Large Ultra-Low Temperature Freezer Measure Offering

Final Report

ET23SWE0016

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Disclaimer

Executive Summary

The Large Ultra-Low Temperature Freezer Measure Offering project will update the existing eTRM Measure Package SWCR017. It will align the measure offering size categories with the new ENERGY STAR® Laboratory Grade Refrigerators and Freezers Specification V2.0 by removing the upper and lower limits of the existing 15-29 ft^3 size categories and modifying the HVAC interactivity methodology. This will align the measure with current market purchasing trends and help reach the state's energy efficiency goals by expanding the model offerings to energy efficiency programs. The project included capturing baseline energy consumption data, a market assessment, updating the eligible building types and incremental measure cost updates for the measure package.

Abbreviations and Acronyms

Acronym	Meaning
CA eTRM	California Technical Reference Manual
Cal TF	California Technical Reference Forum
CPUC	California Public Utilities Commission
DOE	Department of Energy
eTRM	Electronic Technical Resource Manual
Ft^3	Cubic Feet
GWP	Global Warming Potential
HVAC	Heating, Ventilation, and Air Conditioning
IOU	Investor-Owned Utility
kWh	Kilowatt-hour
MP	Measure Package
MPP	Measure Package Plan
PG&E	Pacific Gas & Electric
SCE	Southern California Edison
ULT	Ultra-Low Temperature Freezer

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Introduction

Ultra-Low Temperature (ULT) freezers are critical refrigeration equipment for laboratories, particularly in biotechnology, pharmaceutical, university, and healthcare research facilities, where they preserve valuable reagents and irreplaceable biological material. Once stocked with samples, they are rarely shut off, running 24 hours a day, 365 days a year, with compressor duty cycles of 70 percent or greater, making them large energy consumers. ULTs are designed for laboratory applications that maintain set point storage temperatures between −70 °C and −80 °C (−94 °F and −112 °F), with interior capacity ranging in size from three to 36 cubic feet (ft^3).

Background

The California Electronic Technical Reference Manual (CA eTRM) measure package SWCR017-04 Ultra-Low Temperature Freezer has included ULT freezers in two size categories: 15 to less than 24 ft^3 and 24 to 29 ft^3. These categories were based on market availability and energy efficiency benchmarks when the measure was developed in 2017. They did not include high efficiency units larger than r 29 ft^3, inadvertently excluding the energy savings these models can provide. While the COVID pandemic increased the visibility of ENERGY STAR certified ULTs as an energy-saving measure, an increasing population that needs healthcare, the ever-present research needs, and a growing biotech manufacturing and biobanking industries continue to expand the market. New technology, such as advanced compressors and hydrocarbon refrigerants has enabled large storage capacity models to be as energy efficient as their smaller counterparts, while better insulation and thoughtful design allow these larger units to occupy the same footprint as smaller size models, thus increasing demand for units with volumes larger than 29 ft^3.

The exclusion of units larger than 29 ft^3 prevents ULT freezer dealers from offering rebates for a full line of high efficiency ULT freezers and limits savings opportunities for the investor-owned utility (IOU) energy efficiency programs. As the adoption of large-size ULT freezers increases in the market, expanding the measure to include them will have a positive impact on the program. Energy Solutions has discussed the measure update with the IOU lead Pacific Gas & Electric (PG&E) who is supportive of the effort to remove the upper size limit.

Objectives

This project aims to update the measure offerings within the existing CA eTRM Measure Package (MP) SWCR017 Ultra-Low Temperature Freezer, to include ULT freezers larger than 29 ft^3. This addition would align the measure offerings more closely with current market practices and provide a more comprehensive set of baseline energy consumption data.

Over the course of this project, ENERGY STAR released draft updates and final criteria for the Lab Grade Refrigerators and Freezers Specification v2.0. The new standard created new size categories and efficiency standards for ULTs smaller than 20 ft^3 and larger than or equal to 20 ft^3, replacing the prior version, which had combined all sizes into one category.[1] In contrast, the CA eTRM Measure SWCR017 has the sizes broken into 15 to less than 24 ft^3 and 24 to 29 ft^3 offerings. The change in the ENERGY STAR standard caused the project team to reanalyze the measure update to assess aligning the size offerings with ENERGY STAR, which is preferred by the market, rather than adding a third size offering to the measure. The project team analyzed the available data to understand the number of data points in each size category and ability to calculate savings estimates for each grouping and determined there was sufficient data to proceed with the ENERGY STAR size offerings. The updated measure package will feature two size categories: smaller than 20 ft^3 and larger than or equal to 20 ft^3, which will achieve the original objective of adding units larger than 29 ft^3. Additionally, it will add units under 15 ft^3, which was not part of the original project scope. However, the new efficiency standards are difficult for small ULTs to achieve and there are no units smaller than 15 ft^3 on the ENERGY STAR qualified products list that will meet the v2.0 standards. So, the impact of adding smaller units is expected to be very small, but it will ensure the measure offerings provide opportunity for the full spectrum of model sizes in the market and align the MP with the ENERGY STAR program.

This project performed a monitoring analysis for large standard efficiency units to capture baseline energy consumption data that is not currently available. Additionally, the project provided necessary edits to the existing measure package, including updates to the incremental measure cost of the measure offerings, expanding eligible building types, and updates to the existing heating, ventilation, and air conditioning (HVAC) interactivity methodology.

Finally, the project developed an estimate of the market size for ULTs in CA to provide a better understanding of the savings opportunity in the IOU energy efficiency programs.

Methodology & Approach

The project team developed and submitted a CA eTRM Measure Package update to the California Technical Forum (Cal TF), based on the data and analysis conducted in this scope.

1. **Market Size Estimates of ULFT's Larger Than or Equal to 29 ft^3:** Energy Solutions has interviewed ULT equipment distributors to gather sales and cost data that will support the market characterization and incremental measure cost studies. The market size estimate focuses on assessing the demand and potential adoption of energy efficient ULTs larger than 29 ft^3 in California. This analysis considers the growing needs of key sectors such as biotechnology, pharmaceutical, healthcare, government, and academic research laboratories, all of which require reliable and energy-efficient cold storage solutions.
2. **Site Recruitment:** Energy Solutions leveraged both local and national relationships in the life sciences industry to help recruit monitoring sites and reached out directly to large-volume ULT Freezer equipment operators, such as facilities engineers, to request participation. The

[1] See ENERGY STAR Program Requirements, Product Specifications for Laboratory Grade Refrigerators and Freezers Eligibility Criteria, Final Draft, Version 2.0, released on August 29, 2024, effective date is June 30, 2025.

project team was unable to find units larger than 29 ft^3 to meter but were able to obtain performance data and field data on enough baseline units to provide a valid average consumption value for the energy savings calculation.

3. **Baseline equipment monitoring:** There are two energy monitoring options utilized in the study. The first utilizes a plug-load meter installed by temporarily unplugging the refrigeration unit and then plugging the unit in through the plug-load meter. The second utilizes individual energy loggers installed in the electrical panel that do not require unplugging units. This option was developed after feedback from the market showed that some customers will be hesitant to interrupt the power supply to their units. Specifically, the project team was informed by multiple potential monitoring partners that the initial metering method (i.e., momentarily shutting off power supply to attach meters) would be unacceptable, due to the sensitivity of high-value specimens to slight temperature changes and concerns that compressors on older equipment would not re-start. With both monitoring options, additional loggers will be installed in the facilities and equipment to capture temperatures and events such as door openings.

   In some cases, existing monitoring data exists or can be captured from the participant site's remote monitoring subscription service. These services utilize the same technology, which consists of Wi-Fi modules (motes), sensors, and software used by the third party contracted to do the baseline energy consumption monitoring on this project and capture the same data points. Participant-provided data that met the monitoring scope requirements was curated and included in the analysis. Monitoring data points include:

   - Power (amperage and voltage)
   - Ambient temperature
   - Door openings.

   Remote monitoring services have long been prevalent in the research industry, primarily for temperature tracking. As energy consumption becomes another common metric for monitoring, it is worthwhile to note the opportunities for future long-term studies that existing data can provide. Gathering existing data would circumvent the hurdles of onsite metering, and further research into ULT efficiencies and cost-savings potential is recommended.

4. **Energy Savings Analysis**: In light of the upcoming ENERGY STAR Laboratory Grade Refrigerators and Freezers Standard v2.0, the project team used a blended baseline to calculate energy performance. This methodology blends standard efficiency data collected for this project with performance test data from units that meet the current ENERGY STAR Laboratory Grade Refrigerators and Freezers Standard v1.1 qualifications, but do not meet the v2.0 standards. This presents a more accurate comparison for baseline ULTs. The savings analysis was used to provide deemed savings values for the measure package update.

5. **HVAC Interactivity Analysis:** The project team assessed the current heating, ventilation and air condition (HVAC) interactivity methodology, which accounts for the effects the ULTs have

on the site's HVAC needs and has provided updates in the savings analysis to enhance the measure package's accuracy and effectiveness.

6. **Incremental Measure Cost Analysis:** The project team has reviewed and updated the incremental measure cost for the updated ULT measure offerings to ensure accurate cost-effectiveness evaluations.

7. **Measure Package Plan Development and Submission for IOU consideration:** The project followed the Cal TF process for submitting and approving MPs. The Cal TF website provides details of each step of the process: http://www.caltf.org/submit-a-measure. An overview of the process is listed below:

    1. Submit measure package proposal – Energy Solutions
    2. Measure plan approval – Cal TF
    3. Complete draft measure packet – Energy Solutions
    4. Measure review – Cal TF
    5. Measure affirmation – Cal TF
    6. Submit measure for California Public Utilities Commission (CPUC)approval – PG&E

    Once the Cal TF approves the measure update, the eTRM MP will be assigned to Energy Solutions developers. Energy Solutions will update the packet with the necessary measure package data. When complete, Cal TF will review the measure packet for completeness and adherence to eTRM standards. Energy Solutions will resolve any requested edits. Once the review and affirmation is complete, PG&E, the lead IOU for this measure, will take assignment of the measure packet in the eTRM and submit it to the CPUC for the last step in the measure development process. Responses to comments, edit requests or questions from the CPUC review committee will be managed by PG&E. Once the MP is approved by the CPUC, the measure will be published and publicly accessible in the eTRM.

Results

Market Characterization

This section features overviews of the ULT industry including key market actors, supply chain, and market size as it relates to expanding the measure offering.

Market Actors and Supply Chain

The US ULT freezer supplier market is concentrated among several global manufacturers who sell ULT freezers and other laboratory equipment to end-use customers directly and through local and regional distributors. Table 1 provides a list of the major ULT freezer manufacturers and identifies the manufacturers with models larger than 29 ft^3.

Table 1: Major ULT Freezer Manufacturers

Manufacturers	Markets ULTs >29 ft^3
BINDER	No
Eppendorf	No
ESBE	No
FARRAR	Yes
Haier	Yes
Helmer Scientific	No
Liebherr	No
North Sciences	Yes
Nuaire	Yes
PHCbi	Yes
So-Low	No
Stirling Ultracold	No
Thermo Fisher Scientific	Yes
VWR	No

Source: ENERGY STAR qualified products list

Of the manufacturers listed above, Thermo Fisher Scientific, PHCbi, and Stirling Ultracold together constitute the majority of the market nationally and in California. The approximate market share, based on direct communications with the industry, is illustrated in Figure 1.

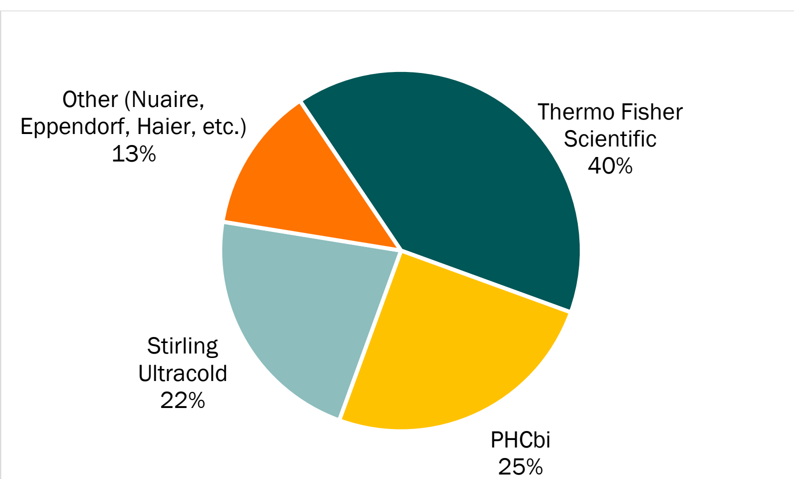

Figure 1: Market share of ULT manufacturers.

Source: Industry communications

There are two very large laboratory equipment and supplies distributors that sell ULT freezers to customers nationwide. Fisher Scientific, which is owned by Thermo Fisher Scientific, and VWR, which is owned by Avantor. In addition to VWR and Fisher Scientific, there are many medium-sized, independently owned distributors, such as Medline, Cardinal Health, Henry Schein, Thomas Scientific, and smaller local independently owned distributors, such as Lab Equipment Company, DAI Scientific, LabRepCo, and Discovery Scientific.

While ULT freezers are sold in standard sizes and configurations (e.g., upright and chest freezers) they are also customized at the factory to meet customer specifications (e.g., rack configuration, back-up systems, etc.) which requires them to be ordered, manufactured, and drop-shipped to the end-use customer. For this reason, ULT freezers are not stocked by distributors.

Sales Process

The sales process is generally the same whether a ULT freezer is replacing a failed unit or being added to a new or expanding laboratory. Distributors collaborate with end-use customers to determine the type, size, and quantity of ULT freezers needed. They then coordinate with manufacturers to develop a comprehensive quote, covering price, configuration, and delivery lead time. End-use customers may include individual researchers, lab building and facilities managers, and environment, health, and safety staff. Once the quote is reviewed and accepted, customers issue a purchase order to confirm the transaction. ULT freezers are either delivered directly to the customer or to a warehouse where distributors arrange the final delivery, with an average lead time of five weeks from purchase to delivery. ULT freezers are usually installed by customer staff in-house or by the distributor.

The target market for ULTs is primarily research universities, university hospitals, and large biopharma outfits. These institutions have centralized purchasing systems that operate as a new link in the supply chain – limiting choice to preferred vendors or contracted suppliers. Smaller ULT manufacturers and distributors have pushed into new markets in an effort to sell product around these purchasing system limitations. See the Building Types section below for an explanation and recommendation of additional building types that will help ensure that energy efficient equipment is being sold into all industries that utilize ULT freezers.

Refrigerants Overview

Refrigerants are an important consideration for laboratory cold storage equipment. After the phase out of chlorofluorocarbon (CFC) and hydrochlorofluorocarbons (HCFC) refrigerants[2], hydrofluorocarbons (HFCs) were the dominant refrigerant used in ULT freezers, lab freezers, and lab refrigerators.

In response to the American Innovation and Manufacturing Act of 2020, ULT manufacturers adopted natural and low-global warming potential (GWP) refrigerants in their product lines with GWP ratings well below the phase-in requirements issued by the EPA in 2023. These requirements specify refrigeration and cooling units with final effective dates depending on equipment type, such as

[2] See Phasedown of Hydrofluorocarbons: Management of Certain Hydrofluorocarbons and Substitutes Under the American Innovation and Manufacturing Act of 2020

industrial process cooling, standalone refrigeration for retail food, and cold warehouses.[3] While lab grade refrigeration is not specifically addressed in the regulations, EPA issued guidance to ULT manufacturers to select a “best fit” equipment category, meet the associated regulations by the specified effective date, and be prepared to defend their response.

Most ULT manufacturers currently employ HC (i.e., hydrocarbon) gas mixtures, typically ethane and propane, with very low GWP ratings. This technology has improved efficiency by up to 30 percent, compared with conventional CFC- or HFC-gassed freezers. Alternatively, ULT freezers may use the Stirling cycle in reverse (a Stirling cooler) for refrigeration. Table 2 provides a list of refrigerants commonly used in ENERGY STAR ULT freezers, lab freezers, and lab refrigerators.

Table 2 ENERGY STAR Refrigerant Listings – Sept 9, 2024

ULT Freezers	HP Lab Freezers	HP Lab Refrigerators
R-170 (ethane) (GWP:6)	R-290 (GWP:3)	R-290 (GWP:3)
R-290 (GWP:3)	R-600a (GWP:3)	R-600a (GWP:3)
R-404A (GWP:3920)	R-404A (GWP:3920	R-744 (CO2)
R-508B (GWP:13396)	--	R-513A (GWP:630)
R-1150 (GWP:4),	--	R-404A (GWP:3920)

Sales and Shipment Data

The project team estimates the CA market for ULT freezers was approximately $33 million in 2023[4]. A large and growing pharmaceutical research and manufacturing presence, and strong public and private funding for medical research drives the demand for laboratory equipment in the United States. The values in Table 3 provide the estimated numbers of units in the field and the annual sales estimates in CA. Units larger than 29 ft^3 make up about eight to 11 percent of the existing market but 12 percent of new annual sales, due to increased use of larger units. According to industry sources, the San Francisco and San Diego markets represent 60 to 70 percent of the California ULT freezer market.

[3] See for example, https://www.cityfm.us/blog/new-epa-refrigerant-regulations/#b

[4] U.S. Biomedical Refrigerators and Freezers Market Report, 2032 (gminsights.com)

Table 3: CA ULT Inventory and Annual Sales

ULTs	Fielded Market (Units)	Est 2024 Unit Sales
<20 ft^3	3,030	480
20-29 ft^3	11,300	1,770
>29 ft^3	1,900	300
All	16,230	2,550

Source: Industry communications

Quotes From the Field About Large ULT Freezers:

- "One biotech company I sell to has over 100 of them across three locations. They like the larger ULT freezers because they are used as a biorepository (for storage), and they have the space for them at their facilities. Also, it makes sense, since it is cheaper to buy a large ULT freezer than buying multiple smaller ones. Buying two small units would cost you $20k more." (Sales Rep)
- "People buy the large ULT freezers primarily when they are doing a cost per box analysis. Overall, the larger freezers are cheaper from that perspective, especially if they know they will fill them. Our large ULT freezer is on the ENERGY STAR list." (ULT Manufacturer)
- "I've sold a few units that are over 29 cubic feet. Probably three to five units a year. It can be tough to get them through lab doors sometimes. Some customers really like them." (Sales Rep)

Standard Efficiency ULT Freezers: During market research for this report, the project team identified a number of factors pushing back on the adoption of energy efficient ULT freezers.

- All of the manufacturers producing energy efficient models continue to offer standard efficiency ULT freezers because there is still a market for low-upfront cost equipment.
- The current CA ULT QPL has 16 brands represented. Of these, two brands have no real distribution in the United States so availability might be overestimated based on model or manufacturer counts.
- There are nine ULT manufacturers that do not offer energy efficient options in models ranging from 24 to 35 ft^3, competing for market share against the generally more expensive ENERGY STAR certified units. Two of the manufacturers are based in California.
- There is a higher number of distributors selling standard efficiency ULT's than expected; notably from industrial suppliers whose market also uses lab cold storage. Eight of the distributors are based in California, and another 17 are online retailers.

- Limited budgets drive labs to maintain old refrigeration units if they are still operational. Previous studies indicate that more than 25 percent of all ULTs in academic settings are 15 years old or older.[5]

Efficiency Incentives: There are three incentive options for ULT freezers in the California market, which the project team found created confusion among end users.

- The California Instant Rebates program, which is a statewide midstream program that provides rebates to end users at the point of purchase
- A downstream, business utility rebate offered by PG&E
- University-sponsored incentives found at several campuses across the state that offer tiered incentives to incentivize the campus laboratories to replace aging equipment.

Expanding Measure Offerings

Larger ULTs (29 to 35 ft^3), fill the same market need as freezers in the 20 to 29 cubic foot volume category, but they allow an end user the option to maximize their storage space with a single ULT due to improved insulation, like vacuum insulated panels replacing blown foam, allowing thinner walls while achieving a higher insulation value. This improves energy efficiency while maximizing the capacity, allowing manufacturers to create freezers that have a higher storage volume in a similar footprint.

In summary, the benefits to these larger models are:

- Reduced energy consumption per cubic foot of storage space
- Reduction in the total number of freezers needed

Building Types

The current eTRM includes four eligible building types for ULT Freezers are commonly installed:

1. Universities
2. Hospitals
3. Biotech Manufacturing
4. Pharmaceutical Manufacturing

These eligible building types do not effectively encompass usage from other industries. An analysis of nationwide ULT claims data from Energy Solutions identified additional building types that should be included to align with industry sales of ULT freezers. Approximately 7.5 percent of claims come from outside the existing eligible building types. Market interview feedback also suggested new building types that would allow for greater program utilization among participants from new

[5] Ultra-Low Temperature Freezers: Opening the Door to Energy Savings in Laboratories, https://www.etcc-ca.com/reports/ultra-low-temperature-freezers-opening-door-energy-savings-laboratories

industries. The project team recommends adding the building types listed in Table 4 to the eligible list.

Table 4 Recommended Additional Building Types

CPUC Building Type	Example Site
Other Agricultural	Ag product manufacturer; Dept of Fish & Wildlife, oceanographic research, Forest Service, analytical chemistry or environmental testing labs, vineyards & processing
Health/Medical - Clinics	Blood/plasma banks, fertility clinics, veterinary clinic, on-site medical in office buildings; prisons/jails, health departments, government research facilities
Education - Community College	Community college science teaching lab
Food Processing	Cultivated meat and seafood producers
Other Industrial	Cosmetics, filtration/separation, consumer care goods, medical materials, chemicals, petroleum, film, water treatment
Metal Production and Fabrication	Automotive, aerospace, wire/cable, coatings
Health/Medical - Nursing Home	Assisted living
Retail - Single-Story Large	Pharmacy/drug store
Warehouse - Refrigerated	Medical shipping & distribution

Baseline Equipment Monitoring

Energy Solutions leveraged local and national relationships with manufacturers and distributors in the life sciences industry to assist with the recruitment of sites to monitor ULT freezer energy consumption. The engagement helped to create interest in and support for the expanded size of the measure offering and laid the groundwork for some eventual data collection, but local distributors and manufacturer representatives ultimately did not have the motivation to assist with site recruitment.

The project team determined that a participation incentive would have been an advantage for site recruitment. Allies from all areas of the supply chain volunteered large amounts of time considering team requests, making introductions, going through data, and meeting with the project team. A stipend or other immediate incentive would have influenced ULT freezer distributors or monitoring service representatives to participate in locating sites for monitoring. Manufacturers were more amenable because they can model how a potential utility rebate program would aid sales of energy efficient ULT's in the future, however, an incentive would likely have resulted in faster turn-around times and increased interest. Direct outreach to potential monitoring sites was the most effective tactic, with many participants having the ability to easily provide energy usage data from their existing monitoring systems. They also saw value in having an outside engineering firm perform the metering that they did not have the internal bandwidth to perform.

Identifying and selecting equipment for monitoring faced several hurdles. Equipment nominated for metering was limited by its physical location at each site. Some units that fit project parameters were inaccessible because they are being used in clean rooms, restricted manufacturing labs, or high-level biosafety facilities. Additionally, the sensitivity and value of the materials housed in the ULTs created hurdles for monitoring the equipment. In some cases, internal temperature logging was not allowed because outside materials or equipment were not allowed inside the ULTs, which can house samples worth $500,000 or more. Facilities also were concerned with unplugging the power supply to their units due to the sensitivity of high-value specimens to slight temperature changes and concerns that compressors on older equipment would not re-start. Ultimately, units were selected that could be unplugged, but this issue highlighted the difficulty of metering lab grade refrigeration equipment.

One facility, conducting biopharma research in Southern California allowed the project team access to their buildings, where two ULT freezers were monitored. The units were monitored for fifteen days with data sampling taken every minute. Data captured includes:

- Energy consumption
- Ambient temperature
- Door openings

Due to the sensitivity of the material inside these units, internal temperature could not be captured with external equipment. Therefore, data from the site's temperature monitoring systems was aggregated with the other data points collected with loggers to provide a wholistic view of the units.

The following list summarizes potential participants Energy Solutions engaged that were unable to comply with the fast-track timeline for metering:

- A San Diego hospital system's medical lab.
- An Oakland-based integrated managed care consortium.
- A vertically integrated ULT manufacturer that offers lab cold storage monitoring service.
- A large biotech company with a sustainable science focus.

- A sustainability director from a multi-campus university system attempted to recruit participation from the campus research labs and various stakeholders but noted a lack of bandwidth to continue following up.
- Two international laboratory sustainability organizations agreed to assist our efforts by introducing the project team and socializing our request to their local California membership. It did not generate any interest, unfortunately.
- A biotechnology company strongly considered our request for information but could not get a monitoring agreement signed by their management within the project timeline.

Existing Monitoring System Data

The project team's knowledge of the research market's usage of remote monitoring systems prompted project team outreach requests to include both onsite equipment metering and sharing of data as an alternative to metering. Sharing data was a better alternative for potential participants that wanted to support the growth of energy efficient equipment but viewed unplugging their ULTs as a dealbreaker. Two campuses and a manufacturer generously shared existing data:

- A research campus from a statewide university system provided existing ULT energy usage data collected from a 34-unit study that justified replacing 300 inefficient ULT freezers with ENERGY STAR certified models. Data from 30 units between 13.4 and 29.3 ft^3 fit the project scope and was included in the analysis.
- A private research university provided an energy usage data set from a joint study of in-use standard efficiency ULT's that was conducted in cooperation with the City of Palo Alto Utility.
- A large lab equipment manufacturer that also provides metering and monitoring services shared a large dataset of ULT freezer energy consumption data from CA laboratory sites.

Energy Savings Analysis

ENERGY STAR Specification Update

Over the course of this project, ENERGY STAR released draft updates and final criteria for the Lab Grade Refrigerators and Freezers Specification v2.0. The final standard created new size categories and efficiency standards for ULTs less than 20 ft^3 and greater than or equal to20 ft^3 where the prior version qualified all sizes in one category. In contrast, the CA eTRM measure SWCR017 has the sizes broken into 15 to less than 24 ft^3 and 24 to 29 ft^3 offerings. The change in the ENERGY STAR standard caused the project team to reanalyze the measure update to assess aligning the size offerings with ENERGY STAR, which is preferred by the market. The project team analyzed the available data to understand the number of data points in each size category and ability to calculate savings estimates for each grouping and determined there was sufficient data to proceed with the ENERGY STAR size offerings.

Data Collection and Analysis

- The project team collected and consolidated data from six sources to provide sufficient data to calculate deemed savings values for the measure package. Data was collected from the ENERGY STAR data set used to develop the new standard, stakeholders monitoring studies noted in the A biotechnology company strongly considered our request for information but could not get a monitoring agreement signed by their management within the project timeline.

Existing Monitoring System Data section above, energy monitoring at sites noted in Baseline Equipment Monitoring, and unique model data from the ENERGY STAR QPL that was not duplicates of the new standard data set.

Energy Savings Methodology

The energy consumption of these data points was analyzed using the kWh/day/ft^3 metric used for the ENERGY STAR specification. Consumption data from the monitoring sites was adjusted using a regression analysis to estimate consumption at −75 °C when the units were operating at −80 °C. Units that were operated at −75 °C or −70 °C were not adjusted. Monitored units that qualify for ENERGY STAR v2.0 specifications were grouped under the measure case regardless of whether the metered consumption met the qualification. Equally, baseline models that met the qualification were still grouped as baseline units. The kWh/day/ft^3 consumption figures for all units in the dataset were then averaged for baseline and measure case in each size category. The difference between baseline and measure case is the calculated measure savings. Measure savings were extrapolated from this calculation by multiplying this value by the average volume for each size category and by the total number of assumed operational days. The average unit volume was calculated over all units in each size category.

- <20 ft^3 offering: 17.5 ft^3 average volume
- ≥20 ft^3 offering: 30.7 ft^3 average volume

Baseline Efficiency

The baseline efficiency is blended daily consumption per cubic foot of the site monitoring data and units that qualify for ENERGY STAR Lab Grade Refrigerators and Freezers Specification v1.1 but do not meet the measure efficiency requirements. Table 5 provides the average energy consumption calculated for the baseline units in the savings calculation.

Table 5 ULT Freezer Baseline Efficiency

Climate Zone	Baseline Energy Consumption (kWh/day/ft^3)
< 20 ft^3	0.81
≥ 20 ft^3	0.62

Measure Efficiency

The measure case efficiency is the average daily consumption per cubic foot of current ENERGY STAR qualifying products that meet the Lab Grade Refrigerators and Freezers Specification v2.0.

Table 6 provides the average energy consumption calculated for the measure case in the savings calculation.

Table 6 ULT Freezer Measure Efficiency

Climate Zone	Measure Energy Consumption (kWh/day/ft³)
< 20 ft³	0.36
≥ 20 ft³	0.30

Minimum Qualifying Efficiency

The minimum qualifying efficiency for this measure is defined by the minimum qualifying efficiency of the ENERGY STAR Lab Grade Refrigerators and Freezers Specification v2.0.

Table 7 ULT Freezer Minimum Qualifying Efficiency

Climate Zone	Maximum Daily Energy Consumption (kWh/day/ft³)
< 20 ft³	0.46
≥ 20 ft³	0.35

Savings Results

Table 8 and Table 9 provide annual savings estimates for ULT freezers using the ENERGY STAR Lab Grade Refrigerators and Freezers Specification v2.0 measure categories. Savings increased compared to the existing measure savings due to the changes in size categories, update to HVAC interactivity analysis, and baseline monitoring data.

Table 8 <20 Cu. Ft. ULT Freezer Annual Energy Savings per Unit

Climate Zone	Indirect Gas Savings (Therms)	Total Electrical Savings (kWh)	Total Demand Reduction per Freezer (kW)	Total MMBTU Savings per Freezer (MMBtu)
CZ01	-27.29	3,149	0.36	8.02
CZ02	-27.29	3,149	0.36	8.02
CZ03	-27.29	3,149	0.36	8.02
CZ04	-27.29	3,149	0.36	8.02
CZ05	-27.29	3,149	0.36	8.02
CZ06	-27.29	3,149	0.36	8.02
CZ07	-24.56	3,237	0.37	8.59
CZ08	-24.56	3,237	0.37	8.59
CZ09	-24.56	3,237	0.37	8.59
CZ10	-24.56	3,237	0.37	8.59
CZ11	-24.56	3,237	0.37	8.59
CZ12	-24.56	3,237	0.37	8.59
CZ13	-24.56	3,237	0.37	8.59
CZ14	-24.56	3,237	0.37	8.59
CZ15	-24.56	3,316	0.38	8.86

Climate Zone	Indirect Gas Savings (Therms)	Total Electrical Savings (kWh)	Total Demand Reduction per Freezer (kW)	Total MMBTU Savings per Freezer (MMBtu)
CZ16	-27.29	3,149	0.36	8.02
Avg	-25.75	3,203	0.37	8.35

Table 9 ≥20 Cu. Ft. ULT Freezer Annual Energy Savings per Unit

Climate Zone	Indirect Gas Savings (Therms)	Total Electrical Savings (kWh)	Total Demand Reduction per Freezer (kW)	Total MMBTU Savings per Freezer (MMBtu)
CZ01	-35.80	4,131	0.47	10.52
CZ02	-35.80	4,131	0.47	10.52
CZ03	-35.80	4,131	0.47	10.52
CZ04	-35.80	4,131	0.47	10.52
CZ05	-35.80	4,131	0.47	10.52
CZ06	-35.80	4,131	0.47	10.52
CZ07	-32.22	4,246	0.48	11.26
CZ08	-32.22	4,246	0.48	11.26
CZ09	-32.22	4,246	0.48	11.26
CZ10	-32.22	4,246	0.48	11.26

Climate Zone	Indirect Gas Savings (Therms)	Total Electrical Savings (kWh)	Total Demand Reduction per Freezer (kW)	Total MMBTU Savings per Freezer (MMBtu)
CZ11	-32.22	4,246	0.48	11.26
CZ12	-32.22	4,246	0.48	11.26
CZ13	-32.22	4,246	0.48	11.26
CZ14	-32.22	4,246	0.48	11.26
CZ15	-32.22	4,350	0.50	11.62
CZ16	-35.80	4,131	0.47	10.52
Avg	-33.79	4,202	0.48	10.96

HVAC Interactivity Analysis

The savings between standard and measure efficiency ULT freezers provide the primary (direct) energy savings for the high efficiency ULT freezers, but SWCR017 also includes secondary (indirect) HVAC interactive effects that estimate ULT freezer impacts on building HVAC systems. The calculation estimated the HVAC impacts of both electricity and gas usage due to reduced air conditioning use in summer and increased natural gas use in the heating season due to the loss of heat rejection from the more efficient units.

The HVAC interactive effects were revised using two sources. The first is the Ultra Low Temperature Freezers: Opening the Door to Energy Savings in Laboratories[6] report prepared by The Center for Energy Efficient Laboratories. The report used a combination of lab facility manager surveys, audits, and studies to create an energy model of a prototype lab for three California climate zones CZ03, CZ09, and CZ15. The model considered the ULT freezer location within the lab space and modeled the average interactive HVAC impacts for the three climate zones based on a model using standard efficiency or high efficiency ULT units. The model estimated HVAC interactivity effects in terms of

[6] https://www.etcc-ca.com/reports/ultra-low-temperature-freezers-opening-door-energy-savings-laboratories

secondary kWh or Therm savings per kWh of primary energy savings from using a higher efficiency unit. The model produced the following correlation:

- CZ03: 0.154 kWh/direct kWh and –0.01 therms/direct kWh
- CZ09: 0.186 kWh/direct kWh and –0.009 therms/direct kWh
- CZ15: 0.215 kWh/direct kWh and –0.009 therms/direct kWh

Using CZ03 as an example, the model estimates the HVAC system saving 0.154 kWh for every primary kWh of savings provided by the high efficiency ULT over a standard efficiency model. Additionally, the HVAC system must use an additional 0.01 therm for every kWh savings since the higher efficiency models will reject less heat thus requiring additional heating from the HVAC system.

The second source Energy Efficiency Comparison - California Energy Commission Staff Report[7] was used to assign the above interactive HVAC impacts to all California climate zones. The Comparison of Climate Designations provides a matchup between the Department of Energy (DOE) and California climate zones. By comparing the California climate zones which match to the same or similar DOE climate zone, the energy modeling results for CZ03 were also assigned to CZ01-CZ06 and CZ16, and the results for CZ09 were also assigned to CZ07-CZ14. Table 10 presents the alignment of California climate zones to similar DOE climate zones.

These ratios were then multiplied by the direct energy savings values for each size category to estimate the secondary HVAC effects per climate zone and added to the ULT measure case savings for a total savings value.

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[7] https://www.studocu.com/en-us/document/harvard-university/introduction-to-computer-science/ashrae-ca-climate-zone-map-california-energy-efficiency-comparison-commercial/12960548

Table 10 Comparison of Climate Designations

CA Climate Zone	DOE Climate Zone
1	4c
2	3c
3	3c
4	3c
5	3c
6	3c
7	3b
8	3b
9	3b
10	3b
11	3b
12	3b
13	3b
14	4b
15	2b
16	4b

Incremental Cost Study

ULT retail pricing data can be difficult to obtain due to the sales channel, which is primarily through distributors and limits publicly available pricing data for this equipment. Additionally, the pricing on an individual unit can vary greatly based on purchasing agreements and discount rates provided to distributors from the manufacturers, which isn't apparent through online dealers. Data was collected on ULTs in quarter three of 2024 via manufacturer outreach and retail pricing data from web scraping of laboratory equipment retailers. Additionally, data collected from Energy Solutions' existing ULT midstream programs on ENERGY STAR qualified models was used to provide real world pricing and to help understand discount factors to calculate retail prices from manufacturer list pricing, including baseline equipment. Costs were not normalized per cubic foot because there is not a strong correlation between size and unit price. The data was aggregated and grouped by size offering to calculate an average retail cost for baseline and measure case ULTs. The difference between measure case and baseline cost is the incremental measure cost.

Table 11 provides the incremental measure cost for ULT freezers.

Table 11 Ultra Low Temperature Freezer Incremental Measure Costs

Freezer Type	Size (ft^3)	Baseline Average Cost	Measure Average Cost	IMC
Ultra Low Temp Freezer	< 20	$12,929	$13,860	$931
	≥ 20	$14,607	$16,606	$1,999

Measure Package Development

The necessary components for a complete CA eTRM measure package have been submitted to Cal TF for approval and review. These include a measure characterization, a savings calculator with all necessary data inputs, incremental measure costs analysis and initial cost effectiveness tool files. The project team also sent a Measure Package Plan (MPP) to the PG&E engineering team for review and submittal to the CPUC.

Recommendations

- Adjust the existing MP to use the ULT size categories and efficiency qualifications defined in ENERGY STAR's Laboratory Grade Refrigerators and Freezers Specification v2.0.

MDEC Requirements (kWh/day/ft3) for ENERGY STAR Certified Ultra-Low Temperature Freezers @ -75 ºC	
0 < V < 20	**≤ 0.46**
20 ≤ V	**≤ 0.35**

- Capture increased energy savings and drive program participation in new industries by adding all feasible CPUC building types to the eligibility list.
- Update the HVAC interactivity method to use previous study results on ULT and HVAC interactivity effects.
- ULTs present a unique opportunity in that a large number of units are currently connected to monitoring systems that collect energy use, temperature, and other data points. The IOUs should leverage data from stakeholders' connected monitoring systems to conduct additional and long-term research on ULT energy use, expected useful life and deterioration of efficiency.
- The complexity and sensitivity of the life sciences stakeholders requires that project engagement with them provide long lead times to coordinate and work within the bandwidth of their facilities and research teams. At least nine months should be planned for

stakeholder outreach and engagement and another nine months for project implementation with stakeholders.

Appendix A: Supplemental Information

ENERGY STAR
Version 2.0 Laborator