DRAFT REPORT

ISP Recommendations: Ultra-Low Temperature Freezers

MA23C02-B-ISPREPOS

Date: September 19, 2023

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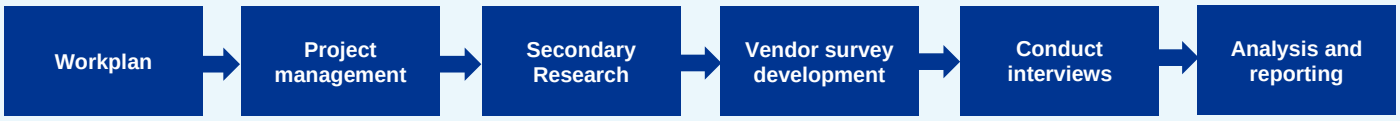
Executive Summary

This low rigor research study investigated the industry standard practice for the purchase of ultra-low temperature freezers.

The study team used a combination of secondary and primary research. Secondary research consisted of interviewing the ULT freezer midstream offering vendor and a review of available ULT freezer models. Primary research consisted of five interviews - three manufacturers, a distributor, and a repair/used equipment vendor.

Methodology and Approach



Results/Key Findings

Measure	2024 ISP
Ultra Low Temperature Freezer	0.55 kWh/day/ft³

Conclusions/Recommendations

The key findings from this study are that the ULT freezer industry has improved its energy performance significantly since the inception of the ENERGY STAR certification for this equipment and that ENERGY STAR plans to update its performance threshold for ULT freezers in 2024.

Recommendation 1: The study team recommends updating the current savings per freezer to account for the different freezer temperatures that are the basis for ISP and ENERGY STAR performance.

Recommendation 2: The study team recommends that Mass Save™ Sponsors update the minimum performance threshold for ULT freezer incentive qualification to follow the new ENERGY STAR threshold when it is finalized in 2024. When the threshold for qualification is updated, the ISP baseline performance is recommended to be updated to the current ENERGY STAR threshold of 0.55 kWh/day/ft^3.

1 INTRODUCTION

Industry standard practice (ISP) research is a method for identifying appropriate equipment baselines and is important for two reasons. First, for measures with an applicable code or equipment efficiency standard, it allows the program to identify whether above- or below-code practices are more appropriate than the code or standard. Second, for measures that do not have an applicable code, determining the industry standard practice is the only appropriate way to determine what common practices look like and how they may be translated into baselines and savings.

According to the C&I Baseline Framework, ISP research is limited by the following:

- It is only for measures that are not unique technology-customer applications. There must be a definable market about which common practice can be researched.
- A below-code ISP is only a relevant option for gross baseline evaluation if there is no PA program that seeks to increase code compliance for the relevant measure.

This report summarizes the low rigor ISP research study and results regarding ultra-low temperature freezers (ULTs).

This study was initialized by the program administrators based on the results of several recent custom electric evaluations. However, new ULTs are currently supported by the Mass Save™ Program Administrators as a prescriptive measure. Incentives are awarded on a prescriptive basis midstream as a discount on the purchase price, and each freezer's savings are calculated with a custom express tool that has the same inputs regardless of freezer model. As a result, all ES certified freezers incentivized claim the same kWh savings as all other incentivized ES freezers.

An ultra-low temperature freezer is defined by ENERGY STAR as a "freezer designed for laboratory application that is capable of maintaining set point storage temperatures between -70°C and -80°C." ULTs are used for the storage of samples for research in laboratory environments. The typical end users include universities, hospitals, government research facilities, and pharmaceutical research and manufacturing facilities. They have become more prevalent in recent years to store vaccines.

1.1 Study purpose, objectives, and research questions

DMI carried out the ULT Industry Standard Practice (ISP) Study (MA23C02-B-ISPREPOS) for the Massachusetts Program Administrators (PAs) and Energy Efficiency Advisory Council (EEAC) Consultants from May 2023 to September 2023. The study's overall purpose was to research and understand what industry standard practice is for new ULTs. The study objectives are as follows:

1. Document the PA practices for determining tracking savings for ULTs, including a review of the current Custom Express Tool and its calculation methods.
2. Determine the standard practice for purchase of ULTs.
3. Use the findings from this study to recommend updates to the ULT Custom Express Tool.

The study was designed to answer the following research questions:

1. Is the current Custom Express Tool representative of baseline freezer performance today?
2. What is the approximate market share of ENERGY STAR rated ULTs?
3. Do ENERGY STAR rated ULTs represent a large enough portion of the market to be considered a baseline freezer?
4. What is the industry standard practice performance of ULTs, expressed in kWh/day/ft^3?

1.2 Organization of report

The rest of the report is organized as follows:

- Section 2: Methodology
- Section 3: Survey results and analysis
- Section 4: Conclusions, recommendations, and considerations
- Appendix A: ULT survey instrument guide
- Appendix B: References

2 STUDY METHODOLOGY

This section outlines the methodology of the ULT ISP study.

2.1 Data collection approach

This study used secondary research in the forms of: product data reviews; product purchase availability checks for those freezers included in the original Custom Express Tool study; ENERGY STAR certification requirements; and, an interview with the mid-stream program vendor. Primary research was performed in the form of ULT industry interviews about the ULT market and freezer energy performance. No site work or metering was performed as a part of this study.

2.2 Secondary research

Current mid-stream incentive program

Incentives for ULTs are currently administrated as a prescriptive midstream offering of $2,000 per new ENERGY STAR ULT. The claimed savings on each ES freezer is 5,737 kWh. In 2022 996 freezers were supported under the Mass Save™ program for a total ULT energy savings of 5,714,052 kWh.

The midstream program started in June 2020. Prior to June 2020 new ULTs were supported as a custom measure. Eversource used a Custom Express Tool to calculate energy savings. The savings methodology used by the other Program Administrators prior to 2020 was not determined.

The midstream program operator, Energy Solutions, stated that they calculated energy savings for each ENERGY STAR listed freezer and then took the average to arrive at the deemed savings of 5,737 kWh/freezer. The savings per freezer are calculated using the formula below.

$$\boldsymbol{S}aved\ kWh = 365\ \text{days/year} * Freezer\ Volume, ft^3 * \left(\frac{kWh/_{day}}{ft^3}_{baseline} - \frac{kWh/_{day}}{ft^3}_{installed}\right)$$

Baseline freezer performance – Calculated based on equation discussed below

Installed freezer performance – kWh/day/ft³ rating listed by ENERGY STAR

Freezer volume – Proposed freezer volume. baseline and proposed freezers are assumed to be the same volume.

Interactive effects on HVAC loads are not considered in the deemed savings values.

The savings calculations performed by the midstream vendor to determine the savings per freezer were not obtained. The current ENERGY STAR freezer list is different than that used in 2020 to establish the energy savings. DMI estimated the baseline performance used in applications today based on the current ENERGY STAR freezer list (as of 9/1/23) as described below:

- Simple average volume of ENERGY STAR freezers (excluding the one outlier 229 ft³ unit) is 24.94 ft³.
- 5,737 kWh / 365 days/year / 24.9 ft³ equals an average performance improvement of 0.63 kWh/day/ ft³.
- Average performance of all ENERGY STAR freezers is 0.409 kWh/day/ ft³.
- Average baseline performance is estimated as 1.04 kWh/day/ ft³ based on the assumptions described.

Current baseline performance

In 2017, DMI performed a metering study of several installed ULTs in order to identify baseline freezer performance.

The original metering study measured freezers manufactured between 2000 and 2014. A list of those freezers has been provided in Appendix B. None of these freezers are ENERGY STAR certified; the EPA did not begin certifying ULTs until 2017. All freezers in this study operate at -80°C. Please note that none of these freezer models are currently available for purchase new any longer. At the time of the study, only 2 of the 14 studied freezers could still be purchased new. However, there is a secondary market with used equipment vendors that have comparable models to those in the metering study. It is challenging to estimate the size of this market. However, based on interviews with industry professionals, the used market is not nearly as strong as the new market. Those who seek used models are typically extremely price sensitive, and do not have the budget to consider any new freezers at all. These used models are purchased as-is, and come with few assurances as to reliability and performance. Market segments like pharmaceutical and the fast-growing biotechnology segment do not seem to participate in the secondary market at all.

The metering study concluded that a baseline freezer performance can be defined by the following equation:

$$\frac{kWh/_{day}}{ft^3} = 2.84 - 0.08 * (Freezer\ Volume, ft^3) + 0.45 * (Freq.of\ Access)$$

Where frequency of access is 2 for frequent access (door is opened on average more than 10 times per day), 1 for moderate access (1 to 10 times per day) and 0 for infrequent access (less than once per day).

It should be noted that the current mid-stream savings calculation did not use the above regression in its final form to calculate prescriptive savings, but uses a similar regression found in a draft version of the original metering study. The draft version used the average number of door openings/day and not the frequency of access level that the final regression uses. The openings/day regression produces very similar average savings to the vendor claimed savings when calculated and averaged for every ENERGY STAR certified freezer. This indicates that the simple average ENERGY STAR freezer volume is a good approximation for the volume that the vendor used when calculating their expected average program unit savings.

TRM

The 2022-2024 MA TRM includes a measure titled “Refrigeration – Lab-Grade Cold Storage”. One of the categories within this measure is ULTs. The baseline for this measure is defined as 40% more energy usage than ENERGY STAR minimum performance, which would be 0.77 kWh/day/ft³. The source of this 40% value is listed as “Cold Storage Forecast Assumptions Word Document", but this document is unknown to the study team. The TRM states that eligibility for savings and incentive begins at 0.55 kWh/day/ft³, equal to the ENERGY STAR minimum performance requirement. Midstream savings values and incentives are not, however, calculated with the TRM methodology. Savings are calculated according to the method described in the above section.

ENERGY STAR Certification

The EPA began its ENERGY STAR certification program for ULTs in 2017. In order to be ENERGY STAR certified, a freezer needs to demonstrate a performance of 0.55 kWh/day/ft³ at -75°C

Between 2017 and September 2023, a total of 106 ULT models have been certified across 15 manufacturers. Figure 2-1 shows that the average performance of ENERGY STAR certified freezers has remained steady since the certification began in 2017.

Figure 2-1. ENERGY STAR ULT performance

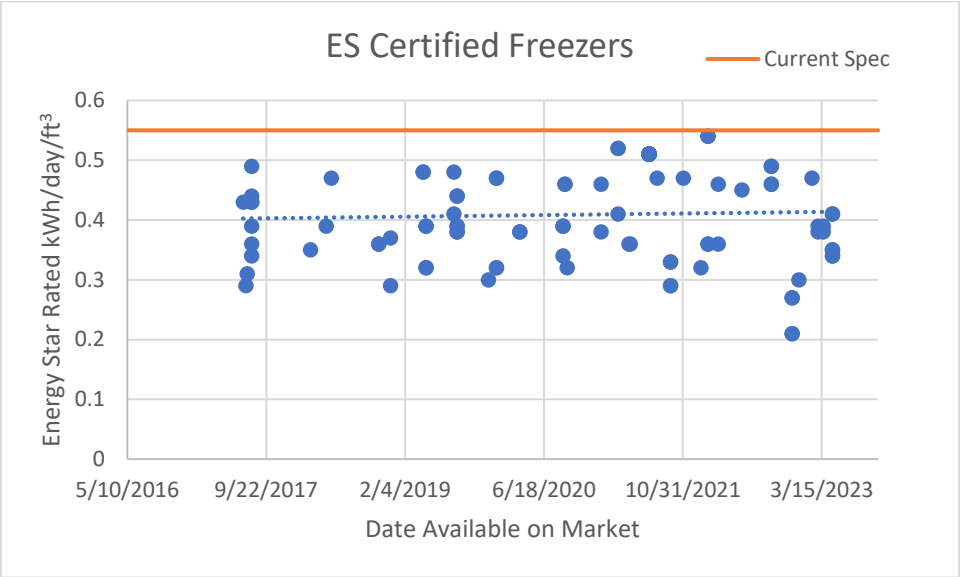
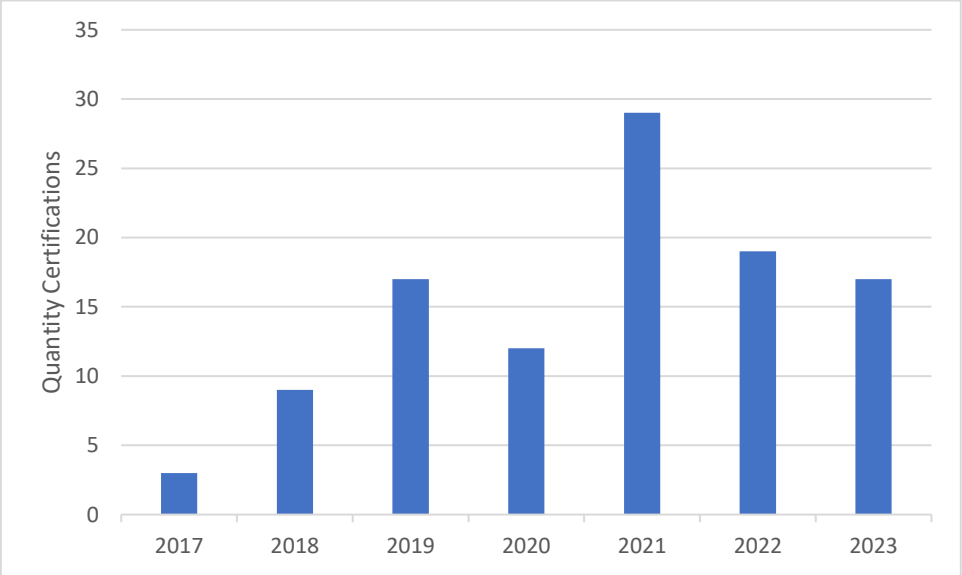


Figure 2-2 below highlights the frequency with which new models of ULTs have achieved ENERGY STAR certification. 2023 data is through August 2023.

Figure 2-2. ENERGY STAR ULT certifications



Programs outside MA

There are other ULT incentive programs outside MA. Program administrators such as Con-Edison in New York, Rhode Island Energy, and Pacific Gas and Electric all offer incentives for ENERGY STAR certified ULTs. Many universities, such as UC San Francisco, University of Pennsylvania, and North Carolina State University, also offer internal rebates to researchers who choose ENERGY STAR freezers. These lists of program administrators and universities is not intended to be exhaustive. The threshold for an incentive is ENERGY STAR certification for all of these programs, except for the University of Pennsylvania. The University of Pennsylvania also requires a rated performance better than 0.50 kWh/day/ft³ in addition to the certification itself, and will provide a greater incentive for performance that exceeds 0.35 kWh/day/ft³.

2.3 Vendor Survey

DMI targeted ULT manufacturers, vendors, and repair services with the purpose of investigating which freezer models are being installed in MA (types and percentages), how end users are making decisions on which freezers to purchase, and available freezer performance data.

DMI interviewed five contacts as part of this task. Contacts were found through previous impact evaluations of ULTs, and were provided to DMI by the midstream rebate manager.

The full survey tool is presented in Appendix A.

3 RESULTS AND ANALYSIS

This section presents the analysis and results of the study.

3.1 ULT survey results

Five surveys were conducted with professionals in the Massachusetts ULT industry. These professionals include:

- A national manufacturer of both ES and non-ES rated ULTs (Contact 1). This manufacturer accounts for 38% of all incentivized ULTs in 2023 to date.
- A national manufacturer of strictly ES rated ULTs (Contact 2). This manufacturer accounts for 17% of all incentivized ULTs in 2023 to date.
- A ULT repair business that also sells used ULTs. This business operates throughout New England, but focuses on MA. (Contact 3)
- A distributor of ULTs, including distribution of multiple manufacturers' products (Contact 4)
- A manufacturer/distributor of ULTs, both ES and not ES rated (Contact 5). This manufacturer accounts for 45% of all incentivized ULTs to date.

These professionals represent 100% of incentivized ULTs in MA year to date.

Manufacturers of strictly non-rated freezers (non-participants) were reached out to for participation in this study, but these contacts were not responsive. As a result, no strictly non-rated manufacturers' input could be included in this study. The contacts who did participate in the survey indicated that these non-rated-only manufacturers make up only a small very fraction of the total ULT market.

3.2 Analysis of survey results

Market Overview

The general consensus of the surveyed industry professionals is that ULT energy performance has improved in the past 10 years, particularly at the bottom end. More and more newly designed freezers on the market are achieving ENERGY STAR certification. Manufacturers with multiple tiers of product performance are retiring their second-tier product lines that do not have ES certification and are focusing solely on new products or existing top-of the line products.

The manufacturer of the very first ENERGY STAR certified freezer in 2017 (0.29 kWh/day/ft^3) claimed an energy savings of 75% compared to the industry average at the time (1.16 kWh/day/ft^3). This manufacturer (Contact 2) also believed that the ENERGY STAR threshold performance was set to 1/2 of the industry average at the time. However, the manufacturer did not remember the source of this value so that it could be validated. There are now many ES products that can achieve a similar level of performance; a total of 29 ES certified freezer products have a rated performance of 0.35 kWh/day/ft^3 or better.

Sales volumes

Different manufacturers reported different sales of ES freezers compared to non-rated freezers.

- A manufacturer of only-ES rated units sells only ES-rated units, and does not believe many non-rated freezers at all are being sold in MA (Contact 2).

- A different manufacturer that sells both rated and non-rated ULTs did not have MA specific data, but estimated that nationally, 65% of all sales are ENERGY STAR certified (Contact 1).
- A distributor stated that a "really high percentage of their sales are ES-rated freezers." (Contact 4)
- A manufacturer that sells both rated and non-rated ULTs estimated that 85% of their sales nationally are ENERGY STAR certified ULTs. They did not have an estimate of sales in Massachusetts. (Contact 5)

The interviewees reported that almost every ENERGY STAR freezer sold in MA has received an incentive. The exceptions are freezers sold in towns that do not have a PA that participates in Mass Save™ (Contacts 2, 4). These units are still generally Energy Star rated. Also, Contact 4 stated that on a sale of 4 freezers, no incentive was processed on the eligible purchase simply because it was not worth the customer's time to do paperwork. This particular sale was only memorable because it was the exception to the rule that every eligible ULT sold is incentivized.

Customer requirements

Customers are generally concerned with the following when considering different options for a new ULT:

- Upfront cost – Many researchers received funding through grants; therefore, they need to be budget conscious in order to fund all expenses associated with the laboratory space.
- Noise
- Space efficiency (cabinet volume per unit floor space)
- Energy efficiency. Even though researchers are not the ones who directly pay the utility bills, they have an interest in being environmentally friendly when possible. Often, facilities departments are involved in new freezer purchases, and push for more efficient options to lower utility usage.
- Cabinet temperature uniformity (throughout the volume of the freezer and through time)
- Reliability- the ability of the freezer to not break and ruin samples by allowing them to warm. The distributor has seen freezers that are approaching 30 years old in the field. He thinks some customers are wary of the impact new technology may have on equipment life.

The two most important factors that a customer considers are temperature uniformity and energy efficiency other than upfront cost. Different tiers of ULTs have typically come with groups of features; the more expensive top tier freezers of a manufacturer all typically have better energy performance, temperature uniformity, and lower noise. Lower tier freezers typically have worse energy performance, worse temperature controls and are louder.

Cost differences between rated and non-rated ULTs

According to the interviews with industry professionals (Contacts 1, 4), the purchase cost difference between tiers is typically not driven by energy performance, but rather by temperature uniformity. The exception to this is for freezers with a Stirling engine. Freezers with this design were introduced into the market in 2017 and cost significantly more than ULTs with a standard ULT refrigeration design (Contact 2). Since then, however, standard designs have been improved and are now more comparable in performance to the Stirling engine, at a lower price. There is no incremental increase in capital cost to increase strictly the energy efficiency of a ULT (Contact 1). However, ENERGY STAR rated freezers are more expensive than non-rated versions because of additional features that customers value greatly, particularly cabinet temperature uniformity. It is difficult to find a new freezer for purchase that provides high energy performance but has other features such

as cabinet temperature uniformity at a “standard” level. As a result, it is not likely possible for Mass Save to incentivize high energy performance without also subsidizing the other features of a top-end freezer.

Customers have also begun to expect to receive a rebate on their purchase (Contact 4). Sales teams will not frequently consider providing a quote that does not have a rebate built-in from the midstream program.

Old model retirement

A large manufacturer of both ES rated and non-rated freezers is beginning to retire its second-tier freezers (contact 1). Because all of its second-tier freezers are not rated and all of its top tier freezers are certified, this manufacturer will begin to sell only ENERGY STAR-rated freezers. This appears to be consistent with secondary research performed—old freezers that could be found in 2017 when the metering study was performed can no longer be purchased new.

According to manufacturers, while it may have been common 10 years ago to find freezers with performance around 1.0 – 1.3 kWh/day/ft³, (as with the 2017 ULT metering study), it is becoming increasingly uncommon to find new freezers that use greater than 0.65 kwh/day/ft³ because the majority of new freezers being sold in MA today are ES certified (Contacts 1, 2). This is due in part to the retirement of older models and models of a second tier.

Future market

When designing new models of ULT, the two most important features that are targeted for improvement mirror the most important customer requirements: cabinet temperature uniformity and energy efficiency (Contact 1, Contact 2). However, good freezer design for cabinet temperature uniformity will also improve energy efficiency; heated door seals, new refrigerants, variable speed compressors, and the use of the Stirling engine have contributed to improvements in both temperature uniformity and energy efficiency across the market.

Manufacturers agree that they expect the ULT market to grow in the future, driven by the medical research market.

ENERGY STAR Certification

Every professional interviewed was asked whether there is any reason for a freezer that meets the requirements for ENERGY STAR certification to not actually get certified. Every interviewee was also confident the entire top end of the ULT market was represented within the ENERGY STAR database.

Contact 5, who is a member of the EPA’s stakeholder committee for ULTs, informed DMI of a new ENERGY STAR performance standard that is in the process of being finalized. The performance requirements will be finalized in Q4 of 2023 or Q1 of 2024, with an effective roll out date 9 months after the finalization of the specification. A draft specification is currently publicly available. The minimum required performance for ENERGY STAR certification in the draft specification is 0.35 kWh/day/ft³. The test procedure to determine freezer performance is not expected to change.

4 CONCLUSIONS, RECOMMENDATIONS, AND CONSIDERATIONS

4.1 Conclusions

Improvements in freezer technology in the last 10 years have closed the gap between the bottom end ULTs and the top end ULTs. Most ULT sales in MA are ENERGY STAR certified. Customers have come to expect to receive a midstream rebate on their new purchases. New ULT models are at least primarily ENERGY STAR certified, and existing non-rated models are being retired from the market. ENERGY STAR rated freezers appear to be in the final stages of being adopted as industry standard practice for new ULT purchases.

4.2 Recommendations

1. The study team recommends adjusting savings calculations for ULTs immediately to accurately reflect operating conditions. The current baseline ULT performance is based on data for freezers operating at -80°C (see Section 2.2 – Current baseline performance). ENERGY STAR ratings are at freezer temperature of -75°C. The most common freezer operating temperature is -80°C (Elemental Machines); therefore, the ENERGY STAR ratings should be modified for use in savings calculations to reflect standard operating temperature and allow for a comparison to the baseline at the same temperatures.

   Research (see Gumpas and Simons in references) on the impact of freezer temperature on energy consumption found that for every 5°C of temperature decrease, the freezer used 16% more energy. Previous custom impact evaluations of ULTs have made adjustments for cabinet temperature setpoint. (See 2019-EVE-0031N, 2020-CLC-0080, 2021-EVE-0194N, 2019-EVE0061N, and 2019-EVE-0245N).

   Energy Solutions' current savings per unit, unadjusted for cabinet temperature, is 5,737 kWh.

   $$Savings_{current} = 5{,}737\ kWh$$

   The cabinet volume-weighted average rated performance of the ENERGY STAR database is 0.409 kWh/day/ft³, and the average savings per ft³ is 0.630 kWh/day/ft³.

   $$\frac{Savings_{current}}{ft^3} = \frac{5{,}737\ kWh/yr}{24.94\ ft^3} = \frac{0.630\ kWh}{day/ft^3}$$

   The baseline energy is the sum of the ENERGY STAR average rating and the savings; or 1.039 kWh/day/ft³.

   $$Performacne_{baseline} = 0.409\ \frac{kWh}{day/ft^3} + 0.630\ \frac{kWh}{day/ft^3} = 1.039\ \frac{kWh}{day/ft^3}$$

   A rated energy increase of 16% to adjust for cabinet temperature from the rating condition at -75°C to the most common operating temperature of -80°C brings the actual energy use to 0.474 kWh/day/ft³.

   $$Performance_{installed,actual} = 1.16 * 0.409\ \frac{kWh}{day/ft^3} = 0.474\ \frac{kWh}{day/ft^3}$$

   The actual realized savings are the difference between the baseline and the actual installed performance:

   $$Savings_{actual} = 24.94\ ft^3 * \left(1.039\ \frac{kWh}{\frac{day}{ft^3}} - 0.474\ \frac{kWh}{\frac{day}{ft^3}}\right) * 365\ days = 5{,}142\ kWh$$

   Increasing proposed unit energy by 16% would lead to a decrease in savings by 10.4%. The adjusted savings would be 5,142 kWh/freezer.

2. The study team recommends maintaining the current baseline performance of ULTs until ENERGY STAR finalizes and rolls out its new specification for ULTs. The study team then recommends that Mass Save™ update the baseline performance to the previous ENERGY STAR minimum performance of 0.55 kWh/day/ft³ when the new specification is finalized (likely 0.35 kWh/day/ft³), and to adopt the new specification as the minimum requirement for ULT incentive eligibility. The study team recommends the value of 0.55 kWh/day/ft³ because the EPA has determined that its current standard has penetrated the market sufficiently to no longer represent high performance practices. Interviews with industry professionals corroborate this statement.

   The study team recommends using the difference between the old ENERGY STAR performance and the new ENERGY STAR performance to serve as the basis for prescriptive savings calculations, with an appropriate adjustment for operating temperature:

$$kWh\ savings = 365 * V * (E_{baseline} - E_{rated}) * (1 - \left(\frac{0.16}{5°C}\right) * (T - -75°C))$$

   Where:

   - 365 days/year
   - V = rated cabinet volume, ft³
   - $E_{baseline}$ is the baseline performance after adoption of the new ENERGY STAR standard. This updated baseline is recommended to be 0.55 kWh/day/ft³ at -75°C.
   - E_{rated} = rated performance of proposed freezer ENERGY STAR at -75°C, kWh/day/ft³. It is expected that the energy use will be no greater than 0.35 kWh/day/ft³, consistent with the new ENERGY STAR performance rating.
   - T = operating temperature of the ULT, commonly -80°C (Elemental Machines)

The EPA currently plans to publish freezer performance at both -70°C and at -80°C. Currently, this information is recorded but not published. Under the specification V2, this information will be published for the public to view. The study team recommends that Mass Save™ revise the 16% factor once data for freezers at the V2 spec at different operating temperatures becomes available. This will ensure that a temperature correction factor is representative of the state of the industry as it is today and not at the time of the Gumpas and Simons study in 2013.

3. DMI recommends adding ULTs to the baseline repository for 2024 after the roll out of the new ENERGY STAR specification. A baseline performance of 0.55 kWh/day/ft³ should be used to reflect the new ISP. The EPA intends to finalize the Version 2 specification in Q4 of 2023 or Q1 of 2024 with a TBD effective date sometime in Q3 or Q4 2024, nine months following the finalization of the specification. This ensures that the ENERGY STAR label is consistent with qualifying performance, making it easier to tell at a glance whether a unit qualifies for savings or not.

4.3 Considerations

One interviewee suggested that incentives be given for consolidation and retirement of old equipment that has not reached the end of its useful life. For example, it is sometimes possible to consolidate samples from three old ULTs into two new ULTs. Under current program rules, the customer will only receive an incentive for purchasing two new freezers but additional savings are achieved by retiring a freezer. Program administrators should consider offering additional incentives for proof of retirement of old freezers in addition to incentivizing new, high-performance freezers.

The vendors and manufacturers interviewed provided positive reviews on the customers' ease of use of the mid-stream program. The vendors also believed that this program approach was simple and effective for them to participate in as well. The study team recommends the program administrators to continue to use a midstream, prescriptive approach to incentives for ULTs.

APPENDIX A. ULT SURVEY INSTRUMENT

Acronyms:
ULT – Ultra Low Temperature Freezer
ES – Energy Star

ULT Vendor Questions:

Background

1. Do you manufacture/sell ES rated freezers?
2. Do you manufacture/sell non-ES rated freezers?
3. Do you sell or distribute your products in MA?

Sales

4. What % of all your ULT sales are ES rated ULTs?
5. What % of your ULT sales in MA have received an incentive (through Mass Save or another program)?
6. Have the % of ES freezer sales shifted over the past few years?
7. How much more do ES certified freezers cost than non-certified freezers?

Customer Care

8. Do you have a particular type of customer that you work with (university, biotech, pharmacy, etc.)?
9. Does the type (ES rating, size, etc.) of freezer purchased vary by customer (university, biotech, etc.)?
10. Do you have any institutional customers that have specific requirements for their ULTs that impact their purchasing decisions? What are those requirements?
11. How do you help the customer determine what freezer is right for their needs?

Research and Development

12. Do you do energy performance tests for your non-ES rated freezers?
    a. Is the test procedure consistent with the ES rating test procedure?
    b. Do you keep those test results available for those that ask if they are not available on your website?
    c. If so, could you please provide that information?
13. Is there any reason why you would choose not to pursue Energy Star certification when the freezer could feasibly achieve certification?
14. Do you have any new ULT products coming out? Is there a focus on energy performance?
15. Are you phasing out any old products?
    a. What characteristics do any such products have in common?
16. Do you see the industry in general moving toward higher energy performance ULTs? Or is there another area that the industry is focusing on instead (reliability, IoT networking, etc.)?
17. Have there been any recent big developments in ULT freezer technology, particularly since 2021 when the COVID vaccine was first distributed?

APPENDIX B. 2017 STUDY FREEZER LIST

Table 4-1. Original ULT study metered freezers

Manufacturer	Model	Year	Rated performance, kWh/day/ft³	Metered performance, kWh/day/ft³	Frequency of Access, (level, value)
Forma Scientific	983	2000	NA	1.53	Unknown
Sanyo	MDF-U71V	2000	1.14	1.33	Infrequent, 0
Thermo Fisher Scientific REVCO	ULT1386-5-A40	2006	1.43	1.81	Infrequent, 0
Thermo Fisher Scientific	ULT1786-10-D43	2008	NA	2.91	Frequent, 2
Thermo Electron Corporation	ULT2186-10-A48	2007	1.00	1.20	Infrequent, 0
Thermo Fisher Scientific	ULT2586-10-A48	2010	0.93	1.01	Infrequent, 0
Thermo Fisher Scientific	ULT2586-10-A48	2010	0.93	0.87	Infrequent, 0
Kendro Laboratory Products	ULT2586-5-D37	2005	1.04	0.79	Infrequent, 0
Thermo Electron Corporation	ULT2586-6-D41	2007	0.86	1.20	Moderate, 1
Kendro Laboratory Products REVCO	ULT2586-9-D37	2004	0.86	0.72	Infrequent, 0
Kendro Laboratory Products REVCO	ULT2586-9-D38	2005	0.86	0.85	Moderate, 1
Thermo Fisher Scientific	ULT3286-10-A41	2008	0.71	0.69	Infrequent, 0
Thermo Fisher Scientific	UXF60086A	2014	1.00	0.89	Infrequent, 0
Thermo Fisher Scientific	UXF60086D	2014	1.00	0.87	Moderate, 1

APPENDIX C. REFERENCES

Hubbard, Jack. “Freezer Retirement Program: Out with the cold, in with the new,” Stanford Report [online], June 2, 2010.

US EPA. “ENERGY STAR Program Requirements for Laboratory Grade Refrigerators and Freezers,” https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20V1.1%20Lab%20Grade%20Refrigerator%20and%20Freezer%20Program%20Requirements_1.pdf

Gumpas, L. M., & Simons, G. (2013). Factors affecting the performance, energy consumption, and carbon footprint for ultra low temperature freezers: case study at the National Institutes of Health. *World Review of Science, Technology, and Sust. Development, 10*(1/2/3), 129-141.

Elemental Machines. "Guide to Cold Storage Monitoring," https://www.freezerchallenge.org/uploads/2/1/9/4/21945752/emeg009_cold_storage_monitoring_rev1[391076].pdf

US EPA. “ENERGY STAR Version 2.0 Lab Grade RF Draft 1 Specification,” https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%202.0%20Lab%20Grade%20RF%20Draft%201%20Specification.pdf

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