

Study of Over-Consuming Household Cold Appliances

Inspection of 100 appliances due for recycling

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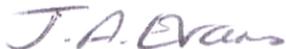


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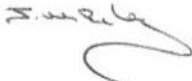
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Summary

This report presents the findings of research into the performance and condition of 100 recycled cold appliances. The research was undertaken by RD&T (partners in this project), in their laboratory in Bristol in January - February 2015.

In total, 100 domestic cold appliances were examined to determine why they were being recycled. The appliances were obtained from a recycling centre and were a mixed batch of appliances that had been obtained from several sources. The 100 appliances consisted of 50 fridge-freezers, 22 freezers, 22 larger fridges and 6 fridges with ice-boxes. The appliances were produced by 32 different manufacturers (although it should be noted that some appliances were brands and had been 'badged', meaning that they had not actually been manufactured by the named brand).

Out of the 100 appliances, 28 were considered to be suitable for re-use. These either had no obvious faults (13 appliances) or had a minor fault such as a missing or damaged drawer/shelf (15 appliances). If this sample is considered to be nationally representative, this corresponds to a large number of appliances (estimated to be ~ 600,000) that could potentially be reused each year in the UK with associated environmental benefits from waste reduction and avoided energy use in the production of new appliances and recycling of old ones.

Most appliances were found to have several faults; with most appliances showing more than two faults that would prevent the appliance being re-used. The greatest numbers of faults were related to missing or damaged drawers/shelves, internal or external damage to the appliance, the appliance not cooling, or damage to door seals. There was no strong relationship between appliance type and the number of faults, however, fridges and fridge-freezers with a higher level of usage were associated with a greater number of minor faults.

It was difficult to ascertain whether age was related to recycling rates because information on the date of manufacture was rarely available on the appliance label, however the date could sometimes be estimated from information on the compressor label. In addition, 12% of the appliances were found to be operating using R12 as the refrigerant, inferring that these appliances must have been at least 20 years old, as R12 was banned in 1994.



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1. Methodology

In total, 100 domestic cold appliances that were destined for recycling were obtained from a recycler (Environcom). The appliances were a mix that came mainly from local recycling facilities. They should, therefore, be broadly representative of what is recycled by households nationally. It was intentionally requested that the recycled appliances should not come from one source (such as a large retailer) to avoid bias introduced by the types of appliances received.

The 100 appliances were a mix between fridges, freezers and fridge-freezers of various ages and conditions. All appliances had direct expansion type refrigeration systems. The appliances were examined to investigate the reason(s) why they had been recycled.

A photograph of the appliances is shown below in Figure 1.



Figure 1. Photograph showing some of the 100 appliances examined in this study in the RD&T laboratory

A methodology was initially developed to collect the information on each appliance. The initial template was tested on a small number of appliances and then updated. The information collected is shown in Table 1.



Appliances were divided into types according to the following categories:

- Larder fridge (no ice-box), under counter, non-fan assisted
- Larder fridge (no ice-box), under counter, fan assisted
- Larder fridge (no ice-box), upright, non-fan assisted
- Larder fridge (no ice-box), upright, fan assisted
- Freezer, under counter, non-frost free
- Freezer, under counter, frost free
- Freezer, upright, non-frost free
- Freezer, upright, frost free
- Chest freezer
- Fridge with ice-box
- Fridge-freezer, side by side (chiller left, freezer right), non-frost free
- Fridge-freezer, side by side (chiller right, freezer left), non-frost free
- Fridge-freezer, side by side (chiller left, freezer right), frost free
- Fridge-freezer, side by side (chiller right, freezer left), frost free
- Fridge-freezer, upright (chiller top, freezer bottom), non-frost free
- Fridge-freezer, upright (chiller bottom, freezer top), non-frost free
- Fridge-freezer, upright (chiller top, freezer bottom), frost free
- Fridge-freezer, upright (chiller bottom, freezer top), frost free

Photographs of all appliances were taken as follows:

1. Rear of appliance
2. Front of appliance (door closed)
3. Front of appliance (door open)
4. Appliance name plate (containing information about the appliance make and model)
5. Compressor name plate or label
6. Any additional items of interest on the appliance

Appliances were assessed either using a visual inspection, or in some cases a physical inspection.



Visually inspected items were:

1. Manufacturer of appliance
2. Appliance model
3. Serial number of appliance
4. Temperature class
5. Size - gross of all appliance and net of compartments
6. Power input
7. Energy usage
8. Year of manufacture
9. Refrigerant type and charge (mass)
10. Star rating of freezer
11. Thermostat setting
12. Whether the appliance had a fast freeze setting and whether it was on
13. Whether the appliance had a winter setting
14. Energy label and class
15. Appliance type
16. Whether the appliance was built-in
17. General condition and damage to the in/outside of the appliance. Damage such as scuffing, scratches, dents, rust and punctures to the cladding on the outside of the appliances were noted. Internal damage such as dents, scratches, rust, damaged shelves and trays were noted.
18. Condition of the door hinges
19. Condition of the condenser (if visible)
20. Whether the appliance had undergone any remedial work
21. Compressor manufacturer
22. Compressor model
23. Compressor serial number
24. Whether the appliance had a light
25. Whether the appliance had a temperature alarm
26. Whether the appliance had a door alarm



Physically inspected items were:

1. PAT (Portable Appliance Test) – the appliance was tested for earth bond, insulation and current leakage.
2. Door seals. All seals were tested with an 80 gsm A4 sheet of paper to determine the grip of the seal.
3. The appliance defrost drain (if present) was assessed visually and by probing with a piece of wire to see if the drain was blocked.
4. If the appliance passed a PAT the appliance was placed into an environmentally controlled room at 30 °C. The appliance was switched on with a thermocouple sensor placed in the geometric centre of each cavity. Temperature readings were taken at intervals after the appliance had been allowed to cool, to determine whether the appliance was capable of maintaining a temperature suitable for the storage of food.

All appliances were assessed for re-use. Appliances were deemed unsuitable for re-use if:

1. They failed the PAT.
2. They were unable to operate at a suitable temperature for food storage (if the thermostat setting appeared to be set too high it was reduced to ascertain whether the appliance temperature could be made suitable).
3. They had more than one damaged or missing shelf/drawer.
4. The interior and exterior condition was poor (appliances were unsuitable rated at less than 7 on a 10 point scale, where 10 was perfect condition and 0 unusable condition).
5. The door seals were in poor condition (rated as poor or awful).
6. The door hinges were damaged (rated as damaged).
7. The condenser was damaged (rated as dirty or damaged).
8. The defrost drain was blocked.
9. The appliance light was faulty. The appliance could potentially be re-used if the light bulb was missing and could be replaced.

**Table 1.** Data collection template

Appliance number				Photo(s) taken (with no. visible)			
Manufacturer name				Model (from name plate)			
Serial no.				Appliance age (name plate)			
Refrigerant		R		Refrigerant charge		g	
Size (internal) (litres)		Gross		Net			
Star rating if freezer				Control setting(s) (setting/max)		out of	
Fast freeze setting		Yes / No		Does appliance have 'winter' setting		Yes / No	
Is it switched on?		Yes / No					
Appliance type				Class			
Input power (W)				kWh/24			
General condition (mark out of 10):		Inside		Outside			
If ice box type, is tray under freezer damaged?				Yes / No			
Energy label present? State class.				Yes / No			
Condition of door seals (use A4 paper test)							
Fridge (excellent / good / poor / awful)							
Freezer (excellent / good / poor / awful)							
Condition of door hinges (OK/worn/damaged) +information if damaged							
Condenser condition (clean, slightly dirty / dirty, damaged)							
Has appliance undergone any remedial refrigeration or refurbishment work (list)				Yes / No			
Compressor:		Manufacturer + model					
		Serial number					



Does appliance have light?	Yes / No
Does appliance have temperature alarm?	Yes / No
Does appliance have door alarm?	Yes / No
Does appliance have defrost drain? If so, is it blocked?	Yes / No Yes / No
PAT test (list reason if fail) EB (earth bond) <0.25 Ω (pass) ISO (insulation) >2 M Ω (pass) I _{LEAK} (current leakage) <3.5 mA (pass)	Pass / Fail If fail list values: EB (earth bond) ISO (insulation) I _{LEAK} (current leakage)
ONLY IF PASS PAT TEST:	
Does light work?	Yes / No
Run appliance for maximum 1 hour, temperature in geometric centre of storage cavity/ies	Yes / No
Temperature in chilled compartment	°C
Temperature in frozen compartment	°C
Other (name compartment)	°C
Could appliance be reconditioned?	Yes / No



2. Results

2.1 Appliance types

Appliance types were divided as shown in Figure 2 and Figure 3. Approximately 50% of all appliances were fridge-freezers. It should be noted that the sample of appliances provided by Environcom contained no chest freezers.

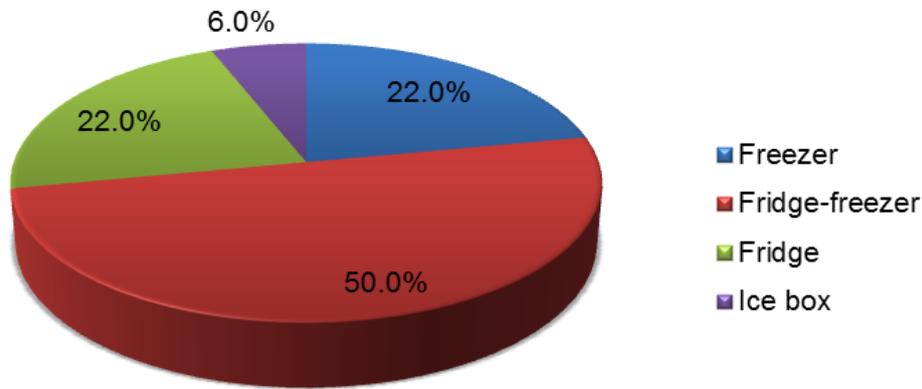


Figure 2. Appliance types divided by main categories

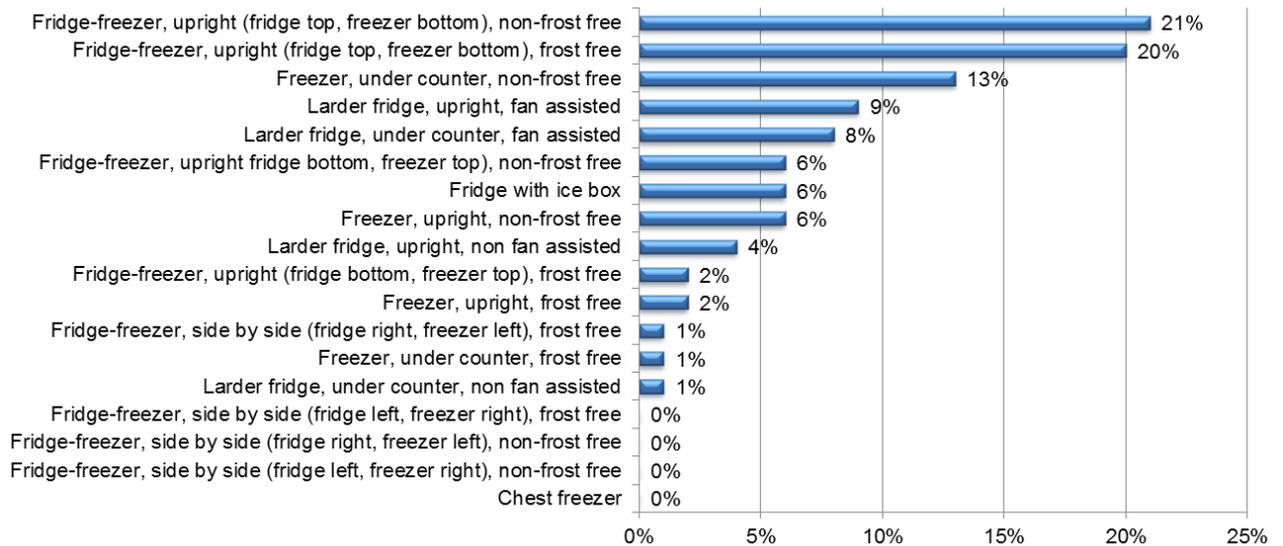


Figure 3. Appliance types divided by sub-categories



Size of appliances

Appliance size (gross volume) varied from 84 to 532 litres. Most appliances were between 100 and 350 litres, the “under counter” appliances being around 100 to 200 litres and the upright appliances being 250 to 350 litres (Figure 4).

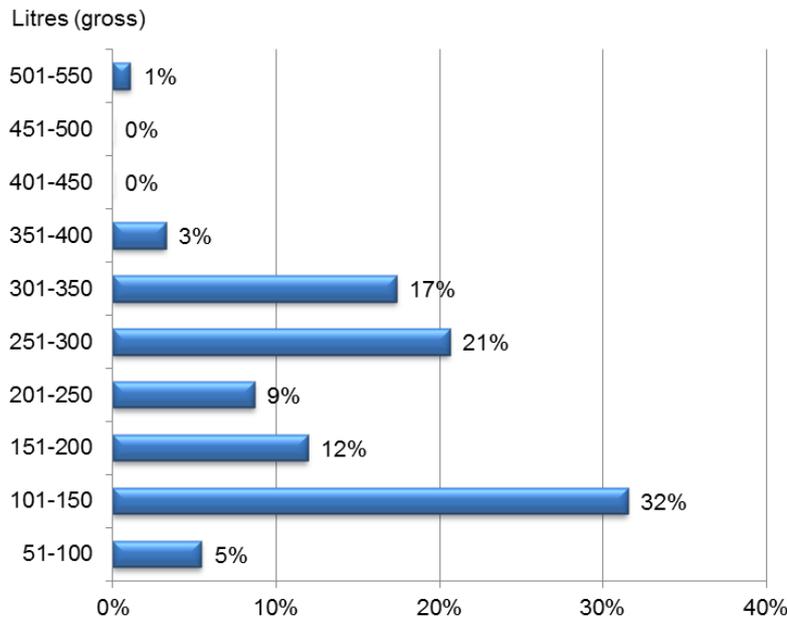


Figure 4. Size of appliances examined

Built-in appliances

More than 90% of appliances were non built-in models (Figure 5).

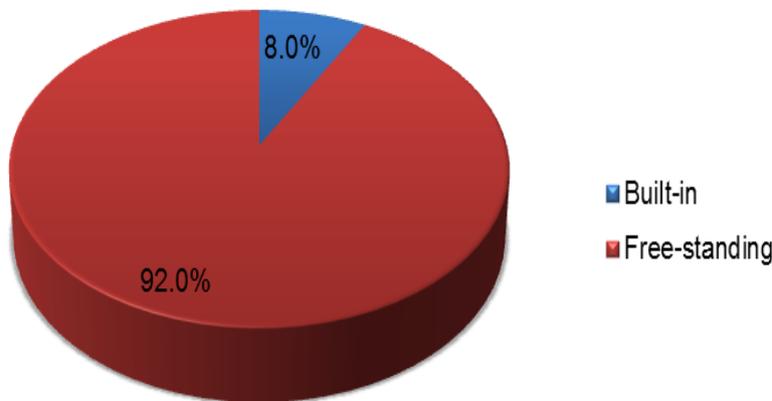


Figure 5. Number of built-in appliances

Refrigerants

Only three types of refrigerant were found in the appliances assessed. A large majority of appliances operated on iso-butane (R600a) as would be expected (Figure 6), as the refrigerant has been the main refrigerant used in domestic refrigerators in Europe for the past 20 years. In total, 12% of appliances operated using the CFC R12 (which has been banned since 1994).

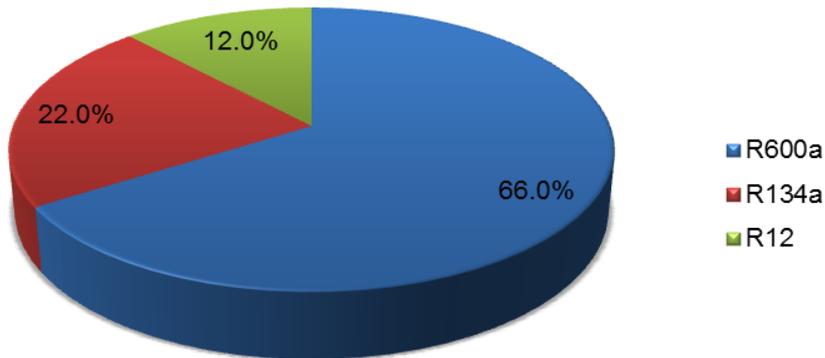


Figure 6. Refrigerants in the appliances assessed

Age of appliance

Determining the age of the appliance was difficult, as very few appliances stated the manufacturing date on the name plate. Occasionally a year of manufacture was provided on the compressor, but this may not be the exact date as the compressor may have been manufactured at an earlier date. Figure 7 presents the information that was able to be collected, including data from compressors, and so it should be borne in mind that some of the information may not be accurate. Additionally, it may be possible to obtain more accurate data on the age of appliances from third party sources (such as manufacturers directly, trade associations or product databases).

Data on the refrigerant used on the appliances showed that 12% of the appliances operated on R12. The refrigerant R12 is a CFC and has been banned since 1994 in Europe, therefore indicating that these appliances where it occurs must be at least 20 years old.

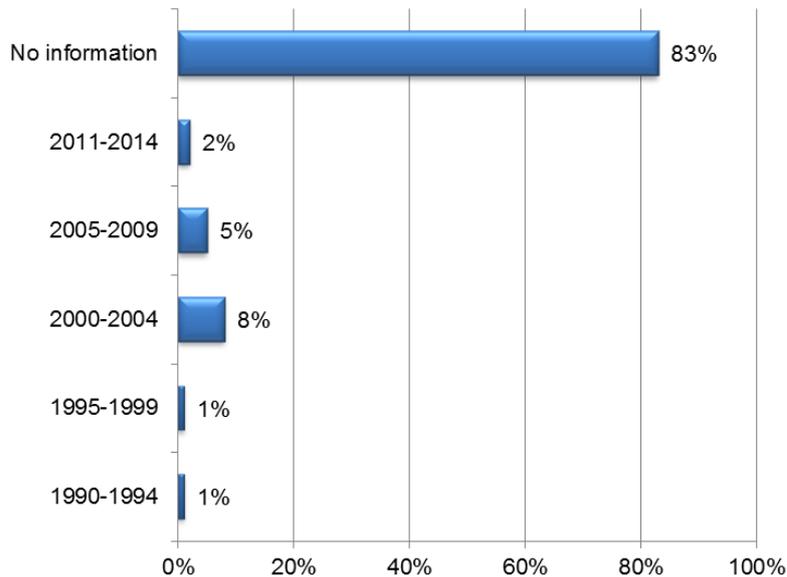


Figure 7. Appliance age

Energy used by appliances

Very little information was available on the energy used by the appliances. Only 12 appliances had a predicted daily energy use listed on the appliance label. Ten appliances had an energy label, with three being labelled 'A+', six labelled as 'A' and one labelled as 'B'. The appliance labelled as 'B' was the only appliance with an energy label where the manufacture date of 2002 could be estimated (this was obtained from the compressor manufacture date and therefore may not be the same as the appliance manufacture date).

It should be noted that energy label levels and MEPS (Minimum Energy Performance Standards) have become tougher over time. Energy labelling for domestic refrigerators was first introduced in 1994 (MEPS introduced in 1995). Additional A+ and A++ categories were added in 2003 and an A+++ label added in 2010. New MEPS were introduced in 2012 (B and worse removed) and 2014 (A and worse removed).

The power input to the appliance was commonly available on the appliance label. However, this provides an indication of peak power and not energy usage and so is not especially useful in determining whether the appliances may have been rejected by consumers due to their high energy use.

Thermostat setting

The thermostat setting may be an indicator of whether an appliance was operating correctly. Users may increase the setting (attempting to reduce the temperature in the appliance) if there was long term fall off in performance caused by refrigerant leakage, reduced condenser capacity or increase in heat loads caused by damage to seals or the insulation. The greatest proportion of appliances (where the thermostat setting was available) had been set to maximum or near maximum setting (Figure 8).

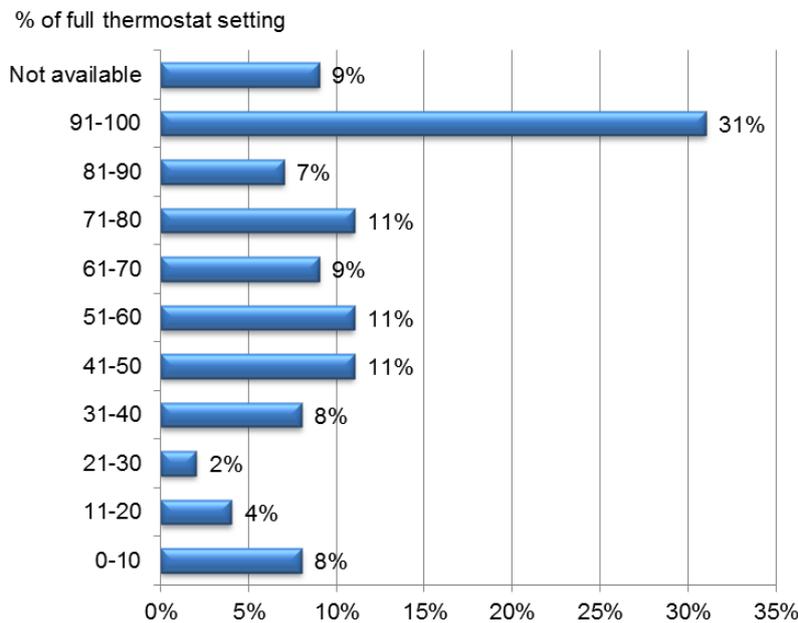


Figure 8. Thermostat setting (% of maximum)

Remedial work

Only three appliances were thought to have undergone any remedial work (assumingly to repair them). Of these:

- In one appliance the skin condenser had been removed from the refrigeration circuit and it appeared that a new compressor had been fitted (the appliance was a fridge-freezer with two compressors).
- Another appliance had the insulation at the rear of the appliance cut away to expose the thermostat. It appeared that the thermostat had not been replaced and the appliance was unable to reduce the temperature to be suitable for food storage when tested.
- The third appliance had a refrigerant line tap still attached to the refrigeration pipework. The appliance was able to operate at a suitable food storage temperature and so it may be possible that the compressor was replaced or the appliance had been re-gassed with refrigerant.

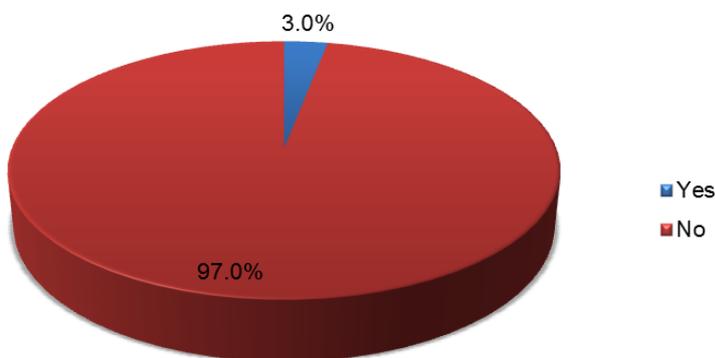


Figure 9. Appliances where repair had been attempted

Re-use of appliances

In total, 28 appliances were considered suitable for re-use (Figure 10). Of these 13 had no faults and 15 had very minor faults (generally a missing or damaged shelf/drawer that would not prevent the appliance being used). The refrigerant in the appliances that were considered suitable for re-use was either R600a (25 appliances) or R134a (three appliances). The date of manufacture was only available on four of the appliances suitable for re-use and varied between 2000-2006 (two dates were obtained from the compressor manufacture date and therefore may not be the same as the appliance manufacture date).

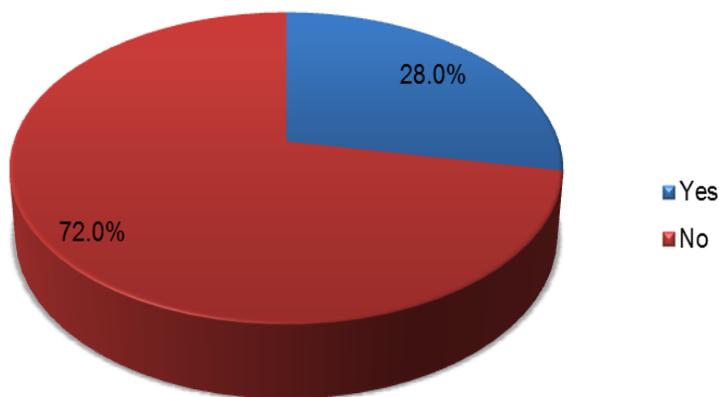


Figure 10. Potential re-use of appliances

Reasons for failure/recycling

The main reasons for an appliance being recycled were examined. Most appliances (74%) had more than one reason for failure and 13% of appliances had five or six failures (Figure 11). Reasons for failure are shown in Figure 12. The majority of appliances were deemed to have been rejected by users due to drawers or shelves being damaged or lost and internal condition of the appliance becoming poor.

Few appliances had extremely poor condition in the interior or exterior, with most being slightly damaged and looking 'old', dented, scraped or chipped (Figure 13). It should be noted that it is possible that some of the damage to the appliances may have occurred at various points after being removed from the household. This includes during transfer to the council recycling site, to Environcom and during transit to RD&T as the appliances are not protected in the transit vehicles. Damage caused at these points may include to the interior (e.g. drawers and shelves) as well as the exterior of each appliance.

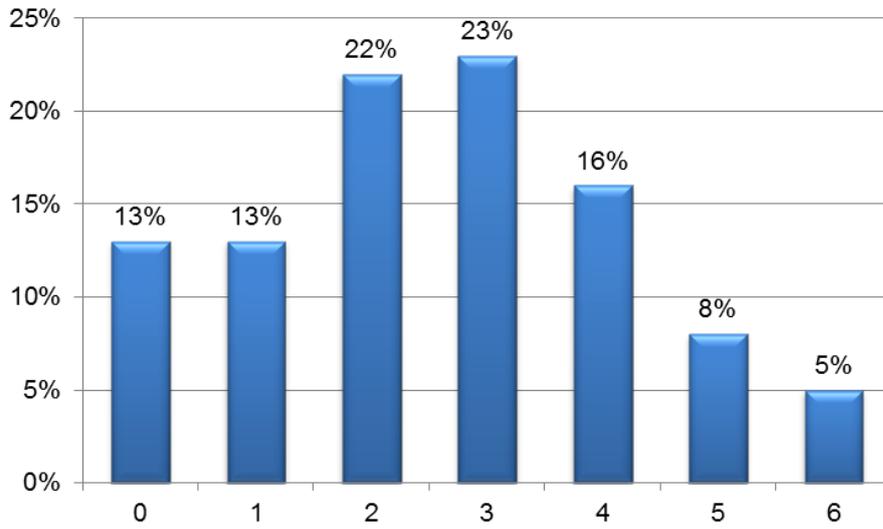


Figure 11. Number of failures

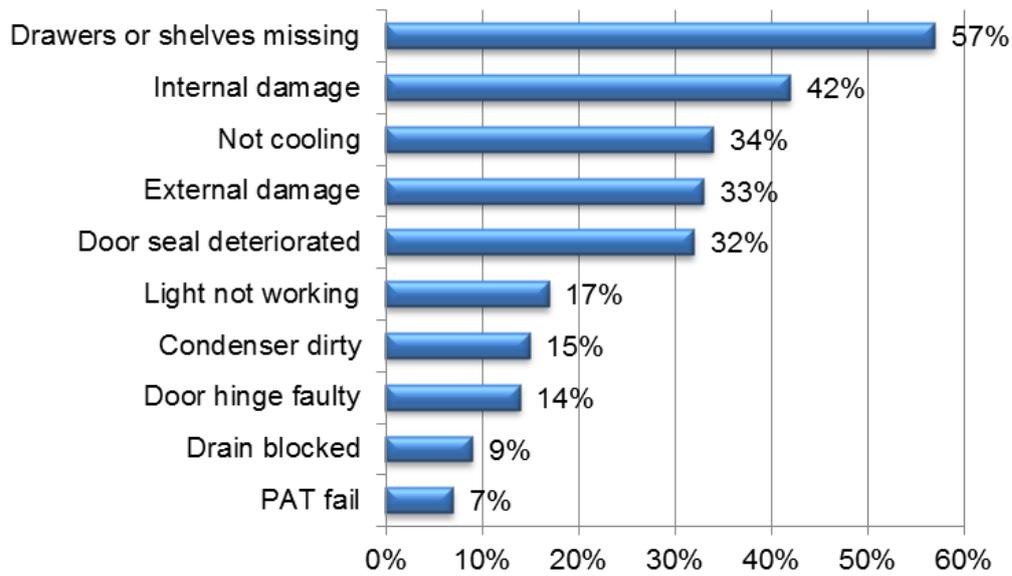


Figure 12. Reasons for failure

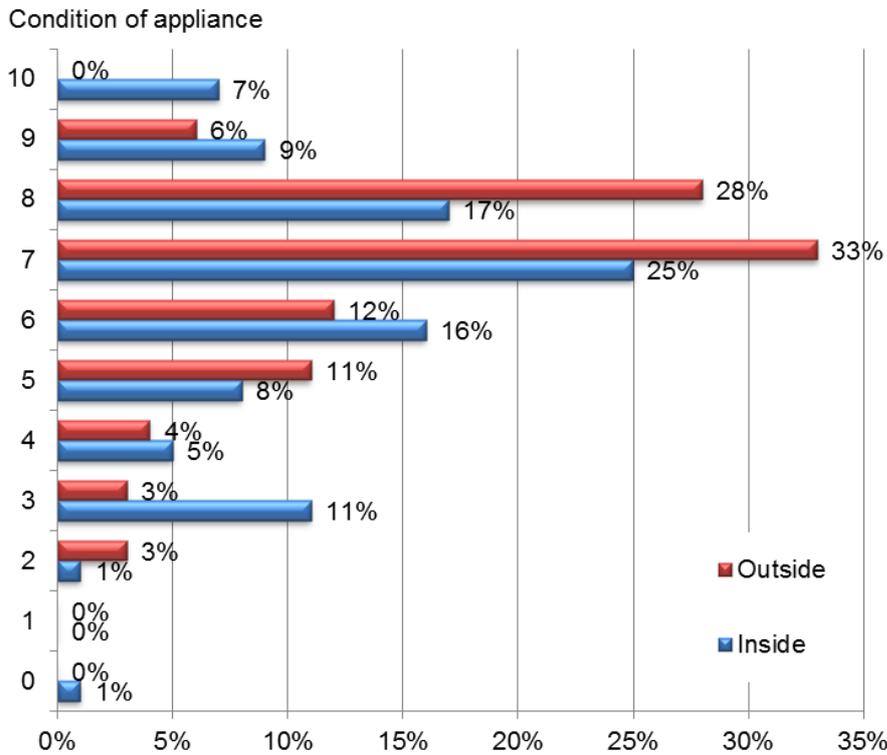


Figure 13. Internal and external condition (marked out of 10) for appliances examined

Failure by appliance type

Whether the failure of appliances was related to appliance type was investigated. The percentage of failures within each appliance type is presented in Figure 14 and Figure 15. The number of failures according to appliance type is shown in Figure 16.

Whether failures varied between different types of appliance was investigated using a Chi-Square test, however, the data set did not contain sufficient replicates to provide a robust analysis (this was especially the case for the fridges with an ice-box where there were only six examples).

There did appear to be some indication of failures directly related to appliance type. For example items such as missing drawers or shelves were higher in fridges and fridge-freezers where it would be expected that there would be more continued and regular usage. There appeared to be a greater level of damage to the outside of appliances in freezers and fridges with ice boxes. Ice-box appliances appeared to have a greater level of drain blockage.

It also appeared that freezers and fridges with ice-boxes tended to be rejected for recycling when they had slightly more faults than fridges or fridge-freezers. In addition only 18% of freezers had one or no faults, compared with 27-33% of other appliance types with one or no faults.

In total, 34 appliances did not cool when tested. The reasons for the lack of performance were mixed. In the case of 26 appliances there was no apparent reason for the lack of cooling. Half of these 26 appliances were very old and battered, but half appeared to be in reasonably good condition. Of the remaining appliances; three appeared to have lost or be losing refrigerant, two had a compressor problem, one had a controller fault, one appeared to have a faulty thermostat and one had an air damper



distribution issue. Although energy consumption of appliances over an extended period was not tested, the appliances that did not cool correctly could be expected to over-consume due to the thermostat demanding temperature which could not be achieved.

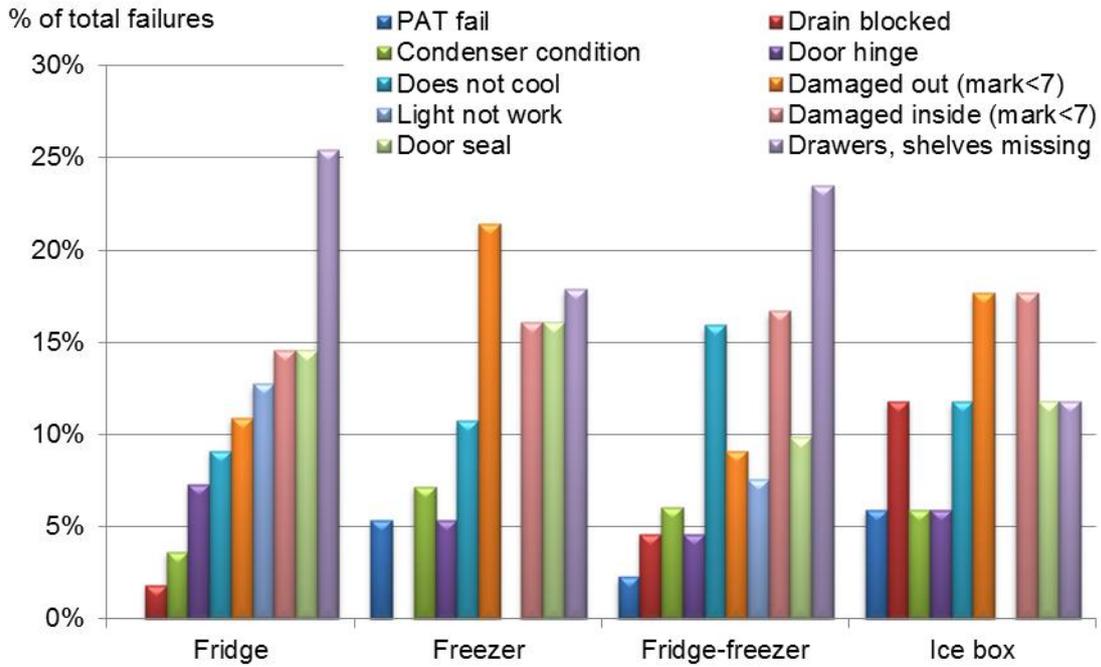
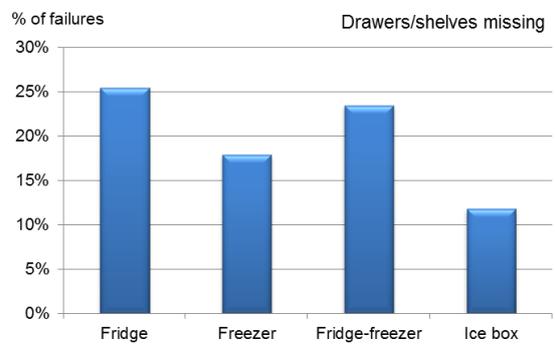
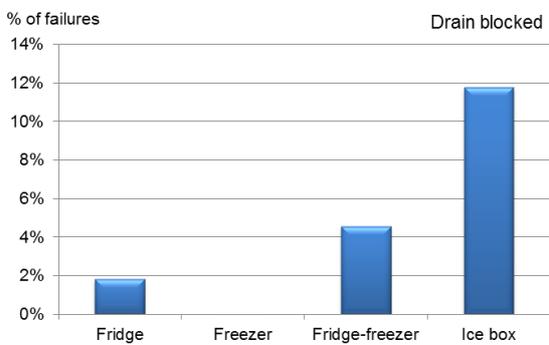
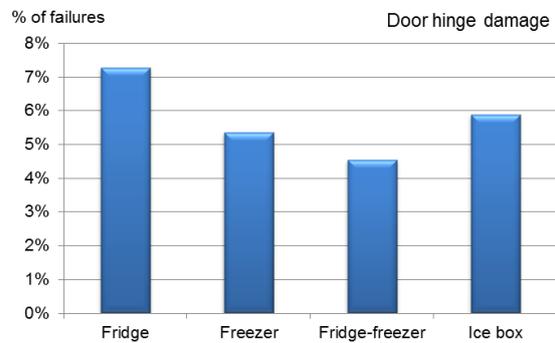
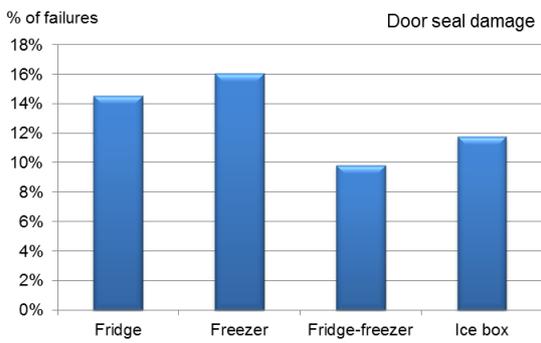
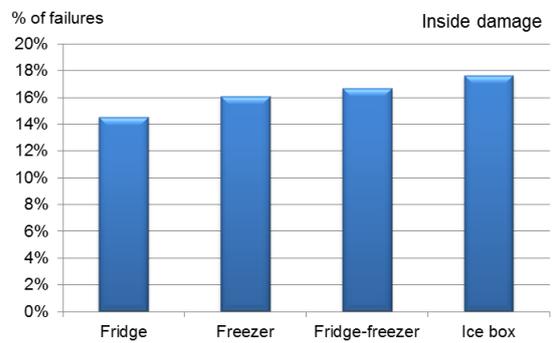
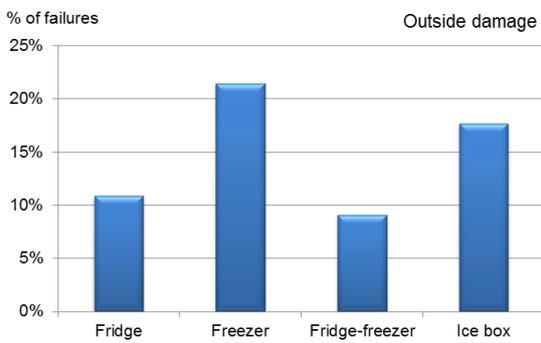
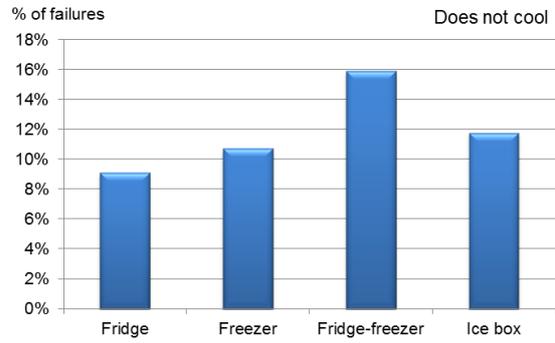
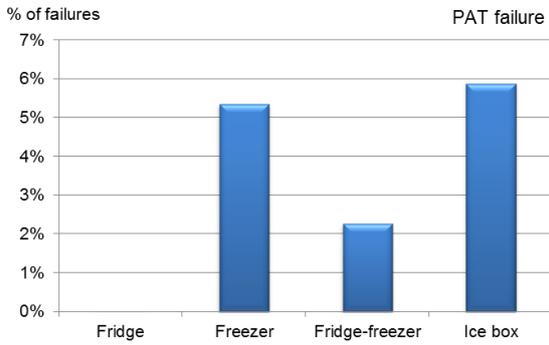


Figure 14. Failure category for all appliance types



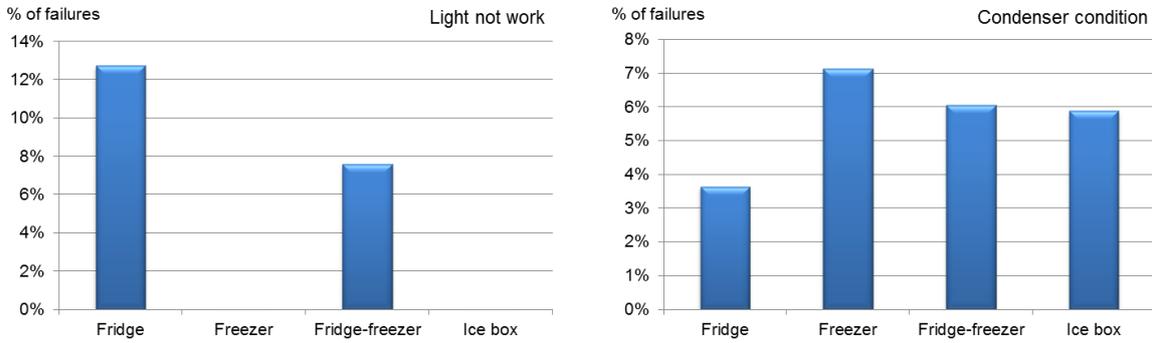


Figure 15. Failure category related to appliance type

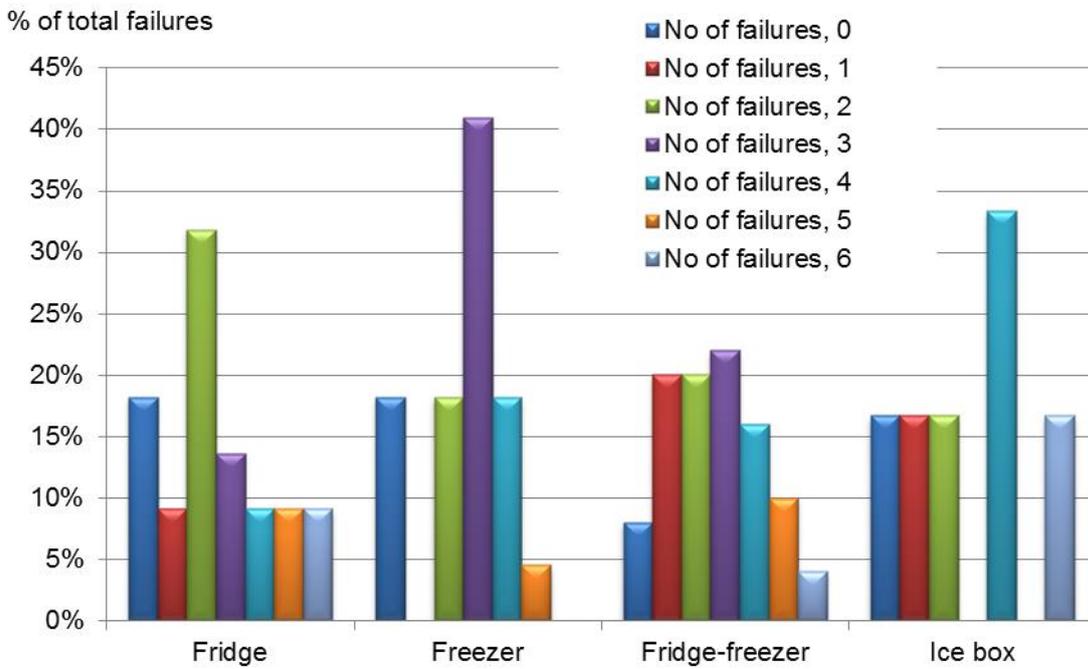


Figure 16. Number of failures related to appliance type



3. Conclusions

This project has examined 100 domestic refrigerators that were obtained from a recycling centre to determine why they were being recycled. The 100 appliances consisted of 50 fridge-freezers, 22 freezers, 22 larder fridges and 6 fridges with ice-boxes. The appliances were produced by 32 different manufacturers.

All appliances were examined to assess whether they would be suitable for re-use. Of the 100 appliances, 28 were considered to be able to be re-used with little or no remedial work. These either had no obvious faults (13 appliances) or had a minor fault such as a missing or damaged drawer/shelf (15 appliances).

Most appliances, however, were found to have several faults; with the majority having more than two faults that are considered to prevent the appliance being re-used. The greatest numbers of faults were related to missing or damaged drawers/shelves, internal or external damage to the appliance, the appliance not cooling, or damage to door seals. There was no strong relationship between appliance type and the number of failures, however, fridges and fridge-freezers with a higher level of usage were associated with a greater number of minor faults.

It was difficult to ascertain the date that the appliances were manufactured and whether age was related to recycling rates. Information on manufacturing date was rarely available on the appliance label but could sometimes be estimated from information on the compressor label. As 12% of the appliances operated using R12 as the refrigerant, these must have been at least 20 years old as R12 was banned in 1994.

This project has provided important new information on the number, types and condition of cold appliances being recycled. We can conclude that the majority of appliances in this sample were recycled because of multiple or severe faults, however, there remains a large proportion (28%) that could readily be re-used. This figure is comparable to the percentage of appliances which WRAP have previously identified as possible for re-use¹. If the sample in this study is considered to be nationally representative, this corresponds to a large number of appliances (estimated to be ~ 600,000) that could potentially be reused each year in the UK with associated environmental benefits for waste reduction, and avoided energy use in the production of new appliances and recycling of old ones.

It is possible, however, that the replacement of older appliances with newer, more energy-efficient, models is more environmentally beneficial overall. To assess this additional work would be required, including: monitoring of the performance of these re-cycled appliances; and comparing actual energy consumption against that of a new model.

¹ WRAP 2011, Realising the reuse value of household WEEE.

<http://www.wrap.org.uk/sites/files/wrap/WRAP%20WEEE%20HWRC%20summary%20report.pdf>