ULT Freezer Inventory Study

Impacts of loading, racking and inventory upon energy usage and temperature performance

Part of ULT freezer best practice is the use of racking (aluminium or stainless steel) in combination with an inventory, also referred to as a 'freezer map' (see diagram 1). By employing these actions, end users can minimise door opening times — reducing both the energy consumption and temperature rises associated with retrieving and placing contents within the freezer.

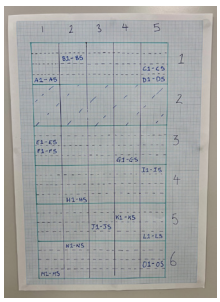
A recent study [1] by independent laboratory sustainability specialist, Green Light Laboratories, demonstrates the positive impact of these best practices in typical laboratory conditions.[2] This case study investigated the use of aluminium freezer racking and basic inventory solutions, and their effects upon temperature performance and energy consumption.

The full case study is available on request, but we have summarised the key findings for you.

Aluminium racking

Stirling Ultracold SU780XLE

Diagram 1: Freezer map



Here's what we've learnt...

The use of aluminium freezer racking:

1. **Increases freezer warm up times to -50 °C by at least 20%**
2. **Reduces energy consumption by up to 18% for timed door openings**
3. **Improves temperature stability on door opening**

Using basic inventory management in a racked freezer:

1. **Shortens door opening times, saving up to 67% in time**
2. **Reduces door opening energy usage, saving up to 70%**

Combining racking with a basic inventory:

1. **Reduces door opening times by 33% compared with an unracked freezer**
2. **Lowers energy consumption of door openings by more than 50% compared with an unracked freezer**

Independent Case Study

Please contact us at enquiriesuk@calibrescientific.com, if you would like more information on this case study or wish to discuss your cold storage requirements.

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Independent study data supplied by Green Light Laboratories Limited.

GREEN LIGHT LABORATORIES LIMITED

The impact of racking on energy consumption and performance

Testing conditions

A Stirling Ultracold SU780XLE 780 Litre ULT freezer was filled (to 79% capacity) with 475 cryoboxes and water (in lieu of samples). A multi-probe wireless monitoring system was used to measure temperature data. The racked freezer was installed with aluminium racking.[3]

Performance data: Energy usage

Installing aluminium freezer racking had a negligible effect on energy usage of a 79% full freezer. The racked unit consumed 0.06 W/L/day (0.052 kWh/day) more than the unracked freezer. This equates to <1% increase in energy consumption.

Aluminium racking

Figure 1)

Energy performance data of the SU780XLE at -80 °C setpoint in two different loading configurations.
Units were 79% full.

Energy usage (-80 °C)	kWh/day	W/L/day
Unracked	7.602	9.75
Racked	7.654	9.81

Data supplied by Green Light Laboratories

Benefit 1: Increased freezer warm up times to -50 °C

The effect of racking on freezer warm up times:

Although the warm up times varied between freezer compartments, the use of racking had an ameliorative effect on freezer warm up times. In fact, racking provided at least **20%** more time before the -50 °C threshold was reached following the units being turned off. The warm up times to -50 °C were increased by between almost **5** hours and **7.63 hours**, depending on the compartment.

Figure 2)

Warm up times of the SU780XLE to -50 °C with and without racking from the -80 °C setpoint.
Each compartment was measured; the lowest and highest warm up times are included below.

Warm up time to -50 °C (-80 °C)	Minutes, lowest	Minutes, highest
Unracked	987	1871
Racked	1350	2247

Data supplied by Green Light Laboratories.

Insight

The increased warm up time would provide users with valuable extra time during a power outage to relocate the unit to a different freezer room or transfer samples to a backup freezer.

Benefit 2: Reduced energy consumption for timed door openings

The effect of racking on door opening energy usage:

The freezer with racking installed consumed less energy than the unracked unit. With aluminium racking in place, the SU780XLE used **18%** less energy with a single 60-second and a single 90-second door opening.

Figure 3)

Energy performance data on door opening of the SU780XLE at the -80 °C setpoint in two different loading configurations. Timed door openings of 60 seconds and 90 seconds were carried out with the energy consumed measured.
The table below shows the combined energy used for a single 60-second and a single 90-second door opening.

Door opening energy (-80 °C)	kWh
Unracked	1.289
Racked	1.057

Data supplied by Green Light Laboratories

Insight

Even for a modern energy efficient freezer such as the SU780XLE, this reduction would assist busy laboratories in their efforts to conserve energy usage throughout the lifetime of the freezer.

Benefit 3: Improved temperature stability after door openings

The effect of racking on temperature stability after door opening:

Racking had a positive impact on temperature stability within the freezer upon door opening.
The temperature increase was lower with racking in place in almost every probe location.

It should be noted, that even without racking in place, the Stirling Ultracold unit demonstrated good temperature stability and recovery — in many probe locations, temperature recovery took less than a minute.

Figure 4)

Temperature performance data of the SU780XLE at the -80 °C setpoint in two different loading configurations.
Data below is for a single 60s door opening.

Temperature increase with a 60s door opening	Highest temperature increase measured	Lowest temperature increase measured
Unracked	3.3 °C	0.1 °C
Racked	1.9 °C	0.0 °C

Data supplied by Green Light Laboratories

Insight

In all probe positions, in both the racked and unracked freezer, the temperature remained safely below -70 °C at all times, after single 60s and 90s door openings.

Something to consider when loading more temperature sensitive samples in a racked freezer: In this particular study, temperature recovery after door opening was slower in the top compartment. This is likely due to warmer air getting 'trapped' towards the top of the freezer.

The impact of inventory management on energy consumption

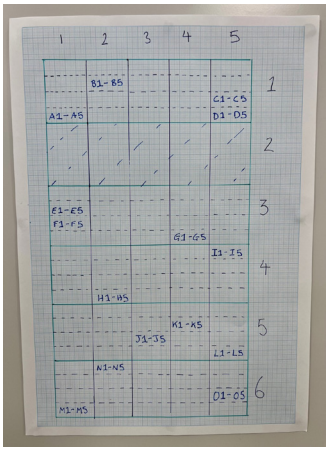
Testing conditions

A Stirling Ultracold SU780XLE 780 Litre ULT freezer was filled, as detailed above. End users from the Learning and Research Centre, University of Bristol were tasked with retrieving and returning named cryoboxes and later specific items.[4] Three access activities were undertaken with the access times measured.

Three scenarios were investigated:

1. Unracked freezer, organised (with a freezer map)
2. Racked freezer, organised (with a freezer map)
3. Racked freezer, unorganised (no freezer map)

Diagram 1: Freezer map



Benefit 1: Shortened door opening times

The effect of inventory management on energy usage and time:

The use of basic inventory management (freezer map) had a clear positive effect on both the time taken to locate/relocate samples, and therefore on the energy used.

Racked freezer, organised versus unorganised:

Energy used: **70%** less energy used in racked, organised unit.
Time saved: **67%** less time used to locate/relocate samples in racked, organised unit.

When the ULT freezer was racked but had no inventory to guide end users, the total door opening time increased by **307%**, consuming an extra **2.214 kWh**.

Figure 5)

Organised and unorganised access data from the SU780XLE at the -80 °C setpoint.
Total time taken for all access activities.

Door opening, energy and time	Energy used, kWh	Time taken, seconds
Racked, organised	0.951	262
Racked, unorganised	3.165	805

Data supplied by Green Light Laboratories

Insight

The energy saved from just 3-4 days of organised door openings of a racked SU780XLE would save enough energy to operate it for 24 hours.[5]

Benefit 2: Lowered energy consumption of door openings

The effect of racking on energy usage and time:

When utilising a freezer map, the addition of racking had a positive effect on both the time taken to locate/relocate samples and energy consumption. Figure 6) shows that by using racking in addition to an inventory reduces energy usage by **>50%**.

Organised freezer, racked versus unracked:

Energy used: **56%** less energy used in racked, organised unit.
Time saved: **33%** less time used to locate/relocate samples in racked, organised unit.

When the freezer was organised but not racked, the total door opening time increased by **149%**, consuming an extra **1.188 kWh**.

It will be reassuring to end users that even with long periods of door openings, the racking ensured that the warmest temperature recorded was -63.4 °C, measured in the top compartment. **All other compartments remained below -70 °C**. These results indicate that within the Stirling Ultracold SU780XLE freezer, highly temperature sensitive samples would be better stored in compartments 2-6.

Figure 6)

Organised freezer, racked and unracked access data from the SU780XLE at the -80 °C setpoint.
Total time taken for all access activities.

Door opening, energy and time	Energy used, kWh	Time taken, seconds
Racked, organised	0.951	262
Unracked, organised	2.139	390

Data supplied by Green Light Laboratories

Insight

The energy saved by the addition of racking is enough to operate a lab grade 300 L fridge at 4 °C for over 24 hours and almost enough energy to power a ~400 L lab grade freezer at -20 °C for 24 hours.[6]

This case study is useful in highlighting the realistic length of freezer door openings for those using no inventory or a basic inventory. The quickest door opening time to retrieve two cryoboxes was: 40 seconds for an organised, racked freezer; 57 seconds for an organised unracked freezer; and 120 seconds for a racked but unorganised freezer. This provides a useful benchmark when end users are considering door opening recovery data supplied by freezer manufacturers and other organisations.

In Conclusion

Previous racking studies[7], also conducted by Green Light Laboratories, have demonstrated the positive impact of racking on ULT freezer temperature stability upon door opening and on warm up times to -50 °C. However, those studies also showed that installing racking increased the energy usage of door openings and the temperature recovery times.[8] These case studies investigated the effect of racking on the performance of an empty freezer. In contrast, this latest study with a 79% full freezer demonstrated that the energy usage on door opening is better for freezers that have racking installed compared to those that don't. This is in line with the concept that, once setpoint temperature is achieved, full freezers run more efficiently than empty ones.

This case study shows that being racked and organised is the most sustainable approach for both sample security and energy efficiency. Racking reduced door opening times during organised access: When compared with accessing the unracked contents, the total door opening time was reduced by **33%** from 390 seconds to 262 seconds. The energy consumption of these door openings was also **56%** lower, saving 1.118 kWh. Furthermore, it is probable that the positive impact of installing racking may be larger with continued access. It is likely that an organised, but unracked freezer will become increasingly untidy with repeated/frequent access. So, the benefits of racking on reducing door opening times would probably increase over time. In fact, Emma Foose **(Core Facility Technician, Deputy Radiation Protection Supervisor / Freezer Manager (L&R), Bristol Medical School)** stated:

"Many of our research groups use the 'unracked but organised' method for their freezers, usually by using a variety of plastic boxes. In theory this works fine, but taking part in the case study highlighted just how unorganised this method can be. Searching for a singular item can cause much disarray and longer door opening times. This is due to the need to reorganise, which is either done immediately, or more commonly is left for a later date. Usually this has a snowball effect causing increasing disorganisation, resulting in the requirement for a sorting session. These sorting sessions often keep the freezer open for long periods of time, at least 10 minutes if not 20-30 minutes. This puts extra strain on the freezer, causes ice build-up, often makes a mess on the floor, and most concerningly can degrade the samples in the freezer."

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1. Green Light Laboratories study: ULT FREEZER INVENTORY STUDY, 2024: Full Case Study available on request.

2. Location: Learning and Research Centre, University of Bristol.
The laboratory space used was air conditioned with an ambient temperature of 23°C (±1.5 °C).

3. 114 kg of aluminium racking (x30 racking units).

4. Full protocol available on request.

5. Energy used in 24 hours for a racked SU780XLE without any door openings.

6. https://www.medlinescientific.co.uk/sustainable-solutions/refrigeration/

7. Green Light Laboratories Study: ULT FREEZER RACKING STUDY (2018) and ULT FREEZER RACKING STUDY – PART II (2019).

8. In the empty unracked ULT freezer, door openings used 0.78 kWh of electricity. In the freezer with aluminium racking, these door openings used 1.27 kWh. For 60, 90, and 120 second door openings, the freezers with aluminium racking and stainless steel racking took twice as along to recover their temperature. Full data available on request.

Calibre Scientific UK
Unit 5A, R-Evolution @ The Advanced Manufacturing Park
Selden Way, Rotherham S60 5XA