

**C O M M E R C I A L R E F R I G E R A T I O N**

U L T R A - L O W T E M P E R A T U R E F R E E Z E R

SWCR017-02

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# MEASURE NAME

Ultra-Low Temperature Freezer

# STATEWIDE MEASURE ID

SWCR017-02

# TECHNOLOGY SUMMARY

Ultra-low temperature (ULT) freezers are primarily used in labs at universities, biotech companies, biopharmaceutical companies, hospitals, and medical testing centers to store samples at temperatures between -70 °C and -80 °C (-94 °F and -112 °F).

Traditionally, ULT freezers use a cascade system to achieve such low temperatures. The cascade system utilizes two individual compressor-refrigerant circuits in which one operates in a high stage and the other in a low stage. The low-stage circuit removes heat from the freezer cabinet and transfers the absorbed heat to the high stage via an interstage heat exchanger that acts as the condenser of the low-stage circuit and the evaporator of the high-stage circuit. The absorbed heat is then rejected to the room through the condenser coils of the high-stage circuit. The compressors cycle ON and OFF based on inputs from the temperature control sensor inside the freezer cabinet. The dual-compressor cascade system continues to be the most widely used technology for ULT freezers.

ULT freezers with temperature setpoints ranging from -56 oC to -86 oC were introduced into the marketplace in the 1970s. Over the past two decades, temperature setpoints of ULT freezers have fallen close to -80 oC with an average temperature of -77.5 oC. These freezers are commonly called “minus

eighties” and are used in a wide range of life science research laboratories to maintain the integrity of

samples and reagents for long periods of time.

The first major development in ULT freezer technology appeared in 2010, when Stirling Ultracold built its ULT freezers around a Stirling cooling engine instead of a dual-cascade compressor system.1 The Stirling freezer uses an electrically driven free-piston engine to provide cooling and a thermosiphon to transport heat from the freezer cabinet to the Stirling engine. The Stirling engine uses helium as the working medium fluid and is a beta configuration that contains a piston and a displacer in the same cylinder. The piston is driven at a fixed frequency by an integral permanent magnet linear motor. Cooling capacity is modulated by changing the piston amplitude based on inputs from the temperature control sensor inside the freezer cabinet. The Stirling engine cold head is connected to a thermosiphon, which is a sealed copper tube that wraps around the cabinet interior. The thermosiphon uses ethane (R-170) as the working medium. Liquid ethane flows via gravity down the length of the tube, where it absorbs heat from the interior of the freezer. As it warms, the ethane transitions from a liquid to a vapor and rises up the tube. At the cold head of the engine, the ethane is condensed back into a liquid.

In 2016, Thermo Fisher Scientific released a new ULT freezer technology – the V-drive, which allows the compressors and condenser fans to run at variable speeds in response to the varying cooling load. For example, the V-drive is likely to operate at ‘high speed’ when the freezer door is opened and at ‘low

1 Lane, Niell. 2013. “Ultra-Low Temperature Free-Piston Stirling Engine Freezers.” October 11.

speed’ at night when the freezer is unlikely to be actively used. The compressor construction is similar to standard compressors with the inverter drive (converting A/C input to simulated 3-phase variable frequency output) and the motor being the unique difference.

Besides Stirling freezers and the V-drive technology, other energy efficiency practices of ULT freezers include optimizing the fans, compressors, and condensers in combination with the adoption of natural hydrocarbon refrigerants, and applications of vacuum-insulated panels and high-performance polyurethane insulation. These technologies are utilized by several ULT freezer manufacturers, including Eppendorf and Panasonic.

In March 2015, My Green Lab published a report on the energy efficiency potential of various laboratory equipment.2 This market study, conducted through the California Emerging Technologies Program, found that laboratories consume more energy per square foot than any other sector other than data centers.

This study also reported that California has the highest density of laboratories in the country (p. 1) and the number of refrigeration units per lab was 20% higher in California than the rest of the U.S. (p. 41).

According to a study conducted by My Green Lab as part of the Center for Energy Efficient Laboratories (CEEL), that was published in 2015, there are an estimated 58,000 ULT freezers in California that consume 400 million kWh/year.3

# MEASURE CASE DESCRIPTION

The measure case of the ultra-low temperature (ULT) freezer is defined by the ENERGY STAR® Program Requirements Product Specification for Laboratory Grade Refrigerators and Freezers, Version 1.1.4 The measure offerings, based upon volume ranges specified below:

Measure Case Specification

|  |  |
| --- | --- |
| Statewide Measure  Offering ID | Description / Volume Range |
| SWCR017A | Refrig-Freezer-High Efficiency Ultra-Low Temperature  (ULT, -80 °C) Freezers, 15 to <24 ft3 |
| SWCR017B | Refrig-Freezer-High Efficiency Ultra-Low Temperature  (ULT, -80 °C) Freezers, 24 to 29 ft3 |

# BASE CASE DESCRIPTION

The base case is defined as a standard efficiency ULT Freezer (-80 °C) with a standard efficiency dual cascade refrigeration system.

2 Paradise, A. (My Green Lab). 2015. *Market Assessment of Energy Efficiency Opportunities in Laboratories.* Emerging Technologies Program Number ET14PGE7591, ET15SCE1070, ET14SDG1111.

3. Paradise, A. (My Green Lab). 2015. *Market Assessment of Energy Efficiency Opportunities in Laboratories.* Emerging Technologies Program Number ET14PGE7591, ET15SCE1070, ET14SDG1111. Tables 75 and 86.

4 ENERGY STAR. 2017. "ENERGY STAR® Program Requirements for Laboratory Grade Refrigerators and Freezers. Eligibility Criteria Version 1.1." Effective on December 21, 2016.

# CODE REQUIREMENTS

Ultra-low temperature (ULT) freezers are not governed by federal or state codes and standards. The standards as they relate to this measure are summarized below *for informational purposes only*.

California Building Energy Efficiency Standards (Title 24). Chapter 10.5 of the California Title 24 2019 Non- Residential Compliance Manual addresses commercial refrigeration systems in retail food stores. The standards apply to retail food stores that have 8,000 square feet or more of conditioned area and utilize either refrigerated display cases or walk-in coolers or freezers, which are connected to remote compressor units or condensing units.

Chapter 10.6 addresses the refrigeration systems serving refrigerated warehouses. The Title 24 standards address the energy efficiency of refrigerated spaces within buildings, including coolers and freezers, as well as the refrigeration equipment that serves those spaces. Coolers are defined as refrigerated spaces designed to operate at or above 28 °F (-2 °C) and at or below 55 °F (13 °C). Freezers are defined as refrigerated spaces designed to operate below 28 °F (-2 °C).

California Appliance Efficiency Regulations (Title 20). Title 20 covers the standards for commercial refrigerators, commercial refrigerator-freezers, and commercial freezers in retail food stores. Title 20 does not pertain to ULT freezers.

Applicable State and Federal Codes and Standards

|  |  |  |
| --- | --- | --- |
| Code | Applicable Code Reference | Effective Date |
| CA Appliance Efficiency Regulations – Title 20 | None. | n/a |
| CA Building Energy Efficiency Standards – Title 24 | None. | n/a |
| Federal Standards | None. | n/a |

Note that in May 2017, ENERGY STAR published standards for ULT freezers.5 The *Product Specification for Laboratory Grade Refrigerators and Freezers Eligibility Criteria Version 1.1* is based on the same data presented in the CEEL 2016 Emerging Technologies Program study.6 The ENERGY STAR® specification includes the following:

* An ULT freezer is defined as a freezer that is designed for a laboratory application and can maintain a setpoint storage temperature between -70 °C and -80 °C (-94 °F and -112 °F);
* The ENERGY STAR test method for ultra-low temperature freezers.
* The ULT energy consumption calculation method for the cabinet temperature of -75 °C, which is calculated and reported as the weighted average of the test results at -70 °C and -80 °C.

5 ENERGY STAR. 2017. "ENERGY STAR® Program Requirements for Laboratory Grade Refrigerators and Freezers. Eligibility Criteria Version 1.1." Effective on December 21, 2016.

6 The Center for Energy Efficient Laboratories (CEEL), A. Paradise (My Green Lab), D. Livchak and E. Ruan (Fisher-Nickel, Inc.), and

1. Farmer (kW Engineering). 2016. *Ultra-Low Temperature Freezers: Opening the Door to Energy Savings in Laboratories.*

Emerging Technologies Program Number: ET14PGE1721, ET16SCE1060, ET15SDG1092.

* + The maximum daily energy consumption (MDEC) of an ENERGY STAR-certified ULT freezer at -75

°C (-103 °F) is 0.55 kWh/day/ft3. This is the criteria to qualify products for this measure.

# NORMALIZING UNIT

Each

# PROGRAM REQUIREMENTS

*Measure Implementation Eligibility*

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

*Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.*

Implementation Eligibility for Investor-Owned Utilities

|  |  |  |
| --- | --- | --- |
| Measure Application Type | Delivery Type | Sector |
| Normal replacement | DnDeemed | Ind |
| Normal replacement | DnDeemed | Com |
| Normal replacement | DnDeemDI | Ind |
| Normal replacement | DnDeemDI | Com |
| Normal replacement | UpDeemed | Ind |
| Normal replacement | UpDeemed | Com |
| New construction | DnDeemed | Ind |
| New construction | DnDeemed | Com |
| New construction | DnDeemDI | Ind |
| New construction | DnDeemDI | Com |
| New construction | UpDeemed | Ind |
| New construction | UpDeemed | Com |

*Eligible Products*

A qualifying ultra-low-temperature (ULT) freezer must meet the following criteria:

* + Upright ULT freezer designed for laboratory application that will maintain a setpoint storage temperature between -70 °C and -80 °C (-94 °F and -112 °F)
  + ENERGY STAR® certification, or the maximum daily energy consumption (MDEC) of an ULT freezer at -75 °C (-103 °F) is 0.55 kWh/day/ft3
  + 15 ft3 < Volume ≤ 29 ft3

*Eligible Building Types*

This measure is applicable for the following existing building types: Education – University, Health/Medical – Hospital, Manufacturing – Biotech, and Manufacturing – Pharmaceuticals.

*Eligible Climate Zones*

The measure is applicable in all California climate zones.

# PROGRAM EXCLUSIONS

None.

# DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

# USE CATEGORY

Commercial refrigeration (ComRefrig)

# ELECTRIC SAVINGS (kWh)

The estimated unit savings (UES) of an ultra-low-temperature (ULT) freezer in laboratory spaces is the sum of direct and indirect energy usage:

* + Controlled ENERGY STAR performance tests to measure direct savings (i.e., no interactive effects), and
  + Indirect energy savings were calculated as the net change in the building HVAC system energy usage due to the increase or reduction of heat release by a new ULT freezer.

The measure case is defined by two volume ranges. Deemed savings were calculated as the average volume multiplied by the average savings per cubic foot for each range.

The range for the first offering, for smaller volumes, is 15 ft3 and < 24 ft3. The UES of the smaller range is based on data for freezers sized 16 ft3 to 23 ft3; the average volume is 19.5 ft3.

The range for the second offering, for larger volumes, is 24 ft3 up to and including 29 ft3. The energy savings is based on data for freezers sized 24 ft3 to 28.8 ft3; the average volume is 26.5 ft3.

The methods to calculate direct and indirect savings are detailed below.7

7 Pacific Gas and Electric Company (PG&E). 2019. “ULT SavingsCalcs\_v04.xls."

Direct Unit Energy Savings

Direct UES from installing a high efficiency ULT temperature freezer was calculated as the difference between the normalized and interpolated unit energy consumption (UEC) of a base case and the measure case ULT freezer with an operating temperature of -75 °C.8 This operating point is interpolated from two measured points at -80 °C and -70 °C.

The direct UES of installing high efficiency ULT freezers is a function of the baseline and measure case unit energy consumption (UEC), the freezer capacity, and operating days per year.

𝑈𝐸𝑆𝑑𝑖𝑟𝑒𝑐𝑡 = 𝑉 × [𝑈𝐸𝐶𝑏𝑎𝑠𝑒 − 𝑈𝐸𝐶𝑚𝑒𝑎𝑠𝑢𝑟𝑒] × 𝐶

*UESdirect = Direct unit electric energy savings*

*V = Average volume capacity of ULT freezer, ft3 (19.5 ft3 for sizes 15 to <24 ft3 and 26.5 ft3 for sizes 24 to 29 ft3)*

*UECbase = Average daily energy consumption of standard efficiency ULT freezers operating with a setpoint temperature of -75 °C, kWh/ft3-day*

*UECmeasure = Average daily energy consumption of high efficiency ULT freezers operating with a setpoint temperature of -75 °C, kWh/ft3-day*

*C = Operating days per year (constant, 365 days/yr)*

Eight ULT freezer brands from five manufacturers that accounted for over 80% of the total ULT freezer market were selected from the emerging technology study that developed the UECs for this analysis. Fifteen new ULT freezers, ranging in size from 16 ft3 to 29 ft3, were evaluated according to the ENERGY STAR test method, seven of which were further tested in a controlled field study that measured energy consumption and temperature performance. Of the 15 ULT freezers tested, 10 utilized the standard dual- compressor technology, while five were marketed as using new, high-efficiency technology. Additional energy data were gathered for 101 existing ULT freezers in the field.

The ENERGY STAR test method monitors the energy consumption of an ULT freezer under controlled environment at -80 °C and -70 °C, respectively. The ENERGY STAR Maximum Daily Energy Consumption (MDEC) requirement of 0.55 kWh/day/ft3 considers the normalized and interpolated monitored energy consumption of a ULT freezer operating with a setpoint of -75 °C.

The energy performance of the 15 ULT freezers tested with the ENERGY STAR test method is summarized in the following table.

8 According to a study conducted by the Center for Energy Efficient Laboratories (CEEL), et. al. through the California Emerging Technologies Program that was published in 2016, the average temperature of ULT freezers found in laboratories is -77.5 °C (p. 146). However, the direct energy savings calculation adopts a conservative ULT freezer operating temperature of -75 °C (p. 147), which is consistent with the ENERGY STAR test method.

ULT Freezer Energy Performance under Controlled Environment ENERGY STAR Test 9

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Freezer | Vol. (ft3) | Refrigerant Type a | Unit Energy Consumption (UEC) | | | | | |
| -80 °C Setpoint | | -70 °C Setpoint | | -75 °C Setpoint  (interpolated) | |
| kWh/day | kWh/ft3/day | kWh/day | kWh/ft3/day | kWh/day | kWh/ft3/day |
| High-Efficiency Units (Measure Case) | | | | | | | | |
| A | 20.1 | HFC | 12.6 | 0.63 | 8.7 | 0.43 | 11.0 | 0.55 |
| F | 27.5 | Natural | 9.7 | 0.35 | 7.9 | 0.29 | 8.8 | 0.32 |
| G | 28.8 | Natural | 12.1 | 0.42 | 8.1 | 0.28 | 10.5 | 0.36 |
| H | 19.4 | Natural | 10.4 | 0.54 | 7.1 | 0.36 | 9.1 | 0.47 |
| I | 27.5 | Natural | 8.7 | 0.32 | 7.0 | 0.25 | 7.9 | 0.29 |
| Average | | | | 0.45 |  | 0.32 |  | 0.40 |
| Standard Efficiency Units (Base Case) | | | | | | | | |
| B | 23 | HFC/Natural Blend | 14.9 | 0.65 | 11.78 | 0.5122 | 13.5 | 0.59 |
| C | 24.7 | HFC | 22.5 | 0.91 | 15.11 | 0.6117 | 19.03 | 0.77 |
| D | 24.0 | HFC | 20.5 | 0.85 | 14.0 | 0.59 | 17.9 | 0.75 |
| E | 25.7 | HFC | 26.7 | 1.02 | 19.9 | 0.77 | 23.8 | 0.93 |
| J | 28.8 | HFC/Natural Blend | 20.0 | 0.69 | 13.8 | 0.48 | 16.9 | 0.59 |
| K | 16.0 | HFC | 14.7 | 0.92 | 11.1 | 0.69 | 12.9 | 0.81 |
| L | 25.7 | HFC | 18.9 | 0.74 | 14.1 | 0.55 | 16.7 | 0.65 |
| M | 18.0 | HFC | 14.8 | 0.82 | 11.7 | 0.65 | 13.2 | 0.73 |
| N | 18.9 | HFC | 20.4 | 1.08 | 15.0 | 0.79 | 17.8 | 0.94 |
| O | 26.0 | HFC | 17.7 | 0.68 | 12.6 | 0.49 | 15.2 | 0.58 |
| Average | | | | 0.84 |  | 0.61 |  | 0.73 |

1. Natural refrigerants are substances that can be found in the nature, such as R290 and R170. HFC is synthetic hydrofluorocarbons-based refrigerants, such as R-508, R-407D, R134 and R404-A.

Seven ULT freezers were further tested in a controlled field study. Comparison between ENERGY STAR test method and field test method are summarized in the following table.

Comparison between ENERGY STAR Test Method and Field Test Method 10

|  |  |  |
| --- | --- | --- |
| Parameter | ENERGY STAR Test Method | Field Test Method |
| Freezers Tested | 15 | 7 |
| Temperature Settings | -80 °C  -70 °C | -80 °C  -70 °C |
| Door Openings | 6 openings, 1x/hour for 15 seconds | Various. |
| Number of Thermocouples | 3 per shelf, diagonally placed | 5 on top and bottom shelves, 3 per middle shelf |

9 The Center for Energy Efficient Laboratories (CEEL), A. Paradise (My Green Lab), D. Livchak and E. Ruan (Fisher-Nickel, Inc.), and

* 1. Farmer (kW Engineering). 2016. *Ultra-Low Temperature Freezers: Opening the Door to Energy Savings in Laboratories.*

Emerging Technologies Program Number: ET14PGE1721, ET16SCE1060, ET15SDG1092. Tables 6, 10, and 11.

10 The Center for Energy Efficient Laboratories (CEEL), A. Paradise (My Green Lab), D. Livchak, and E. Ruan (Fisher-Nickel, Inc.), and A. Farmer (kW Engineering). 2016. Ultra-Low Temperature Freezers: Opening the Door to Energy Savings in Laboratories. Emerging Technologies Program Number: ET14PGE1721, ET16SCE1060, ET15SDG1092. Table 4 and Appendix E.

|  |  |  |
| --- | --- | --- |
| Parameter | ENERGY STAR Test Method | Field Test Method |
| Full/Empty Freezer | Empty | Full |
| Duration of Test | 30 hours at each temperature setting | 7 days at each temperature setting |

A summary of the energy performance of the seven ULT freezers under the field test are summarized in below.

ULT Freezer Energy Performance Under Field Test 11

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Freezer | Vol. (ft3) | Refrigerant Type a | Unit Energy Consumption (UEC) | | | | | |
| -80 °C Setpoint | | At -70 °C Setpoint | | At -75 °C Setpoint  (interpolated) | |
| kWh/day | kWh/ft3/day | kWh/day | kWh/ft3/day | kWh/day | kWh/ft3/day |
| High-Efficiency Units (Measure Case) | | | | | | | | |
| A | 20.1 | HFC | 10.0 | 0.50 | 7.2 | 0.36 | 9.4 | 0.47 |
| F | 27.5 | Natural | 9.6 | 0.35 | 7.6 | 0.28 | 8.6 | 0.31 |
| G | 28.8 | Natural | 9.5 | 0.33 | 7.5 | 0.26 | 10.2 | 0.35 |
| Average | | | | 0.39 |  | 0.30 |  | 0.38 |
| Standard Efficiency Units (Base Case) | | | | | | | | |
| B | 23.0 | HFC/Natural Blend | 14.5 | 0.63 | 12.0 | 0.52 | 13.0 | 0.57 |
| C | 24.7 | HFC | 18.1 | 0.73 | 10.5 | 0.43 | 14.7 | 0.60 |
| D | 24.0 | HFC | 16.9 | 0.70 | 13.4 | 0.56 | 16.1 | 0.67 |
| E | 25.7 | HFC | 23.3 | 0.91 | 17.9 | 0.70 | 21.8 | 0.85 |
| Average | | | | 0.74 |  | 0.55 |  | 0.67 |

* + 1. Natural refrigerants are substances that can be found in the nature, such as R290 and R170. HFC is synthetic hydrofluorocarbons-based refrigerants, such as R-508, R-407D, R134 and R404-A.

Installed baseline energy data from 101 existing ULT freezers were also analyzed. The data were collected from academic institutions and biotech/pharmaceutical companies, obtained through solicitations by the Green Labs Planning Group and through existing relationships with many of the participating organizations. The data were then analyzed based on freezer brand and age. The resultant normalized UEC as a function of freezer capacity reveals that the average UEC of an ULT freezer set to -80 °C in the study is 1.1 kWh/ft3/day, and the average UEC of an ULT freezer set to -70 °C is 0.8 kWh/ft3/day, which are roughly 30% higher than the measured base case calculated through the ENERGY STAR methodology to produce a more conservative result.

11 The Center for Energy Efficient Laboratories (CEEL), A. Paradise (My Green Lab), D. Livchak and E. Ruan (Fisher-Nickel, Inc.), and

* + - 1. Farmer (kW Engineering). 2016. *Ultra-Low Temperature Freezers: Opening the Door to Energy Savings in Laboratories.*

Emerging Technologies Program Number: ET14PGE1721, ET16SCE1060, ET15SDG1092. Tables 18 and 19.

Indirect Energy Savings

The waste heat created by an ULT freezer is rejected to the indoor space;12 during cooling season, the effect is an increase of the energy needed to cool down the space. During the heating season the effect is the opposite – the amount of heat created by the ULT freezer offsets the energy used by the heating system. Because a high-efficiency ULT freezer produces less heat than a standard ULT freezer, the HVAC system will produce less cooled conditioned air and increase the amount of heated air to maintain the space setpoint temperature.

The percent of the year that a building HVAC system is in cooling or heating mode13 was used to estimate the effects of improved ULT freezer efficiency on HVAC system energy use.14 Bin temperatures data for all 16 California climate zones15 were used to calculate the percent that an HVAC of a given building will be in cooling or heating mode thought a calendar year. The net indirect energy savings are estimated by the following:

𝑈𝐸𝑆𝑖𝑛𝑑𝑖𝑟𝑒𝑐𝑡 = % 𝑜𝑓 𝑦𝑒𝑎𝑟 𝑖𝑛 𝑐𝑜𝑜𝑙𝑖𝑛𝑔 𝑚𝑜𝑑𝑒 × [𝑈𝐸𝑆𝑑𝑖𝑟𝑒𝑐𝑡] − % 𝑜𝑓 𝑡ℎ𝑒 𝑦𝑒𝑎𝑟 𝑖𝑛 ℎ𝑒𝑎𝑡𝑖𝑛𝑔 𝑚𝑜𝑑𝑒 𝑥 [𝑈𝐸𝑆𝑑𝑖𝑟𝑒𝑐𝑡]

*UESindirect = Indirect unit electric energy savings*

The percentage of a year that a building is in cooling mode was determined by dividing the number of hours the outdoor air temperature (OAT) for a given zone is larger or equal to 77 oF by the total hours per year (8760):

*% of year in cooling mode = (No. Hours OAT≥ 77 °F) / 8760*

Similarly, the percentage in heating mode was calculated dividing the number of hours the OAT is below 65 oF by 8760:

*% of year in heating mode = (No. Hours OAT ≤ 65 °F) / 8760*

# PEAK ELECTRIC DEMAND REDUCTION (kW)

Peak demand reduction was calculated as the sum of the direct average demand reduction and the indirect average demand reduction. The direct and indirect peak demand reduction from the installation of a high-efficiency ULT freezer was calculated by dividing the average unit energy savings (UES) by the annual freezer operating hours.

𝑃𝐷𝑅𝑡𝑜𝑡𝑎𝑙 = 𝐷𝑅𝑑𝑖𝑟𝑒𝑐𝑡

12 Stirling Ultracold, Global Cooling, Inc. 2014. “Technical Data Sheet: Stirling Ultracold SU780U Ultra-Low Temperature Freezer.”

April 17.

13 Legett, R. (Navigant Consulting, Inc.). 2014. *Field Demonstration of High Efficiency Ultra-Low-Temperature Laboratory Freezers.* Prepared for Better Buildings Alliance, Building Technologies Office, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy. September.

14 Pacific Gas and Electric (PG&E). 2019. “ULT SavingsCalcs\_v04.xls."

15 Pacific Energy Center. 2006. “The Pacific Energy Center’s Guide to: California Climate Zones and Bioclimatic Design.” October.

𝑈𝐸𝑆𝑑𝑖𝑟𝑒𝑐𝑡

𝐻𝑂𝑈𝑅𝑆𝑦𝑟

𝐷𝑅𝑑𝑖𝑟𝑒𝑐𝑡 = 𝐻𝑂𝑈𝑅𝑆

𝑑𝑎𝑦

*PDRtotal = Total peak demand reduction DRdirect = Direct average demand reduction HOURSyr = Annual freezer operating hours HOURSday = Hours per day*

The inputs for the peak demand reduction calculation are provided below. Because the energy consumption of a ULT freezer is relatively constant and does not vary throughout the day or year, this measure operates within the Database of Energy Efficient Resources (DEER) peak period of 4 p.m. to 9

* 1. on weekdays16 at a constant load throughout the day.

Peak Demand Reduction Inputs

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Source |
| Annual operating hours (hr/yr) | 8,760 | Professional judgement. |
| Hours per day | 24 |

# GAS SAVINGS (THERMS)

The estimated gas unit energy savings (UES) of ULT freezers are based solely on the estimated change of gas consumption as reflected by a gas HVAC interactive effects that were calculated using the percentage in heating mode indicated in the Electric Savings section.

# LIFE CYCLE

Effective Useful Life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. EUL is often, but not always, derived from measure persistence or retention studies. Remaining Useful Life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would have remained in service and operational had the program intervention not caused the replacement or alteration.

The EUL specified for this measure are specified below.17 Note that RUL is only applicable for add-on equipment and accelerated replacement measures and is not applicable for ULT freezers.

16 California Public Utilities Commission (CPUC). 2018. *Resolution E-4952.* October 11. O.P. 1.

17 The EUL is associated with the closest measure identified in the Database for Energy Efficient Resources (DEER). According to *Ultra-Low Temperature Freezers: Opening the Door to Energy Savings in Laboratories* study conducted by Center for Energy Efficient Laboratories (CEEL) et. al., laboratory audits and analysis of procurement patterns indicate the average lifetime of a ULT freezer is approximately 10 years (p. 127).

Effective Useful Life and Remaining Useful Life

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Source |
| EUL (yrs) | 12.0 | California Public Utilities Commission (CPUC), Energy Division. 2014. “DEER2014-EUL- table-update\_2014-02-05.xlsx.” |
| RUL (yrs) | n/a | n/a |

# BASE CASE MATERIAL COST ($/UNIT)

The base case material cost for equipment *delivered via direct install* is equal to $0.

For *all other delivery types*, ULT freezer cost data was acquired in 2016 and 2017 from eleven universities and four large biotech companies with multiple sites across California.18 The ultra-low-temperature (ULT) freezer pricing varies by manufacturer and purchaser, with larger buyers receiving greater discounts. The cost data was divided into two volume categories (15 ft3 to <24 ft3 and 24 ft3 to 29 ft3) and include 34 models for the small category and 40 models in the large volume category. The material cost of a base case ULT freezer was calculated by the following methodology:

* + 1. All price data for the same make and model freezer were averaged for academia and for the biotech industry.
    2. Base case freezer costs at least one standard deviation above the mean were excluded because average pricing for standard-efficiency units is likely to reduce over time.
    3. The average ULT freezer volume for each size category was set to (19.5 ft3 for the smaller size category and 26.5 ft3 for the larger).
    4. The average price per unit was divided by the average ULT freezer volume to determine the price per cubic foot.
    5. The final price was normalized by multiplying the average price per cubic foot by the average ULT freezer volume.

Costs for 2020 were adjusted using RSMeans Price Index.

# MEASURE CASE MATERIAL COST ($/UNIT)

The data to calculate the measure case material cost for *all delivery types* was acquired in 2016 and 2017 from 11 universities and four large biotech companies with multiple sites across California. ULT freezer pricing varies by manufacturer and purchaser, with larger buyers receiving greater discounts.

Manufacturers do not disclose pricing details for competitive reasons. The cost data was divided into two volume categories (15 ft3 to <24 ft3 and 24 ft3 to 29 ft3) and includes five models for the small category and 17 models in the large volume category. The material cost of a measure case ULT freezer was calculated by the following methodology:19

1. All price data for the same make and model freezer were averaged for academia and for the biotech industry.

18 These data were obtained with the guarantee of confidentiality, as manufacturers do not disclose pricing details for competitive reasons.

19 Pacific Gas and Electric (PG&E). 2017. "ULT Freezer Academic Biotech Pricing.xlsx." Proprietary database.

1. Energy-efficient freezer costs at least one standard deviation below the mean were excluded because these were often introductory pricing that will be less common going forward.
2. The average ULT freezer volume for each size category was set to 19.5 ft3 for the smaller size category and 26.5 ft3 for the larger.
3. The average price per unit was divided by the average ULT freezer volume to determine the price per cubic foot.
4. The final price was normalized by multiplying the average price per cubic foot by the average ULT freezer volume.

Costs for 2020 were adjusted using RSMeans Price Index.

# BASE CASE LABOR COST ($/UNIT)

The base case labor cost for equipment *delivered via direct install* is equal to $0.

For *all other delivery types*, the base case and measure case model installation costs are expected to be the same for the customer and thus were not estimated for the incremental cost analysis.

# MEASURE CASE LABOR COST ($/UNIT)

The measure case labor cost for equipment *delivered via direct install* will be derived as the average installation cost submitted by one or more implementation contractors. The actual installation cost can vary by contractor, the date when the work occurred, and by the volume of each specific contractor’s business. Contractor costs are confidential information and are based upon contractually agreed upon pricing as established in their purchase order with the program administrator. Therefore, the program administrator program tracking systems are the only source for the labor installation cost data. The program administrator will utilize the actual program cost to evaluate the cost-effectiveness of the measure.

For *all other delivery types*, a high efficiency model does not require additional installation labor compared to a base case model. Since this measure is applicable for normal replacement and new construction installations, the base case and measure case model installation costs are expected to be the same for the customer and thus were not estimated for the incremental cost analysis.

# NET-TO-GROSS (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. The NTG value adopted for these measures is the latest “default” DEER NTG value as directed by the CPUC Memorandum dated November 10, 202020.

20 California Public Utilities Commission (CPUC). 2020. Memorandum 11-10-2020 CPUC Guidance on the Applicability of Emerging Technology (ET) Net-to-Gross (NTG) Values.

Net-to-Gross Ratios

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Source |
| Com-Default>2yrs Ind-Default>2yrs | 0.60 | NTG value adopted for this measure is the latest “default” DEER NTG value (DEER2019). |

# GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. This GSIA rate is the current “default” rate specified for measures for which an alternative GSIA has not been estimated and approved.

Gross Savings Installation Adjustment Rates

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Source |
| GSIA | 1.0 | California Public Utilities Commission (CPUC), Energy Division. 2013.  *Energy Efficiency Policy Manual Version 5*. Page 31. |

# NON-ENERGY IMPACTS

Non-energy impacts for this measure have not been quantified.

# DEER DIFFERENCES ANALYSIS

The table below summarizes the inputs and methods that are and are not based upon the Database for Energy Efficient Resources (DEER). This measure is not in DEER, since no laboratory building prototype has previously been developed by DEER, and DEER does not include measures evaluating ULT freezers.

DEER Difference Summary

|  |  |
| --- | --- |
| DEER Item | Comment / Used for Workpaper |
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | No |
| DEER Measure Case | No |
| DEER Building Types | No |
| DEER Operating Hours | No |
| DEER eQUEST Prototypes | No |
| DEER Version | n/a |
| Reason for Deviation from DEER | DEER does not contain this type of measure. |
| DEER Measure IDs Used | n/a |
| NTG | Source: DEER. NTG of 0.60 is associated with NTG ID: *Com-Default>2yrs and Ind-Default>2yrs* |
| GSIA | GSIA ID: *Def-GSIA* |
| EUL/RUL | Source: DEER2014. The EUL of 12 years is associated with EUL ID:  *GrocDisp-FixtDoors* |

# REVISION HISTORY

Measure Characterization Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| Revision Number | Revision Completion Date | Primary Author, Title, Organization | Revision Summary and Rationale for Revision  Effective Date and Approved By |
| 01 | 03/31/2018 | Jennifer Holmes Cal TF Staff | Draft of consolidated text for this statewide measure is based upon: |
|  |  |  | PGECOREF130 Revision 0 (August 7, 2017) |
|  |  |  | SCE17RN029 Revision 0 (November 6, 2017) – short form |
|  |  |  | WPSDGENRRN0016 Revision 0 (September 25, 2017) –  short form |
|  |  |  | Consensus reached among Cal TF members. |
|  | 05/31/2019 | Adan Rosillo, | Revisions for submittal of version 01. |
|  |  | PG&E |  |
|  |  | Jennifer Holmes |  |
|  |  | Cal TF Staff |  |
| 02 | 01/15/2021 | Danielle Dragon, PE, CEM, CDSM  PG&E | NTG update from 0.85 to 0.60 Cost update  Update: “CA Title 24 2016 Non-Residential Compliance Manual” to “CA Title 24 2019 Non-Residential Compliance Manual” |