborne disease (under 4 years old, over 65 years old, pregnant or immunocompromised). No difference was seen in any of the analysis breakdowns for the household for fridge temperatures.

As an optional ask of FROST, citizens could also submit a photograph of the inside of their fridge at any point during the trial. Over 100 photographs were submitted to FSS, which allowed us to perform a qualitative analysis of how citizens were typically using their fridges. There were examples of citizens overfilling their fridges, as well as storing high-risk products such as raw meat in the incorrect areas of their fridge. Sixty-nine percent of respondents in Food and You 2 reported that they stored raw meat and poultry at the bottom of the fridge [5] and a similar result was seen in FROST, with the majority storing meat on the bottom shelf. However, some citizens clearly stored raw meat where there was space, sometimes on top of or in close proximity to RTE products, including salads. A similar survey of fridge temperatures found that the majority of their participants did not correctly place food commodities within the fridge, including for raw meat [11]. Handling of these high-risk products by consumers remains an area of concern with regards to fridge usage, with studies showing a lack of knowledge and adherence to recommendations from food safety organisations [23]. While the majority of respondents who did share a photo as part of FROST were storing food products correctly, there is still work needed to educate consumers on the importance of storing food safely, not only for allowing suitable air flow within the fridge to maintain temperature, but to avoid cross-contamination from high-risk products onto RTE products.

There is also work that can be done to help educate consumers on typical products that should be stored in the top areas of the fridge. The photographs showed that dairy products and leftovers were some of the most common products stored on the top shelf of the fridge, which was found to be hotter than the bottom of the fridge. Shelf life of these products could be shortened and food safety could be compromised by storing in the warmer zone within the fridge due to the growth of bacteria. Leftovers are a product of particular risk, as it is recommended that leftovers are cooled and stored within two hours of cooking, however studies have found surveyed consumers worldwide would leave food out for hours before refrigeration [24]. Leftovers therefore can spend significant time within the “danger zone” (8-63°C) for bacterial growth. Furthermore, it has been reported that over a fifth (22%) of Scottish consumers surveyed in Food and You 2 would store and use leftovers within three to five days, longer than the recommended 2 days [5]. Fourteen percent of consumers also stated they would reheat food multiple times [5]. By storing leftovers in this warmer region of the fridge, especially for longer periods of time than recommended, and potentially reheating multiple times, this can give more opportunity for bacteria to grow, resulting in possible foodborne illness. Therefore, work is needed to remind consumers of the importance of storing leftovers safely and correctly, as well as recommending items of low-risk, such as canned beverages, are stored in the warmer areas of the fridge.

Limitations of this study include that factors known to impact fridge temperature were not monitored due to the feasibility of the temperature monitoring, such as the number of door openings, the ambient room temperature and the amount of food stored within the fridge. As a citizen science approach was used, placement of the loggers was carried out by the citizens, which could lead to variability in the data, although recommendations were given by FSS on placement of the loggers for the study (Appendix 7.3) to help minimise this where possible.

In summary, this study has shown that fridges in Scotland are typically running hotter than recommended, despite the majority of citizens knowing the correct temperature range a fridge should operate at to ensure food remains safe. Differences were seen in the type of fridges, with American-style and free-standing fridges having the lowest temperatures overall. The number of people within the household did not impact the average fridge temperature, despite presumably more fridge usage occurring. Therefore, the influence from the citizens on fridge temperature is potentially due to factors such as overstocking of the fridge, although this was untested in FROST and would need to be followed up in a future study to determine this. This study has highlighted further work is needed to raise awareness with citizens in Scotland of the importance of checking fridge temperatures, of ensuring suitable air flow within the fridge and that foods of high risk are placed in the lower areas of the fridge rather than the top. There is also work to be done on emphasizing the importance of reducing cross-contamination within the fridge, ensuring raw and RTE foods are kept separate and that raw meats are stored at the lowest shelf.

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Appendix 1

Once the citizens data had been analysed by FSS, the following e-mail was sent with a graph of their results. A graph has been included as an example of what would be received.

E-mail message

Dear *Citizen*,
Citizen Code: *citizencode*

Thank you for taking part in Food Standard Scotland's FROST (Fridge Recording Over a Set Time) project!

Your fridge is a weapon in the battle against germs to help stop or slow down any bacterial growth. Fridges should be kept between 0 and 5°C to keep food fresh and safe – however, due to a variety of factors, sometimes they can run colder or hotter than this.

We have downloaded the data from the temperature loggers that you stored in your fridge.**Overall, the average temperature of your fridge over the two-week period was *average*°C**.

We provided you with two temperature loggers for the trial: one to be stored at the top of the fridge and one at the bottom. This is because there can be temperature differences between the top and bottom of your fridge, but initial results from FROST suggest this is very dependent on the type of fridge that you have.
The average temperature for the top of your fridge was «Top_av»°C and the average temperature for the bottom of your fridge was *bottom*°C.

It's important to regularly check the temperature of your fridge using a built in or freestanding thermometer. If it's not reading between 0-5°C you can use the built in dial/gauge inside the fridge to change the power setting (typically the higher the value the more power the fridge uses to take the temperature down; if in doubt, check the manufacturer's instructions for your fridge). Note: this built in dial/gauge does not represent the temperature in °C.

A fridge doesn't work best when it's overstuffed, so another top tip is to increase the power to turn the temperature of your fridge down after doing a main food shop. Try to keep the door closed as much as possible too when filling up your fridge.
For more information on chilling your food safely head over to our website.

Thanks again for taking part, your participation has helped us collect important data to improve food safety standards in Scotland. *Any questions? Feel free to get in touch with us at fridgetemperatures@fss.scot*

Example graph

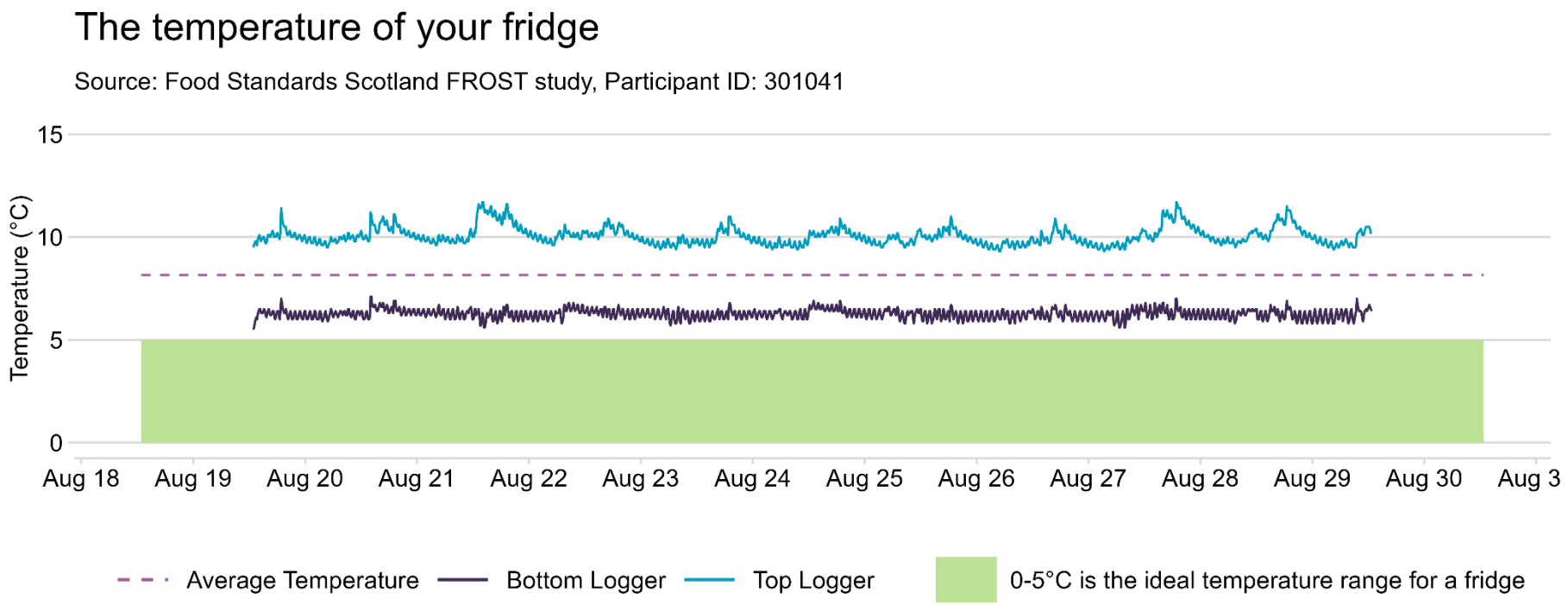

Figure 28. Example of the graph that would be received by the citizen after completing their trial and submitting the data loggers to FSS. The graph would show the results for the bottom logger (dark purple), the top logger (light blue) and the average temperature of their fridge overall. The correct temperature range of 0-5C would be highlighted in green to show if their temperatures results fell in this correct region.

Appendix 2

The following details the citizen recruitment questionnaire used during the sign-up of FROST.

(Tickboxes)

- Please tick this box to confirm you are over 18+ years old.
- Please tick this box to confirm that you are currently living in Scotland.
- Please tick this box to confirm that you have a food fridge in your home.

1. Name: *(open text)*

2. Address (including postcode): *(open text)*

3. E-mail address: *(open text)*

4. Of the people who usually live in your house (including yourself), how many are in the following age groups:
   - 0 – 4 years old *(box, numbers only allowed)*
   - 5 – 16 years old *(box, numbers only allowed)*
   - 17 – 30 years old *(box, numbers only allowed)*
   - 31 – 50 years old *(box, numbers only allowed)*
   - 51 – 64 years old *(box, numbers only allowed)*
   - 65 – 74 years old *(box, numbers only allowed)*
   - 75 years old and above *(box, numbers only allowed*

5. Are you or is someone in your household typically at home during the day throughout the week (Monday – Friday)? (e.g. retired, unemployed, works from home, parent/carer)
   (Choose one of the following)
   - Yes – all week
   - Yes – part of the week
   - No

7. Do you or does someone in your household have a weakened immune system (e.g. this could be due to medication, cancer treatment or a health condition)?
   (Choose one of the following)
   - Yes
   - No
   - Unsure/Prefer not to say

8. Are you or is anyone in your household currently pregnant?
   (Choose one of the following)
   - Yes
   - No
   - Unsure/Prefer not to say
9. Roughly how old is the main food fridge in your household?
   (Choose one of the following)

- Under 5 years old
- 5 to 10 years old
- More than 10 years old
- Unknown, as I rent and it was here when I moved in
- Unknown, as I bought my house and it was here when I moved in
- Unknown, as it was donated/acquired second-hand
- Unknown, other reason (*open text*)

10. Is your fridge free-standing or an integrated fridge?
    Free-standing means that they are not built-in to your kitchen and therefore can be more easily moved to a different plug socket if needed. Integrated fridges are fitted into your kitchen, sitting behind a cupboard door as a more permanent fixture (cannot be moved as easily).
    (Choose one of the following)
    - Free-standing
    - Integrated
    - Unsure

Appendix 3

An A5 flyer was provided in each citizen pack, which contained the trial instructions (Figure 29) and the post-trial questionnaire (Figure 30) that was to be completed by the citizens and returned to FSS with the two temperature loggers in the pre-paid envelopes.

Trial instructions

Thank you for participating in our citizen science project! Your contribution helps us to develop important food safety messaging – keeping public health and consumer protection at the heart of what we do at Food Standards Scotland.

The temperature of your fridge can vary across different areas inside it. It's important to regularly check that your fridge temperature is between 0-5 °C to help keep food fresh and safe for longer.

For this test, you've been provided with two temperature loggers, which will automatically record the temperature in your fridge every 10 minutes.

IMPORTANT – we would like to record data during a typical two-week period in your home so please use your fridge as you would normally. Acting as though the temperature loggers are not there will give us the best and most accurate results.

Need help?

If you have questions or experience any issues during the trial, please contact us at **fridgetemperatures@fss.scot** – we'll be happy to help!

Step 1:
Remove the temperature loggers from the envelope.
One temperature logger will be labelled 'TOP' and the other is labelled 'BOTTOM.

The loggers are ready to use - all you need to do is put them in your fridge.

Please ignore the buttons on the loggers. These have been disabled, but don't worry if you press them by accident - they won't interfere with the recording.

Step 2:
Put both temperature loggers into your main fridge that you use for storing food.

Place the logger labelled **'TOP'** on the top shelf of your fridge.

Place the logger labelled **'BOTTOM'** on the bottom shelf of your fridge. If you have drawers at the bottom of your fridge, place it on the shelf above if possible.

It doesn't matter if the temperature loggers are positioned standing up, sideways or down flat.

Place the loggers in a similar area of each shelf. For example, keep both on the left hand side, towards the back of the shelf. Put the logger on the shelf itself rather than on top of any food products. This will prevent the food products affecting the temperature that is recorded.

Please record the date and time that you put the temperature loggers inside your fridge below.

Date:_____ Time:_____

Step 3:
Leave the temperature loggers in the fridge for two weeks.

The loggers will record fluctuations over time. Just use your fridge as you normally would. Try to not move the loggers during this period.

Step 4:
After two weeks, remove the temperature loggers from your fridge. Then complete the post-trial questionnaire on the back of this pamphlet.

Please record the date and time that you removed the temperature loggers from your fridge below. If you have a built-in display on your fridge, write what temperature the display shows when you finished the trial.

If you don't have a built-in temperature display, just leave the temperature field below blank.

Date:_____ Time:_____ Temp:_____

Step 5:
Return both loggers and the post-trial questionnaire to us.

Place the two temperature loggers and this pamphlet into the prepaid envelope provided. You can pop it into your nearest post box, or drop it off at a Royal Mail post office if you prefer.

Thank you for taking part and for contributing to citizen science!

Figure 29. Trial instructions for citizens for the FROST trial.

Post-trial questionnaire

Citizen code:

Please answer the following questions:

1. During the two weeks the temperature loggers were in your fridge, did you do a main food shop (for example a weekly or fortnightly shop)? If so, on what date(s):

2. Did you have any issues with placing the temperature loggers at the top and bottom of your fridge?

3. Did you encounter any problems with your fridge (for example a fault or breakdown) during the study?

4. Is there any other information about your fridge or the loggers that you think we should be aware of?

5. Did your household spend a significant period of time away from home (longer than 48 hours), during the trial? If so, please note the dates here.

☐ **Want to receive a copy of your results?** Please tick this box to confirm you are happy for us to contact you by email with your results and in case we have any follow-up questions regarding your data.

☐ Please tick this box if you'd be interested in participating in future citizen science projects and would be happy for us to contact you regarding this. You can be removed from this list at any time upon request.

OPTIONAL:

Send us a photo of your fridge.

This is not a mandatory requirement for the study. If you don't want to submit a photo you can skip this step.

Please take a photo of the inside of your fridge. Then send it to us in one of the following ways:

- email it to fridgetemperatures@fss.scot
- scan the QR code below on your smartphone and follow the instructions

These photos will help us to overall evaluate both how and where different food types are being stored in Scotland's fridges. **Submitted photos are completely anonymous and will be filed separately from any personal details or identifying information.**

Don't feel like you need to clean the fridge or rearrange the food to make it look tidy! Just snap a photo showing the contents of your fridge as it is. The more accurate to 'real life', the better.

Food Standards Scotland
For safe food and healthy eating

Food Standards Scotland
For safe food and healthy eating

FROST: guide for participants

Figure 30. Post-trial questionnaire for citizens to complete after the trial, as well as instructions for the optional task to submit a photograph of their fridge at any point during the trial.