DOI: 10.18462/iir.iccc2024.1003

Commercial, professional and domestic refrigeration equipment efficiency in the UK: current and future trends

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ABSTRACT

In the UK food cold-chain refrigeration accounted for 28.6 TWh/a of electrical energy consumption in 2019, of which 24.4 TWh was from commercial, professional and household refrigeration. Using the most recent UK projections of energy consumption for domestic, professional and commercial refrigeration, this work found that UK Government projections for domestic refrigeration are not realistic and should be adjusted to reflect that current UK sales of domestic refrigerators have higher energy consumptions than currently assumed. To drive energy improvements in professional refrigeration will require removing the 3 worst performing classes from energy labelling. Banning open fronted supermarket cabinets and/or removing the last 3 tiers of the energy label, would bring supermarket commercial refrigeration in line with current projections, but only if it happened immediately. For other commercial refrigeration equipment (beverage coolers and ice cream freezers) a more gradual approach of removing labels is suggested to be appropriate.

Keywords: greenhouse gas emissions, equipment efficiency, commercial, domestic, professional.

1. INTRODUCTION

Cold chains are energy intensive. According to Foster et al (2022) refrigeration in the UK food cold chain accounted for approximately 28.6 TWh/a of electrical energy consumption and 24.4 TWh was from retail (commercial), food service (professional) and domestic (household) refrigeration.

Refrigerated food must be kept at a defined temperature and the equipment used must conform to energy performance standards. The EU and UK apply regulations that prescribe minimum energy performance standards (MEPS) and energy labelling for domestic, professional and commercial refrigeration products. Since leaving the EU the regulations in the UK have mirrored those in Europe. Domestic refrigerators and freezers have been subject to energy labelling since 1994 (and recently updated in 2021). Professional refrigerated storage cabinets have been labelled since 2016 and refrigerating appliances with a direct sales function (commercial refrigerators) since 2021.

The UK has a Net Zero Strategy (HM Government, 2021). This strategy sets out policies and proposals for decarbonising all sectors of the UK economy to meet the net zero target by 2050. The UK Net Zero Growth Plan (HM Government, 2023) highlights that although the UK is expected to achieve all the savings required to meet Carbon Budget 4 and 5 (CB4 and 5), it will only achieve 97% of the emissions reductions required to meet Carbon Budget Six (CB6) (2033-37). CB6 represents a very significant increase in the pace of the power sector decarbonisation, coupled with increased demand due to the roll-out of heat pumps and electric vehicles. Electricity demand is expected to be around 50% higher by 2035 and 100% higher by 2050 (UK Parliament, 2023). Significant reduction in energy demand and changes to how energy is managed and consumed are therefore required to meet these targets.

The aim of this work was to examine the validity of the most recent projections of energy consumption for domestic, professional and commercial refrigerated equipment in the UK. In cases where projections were no longer valid, options to bring them back in line are suggested. Measures to promote more rapid energy reduction are also evaluated.

1. METHOD

Three refrigerated equipment product categories were included in this study. These 3 types were categorised by the sector in which they operate and are regulated in the UK and EU by different energy labelling (Ecodesign) regulations.

* Domestic refrigerators are defined by Regulations (EC) 643/2009 and (EU) 1060/2010, as electric mains-operated household refrigeration appliances with a storage volume up to 1500 litres.
* Professional refrigerated storage cabinets are regulated under the EU regulations 2015/1094 and 2015/1095 and are used in professional kitchens and catering (food service sector).
* Commercial refrigerators are refrigerating appliances with a direct sales function and are regulated under the EU regulations 2019/2018 and 2019/2024.

The latest projections carried out in a UK Government study (for domestic refrigeration only) and the EU Ecodesign studies for all 3 sectors were examined. As these studies were completed some time ago, an evaluation of energy performance of current equipment was compared with that used in the study predictions, to determine whether the projections were still realistic.

The European Product Registry for Energy Labelling (EPREL) was used to establish the energy consumption of new equipment purchased. Where EPREL was not able to provide adequate information, UK online refrigeration retailer sales information was used. It should be noted that EPREL and retailer web sites, do not provide sales data (number of sales of each product), therefore these databases cannot be used to show the proportion of cabinets sold with a specific energy class, only the number of models available. For the purpose of this work, an assumption was made that number of models and sales correlate.

Where current energy efficiency was lower than the predictions in the studies, analysis was carried out to determine what actions could be applied to realign the projections and what policy and technical changes might be required to achieve this.

1. RESULTS
   1. Domestic

Fig. 1 shows mean annual energy consumption (AE) of domestic refrigerators in the UK projected up to 2050 from UK Government projections.

Biglia et al (2018) carried out a large-scale survey in which 998 cold appliances were monitored in 766 properties in England. This study was carried out in 2015 and showed (AE) and numbers of each type of appliance. The AE and proportion of each unit in use in 2015 were compared between the UK Government projections and the Biglia et al data (Table 1). The average AE is a mean of the 4 appliances, weighted by their proportion in use. Biglia et al showed an average AE 9.4% higher than the UK value, with higher energy consumption for all 4 types of appliances. This could be due to a number of factors, e.g. differences between energy consumption from testing and real life, deterioration of the performance of equipment over time, and the appliances in Biglia et al study not perfectly reflecting the stock of appliances assumed in the UK projection.

A French study in 2015 (Dupret and Zimmerman, 2019) showed energy consumption of refrigerators and fridge-freezers to be in between those of the UK and Biglia et al study.

Chart, line chart

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Figure 1. Mean electrical energy consumption of domestic refrigerators in the UK projected up to 2050.

Table 1. Stock energy consumption and proportion of different types of domestic refrigerator.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Chest freezer | Fridge-freezer | Refrigerator | Upright Freezer | Average |
| **UK** |  |  |  |  |  |
| Energy per appliance (kWh/a) | 416 | 376 | 185 | 316 | 329 |
| Proportion of each appliance (%) | 12% | 47% | 21% | 20% |  |
| **Biglia et al.** | |  |  |  |  |
| Energy per appliance (kWh/a) | 420 | 390 | 274 | 342 | 360 |
| Proportion of each appliance (%) | 9% | 52% | 20% | 19% |  |
| **Dupret et al.** |  |  |  |  |  |
| Energy per appliance (kWh/a) | 354\* | 386 | 211 | 354\* |  |

\* Value given was for freezer, not separated into upright or chest.

The European Commission’s most recent Preparatory Study on household refrigerating appliances (VHK and ARMINES, 2016) predicted the average energy consumption of units sold over the period 2005-2030 in the EU, for different scenarios, business as usual (BAU), ambitious and lowest life cycle cost (LLCC). The BAU scenario is the ‘realistic’ energy saving scenario as indicated in the 2007 preparatory study. The ambitious scenario is technically possible but requires the consumer to pay more over the life-time of the equipment.

The EU total annual energy consumption from the above study was adjusted for the UK by using the proportion of the UK population compared to the EU population and is shown in Fig. 2. The UK Government projections have also been plotted on the same graph. It can be seen that the UK projections very closely match the BAU scenario up to 2030 (end date of EU projections) and it is reasonable to conclude that the Ecodesign data may have been used to guide the UK projections. The UK projection extends beyond the Ecodesign projections to 2050.

Figure 2. Total electrical energy consumption in UK according to different EU scenarios.

The EU based projections above are based on assumptions of the average AE of replacement stock each year from VHK and ARMINES (2016) shown in Fig. 3.

Graphical user interface, text, application

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Figure 3. Projected AE of domestic refrigerators being sold in EU for different scenarios. From VHK and ARMINES (2016).

The best available technology (BAT) in the UK and EU at time of writing (February 2023) was considered as the lowest AE appliances found on the TopTen list (https://www.toptenuk.org/ and https://www.topten.eu/). These are shown in Table 2 with the average being a weighted calculation using proportions of appliances from the UK study for 2023.

Table 2. BAT AE for UK And EU for different refrigerator types. Energy label shown in brackets.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Chest Freezer | Fridge-freezer | Refrigerator | Upright freezer | Average (weighted) |
| BAT UK (kWh/a) | 210 (E) | 110 (A) | 65 (A) | 179 (C) | 127 |
| BAT EU (kWh/a) | 144 (C) | 108 (A) | 65 (A) | 179 (C) | 118 |

BAT (EU) and BAT (UK) were the same or similar except for chest freezers. This was due to the 5 BAT (EU) chest freezer models not being available for sale in the UK. However, as only 11% of domestic refrigerators in use are chest freezers it makes only a small difference to the weighted mean (8%).

If we compare the average BAT with EU projections for 2023 (Fig. 3) we can see that the BAT closely matches the two LLCC projections. We can conclude that for the whole market to align with the LLCC projections all appliances would need to be BAT and that this has not been achieved..

Additionally it is clear that not all customers will purchase the BAT and therefore a likely replacement stock AE needs to be found. From the European Product Registry for Energy Labelling (ERPREL) half (50%) of the domestic refrigerator models are class F (Fig. 4).

Figure 4. Proportion of domestic refrigerator models at each label class from EPREL in March 2023.

EPREL does not allow different model types to be searched, however, from a major retailer’s web site (https://www.argos.co.uk/) the modal energy label class was F for all 4 types of appliances. Based on an F label class, Table 3 shows a representative energy consumption based on models from the major retailer. Comparing this energy consumption with the EU Projections (Fig. 3) shows AE of replacement stock in 2023 is similar to that predicted by VHK and ARMINES (2016) for the period before 2010.

Table 3. Representative AE for new stock in 2023.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Chest freezer | Fridge-freezer | Refrigerator | Upright freezer | Weighted average |
| (kWh/a) | 250 | 280 | 140 | 300 | 259 |

Table 2 shows that current BAT products are available which fit the EU LLCC scenario, however, the products currently being sold (Table 3) use about 50% more energy than even the BAU scenario. Although A-class fridge-freezers are available for sale from the retailer, these accounted for 1.5% of the products available whereas F-class products accounted for 80%. According to the EPREL database, 50% of fridges, freezers and wine storage appliances are F label and only 0.6% are A and B label (Fig. 4).

To follow the trajectory of the UK projection from 2023 and EU BAU scenario would require an average AE of approximately 160 in 2023. For fridge-freezers this would likely require a B-class and only 0.9% of the 319 fridge-freezers on the retailer’s web site were A and B-class.

It is not clear why C and D-class chest freezers are not available in the UK (Table 2). Also, the BAT for freezers (chest and upright) are much higher than for fridges and refrigerators. Some of this may be due to the calculation methodology used in creating the labels. The label class (A to G) is related to the actual energy consumption compared to a calculated energy consumption (standard energy consumption). This is described in detail in EUR-Lex (2009). Based on this calculation, refrigerators with a 3-star compartment, refrigerator-freezers and upright freezers are all allowed to use more energy than chest-freezers for the same energy label classification and volume.

Due to the new IEC standard (IEC, 2015) which is a requirement for the updated energy labelling Directive, chest freezers are expected to use 2% less energy and fridge-freezers 19% more energy than when measured by the previous standard (VHK and Armines, 2016). This will somewhat reduce the disparity between chest-freezers and fridge-freezers.

The poor efficiency of chest-freezers may also be due to commercial factors. Chest-freezers are the least common type of the 4 appliances and according to UK projections their market size is shrinking and the market for fridge-freezers is growing. Therefore, there is less incentive for manufacturers to invest in energy reducing technologies or optimising performance.

* 1. Professional

3.2.1 Eco-design projections

The most recent Eco-design study for the European Commission (Kenma et al., 2022) presents professional refrigeration energy consumption projected to 2050 for 4 main types of cabinet (Table 4). Products are categorised as chilled vertical (CV), frozen vertical (FV), chilled horizonal (CH) and frozen horizontal (FH), where horizontal includes counter and under counter. Total energy consumption for the UK was calculated on a pro rata population basis.

Table 4. Total energy consumption of the 4 types of professional refrigeration in the UK projected to 2050 (TWh/a).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 2020 | 2025 | 2030 | 2050 |
| CV | 0.27 | 0.21 | 0.21 | 0.24 |
| FV | 0.31 | 0.25 | 0.24 | 0.27 |
| CH | 0.21 | 0.17 | 0.16 | 0.20 |
| FH | 0.13 | 0.09 | 0.09 | 0.10 |
| **Total** | **0.93** | **0.72** | **0.69** | **0.81** |

Table 5 shows the energy efficiency index (EEI) and energy label classes of the 4 products.

Table 5. EEI and energy label class of professional refrigeration in the UK

|  |  |  |  |
| --- | --- | --- | --- |
|  | Sales:  EEI (label) | Stock:  EEI (label) | |
|  | 2020 and after | 2020 | 2030 + |
| CV | 57 (D) | 83 (E) | 57 (D) |
| FV | 53 (D) | 79 (E) | 53 (D) |
| CH | 65 (D) | 94 (F) | 65 (D) |
| FH | 61 (D) | 91 (F) | 61 (D) |

The Ecodesign study suggested changing the calculation of the EEI and changing the threshold for the labelling. This revised policy change (ECO scenario) is predicted to reduce energy consumption of storage cabinets up to 2050 and is shown in Table 6 along with the current scenario (BAU scenario). The ECO scenario is predicted to reduce emission of professional refrigeration by 19% in 2030 and 41% by 2050.

Table 6. Total energy consumption of professional refrigeration in the UK projected to 2050 under different scenarios with approximate an approximate representative current energy label in brackets (TWh/a).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 2020 | 2030 | 2040 | 2050 |
| BAU | 0.93 (F) | 0.69 (D) | 0.76 (D) | 0.82 (D) |
| ECO | 0.93 (F) | 0.56 (C) | 0.47 (B) | 0.48 (B) |

3.2.2 Feasibility of projections

Whether the above energy reductions are achievable and go far enough was assessed. Fig. 5 shows the proportion of professional storage cabinets within each label class on the EPREL as of March 2023. According to the EPREL, 1% of storage cabinets are G-class and 4.3% are F-class. Many of the worst performing storage cabinets on the EPREL were labelled incorrectly, being commercial cabinets with glass doors or blast cooling cabinets. Chillers have a better energy class than freezers.

Figure 5. Proportion of professional storage cabinets (%) falling within each label on EPREL as at March 2023.

The EPREL does not allow searching by cabinet type (apart from chilled and frozen volume), so it is not possible to tell how many cabinets within each label class were vertical or horizontal. Therefore, the web site of a major UK supplier of professional refrigerated cabinets (https://www.nisbets.co.uk/) was searched and label classes for different cabinet types were collected (Table 7). This was from a total of 175 appliances.

Table 7. Energy label and percentage of cabinets in that label from a UK retailer of professional refrigeration.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Top label class (%) | Modal label class (%) | Bottom label class (%) |
| CV | A (4) | C (52) | F (4) |
| CH | A+ (7) | B (36) | E (1) |
| FV | B (16) | D (22) | E (10) |
| FH | B (12) | D (76) | D (76) |

This data correlated well with the EPREL data showing most cabinets falling in the C and D class and chillers performing better than freezers. However, this data also shows a difference between the different model types, with CV providing label class one higher than CH which were one higher than FV and FH.

The Eco-design ECO scenario aims to lead average cabinets to a B-class by 2040. For all cabinets this is already achievable for all cabinet types. However, it would be more difficult for freezers than chillers. For CH type, this would probably be too lenient, as the modal class is already a B. The ECO scenario is based on new labelling calculations that have a different effects on different cabinet types. The proposed new labelling will address the better label classes for the CH type, making the label classes for this type more difficult to achieve. It will also address the worse label classes of the freezers, making the better label classes easier for these types to achieve.

3.2.3 Removing labels

The effect of removing the worst energy label classes is discussed below. It was assumed that when the worst class is removed, the models in that class were replaced with models in the energy class one better than the one that was removed. The total energy consumed in each class was assumed proportional to the EEI of that label multiplied by the number of pieces of equipment in that class (from EPREL). This assumes that number of models correlates well with number of sales. The energy savings calculated from removing the worst class in turn are shown in Fig. 6.

According to Kenma et al (2021) the new G class will be phased out by 1.1.2026 and the new F class by 1.1.2028. However, the G class is already rare and if removed immediately, would have little effect. Considering that there are so few F class cabinets, removing this class would still have little impact on energy consumption. To drive energy improvements will require removing the E category, although this would be better applied after the new labelling calculations are applied so as to not unfairly impact the freezers and better impact CH cabinets.

Figure 6. Energy saving from removing each label in turn.

From these results we can conclude that removing the worst performing label classes from chillers may remove the cheapest smaller chillers with R600a components. Removing these labels from freezers might have the opposite effect, removing the more expensive R290 units (which have higher cooling capacities) and this will depend on the size of the units.

3.3 Commercial

Commercial refrigeration covers refrigerating appliances with a direct sales function. They include super-market cabinets (SM), cabinets for scooping ice-cream (SIC), refrigerated vending machines (VM), beverage coolers (BC) and ice-cream freezers (ICF).

The most recent study for the European Commission (Moons, 2014) shows commercial refrigeration energy consumption projected from 2010 to 2030 and was based on energy labelling and MEPS which have now been applied. As the regulations came in later than anticipated in the study, we might expect the improvements to occur later. As the projections assumed the regulations would enter into force in 2016, the benefits are assumed to have occurred 5 years later. This data was corrected for UK on a pro rata basis on population and shows total energy consumption of commercial refrigeration for 2015, 2020, 2025 and 2035, as 12.1, 11.6, 9.1 and 4.3 TWh/a respectively.

This projection is based on assumptions that average products sold are A class by 2026 and halfway between A class and D/E class by 2023. These dates include the additional 5 years added due to the delay in implementation.

Table 9 shows the modal label class and the approximate median daily energy consumption Edaily for that label class for the 5 product types from the EPREL database in March 2023. The proportion of sales comes from Moons et al (2014) and the sales x Edaily shows the proportion of total energy consumption for each product.

Table 8. Energy consumption and sales for 5 different types of commercial refrigerated product.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | VM | BC | ICF | SM | SIC |
| Label (modal) | D | D | D | F | E |
| Edaily (kWh/a) | 3.45 | 2.09 | 2.11 | 44.90 | 33.89 |
| Sales (%) | 9.2 | 45.1 | 19.3 | 26.0 | 0.4 |
| Sales x Edaily | 0.32 | 0.94 | 0.41 | 11.67 | 0.14 |

Table 9 shows that the modal label class is an F for the product type with the largest influence on energy consumption (based on Sales x Edaily) which is a SM type. Given that the projections in Table 8 are based upon products sold being A class by 2026 and half-way between A class and D/E class by 2023, this shows that the projections are over optimistic based on current sales (Table 9).

3.3.1 Supermarket cabinets

The most significant factor in determining the performance of a supermarket chiller, is whether it has doors or not. Open fronted vertical chilled supermarket cabinets are classed as VC2 and doored versions are classed as VC4. This allows them to be searched in the EPREL. Searching for remote (refrigeration system separate from cabinet) cabinets shows that for remote open fronted vertical chilled supermarket cabinets (RCV2), 93.7% are E class and below and for remote doored vertical chilled supermarket cabinets (RCV4) 96.7% are D class and above (Fig. 7).

Figure 7. Percentage of models of that fall within each label class.

If labels E to G were removed, this would remove almost all remote open cabinets and leave almost all remote closed cabinets. This would mean that remote supermarket cabinets sold would predominantly be C and D class. If done immediately this could make remote supermarket cabinets fall in line with the projections used in Table 8.

For integral supermarket cabinets the proportion of doored (ICV4) and open (ICV2) is shown in Fig. 7. For ICV4, 89.3% are D class and above and for ICV2 45% are E class and below. Removing labels E to G would have less of an impact on open integrals than it does on open remotes, keeping 55% of open integrals (ICV2) on the market (45% removed). However, it would have more of an impact on closed integrals (ICV4), than closed remotes, removing 10.7% of the models.

1. CONCLUSIONS

The UK Government projections for domestic refrigeration are not realistic and should be adjusted to reflect current sales. Current BAT products are available which fit the EU LLCC scenario; however, the products currently being sold use about 50% more energy than even the BAU scenario. To follow the trajectory of the UK projections from 2023 would require fridge-freezers to be a B-class. Only 0.9% of the fridge-freezers on the suppliers’ web site examined were A and B-class at the time of writing.

For professional refrigeration the new G class will be phased out by 1.1.2026 and the new F class by 1.1.2028. This will probably have little effect on the energy consumption of UK stock, as there are already very few models in these label classes. To drive energy improvements will require removing the E-class, and this is better done after the new Eco-design labelling regulations are applied, so as not to unfairly impact the freezers and better impact the CH type.

It is clear that all commercial cabinet types use more energy than the Eco-design study projection timescale. Banning open fronted supermarket cabinets and/or removing the lowest 3 label classes, would bring these model types in line with current projections, but only if it happened immediately.

The following recommendations have been concluded from this work with the aim of aligning UK Government projections closer to reality and reducing energy consumption in the future.

* Determine up to date domestic stock energy consumption.
* Adjust UK Government domestic predictions based on up-to-date stock, current sales and realistic projections.
* Introduce policy to phase out the worst performing professional cabinet labels as soon as possible.
* Introduce policy to phase out open fronted supermarket display cabinets, either directly or by removing label classes.

ACKNOWLEDGEMENTS

This work was carried out as part of an EPSRC UK Energy Research Centre Project (EP/S029575/1) and EPSRC grant (EP/V042548/1). We would like to thank BEIS for supporting us with UK government statistics.

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