

Fridge recycling standards

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Report on comparative UK performance

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Objective

To review whether UK fridge recyclers meet the treatment standards required by legislation

- In 2002, the Ozone Depleting Substances Regulations (ODS) were introduced in the UK, to regulate the use of specific substances in household fridges and freezers. The aim was to control and eradicate man-made ozone-depleting substances, some of which have a global potential up to 4,250 times greater than carbon dioxide (CO₂)*.
- These regulations make it illegal to dispose of fridges in a way that releases emissions into the atmosphere, ensuring that they are recycled by appropriately licensed operators.
- CFCs, present in waste fridges sold some time ago, cause damage to the ozone layer and contribute to climate change at a rate that is considerably greater than equivalent amounts of CO₂.
- The use of CFCs in fridges and freezers was phased out by the Montreal Protocol, and they were replaced by Pentane which does not cause the same amount of damage to the ozone layer, but still contributes to climate change when emitted (albeit to a lesser extent).
- The Environment Agency issues permits to fridge recyclers, requiring minimum treatment standards and periodic reporting on performance. Non-compliance of this can be a criminal offence.
- The objective of this study is to compare the reported performance of fridge recyclers to the standards required by permits issued by the Environment Agency.

* ec.europa.eu/clima/policies/ozone_en

About this report

Anthesis Group

Anthesis is a global sustainability services and solutions consultancy. We're founded on the true belief that commercial success and sustainability go hand in hand. We develop financially-driven sustainability strategies, underpinned by technical experience and delivered by innovative teams across the world. Having now grown to more than 450 experts across 14 countries in five years, the company combines the reach of big professional services groups with the deep expertise of boutiques.

Dr Richard Peagam

Richard leads on Producer Responsibility at Anthesis, working across EMEA, Asia, the USA and Canada. Key clients include some of the largest electronics manufacturers in the world, key players in the minerals and extractives sectors, recycler and compliance schemes, market leaders in FMCG and retail and national governments and policy makers.

Background

This report was commissioned by AO.

Scope

Fridges are predominantly recycled at sites with permits that require regular reporting to the Environment Agency, but there are others

- Eight fridge plants are currently reporting to the Environment Agency in the UK (one via National Resources Wales) and we have access to data returns from 2017 and 2018.
- A number of fridge processors have not provided data, so cannot be analysed:
 - The GAP fridge plant was constructed recently, so would not have provided returns to the Environment Agency in 2017/18.
 - Data from Clear Circle in Northern Ireland was not requested.
 - Viridor Perth (falling under the jurisdiction of SEPA rather than the EA) is not required to provide the level of detail needed for comparative analysis.
 - eSynergy has not provided any returns to the EA.
- This study focusses on the UK fridge plants that data is available for, but any interpretation of the results should consider the fact that some fridge plants are operating outside of this regime.
- Commercial and ammonia fridges have also not been included in our analysis. There is very little reporting of the processing of these units, and this is either due to poor reporting or the processing of these units outside the approved fridge processors contained within this report.

Definitions and key concepts

The following technical principles are key to interpreting the relative performance of UK fridge plants

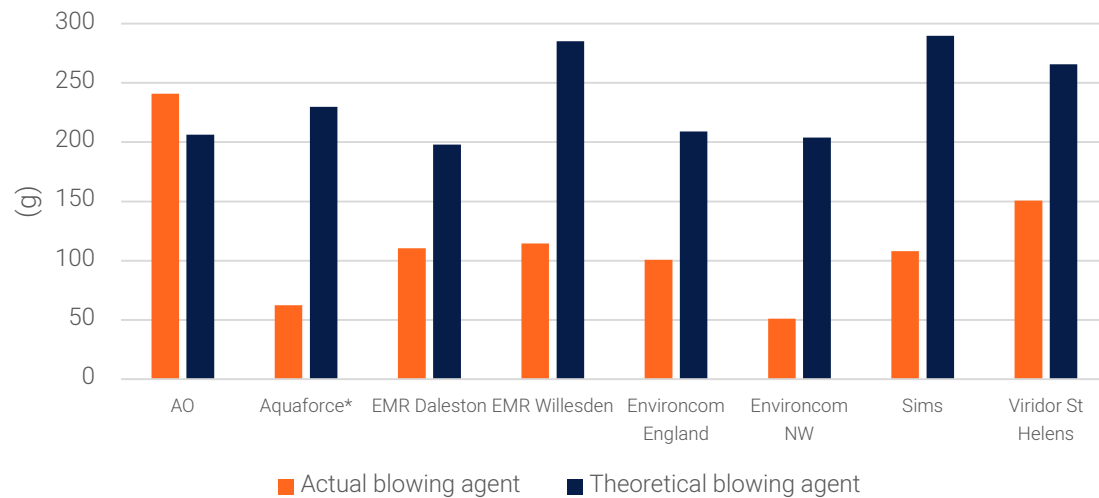
- Refrigerant – A substance or mixture, can be a fluid or a gas depending on where it is in the cooling circuit, used in the cooling system of fridges and freezers. The use of CFC refrigerants has been banned, replaced by HCFCs and latterly HFC's, which do not damage the ozone to the same extent.
- Blowing agent – A gas used to create bubbles in the insulating foams that are used in fridges and freezers. The use of CFC blowing agents has been banned and they have been replaced, primarily, with Pentane which does not damage the ozone to the same extent. More blowing agent (by weight) is used in a fridge than refrigerant.
- Theoretical targets – These values cover both the amount of blowing agent and refrigerant that should be recovered from fridges of different size classes, under the proper operating conditions. The values are provided to operators by the EA, as part of their permit. The theoretical targets were defined through several studies and have been validated by the European Commissions' WEEELABEX Project, which has been written into the European Standard EN50625-3-4.
- Data return – Licensed fridge recyclers must submit reports on the amount of fridges they recycled (split by size, class and blowing agent type) and the amount of blowing agent and refrigerant they recover. They must also compare this with the amount of blowing agent and refrigerant they should have recovered, in comparison with the theoretical targets described above.

Executive summary

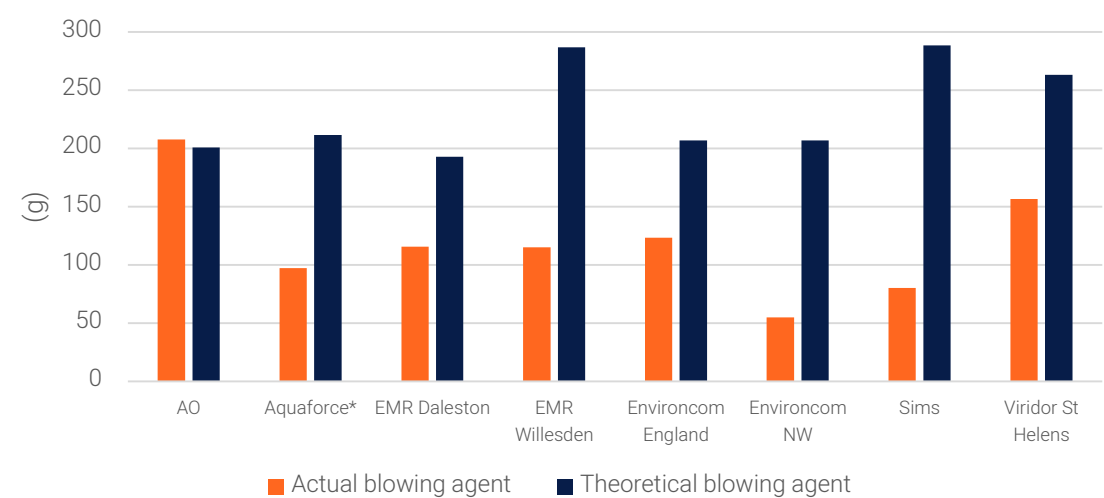
UK fridge recyclers are apparently underperforming

- The data returns from reporting UK fridge plants are incomplete, inconsistent and that there were a number of calculation errors in the reporting.
- The data on the extraction of blowing agent shows that most UK fridge plants are underperforming and in some cases, to a considerable extent (based on standard expected values, set by the Environment Agency).
- The uncaptured CFCs alone were equivalent to releasing 418,660 tonnes of CO2 into the atmosphere, over the two years.
- This is the equivalent to the emissions of around 100,000 family cars in the UK.

Weight of blowing agent collected per fridge (2017)



Weight of blowing agent collected per fridge (2018)



Background

Context for this report

- Why fridge recycling standards are high
- The fridge recycling process
- Our approach



Why fridge recycling standards are high

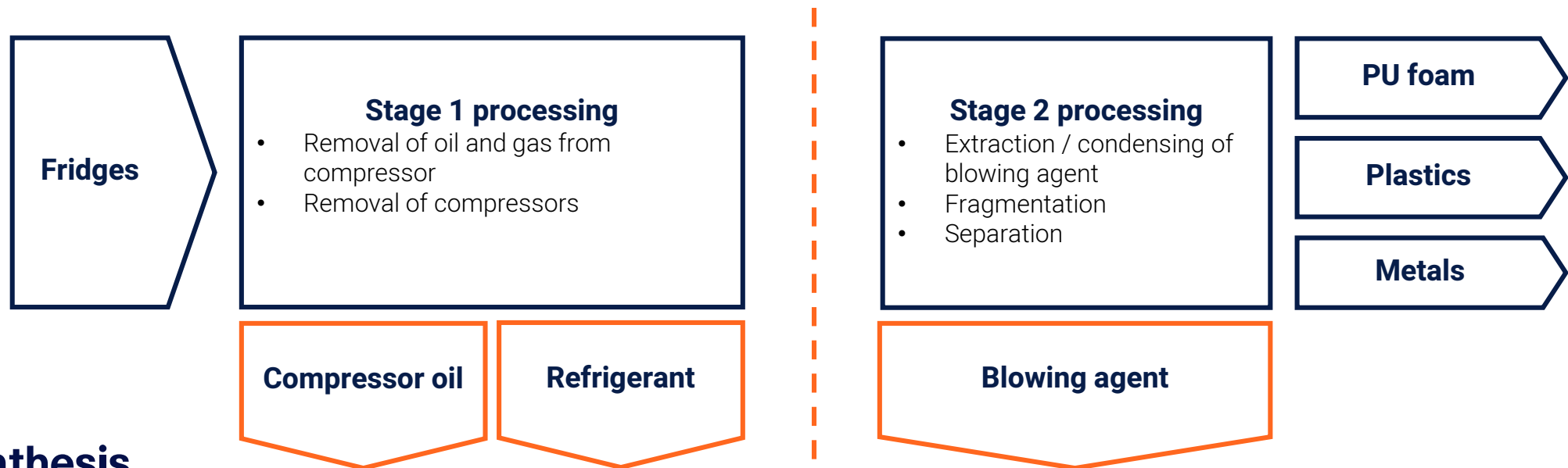
Fridges are hazardous and have specific treatment requirements at end-of-life

- In 2018, 204 Kt of household appliances containing refrigerants were sold in the UK, the majority being domestic refrigerators “fridges”. During the same period, 132 Kt were collected for recycling (Environment Agency data).
- There are eight fridge recycling plants in the UK currently reporting to the Environment Agency (or National Resources Wales), with six operators. Seven of these are in England and one is in Wales. Some of these plants were built in response to the 2002 ODS regulations, so are more than 15 years old, but all must be capable of meeting minimum treatment standards as a condition of their environmental permits.
- Environmental Permits set out conditions of operation that cover processing techniques, storage and treatment, emissions, monitoring, fire prevention and information (record keeping and reporting).
- Waste fridges are hazardous, with refrigerant in the compressor oil and the blowing agent used in insulating Polyurethane (PU) foam of particular concern. The use of CFCs for these applications was banned by the Montreal Protocol, though fridges containing CFCs sold before this ban are still present in the UK WEEE system and the Hydrocarbon (HFC's) replacements still have the potential to damage the ozone layer.
- UK fridge recyclers must report the number of fridges they recycle, by size category, and the amount of hazardous material that they separate and dispose of properly, periodically and at regular intervals. As part of their periodic reports, they compare recycling performance with the theoretical values set by their environmental permits, which shows how much hazardous material they should be collecting.
- It should therefore, be straightforward to compare the relative performance of UK fridge recyclers, by examining the regular data returns they submit to the relevant competent authority (primarily the Environment Agency).
- Furthermore, comparison with the theoretical recovery rates for hazardous material as defined in the operators' permit and also the European standard (EN50625-3-4), gives a clear benchmark for minimum standards.

The fridge recycling process

Two stages with a focus on the legally required management of hazardous wastes

- Fridge recycling is a two stage process, with the second stage requiring a significant investment in infrastructure and being costly to run.
- The objective of both stages is to extract materials with the potential to damage the environment; compressor oil and refrigerant at Stage 1 and gases used in the insulating Polyurethane (PU) foam at Stage 2, leaving sorted commodity fractions like plastics, metals and PU foam (with very low levels of residual blowing agent, 0.1% or 0.2% depending on the regulatory regime).
- Fugitive emissions from these processes are limited to 5g per hour by the environmental permit for fridge plants, as refrigerants and both CFC and Hydrocarbon blowing agents have ozone depleting properties.
- Regular data returns to the relevant competent authorities, provide a mass balance of fridges in to the process and hazardous and commodity material streams out of the process.
- Furthermore, the theoretical values from the environmental permit provide a working check on minimum standards that are comparable across the sector.



Our approach

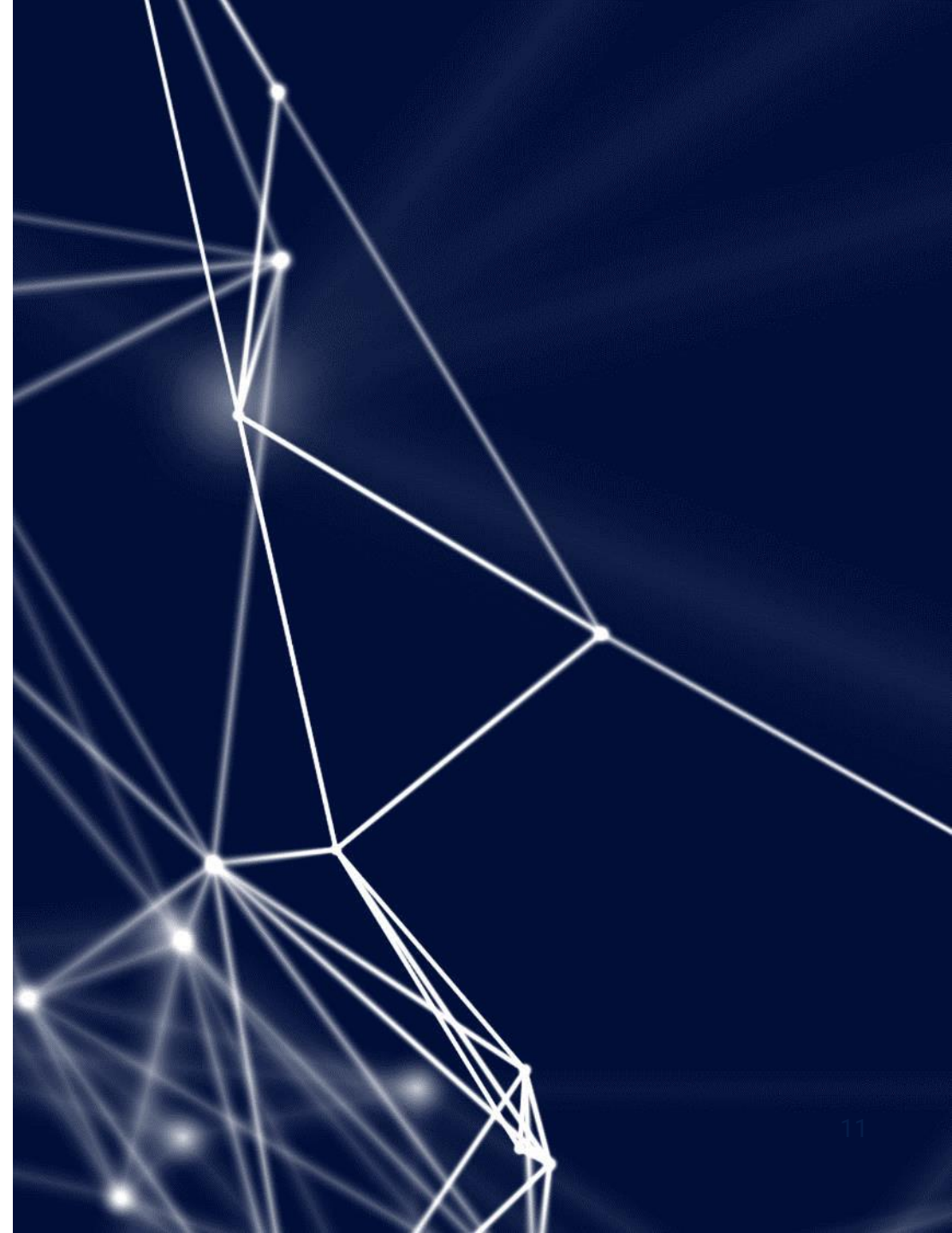
Review of fridge plant returns from the EA, synthesis and presentation of the data

- Gather all available periodic reports for 2017 and 2018 from UK fridge recyclers, via Freedom of Information requests, from the Environment Agency.
- Consolidate data into a comparable format and review for completeness, consistency and accuracy of calculations.
- Analysis on the clean data set of returns, through Stage 1 and Stage 2 processing at each UK fridge recycling plant (where information is available), evaluating recovery rates for refrigerant and blowing agent (separating CFC and Pentane, where reported).
- Further analysis on the unaccounted emissions, articulating how material they are, using language suitable for a non-technical audience.
- Commentary on deviations from expected performance and implications for the UK WEEE recycling sector, compliance and investment.

Analysis

Synthesis of data from the EA monthly returns

- Profile of the fridges being recycled
- Availability of data
- Understanding Stage 1 reporting
- Comparative performance of Stage 1 processing
- Understanding Stage 2 reporting
- Comparative performance on Stage 2 collection of blowing agent
- Key findings

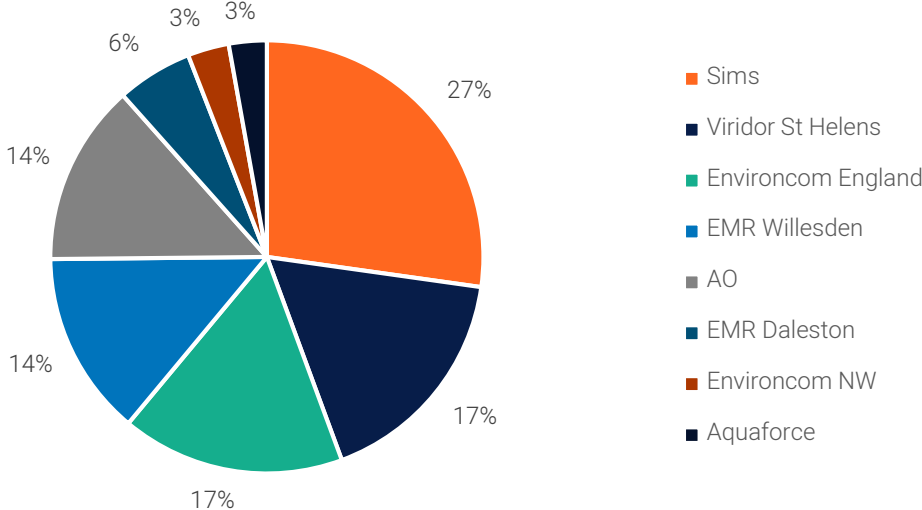


Profile of the fridges being recycled

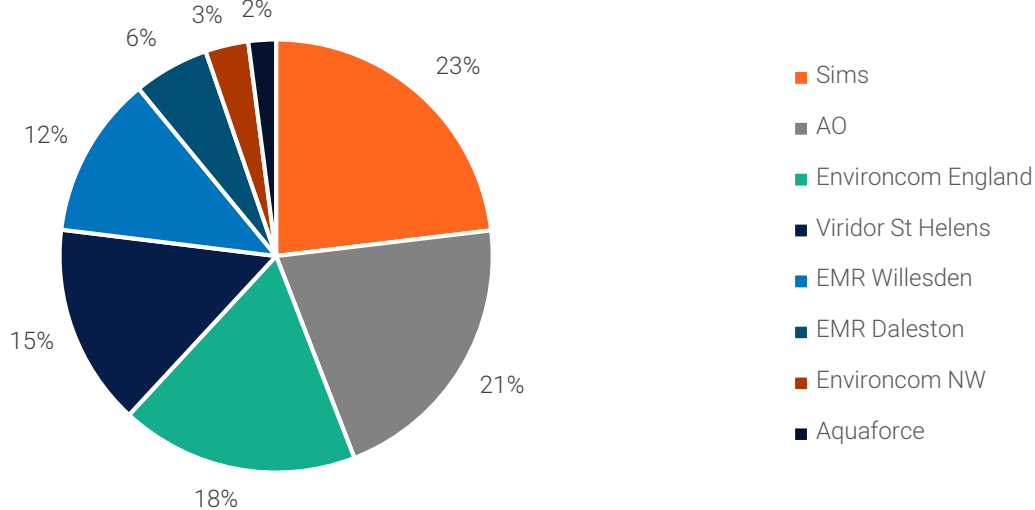
We estimated that 2.7M fridges were processed by UK fridge recycling plants in 2017 and 2.5M in 2018*

- SIMS process the most fridges, with AO gaining market share to be roughly equal to the combined throughput of the two Environcom plants. The combined EMR plants and the single Viridor plant also have significant market share.
- We estimate that 20% of fridges processed in in 2017 contained CFCs and 16% in 2018. There were several inconsistencies, omissions and errors in the reporting and these estimates are based on averages.

Market share of fridges processed (2017)



Market share of fridges processed (2018)



* Average values used for months where reports are not available

Availability of data

Not all periodic reports are available and some contain inaccurate calculations

- It is not clear why data is unavailable in some cases.
- To compensate, we have used monthly or per fridge, averages in our analysis to compare performance.
- The reports require recyclers to make calculations based on the data they submit, and some made mistakes.

Months complete data	2017	2018
AO	100%	100%
Aquaforce	100%	100%
EMR Daleston	50%	75%
EMR Willesden	100%	83%
Environcom England	100%	92%
Environcom NW	92%	75%
Sims	100%	50%
Viridor St Helens	100%	100%
eSynergy	0%	0%

Fridge plant	Under/over reporting of blowing agent recovered through mathematical error (g/fridge 2017)
AO	0.0
Aquaforce	4.8
EMR Daleston	0.0
EMR Willesden	3.2
Environcom England	0.0
Environcom NW	0.0
Sims	-108.1*
Viridor St Helens	-13.4

* SIMS did not complete this part of the reporting themselves, for completeness we have made the necessary calculations based on the data they have submitted.

Understanding Stage 1 reporting

Appendix B of permits includes reporting requirements

Sites report on:

- The number of fridges they receive that are damaged, so may have lost refrigerant before arriving.
- The number of fridges processed that use CFC refrigerants (with an assumed value for how much is recoverable).
- The number of fridges processed that use hydrocarbon, ammonia and other refrigerants.
- The amount of refrigerant theoretically available.
- The amount of refrigerant actually recovered.

Appendix B

Permit Number:

Operator:

Facility:

Form Number:

Destruction process efficiency reporting from DD/MM/YYYY to DD/MM/YYYY

Stage 1 Degassing

Record of refrigeration units received for Stage 1 degassing			
Type of unit	Number of units	Assumed refrigerant content	Refrigerant totals
Number of defective units ¹		--	--
Number of units containing halogenated refrigerants (CFCs, HCFCs and HFCs) (A)		x 100 g per unit =	
Number of units containing a hydrocarbon refrigerant (B)			
Number of units containing ammonia refrigerant (C)			
Number of other non-defective appliances ²			
Total number of viable units (D) = (A) + (B) + (C)		Total refrigerant	g

[1] Identified from visual inspection (i.e. no compressor or damaged cooling circuit, manometer (no gas pressure), or foam formation in inspection glass.

[2] Includes heat-pump tumble driers, de-humidifiers and air conditioners.

Theoretical recovery of refrigerant per unit	
Total refrigerant / (D)	g per unit

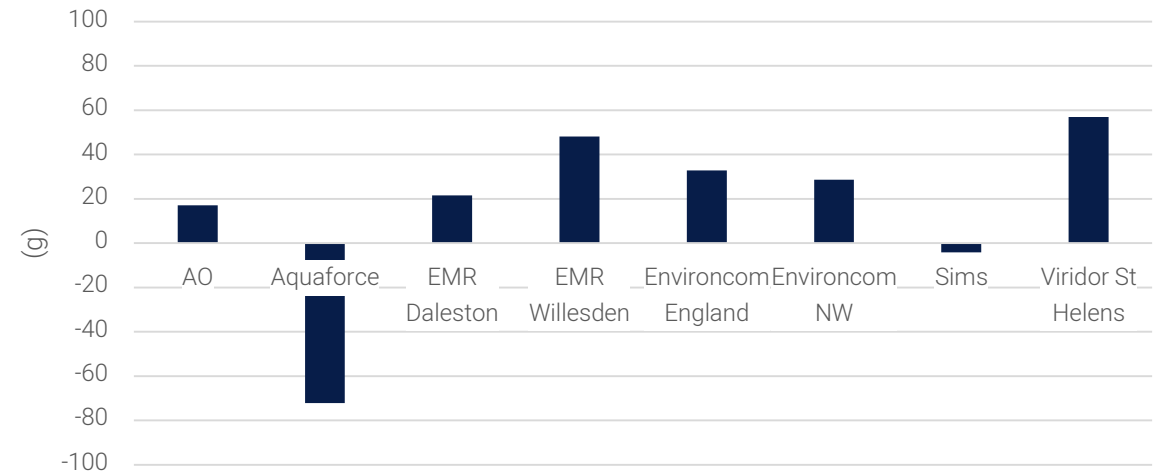
Recovery of refrigerant	Amount / unit
Weight of refrigerant storage container at start of reporting period (E)	g
Weight of refrigerant storage container at end of reporting period (F)	g
Weight of refrigerant recovered during reporting period (G) = (F) – (E)	g
Average weight of recovered refrigerant per unit = (G) / (D)	g per unit

Comparative performance of Stage 1 processing

The number of units reported as defective is highly variable, calling into question the reliability of the data on refrigerant

- Taking the periodic reporting from fridge plants at face value, the variation between the actual amount of refrigerant captured and the amount theoretically available is significant.
- Uncaptured refrigerant = Amount theoretically available – amount captured / number of viable fridges processed.
- The amount of units reported as defective, which are discounted from this calculation, varies considerably (ranging from 0 – 93% across the year).
- Given the amount of data being discounted from the calculations, it is difficult to draw conclusions on how the sites are performing in terms of uncaptured refrigerant during Phase 1.

Weight of uncaptured refrigerant per fridge (2018)



Percentage of units reported as defective

	AO	Aquaforce	EMR Daleston	EMR Willesden	Environcom England	Environcom NW	Sims	Viridor St Helens
2017	5%	26%	16%	44%	2%	20%	0%	9%
2018	6%	93%	20%	43%	5%	19%	0%	9%

Understanding Stage 2 reporting

Appendix B of permits includes reporting requirements

Sites report on:

- The type of unit processed (CFC/Pentane blowing agent, split by size), with an assumed amount of blowing agent that is theoretically recoverable for that fraction.
- The total amount of blowing agent that is theoretically available.
- The volume of panels processed.
- The actual amount of blowing agent recovered.

Stage 2 Destruction

Record of unit carcasses processed for destruction			
Type of unit	Number of units	Assumed blowing agent content	Blowing agent totals
Carcasses containing halogenated blowing agents (CFCs, HCFCs, HFCs)			
Type 1		x 240 g BA/unit =	g
Type 2		x 320 g BA/unit =	g
Type 3 & 4		x 400 g BA/unit =	g
Carcasses containing hydrocarbon blowing agents (CFCs, HCFCs, HFCs)			
Type 1		x 130 g BA/unit =	g
Type 2		x 227 g BA/unit =	g
Type 3 & 4		x 341 g BA/unit =	g
Total number of units processed for destruction (H)		Theoretical total blowing agent to be recovered	

Theoretical blowing agent recovery per unit for given unit type mix	
Theoretical total blowing agent / number of units (H)	g per unit

Record of insulation panel foam processed for destruction	Amount
Volume of panel processed	m ³

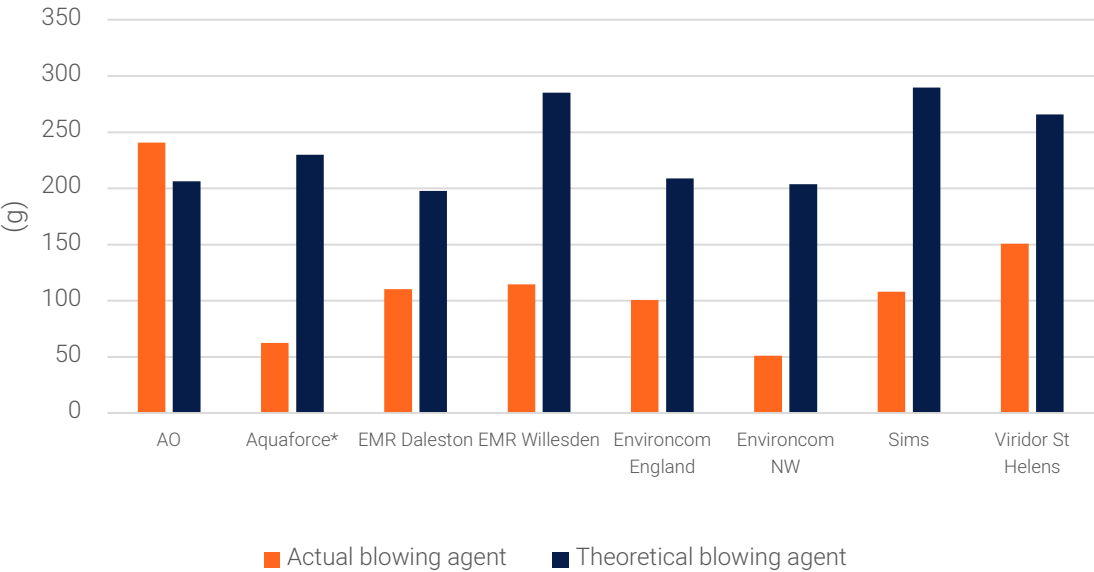
Actual recovery of blowing agent	Amount / unit
Weight of blowing agent container at start of reporting period (I)	g
Weight of blowing agent container at end of reporting period (J)	g
Weight of recovered blowing agent during reporting period (K) = (J) – (I)	g
Average weight of recovered blowing agent per unit = (K) / (H)	g per unit

Comparative performance on Stage 2 collection of blowing agent

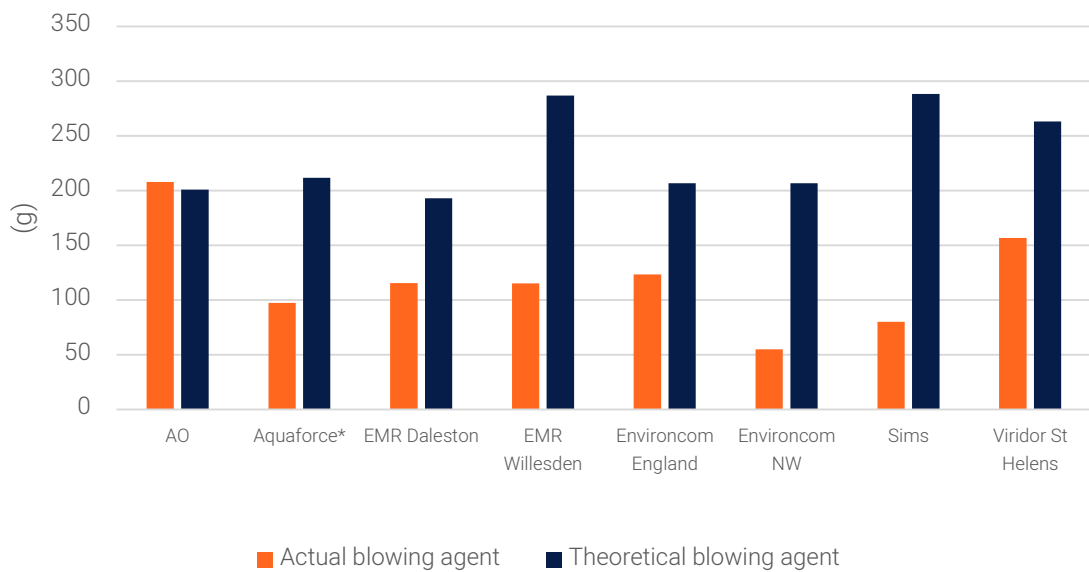
Some fridge recyclers report to collect much less blowing agent than they theoretically should

- The lowest performer collected 25% of the blowing agent that should have been available in 2017 and 27% in 2018, using the permit values as a benchmark.
- 327 tonnes of blowing agent were captured in 2017 and 303 tonnes in 2018, 51% and 59% of the amount theoretically available respectively.
- There is no discounting of damaged units at Stage 2, as this does not impact the foam, so the data is much more reliable.

Weight of blowing agent per fridge (2017)



Weight of blowing agent per fridge (2018)



Outcomes

Understanding the impact

- Key findings
- Interpretation



Key findings

The following insights could be determined

- Data returns are inconsistent, incomplete and our analysis showed some to be inaccurate. The data returns require calculations to be made, based on data included in the forms, and in some cases these had been made inaccurately.
- Furthermore, one fridge recycler had recorded all fridges as containing CFCs, which is unlikely, and (in particular the biggest collector SIMS) some are reporting simplified metrics in a format inconsistent with other recyclers.
- Based on a cleaned version of the data, which uses averages for months where fridge plants did not report, UK fridge plants released 318 tonnes of blowing agent into the environment in 2017 and 212 tonnes in 2018.
- The sector as a whole is underperforming in the recovery of refrigerant from compressor oil. The data, however, is distorted by highly variable rates of damaged units which are discounted from the calculations.

Interpretation

Reporting from UK fridge recyclers is imperfect, but indicates that performance is low

- There are three potential explanations for this low performance:
 1. Most UK fridge recycling plants do not collect enough blowing agent or refrigerant through their treatment processes.
 2. There are mistakes in UK fridge recycling reporting to the competent authorities, which exaggerate poor performance.
 3. The theoretical values for blowing agent in fridges from the fridge recyclers' environmental permits are no longer representative.
- The implications of the apparent shortfall are considerable, blowing agents are ozone depleting and some of the fridges in the UK WEEE system still contain CFCs (the reporting suggests that around 98 tonnes CFC were not captured across 2017 and 2018).
- CFC 11 has a global warming potential of 4,250 CO₂e (100 year time horizon), so the 98 tonnes would be equivalent to releasing 416,500 tonnes of CO₂ into the atmosphere. It would also cause some damage to the ozone layer.
- Pentane has a global warming potential <5 CO₂e, so the total released emissions from UK fridge plants in 2017 and 2018 was equivalent to releasing 418,660t CO₂*
- This is the equivalent to the emissions of around 100,000 family cars in the UK[†].
- While it is clear that there are mistakes in the reporting, consistent and universal misreporting is unlikely. There are also isolated examples of high performance in the recovery of blowing agent, which suggests that the theoretical values from environmental permits are achievable.
- It should be noted that some fridge recyclers operate outside of the Environment Agency reporting regime, it is not clear why this is.
- Also, some operators report simplified metrics to the Environment Agency or equivalent local regulatory authority (such as SEPA) and it is not clear why this is either.

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