Energy performance of domestic cold appliances in laboratory and home environments

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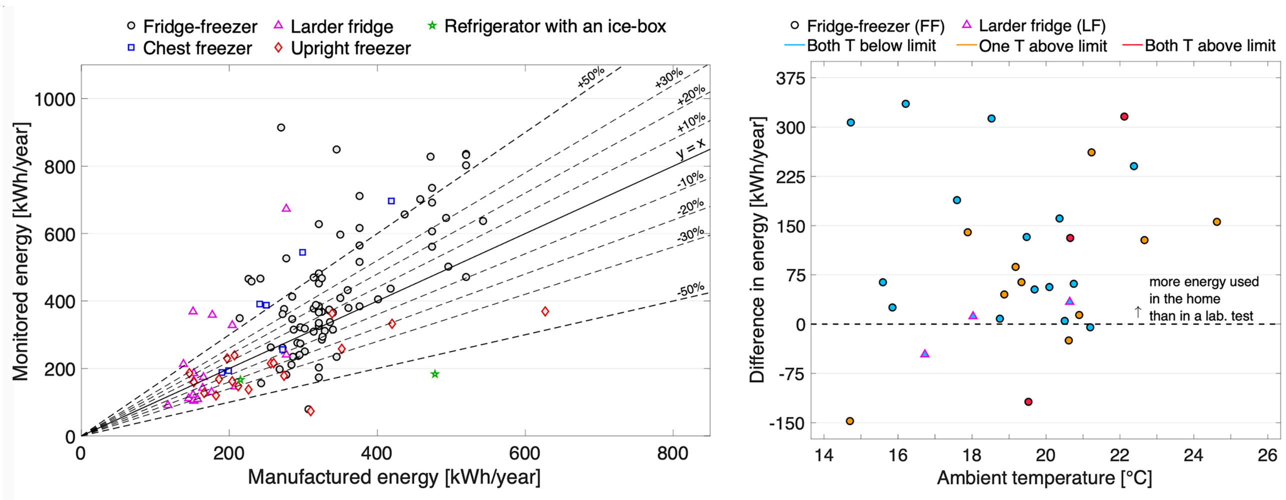
Abstract

Energy used by domestic refrigerators can be a large part of household energy use. In most countries, consumers are informed of the energy used by their appliance through energy labels or manufacturers data provided with the appliance. Work was carried out to ascertain whether the information provided to consumers provided an accurate reflection on the energy used in real life.
Data was extracted from a large-scale survey of the performance of domestic cold appliances. Information on temperature control and electricity consumption as well as information about the appliances was collected in the survey. In total 998 appliances were examined, of which 124 were used for the analysis in this paper. For each of these appliances, the electricity measured by the appliance manufacturer in a test laboratory was compared to the energy consumed in the home. Sixty-one percent of appliances consumed more energy in the home than the laboratory. The rank order of energy used by appliances was also assessed and found to vary considerably between the laboratory and the home. A more transparent test method to assess performance of refrigerated appliances in the home is suggested.

Keywords: Survey; Residential refrigerators; Residential freezers; Electricity consumption; Temperature; Laboratory testing

Graphical abstract



1. Introduction

According to the International Energy Agency (IEA) [1], more than 30% of global energy consumption and nearly 40% of carbon-dioxide emissions [2] were related to the buildings sectors. In 2018, worldwide energy use by household appliances was 3023 TWh [3], and of total energy use from all residential appliances, refrigerators and freezers accounted for around 500 TWh. Domestic refrigerators account for 14.2% of the household electricity use in Japan, 14% in USA and 21% in South Korea [4]. Worldwide there are more than 1.4 billion domestic refrigerators and freezers, each of which is claimed to consume on average 453 kWh of energy per year [5]. The worldwide market and electricity use of domestic cold appliances are expected to increase by 2030 [3]. In 2012, Barthel and Götz [5] stated that a 27% increase in numbers of cold appliances worldwide is expected by 2020 and that this will increase to 62% by 2030 (compared to a 2009 baseline).

It is therefore clear that improving the energy efficiency of refrigerators and freezers will have a significant impact on future electricity consumption [6-8]. A number of countries and areas have applied methods to reduce energy consumed by refrigerated appliances through the application of energy labelling and/or minimum energy performance standards (MEPS) [9-11]. The EU applied MEPS and energy labelling in 1993 and since that time the MEPS have been reduced. In 1995 less than 5% of appliances were labelled class A. By 2005 80% of all new appliances were declared as being A rated or better [12]. Energy labelling requirements are prescribed in European energy labelling regulations and are based on specific energy consumption (volume) of an appliance. Although new regulations will come into force in 2021, the current requirements are contained in the Commission Delegated Regulation (EU) No 1060/2010 [13].

Reported information suggests that older appliances use more energy. Gemmell et al. [14] demonstrated that older appliances (especially those aged over 11 years) used more energy in the home than newer appliances. There was however, less difference between appliances under 7 years of age and very large variations in the energy used by appliances of the same age. In 2000, Carlsson-Kanyama and Faist [15] stated that a 10 year old refrigerator used 2.7 times as much energy per litre of usable volume compared with an A-class refrigerator. In 2006, Kim et al. [16] stated that a typical mid-sized refrigerator model, from 1994 or earlier, consumed more than 1,000 kWh per year of electricity and should be replaced as an energy efficiency strategy.

Data on energy used by domestic refrigerators in test laboratory conditions is widely available, as all domestic refrigerators in Europe are energy labelled. However, there is limited comprehensive information on whether tests carried out in a test room reflect performance of refrigerators in the home. Authors such as Bansal [17] consider that a more lifelike test should be carried out but evidence also suggests that the test regime is a good estimate of usage in the home [18-19]. Real operating conditions of appliances are difficult to test in the laboratory since the behaviour of householders is quite varied. For example, little information is available on the number of times appliance doors are opened, the types and temperatures of food placed in the appliances and the ambient temperatures where the appliances are installed which do not remain constant over time. Several research activities have been carried out in order to evaluate the effects of operating conditions on the energy consumption of domestic refrigerated appliances. Meier [20] found that the energy used by similar refrigerators varied widely in consumers' homes and that this was primarily due to ambient temperature, while door openings and ambient humidity had relatively minor impact on energy consumed. Saidur et al. [21] and Hasanuzzaman et al. [22] claimed that ambient temperature and internal appliance temperature strongly influenced the appliance energy consumption. Saidur et al. [21] proved experimentally that when a freezer thermostat setting was reduced by 1°C the energy consumption increased by 8%. Foster [23] reported as the three main factors affecting the electricity consumption of domestic cold appliances are, in order of importance: the appliance type, the appliance age and the room temperature. The effect of ambient temperature surrounding appliances on energy consumption and refrigerant charge has also been corroborated by several authors [24-26]. Also Harrington et al. [27-28] investigated the energy response to room temperature variation for several cold appliances (111 appliances monitored in laboratory and 235 measured in the field). The analysis showed that room air temperature accounted for 75-85% of the energy consumption of cold appliances in the home.

The impact of the location of refrigerators was investigated by Lepthien [29]. Placing a refrigerator next to an oven had little effect on energy use (an observed increase of approximately 1%). In a survey in the UK James and Evans [30] found that 26% of refrigerators, and in a survey in France Laguerre et al. [31] found that 30% of refrigerators had a heat source by the side of the appliance. The effect of lack of air circulation over the condenser in built in refrigerators was investigated by Lepthien [29] who found (contrary to refrigeration appliance manufactures advice) that complete inhibition of air circulation did not affect energy consumption greatly even though the temperature around the condenser increased.

Door openings have also been shown to influence energy consumption of refrigerated appliances and the impact can be high, since a lot of heat gains are introduced into the appliance from the ambient surroundings. There is relatively little comprehensive information available on how often refrigerators door are opened by consumers. In a study by Laguerre et al. [31] 19% of consumers claimed that they opened their refrigerator less than 10 times per day, 43% claimed that they opened their refrigerator 10-20 times per day and 38% claimed that they opened their refrigerator more than 20 times per day. In Malaysia, Rahman et al. [32] found that 8% of household opened their refrigerator less than 10 times per day, 73% opened the door 10-20 times and 19% opened the door more than 20 times. Thomas [33] found that in Europe each person in the households examined opened the refrigerator door 8.2 times per day.

Böhmer and Wicke [34] stated that 3% of the total energy consumption of a refrigerator was due to door openings. Liu et al. [35] found that energy consumption increased by 5-10% when doors were opened for 5 seconds every 12 minutes over a 10 hour period in an ambient temperature of 15°C. In an ambient temperature of 30°C, the same length of door openings every 40 minutes over a 10 hour period increased energy consumption by 1-4%. Hasanuzzaman et al. [36] also tested the effect of door openings. They found that energy consumption increased by 24 Wh per door opening during 8 hours of testing while the energy consumption increased by 16 Wh for each second that the door remained open during 8 hours of testing. Brown and Evans [37] found energy consumption increased by 10% when the freezer door was opened for two minutes, and consumption increased by 27% when warm food was added during the two minute door opening.

Loading warm food into a refrigerator also has been reported to increase energy usage. Böhmer and Wicke [34] reported that loading warm food increased energy use by 10%. If the food was loaded over 2 stages then the energy increase was only 5%. Lepthien [29] found that cooling food from 50°C in a refrigerator used 3 times as much energy as cooling food from 20°C. Thawing food in a refrigerator reduced energy consumption by 26%. Geppert and Stamminger [38] tested four different appliances from the same manufacturer in the laboratory as a function of three independent variables at the same time. In the tests they varied ambient temperature, internal compartment temperature and heat load by adding warm food into the appliance. They showed that the energy consumption of the appliances was highly affected by real operating conditions.

Door seals potentially have an influence on energy consumed by refrigerators James and Evans [30] found that 10% of refrigerators had badly torn and perished door seals. This would be expected to increase energy consumption but further work is required to determine the impact of maintenance on the energy consumption of refrigerators.

In Europe most testing in laboratories is carried out according to EN 62552:2013 (Household refrigerating appliances - Characteristics and test methods) and this standard is used for energy labelling of appliances. A more recent test standard; IEC 62552:2015 (Household refrigerating appliances - Characteristics and test methods) exists which is likely to be used in the future for energy labelling. Both tests require appliances to be tested in a specific test room with controlled ambient temperature and air flow. In the EN 62552:2013 the freezer and chiller section of appliances is loaded with a simulated load consisting of 'tylose' test packs. The refrigerated food storage section (refrigerated section that operates between 0 and 8°C) is not loaded and temperatures are measured at 3 positions in the vertical centre of the compartment using temperature sensors that are 'damped' by insertion into brass blocks. In the IEC 62552:2015 standard test for energy consumption none of the compartments are loaded and all temperature measurements are carried out using temperature sensors inserted into brass blocks. None of the energy tests simulate usage of the appliance as appliance doors remain closed during the tests and the appliances are not loaded or used as they would be in the home. These tests therefore do not replicate real usage. Ideally, testing should provide the consumer with some indication of how much energy an appliance should use in real life usage. As consumer usage of appliances is known to be extremely variable it is probably unrealistic to expect a test to be able to accurately predict usage in the home. However, it would be reasonable to expect that the best performing appliance in a test should also be the best performing in the home. This means that if a consumer purchases a product with claimed low energy consumption (in a laboratory test) it should also have relatively low energy consumption when used in the home.

Over the past years, there have been several surveys of performance of residential refrigerators in more than 20 countries [39]. However, most surveys consisted of limited number of samples (generally less than 150), and few monitored temperature and energy performance simultaneously. There has therefore been no recent comprehensive assessment of refrigerator temperature and energy performance using a large data set to be able to assess the impact on how refrigerators perform in the home. The aim of this work was to determine whether a laboratory test provides a reasonable indication of energy consumption in the home. Information on appliances was collected from one of the largest surveys on performance of domestic cold appliances to simultaneously measure temperature and energy performance of refrigerators and freezers in the home in the UK [40]. The survey involved 998 domestic cold appliances. Results of the work are analysed to assess the relationship between performance in a test facility and the home.

2. Materials and methods

2.1 Overview of field trial design

A large-scale survey was conducted across the UK in which 998 cold appliances were monitored in 766 properties [40]. Data was collected over a period of 9 months, from March to November 2015. There were four waves of data collection, each lasting between three and five weeks distributed to coincide with different climatic conditions (Wave 1 - March; Wave 2 - from April to June; Wave 3 - from July to August and Wave 4 - from October to November).

Simultaneous measurements of the temperature inside and outside of the cold appliances, as well as the electricity consumption were taken over a period of seven days. The cold appliances monitored in the survey included: (1) Fridge-freezers; (2) Refrigerators with an ice-box; (3) Larder fridges; (4) Chest freezers and (5) Upright freezers [40].

Only data sets where appliance volume and information on the manufacturer's claimed energy use could be used in the analysis. Often details of the appliance model were not available as appliance name plates had been removed or were not able to be read. This reduced the data set to 124 appliances (around 12% of the total data set). Table 1 presents the numbers of each type of cold appliance with valid monitoring data.

2.2 Data collection method

Data and information on appliances were collected by trained interviewers from a market research company. On the first visit to each property the interviewers installed monitoring equipment and obtained information about each appliance. One week later they returned to remove the equipment and data was downloaded ready for analysis. The appliances were monitored for seven days to ensure the data reflected the performance of the cold appliances over a representative usage period.

The temperatures inside and outside the appliance were monitored using TinyTag Transit 2 data loggers with a monitoring range of -40°C to 70°C, a reading resolution of 0.01°C and a reading accuracy of <0.8°C between -40-0°C, and <0.4°C between 0-50°C. One data logger was placed on the middle shelf of each appliance compartment in a plastic bag and one was attached in a plastic bag to the outside of the door of the appliance.

The electricity consumption data of each cold appliance was collected using a Watts Up PRO monitor and data logger with an accuracy of +/- 1.5%. Each appliance was connected to a data logger, which itself was plugged into an electrical supply wall socket. The electric power in Watts was recorded every 30 seconds for the period the appliance was plugged in.

During the survey information on age of appliances, levels of loading and the number of door openings (from interviews with the householder, not directly measured) was collected. Information on the manufacturer's claimed energy use was obtained either from the survey interviews (where information was obtained from appliance name plates or the manufacturer's manual) or from information published by manufacturers related to specific appliance models.

2.3 Data analysis

Data were analysed to determine whether there was any relationship between energy used in the survey and the energy usage claimed by manufacturers (measured in a test laboratory).

In addition the differences between the energy consumed in the laboratory and in the home were correlated with factors that might influence energy consumed in the home. In particular, the following were assessed: age of the appliance; compressor run time (when consuming > 20 W to exclude any components that may operate continually such as fans or trace heaters); the number of door openings per day; and the level of food loaded in the appliances.

2.4 Statistical analysis

Statistical analysis was conducted on temperature and electricity consumption data using IBM SPSS Statistics program (version 21). Homogeneity of variance and normal distribution of residuals were tested using Levene and Kolmogorov-Smirnov tests respectively, and if applicable, parametric statistical analysis was performed by using Analysis of Variance (ANOVA). Where data was not normally distributed, non-parametric statistical analysis was used in the form of a Kruskal-Wallis test. Post-hoc tests were conducted using a Tukey test for parametric analysis, and a Mann-Whitney test for non-parametric analysis. Significance was reported at the 95% confidence level (when $p<0.05$).

3. Results

When refrigerator types were compared, refrigerators with an ice-box were not considered in the statistical analysis since the available data were not considered sufficient to conduct the analysis (Table 1). They were however, included in the analysis where there were direct comparisons between home and laboratory usage.

The data used in the analysis was a subset of the primary survey data. Table 2 presents a comparison of the temperature and energy consumption data from the whole survey (with the sub-set removed in order to obtain two independent datasets) and the sub-set used for this analysis. There was no significant difference between mean ambient temperatures, mean freezer temperatures and energy consumption in the whole survey and the sub-set used for the analysis in this paper. The mean refrigerator temperatures were found to vary ($p = 0.043$) between the survey and sub set used for analysis with the sample used for analysis having slightly lower mean temperatures than the refrigerators in the whole survey.

3.1 Energy used in the home and in the laboratory

The annual energy consumption based on measurements in a test laboratory as claimed by the manufacturers is compared in Figure 1 with the annual energy used in the home based on results from the survey. It can be seen that there was considerable variation between the energy used in the laboratory and the home. In terms of the percentage differences between what was claimed by the manufacturers and what was measured in the home; 61% of appliances used more energy in the home than they did in the laboratory. Figure 2 shows the percentage of appliances that had energy use in the home above/below that claimed by manufacturers. If analysing appliances by type, fridge-freezers used more energy in the home than the laboratory in 74% of cases, larder fridges used more energy in 44% of cases, chest freezers used more energy in 57% of cases and upright freezers used more energy in 28% of cases.

Table 3 shows the difference in energy (percentage and absolute) between the energy used in the laboratory and the home. Overall appliances used 19% more energy in the home than the laboratory. However, the differences between energy used in the laboratory and home varied considerably between appliance types. Therefore there was no consistent average 'offset' that could show that the laboratory test was a good indicator of energy used in the home.

Differences between energy measured in the home and in the laboratory would be less important if the rank order of energy consumed did not change. The best performing appliance in the laboratory would then also be the best performing appliance in the home. Figure 3 shows the rank order for each appliance type in the laboratory and in the home. It can be seen that considerable differences occurred between the rank order in each situation. Table 4 shows the change in rank order for the appliances considered. It can be seen that although the rank order of the energy used by a limited percentage of appliances changed by a relatively small number, the rank order changed by at least 5 places for 23% of appliances. Therefore it appears that not only did the energy usage differ between laboratory and home but so did the rank order of the energy used by the appliances.

3.2 Reasons for differences in energy consumption

Since there was no significant energy difference between fridge-freezers and chest freezers (Table 2) data from those appliances were combined.

Correlating the difference in energy consumption between laboratory and home demonstrated that door openings and food loading levels had minimal impact on energy used (Table 5). This may partly be due to the fact that these factors were assessed subjectively and were the views of the householder and any correlation may be masked by other factors affecting energy consumption [23]. A relatively good correlation existed for all appliance types between compressor run time and the difference between energy consumed in the laboratory and the home. This indicates that the differences between energy consumed in the laboratory and the home were primarily due to higher compressor run times. This may be related to usage of appliances in the home, appliance faults or appliance design issues. There was also a weak link between appliance age and the difference between energy consumption in the laboratory and the home [40]. It is possible that older appliances may consume more energy than they did when manufactured due to wear of components, damage to seals, loss of refrigerant or breakdown of insulation. The correlation between ambient temperature and appliance temperature was not found to be significant.

3.3 Energy used by similar appliance models

Within the survey population there were a limited number of replicate appliance models. The energy consumed by these appliances was compared to assess the impact of the same appliance operating in different households. Figure 4 shows the results from 32 appliances divided across 9 appliance models where the energy consumption of each appliance was compared across two to seven households (Fig. 4a). In almost all cases the appliances used more energy in the home than had been measured in the laboratory even if the average ambient temperature of the room in which the appliances were installed was lower than the one used during laboratory tests (Fig. 4b). It can be noticed that most of the appliances which consumed less energy in the home than the label would indicate had an inner temperature higher than the recommended range and the ambient temperature was also lower than 25°C. The results indicate that on occasions the energy used by an appliance in different homes was quite similar. Conversely differences in the energy consumed by the same appliance model could also vary widely with some appliances using half or twice the energy of another. This indicates that usage in the home has a significant impact on energy consumption.

4. Discussion and Conclusions

Reducing energy consumption is a major policy driver for many governments. To be able to accurately identify the best performing appliances is an important aspect of developing policy and encouraging consumers to purchase the most efficient appliances. Organisations such as Global Action Plan (GAP) have stated that policy makers must respond to environment and climate changes by providing policies that deliver low cost and efficient solutions to consumers [41]. They state that this should include the uptake of highly efficient electrical appliances. To ensure that these aims are met the methods used to identify the most efficient appliances need to be robust and transferable between laboratory and the home. The analysis carried out in this paper indicates that for domestic cold appliances the laboratory tests are not a true indicator of energy used in the home. Although there has been an increased uptake of 'A' rated and better appliances since 2000 this may not necessarily be reducing energy consumption as much as policy makers anticipate. There is evidence that over time energy consumed by appliances in the home has been reduced. Gemmell et al. [14] reported that newer appliances consumed less energy in home than older appliances (particularly those over 11 years of age); less difference between appliances aged under 7 years was detected. There was however, large variations in the energy used by appliances of the same age. It is known that the energy use of equivalent dwellings may vary by 100% due to the behaviour of the occupants [42]. It is therefore not surprising that the energy consumed by domestic appliances can vary. However, it seems reasonable to expect that any laboratory test should provide a reasonable average indicator of energy used in the home. This was shown not to be the case as on average energy used in the home was 19% higher than in the laboratory. When assessing different types of refrigerated appliances this difference was even greater and demonstrated that for most appliance types more energy was generally used in the home than the laboratory (fridge-freezers, larder fridges, chest freezers) but for some types the opposite was true (upright freezer).

To be sold in Europe the appliances assessed would have had to be energy labelled and tested to EN 62552:2013 (or a similar earlier version of the standard). A direct comparison between energy used in a laboratory and in the home cannot necessarily be assumed to be comparable. However, a laboratory test should provide a means to highlight the most efficient appliances in the home so that consumer make energy efficient purchasing choices.

Overall appliances in the home used more energy than the same appliance in a laboratory test and this was particularly apparent for fridge-freezers (Fig. 4). Obvious differences occur between the ambient and internal temperatures in laboratory and tests in the home. In the laboratory, energy is measured with the fresh food compartment at a mean temperature of 4°C and the freezer at ≤-18°C. The ambient temperature for laboratory energy testing is 25°C. An argument may be made that the higher ambient temperature in the laboratory test may not align with ambient temperatures in the home (which were on average 18.9°C in this survey [40]) but may provide some compensation for the lack of any door openings or use of the appliance in the laboratory. This assumption does not appear to be true as appliances tended to use more energy in the home than the laboratory.

Ideally the laboratory test should identify the most efficient appliance in the home. This was shown not to be the case as rank order of energy usage in the laboratory and the home varied widely. When analysing data the rank order of 23% of appliances changed by more than 5 ranking positions and 42% changed more than 10 places indicating that the lowest energy appliances in the laboratory were not necessarily the lowest energy consuming appliances in the home.

Reasons for the difference between laboratory and home energy use would appear to be related to usage of the appliances. Even when the same appliance model was compared across several households there were often differences in energy use of over 100%. This would indicate that although the laboratory test tends to under-estimate the energy consumed in the home it would be challenging to develop a comprehensive laboratory test that reflected the range in real life usage accurately. Further work is required to better understand how consumer usage of appliances affects energy use. This could lead to more realistic laboratory tests that provide more accurate information on performance of appliances to householders. This should ideally provide a means to ensure that appliances identified as being energy efficient in the laboratory are also efficient when used in the home. It is suggested that such a test for energy consumption should include some form of usage such as door openings, different loading patterns or food temperature reduction that better mimics the way consumers use refrigerated appliances in the home. To achieve this a better understanding of how consumer use refrigerators is required.

Table 1. Numbers of cold appliances in the survey (percentage values in brackets).

Appliance type	Total number in the survey [40]	Number available for the analysis in this paper
Fridge-freezer	524 (52%)	79 (64%)
Refrigerator with an ice-box	57 (6%)	2 (2%)
Larder fridge	145 (14%)	18 (14%)
Chest freezer	86 (9%)	7 (6%)
Upright freezer	186 (19%)	18 (14%)
Total	998	124

Table 2. Comparison of data from whole survey of 998 appliances and the sub-set used to analyse laboratory and home use.

Measurement	Value ± standard deviation (number of samples)	
	Whole survey [40] excluding sub set for analysis	Sub-set used to compare laboratory and home use
Mean ambient temperature [°C]	18.5 ^{a} ± 3.5 (778)	18.9 ^{a} ± 2.6 (122)
Mean refrigerator temperature [°C]	5.3 ^{b} ± 2.6 (574)	4.6 ^{c} ± 2.3 (97)
Mean freezer temperature [°C]	-20.3 ^{d} ± 4.4 (641)	-20.5 ^{d} ± 4.2 (104)
Energy consumption [kWh/year]	349 ^{e} ± 208 (543)	372 ^{e} ± 225 (122)
Specific energy consumption [kWh/m^3]	1893 ^{f} ± 1427 (99)	1666 ^{f} ± 1049 (122)

Mean with different superscript letters (a - f) are significantly different.

Table 3. Comparison of data from whole survey of 998 appliances and the sub-set used to analyse laboratory and home use.

Appliance type	Number	Energy difference [kWh/year]	% difference[(1)]
Fridge-freezer	79	92.3 [a]	26%
Larder fridge	18	36.1 [b]	21%
Chest freezer	7	112.5 [a]	42%
Upright freezer	18	-57.5 [c]	-22%
Mean		59.3	19%

[(1)] increase/decrease in energy used in the home

Mean with different superscript letters (a, b, c) are significantly different.

Table 4. Comparison of data from whole survey of 998 appliances and the sub-set used to analyse laboratory and home use.

	% of appliances
Change by 0 place in rank order	4%
Change by 1 place	6%
Change by 2 places or less	11%
Change by 3 places or less	15%
Change by 4 places or less	17%
Change by 5 places or less	23%
Change by 10 places or less	42%
Change by 15 places or less	55%
Change by 20 places or less	66%
Change by 25 places or less	73%

Table 5. Correlation of differences in energy consumption between home and laboratory with factors potentially influencing energy consumption.

	Fridge freezer and chest freezer	Larder fridge	Upright freezer
Age of appliance	0.325	0.336	-0.477
Compressor run time	0.787	0.844	0.166
Door openings	-0.010	0.039	0.018
Food loading level	0.128	-0.144	0.056
Ambient vs appliance temperature	-0.145	0.220	0.009

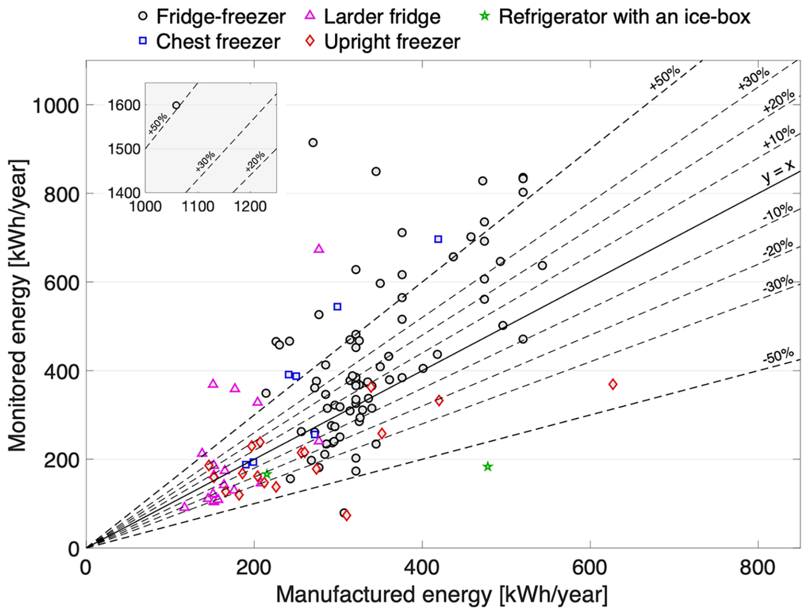


Fig. 1. Energy used in the home versus energy claimed by manufacturers.

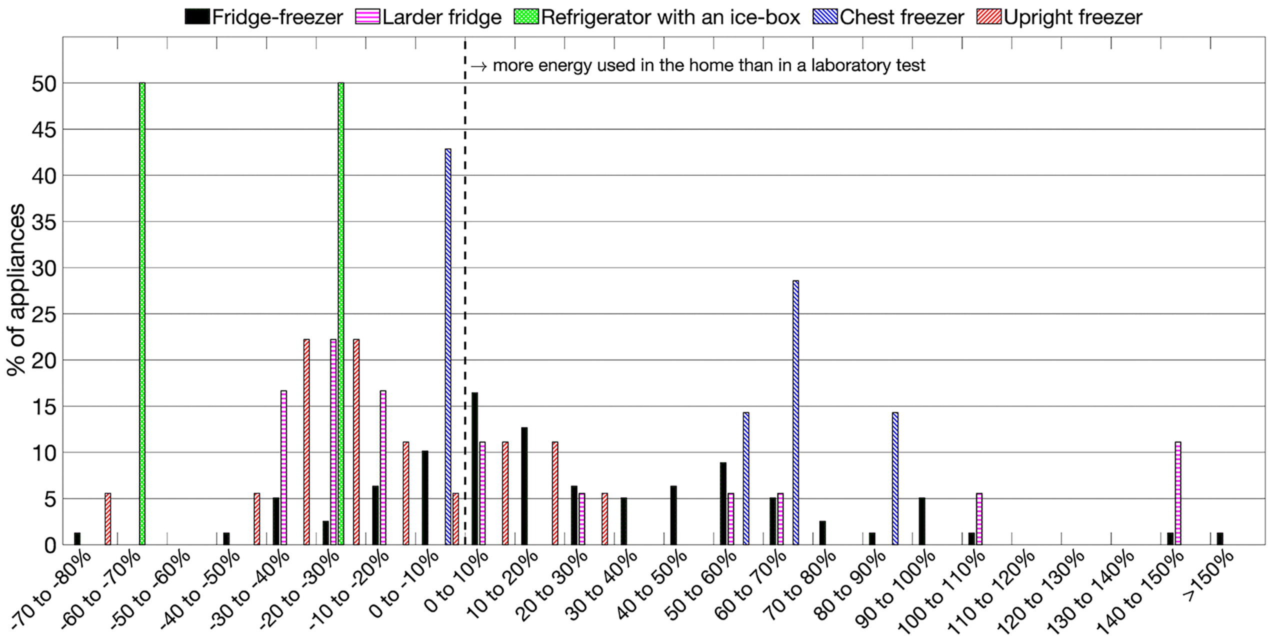


Fig. 2. Percentage difference in energy used in the home compared to energy claimed by manufacturer.

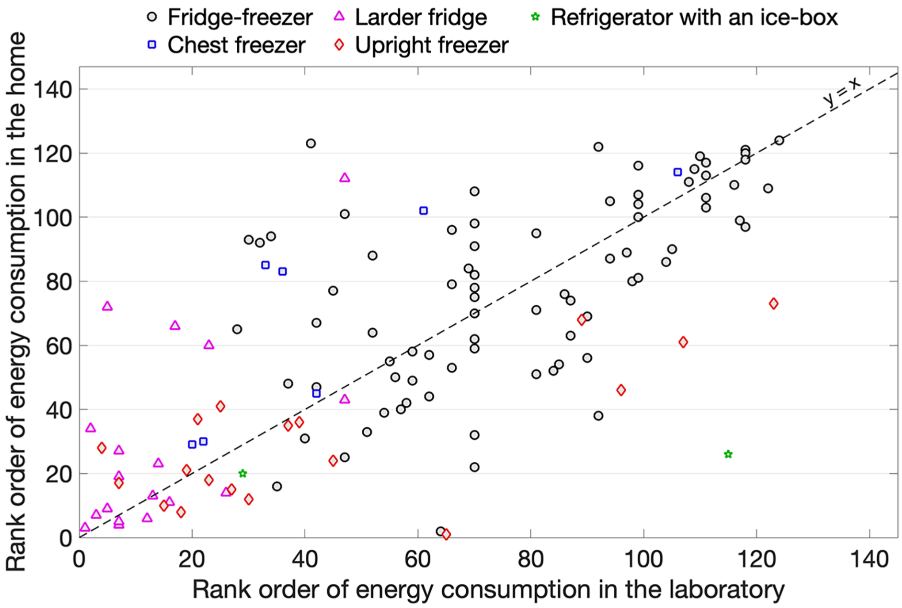


Fig. 3. Ascending rank order of energy used by appliances in the home and in the laboratory.

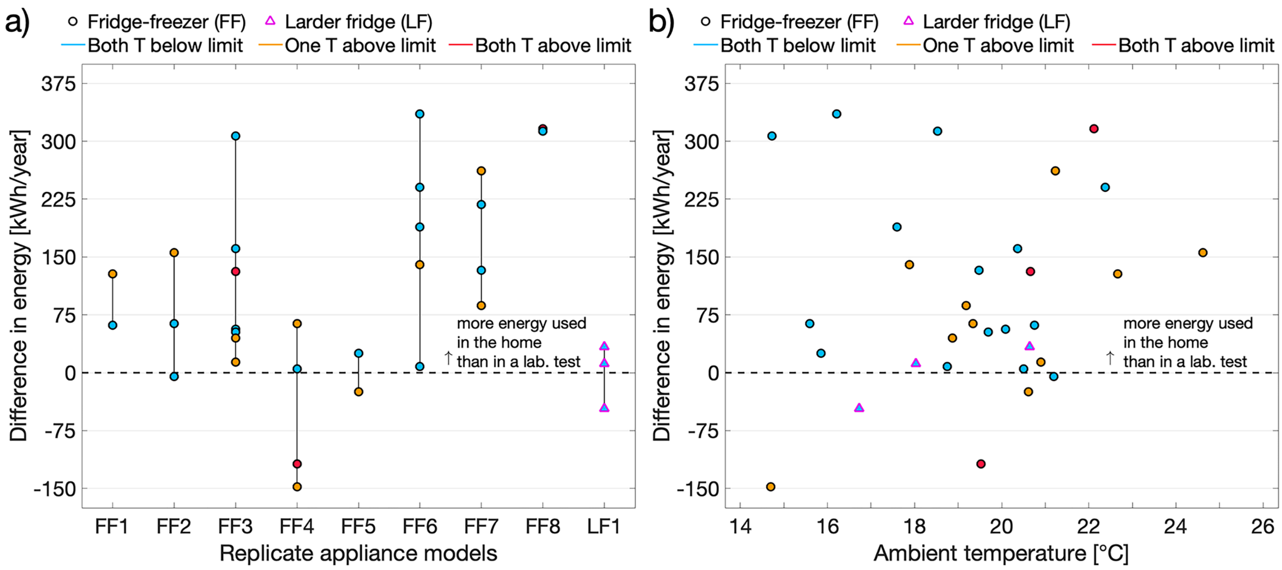


Fig. 4. a) Difference in energy used by the same appliance model in different households. b) Difference in energy used plotted as a function of ambient temperature. Inside appliance temperature indicated by colour of data point according to the recommended limits (4 and -18°C).

Credit author statement

Alessandro Biglia: analysed data, jointly responsible for writing paper. Andrew Gemmell: experimental design, management of data collection, input into paper editing. Helen Foster: experimental design, analysis of data, input into paper editing. Judith Evans: experimental design, analysis of data, jointly responsible for writing paper, management of paper development.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data are provided online in the electronic version of the paper.

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