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COMPARING THE PERFORMANCE OF FRIDGES

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INTRODUCTION

Fridges are widespread throughout scientific research and teaching. They are found in molecular sciences, life sciences, chemistry and stores departments throughout the UK. With UK labs aiming to minimize their running costs, highlighting the fridge with the lowest running costs is a useful exercise. However, energy consumption values alone would not be serving end user requirements. This study aimed to highlight some of the data and criteria which should be considered when selecting the most sustainable solution based on the specific needs of the researcher, their laboratory and the materials they are storing.



Figure 1. The three units being tested, from left to right, Liebherr, Lec and Biocold.

STORING AT 4C

Typically, fridges are used to store their contents at the set point of 4C. Scientific Laboratory Supplies Ltd (S.L.S.) commissioned this study to investigate the differences in performance between three well-known brands of under bench fridges which they supply to the UK market. The three units were selected based on having similar capacities, refrigerant type and volume and having spark reduced or spark free interiors. The three units (Figure 1) were tested under controlled conditions at the Healthcare Technologies Institute, University of Birmingham. The three units were monitored at the 4C set point, with their temperature performance, energy consumption and door opening recovery times recorded. It must be noted that the Biocold unit did not have a digital temperature controller, instead a simple dial was fixed on the back of the unit marked from 1 to 10, and these numbers do not represent a temperature. Therefore the dial was set to a point between 4 and 5 which brought the sample temperature probe to ~4C.

MEASURING TEMPERATURE AND ENERGY

This case study used the Koolzone energy monitors, temperature probes and online platform to record all the data. One difference that must be highlighted in terms of monitoring is the **pull down time.**

Traditionally, the pull down time is measured by placing one probe inside the unit and measuring the time taken for the probe to reach the average chamber temperature. This study employed a more representative method. Whereby the pull down time is defined as the time taken for **each compartment/section to reach its average temperature** (accurate to 0.1C) measured at the 4C set point with no door openings over a 24 hour period. Please note that the Lec and Biocold unit had three more temperature probes as they have storage sections located on their doors (figure 2).



Figure 2. Each fridge with a temperature probe in each compartment together with a temperature probe placed in glycol at the centermost point to represent a sample. Dan Smith from the University of Birmingham holding open the Liebherr door which is self-closing.

The data collected for each unit concerning pull down time, temperature performance and energy consumption without door openings is shown in figure 3. The compartments are numbered in descending order with the top compartment being named compartment 1. The sample probe was placed in the centermost compartment of each unit. This compartment, along with the sample probe is highlighted in light blue in both figures 3 and 4.

Manufacturer	Liebherr	Lec	Biocold
Model	LKUexv1610	LSFSR158UK	BIO130FRSS
Net Capacity	130	154	128
kWh/Day at 4C Set Point	1.009	0.314	0.307
Energy - W/L/Day	7.76	2.04	2.40
Fan/Convection	Fan	Convection	Convection
Compartment 1 Avg. Air Temperature at 4C Set Point (Lowest/Highest)[Pull Down Time]	2.1C(1.9C/3.9C)[81 minutes]	3.90C(3.3C/4.8C)[90 minutes]	5.1C(4.8C/5.6C)[298 minutes]
Compartment 2 Avg. Air Temperature at 4C Set Point (Lowest/Highest)[Pull Down Time]	1.3C(1.0C/3.1C)[83 minutes]	2.8C(2.0C/3.8C)[62 minutes]	4.60C(4.1C/5.2C)[260 minutes]
Sample Avg. Temperature at 4C Set Point (Lowest/Highest)	2.7C(2.5C/3.6C)	1.60C(1.30C/2.10C)	4.10C(3.7C/4.6C)
Compartment 3 Avg. Air Temperature at 4C Set Point (Lowest/Highest)[Pull Down Time]	1.0C(0.6C/3.8C)[45 minutes]	3.2C(2.6C/4.0C)[60 minutes]	5.00C(4.4C/5.7C)[258 minutes]
Compartment 4 Avg. Air Temperature at 4C Set Point (Lowest/Highest)[Pull Down Time]	3.6C(3.3C/5.5C)[79 minutes]	2.2C(1.1C/3.5C)[48 minutes]	7.20C(7.0C/7.5C)[368 minutes]
Door Section 1 Avg. Air Temperature at 4C Set Point (Lowest/Highest)[Pull Down Time]	No Door Sections	4.8C(4.4C/5.3C)[107 minutes]	9.30C(8.5C/10.0C)[224 minutes]
Door Section 2 Avg. Air Temperature at 4C Set Point (Lowest/Highest)[Pull Down Time]	No Door Sections	2.6C(2.0C/3.3C)[54 minutes]	6.20C(5.5C/7.0C)[332 minutes]
Door Section 3 Avg. Air Temperature at 4C Set Point (Lowest/Highest)[Pull Down Time]	No Door Sections	2.7C(2.1C/3.5C)[60 minutes]	8.50C(7.5C/9.5C)[254 minutes]

Figure 3. Fridge performance data recorded at ambient condition of 21C (+/-1C)

Each unit was then subjected to 2 timed door openings. The first door opening was for a duration of 60 seconds. It was estimated that 2 hours and 45 minutes would be long enough for temperatures to fully recover from the 60 second door opening. Following this time a second, longer door opening was carried out, this time for a duration of 90 seconds. The recovery time was measured as the time taken for the temperature to recover to the exact temperature it was at the time of the door opening, accurate to 0.1C. The results of the timed door openings are shown in figure 4.

Manufacturer	Liebherr	Lec	Biocold
Model	LKUexv1610	LSFSR158UK	BIO130FRSS
60 Second Door Opening Data			
Compartment 1 Avg. Air Temperature at 4C Set Point (Recovery)	2.0C up 0.8C to 2.8C (30 minutes)	3.7C up 4.0C to 7.6C (62 minutes)	5.0C up 1.6C to 6.6C (105 minutes)
Compartment 2 Avg. Air Temperature at 4C Set Point (Recovery)	1.1C up 0.6C to 1.7C (31 minutes)	2.6C up 3.7C to 6.3C (25 minutes)	4.3C up 1.7C to 6.0C (110 minutes)
Sample Avg. Temperature at 4C Set Point (Recovery)	2.8C up 0.2C to 3.0C (16 minutes)	1.3C up 1.7C to 3.0C (71 minutes)	3.9C up 1.0C to 4.9C (N.R. 174 minutes)*
Compartment 3 Avg. Air Temperature at 4C Set Point (Recovery)	0.8C up 0.7C to 1.5C (7 minutes)	2.8C up 3.7C to 6.5C (28 minutes)	4.6C up 1.4C to 6.0C (74 minutes)
Compartment 4 Avg. Air Temperature at 4C Set Point (Recovery)	3.5C up 0.9C to 4.4C (16 minutes)	1.9C up 2.2C to 4.1C (19 minutes)	7.2C up 0.6C to 7.8C (151 minutes)
Door Section 1 Avg. Air Temperature at 4C Set Point (Recovery)	No Door Sections	4.5C up 2.4C to 6.9C (107 minutes)	9.0C up 2.0C to 11.0C (107 minutes)
Door Section 2 Avg. Air Temperature at 4C Set Point (Recovery)	No Door Sections	2.3C up 2.5C to 4.8C (31 minutes)	6.0C up 2.0C to 8.0C (67 minutes)
Door Section 3 Avg. Air Temperature at 4C Set Point (Recovery)	No Door Sections	2.5C up 1.9C to 4.4C (27 minutes)	8.0C up 2.0C to 10.0C (65 minutes)
90 Second Door Opening Data			
Compartment 1 Avg. Air Temperature at 4C Set Point (Recovery)	2.0C up 1.4C to 3.4C (32 minutes)	3.6C up 5.0C to 8.6C (60 minutes)	5.3C up 1.7C to 7.0C (106 minutes)
Compartment 2 Avg. Air Temperature at 4C Set Point (Recovery)	1.1C up 1.0C to 2.1C (27 minutes)	2.3C up 5.0C to 7.3C (58 minutes)	4.9C up 1.4C to 6.3C (72 minutes)
Sample Avg. Temperature at 4C Set Point (Recovery)	2.6C up 0.5C to 3.1C (51 minutes)	1.6C up 1.6C to 3.2C (29 minutes)	4.5C up 0.8C to 5.3C (78 minutes)
Compartment 3 Avg. Air Temperature at 4C Set Point (Recovery)	0.8C up 1.1C to 1.9C (10 minutes)	3.1C up 4.0C to 7.1C (23 minutes)	4.8C up 1.5C to 6.3C (109 minutes)
Compartment 4 Avg. Air Temperature at 4C Set Point (Recovery)	3.5C up 1.3C to 4.8C (19 minutes)	1.5C up 2.1C to 3.6C (17 minutes)	7.4C up 0.7C to 8.1C (136 minutes)
Door Section 1 Avg. Air Temperature at 4C Set Point (Recovery)	No Door Sections	4.8C up 2.7C to 7.5C (61 minutes)	9.5C up 2.0C to 11.5C (70 minutes)
Door Section 2 Avg. Air Temperature at 4C Set Point (Recovery)	No Door Sections	2.6C up 2.6C to 5.2C (27 minutes)	6.5C up 2.0C to 8.5C (45 minutes)
Door Section 3 Avg. Air Temperature at 4C Set Point (Recovery)	No Door Sections	2.6C up 2.0C to 4.6C (23 minutes)	8.5C up 2.0C to 10.5C (42 minutes)

Figure 4. Fridge door recovery performance data. *Sample temperature in the Biocold unit did not recover in time for the second door opening.

DISCUSSION

When considering the pull down times the Liebherr unit was fastest with all compartments reaching their average temperature within 83 minutes. With the Lec unit this figure is 90 minutes, (compartments only), 107 minutes if the door compartments are included. The Biocold model required 6 hours and 8 minutes to for its compartments to pull down to their average temperature, during this time its door sections all reached their average set point temperatures. When looking at compartment air temperatures only the Liebherr unit was the coldest at 2.0C, the Lec followed at 3.0C and the Biocold unit was significantly warmer at 5.5C. It must also be noted that the automatic defrost cycle was responsible for the highest temperatures observed in the Liebherr unit, including temperatures measured following the timed door openings (figure 5).

The recorded sample temperatures were coldest in the Lec unit, with the Liebherr sample being 1.1C warmer. The sample temperature in the Biocold unit was 4.1C.

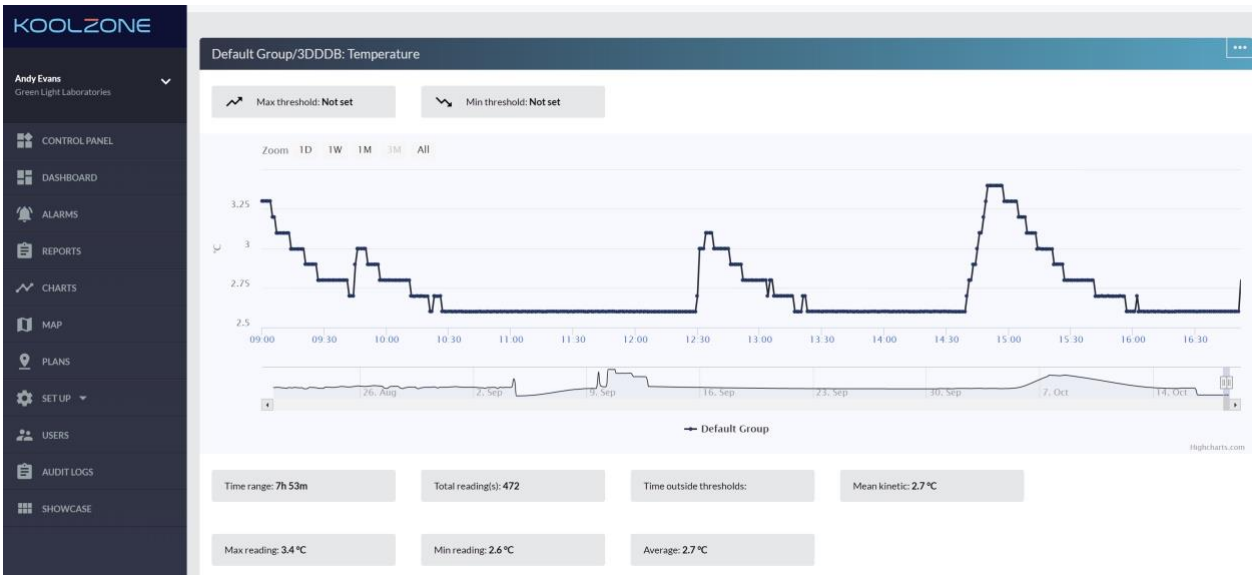


Figure 5. Liebherr door opening data from the sample probe. Door openings occurred at 9.41am and 12.26pm. The larger peaks in temperature are caused by the auto defrost function which occurs every 6 hours.

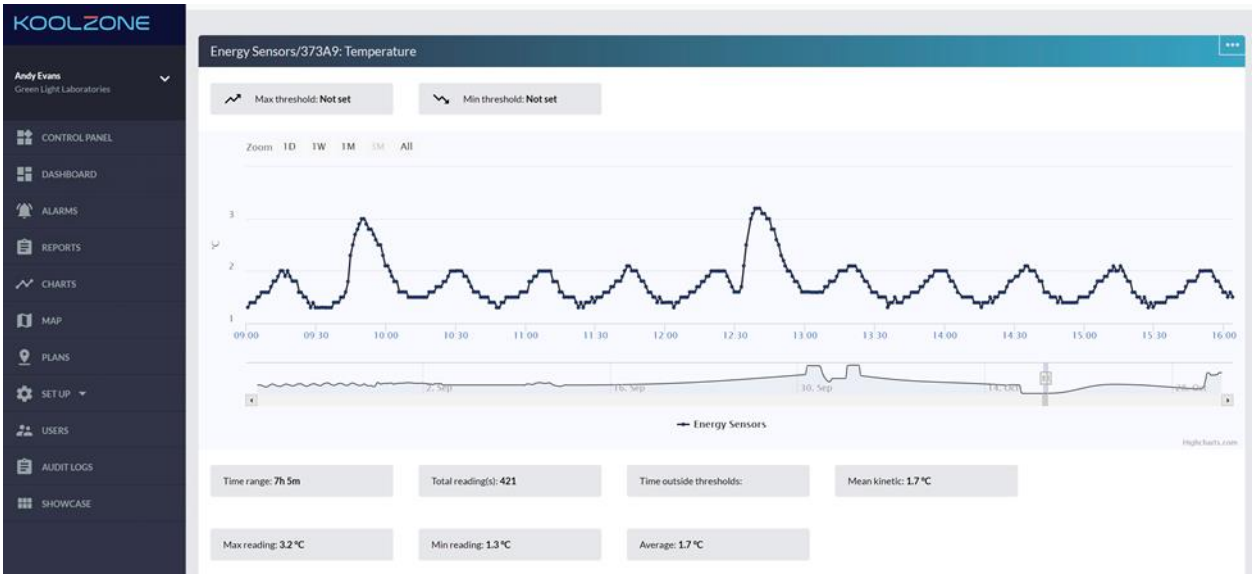


Figure 6. Lec door opening data from the sample probe. Door openings occurred at 9.39am and 12.28pm.

Door opening data indicated that when looking at the compartment air temperatures the Liebherr unit had the fastest recovery times. It was also noted that the recorded temperature rises were the smallest in the Liebherr unit (under 1C following a 60 second door opening). The Lec unit took approximately twice the time to recover its compartment temperatures compared to the Liebherr unit with the Biocold taking over 4 times longer to recover its compartment temperatures. Furthermore it must be noted that the Biocold was also recovering to warmer temperatures compared to those in the Lec and Liebherr models.

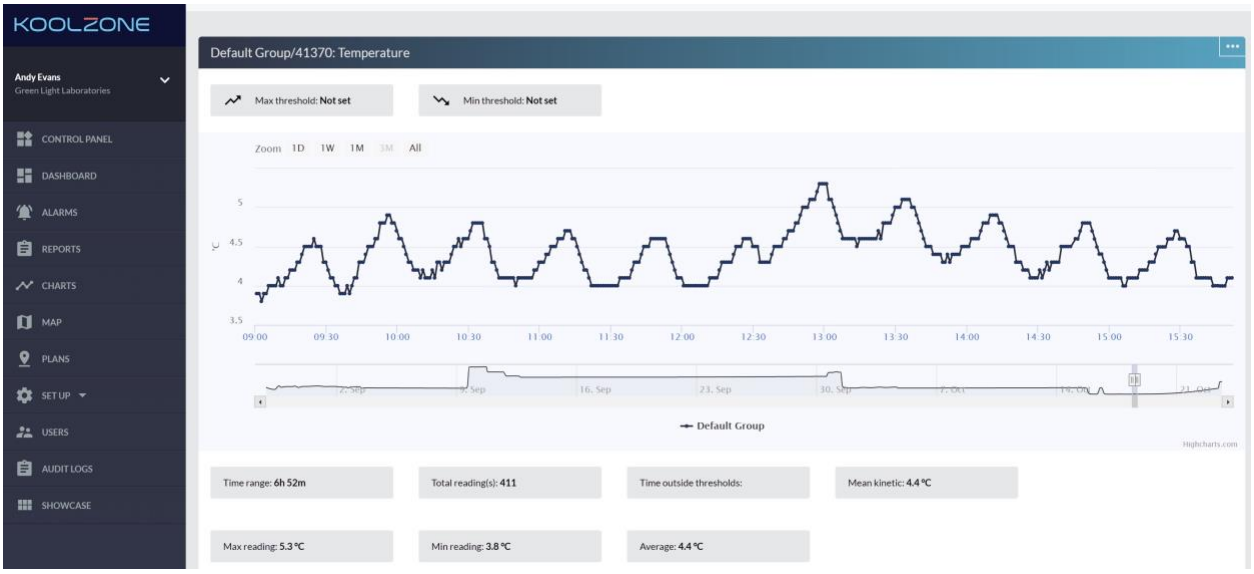


Figure 7. Biocold door opening data from the sample probe. Door openings occurred at 9.37am and 12.31pm.

The door opening data may also be linked to energy consumption. The Liebherr unit, with an energy consumption of 1.009 kWh/day had the faster pull down times and door opening recovery times. The colder recorded air temperatures and use of a fan would require greater energy consumption compared to units without a fan and with warmer temperatures. The Lec and Biocold units had similar energy consumptions, however, the standardized energy consumption (watts per litre per day) of the Lec unit was lower than the Biocold unit. Furthermore the Lec unit was cooling to colder temperatures than the Biocold unit.

The Biocold and Lec units both had door sections used for sample storage. In the Biocold unit the air temperatures in these sections were warmer than 10C following the timed door openings which may not be a suitable environment for some samples or contents.

This case study was designed around the performance of these models. By this it is meant that their recovery from a door opening was waited for instead of seeing the effects of multiple door openings upon the contents of these units. Therefore, this study may be expanded and developed to include sample probes in all fridge compartments and sections with each unit subjected to a variety of door openings of known durations and frequencies so that the data may more closely reflect the demands placed upon these units by laboratory users. In turn, this would help end users to select the most appropriate fridge based upon their specific requirements.

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