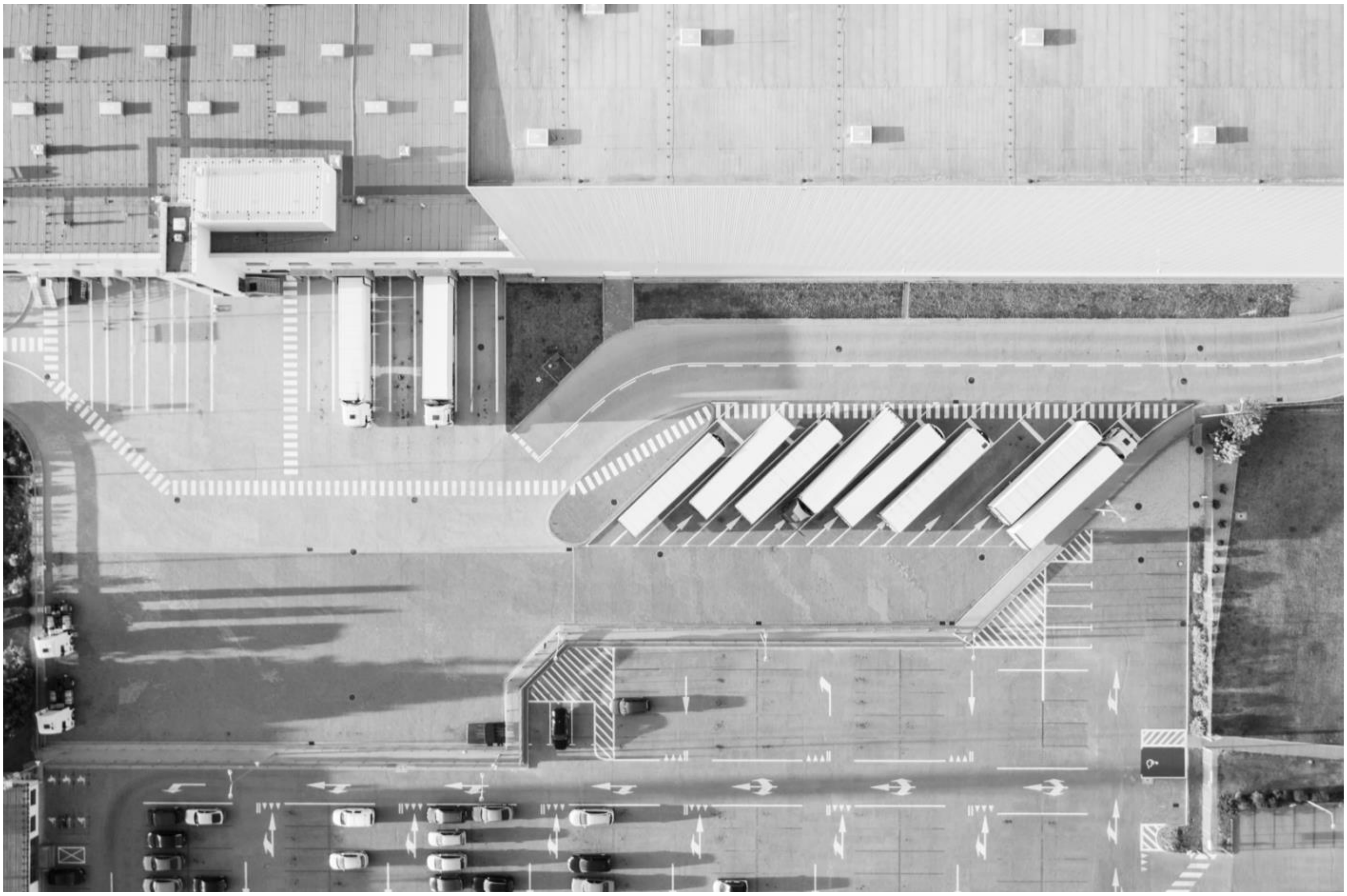
Codes and Standards Enhancement (CASE) Initiative

2025 California Energy Code

Refrigeration



Nonresidential, Covered Processes
Prepared by VaCom Technologies

July 2023
2025 Refrigeration System Proposal
Based on 2022 Refrigeration Final CASE Report

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1. Introduction

This proposal outlines a recommendation for the CEC to adopt specific efficiencies for different evaporator applications, types, and refrigerants. If adopted, this measure would save 0.872 MWh of electricity in the first year and reduce peak electrical demand by 85.569 kW during the same timeframe.

The Statewide CASE Team recommended the same change for the 2022 code cycle, but the CEC did not adopt the proposed requirements for the 2022 code cycle due to resource constraints. Therefore, the Statewide CASE Team is proposing again for the 2025 code cycle.

The Codes and Standards Enhancement (CASE) initiative presents recommendations to support the California Energy Commission's (CEC's) efforts to update California's Energy Code (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. The three California Investor Owned Utilities (IOUs) — Pacific Gas and Electric Company, San Diego Gas and Electric, and Southern California Edison – and two Publicly Owned Utilities — Los Angeles Department of Water and Power and Sacramento Municipal Utility District (herein referred to as the Statewide CASE Team when including the CASE Author) — sponsored this effort. The program goal is to prepare and submit proposals that would result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposal presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy-efficient design practices and technologies.

The CEC is the state agency that has authority to adopt revisions to Title 24, Part 6. One of the ways the Statewide CASE Team participates in the CEC's code development process is by submitting code change proposals to the CEC for consideration. CEC will evaluate proposals the Statewide CASE Team and other stakeholders submit and may revise or reject proposals. See [the CECs 2025 Title 24 website](https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2025-building-energy-efficiency) (https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2025-building-energy-efficiency) for information about the rulemaking schedule and how to participate in the process.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with many industry stakeholders including manufacturers, contractors, and others involved in the code compliance process. The proposal incorporates feedback received during a public stakeholder workshop that the Statewide CASE Team held on January 31, 2023.

The following is a summary of the contents of this addendum report to the 2022 Refrigeration System Opportunities CASE Report:

- Section 2.1 – Reintroducing Evaporator Specific Efficiency Proposal offers a history of the code change proposal and where readers can find more information from the analyses completed for the 2022 code cycle.
- Section 2.2 – Measure Description of this CASE Report provides a description of the measure and its background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- Section 2.3 – Energy Savings presents the per-unit energy, demand reduction, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per-unit energy, demand reduction, and energy cost savings.
- Section 2.4 – Cost and Cost Effectiveness presents the Long-term Systemwide Cost and cost-effectiveness analysis. This includes a discussion of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs, i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.
- Section 3 – Proposed Revisions to Code Language concludes the report with specific recommendations with ~~strikeout~~ (deletions) and underlined (additions) language for the Standards, Reference Appendices, and Alternative Calculation Method (ACM) Reference Manual. Generalized proposed revisions to sections are included for the Compliance Manual and compliance forms.
- Section 4 – Bibliography presents the resources that the Statewide CASE Team used when developing this report.
- Appendix A: Costs in Nominal Dollars presents energy cost savings over the period of analysis in nominal dollars.
- Appendix B: 2026 Construction Forecast presents assumptions used to calculate statewide impacts.

Refer back to the [2022 Refrigeration System Opportunities CASE Report](https://title24stakeholders.com/wp-content/uploads/2023/01/T24-2022-CASE-Study-Results-Reports-Refrigeration-System-Opportunities_Final-1.pdf) (https://title24stakeholders.com/wp-content/uploads/2023/01/T24-2022-CASE-Study-Results-Reports-Refrigeration-System-Opportunities_Final-1.pdf) for additional information not included in this addendum report including market analysis and material impacts.

The California IOUs offer free energy code training, tools, and resources for those who need to understand and meet the requirements of Title 24, Part 6. The program recognizes that building codes are one of the most effective pathways to achieve energy savings and GHG reductions from buildings – and that well-informed industry professionals and consumers are key to making codes effective. With that in mind, the California IOUs provide tools and resources to help both those who enforce the code, as well as those who must follow it. Visit EnergyCodeAce.com to learn more and to access content, including a glossary of terms.

Statewide energy savings for the evaporator specific efficiency measure are summarized in Table 1 below.

Table 1: Summary of Impacts for Evaporator Specific Efficiency

Category	Metric	New Construction & Additions	Alterations
Cost Effectiveness	Benefit-to-Cost Ratio Range (varies by climate zone and building type)	5.18– 9.6	4.99– 9.6
Statewide Impacts During First Year	Electricity Savings (GWh)	0.38	0.49
	Peak Electrical Demand Reduction (kW)	37.71	47.86
	Natural Gas Savings (Million Therms)	0.00	0.00
	Source Energy Savings (Million kBtu)	0.61	0.78
	LSC Electricity Savings (Million 2026 PV$)	2.10	2.67
	LSC Gas Savings (Million 2026 PV$)	0.00	0.00
	Total LSC Savings (Million 2026 PV$)	2.10	2.67
	Avoided GHG Emissions (Metric Tons CO2e)	32.52	41.20
	Monetary Value of Avoided GHG Emissions ($)	4,004	5,074
	On-site Indoor Water Savings (Gallons)	0.00	0.00
	On-site Outdoor Water Savings (Gallons)	0.00	0.00
	Embedded Electricity in Water Savings (kWh)	0.00	0.00
Per Square Foot Impacts During First Year	Electricity Savings (kWh)	0.9280	0.8744
	Peak Electrical Demand Reduction (W)	0.0911	0.0859
	Natural Gas Savings (kBtu)	0.0000	0.0000
	Source Energy Savings (kBtu)	1.4842	1.3971
	LSC Savings (2026 PV$)	5.0794	4.7859
	Avoided GHG Emissions (kg CO2e)	0.0785	0.0739
	On-site Indoor Water Savings (Gallons)	0	0
	On-site Outdoor Water Savings (Gallons)	0	0
	Embedded Electricity in Water Savings (kWh)	0.00	0.00

2. Code Change Proposal

2.1 Reintroducing Evaporator Specific Efficiency Proposal

The Statewide CASE Team recommends that the CEC adopt requirements for evaporator specific efficiency affecting refrigerated warehouses. The Statewide CASE Team recommended the same change for the 2022 code cycle, but the CEC did not adopt the proposed requirements for the 2022 code cycle citing resource constraints. Therefore, the Statewide CASE Team is proposing again for the 2025 code cycle.

This addendum contains pertinent information to recommend the proposal for consideration for the 2025 code cycle. The Statewide CASE Team completed a full analysis during the 2022 code cycle and provided CEC with the information needed to consider a code change. Much of the information in the Final CASE Report from the 2022 cycle remains relevant without updates. This addendum provides updated demand savings, energy cost savings, and cost effectiveness using the CEC's new Long-term Systemwide Cost (LSC) factors. The proposed specific efficiency requirements included in this proposal match the proposed specific efficiency requirements for ammonia and halocarbon refrigerant applications from the 2022 CASE Report for Refrigeration System Opportunities. Added to the proposal with this addendum is including CO2 refrigerant applications and specifically referencing test procedures for establishing the efficiency ratings.

The Refrigeration System Opportunities Final CASE Report from the 2022 code cycle (hereby referred simply as "CASE Report") is available here: https://title24stakeholders.com/wp-content/uploads/2020/09/NR_Refrig-System-Opps_Final-CASE-Report.pdf. The full report is also provided as an attachment to this addendum. The CASE Report recommended five unique proposals related to a combination of commercial refrigeration and refrigerated warehouses. This addendum provides updated information for the evaporator specific efficiency proposals, which is submeasure C evaporator specific efficiency in the CASE Report.

The Statewide CASE Team completed a full analysis during the 2022 Title 24, Part 6 code cycle, which included market feasibility, energy, and cost-effectiveness calculations. The proposed measure was not adopted for the 2022 code cycle due to CEC resource constraints, so the Statewide CASE Team is proposing again for the 2025 code cycle with updated research and information. This addendum updates energy modelling cost effectiveness, and statewide impacts. Please see the CASE Report for additional supporting details.

2.2 Measure Description

A minimum specific efficiency is proposed for all non-process cooling/freezing evaporators used in refrigerated warehouses. Evaporator specific efficiency is defined as cooling capacity of the evaporator (Btu/hour) divided by the power input (watts) required for the fan motors at rated temperature conditions at 100 percent fan speed. The efficiency parameter is specified in units of BTUh/watt. BTUh/watt is defined as and understood to be "BTU/(hour x watt)" by the refrigeration industry. The rated capacity is defined at 10°F of temperature difference between the incoming air temperature and the saturated evaporating temperature of the refrigerant, assuming a dry coil.

The following values are proposed for different evaporator applications, types, and refrigerants. All evaporator sizes for the refrigerated warehouse building cooler and freezer application would have requirements.

Table 2: Proposed Evaporator Specific Efficiency Values

Evaporator Application	Liquid Feed Type	Refrigerant Type	Minimum Efficiency
Freezer	Direct Expansion	Halocarbon	40 Btuh/watt
Freezer	Direct Expansion	Ammonia	25 Btuh/watt
Freezer	Flooded/ Recirculated Liquid	Ammonia	45 Btuh/watt
Freezer	Direct Expansion	CO2	25 Btuh/watt
Freezer	Flooded/ Recirculated Liquid	CO2	45 Btuh/watt
Cooler	Direct Expansion	Halocarbon	45 Btuh/watt
Cooler	Direct Expansion	Ammonia	35 Btuh/watt
Cooler	Flooded/ Recirculated Liquid	Ammonia	50 Btuh/watt
Cooler	Direct Expansion	CO2	35 Btuh/watt
Cooler	Flooded/ Recirculated Liquid	CO2	50 Btuh/watt

Evaporators that use a penthouse configuration have additional static pressure drop, resulting in higher fan power draw. To account for this, evaporators in penthouse configurations would be required to submit capacity and power ratings assuming zero inches water column (WC) in order to compare to the proposed specific efficiency thresholds in the table above.

The rating conditions described above are further expanded with the proposed code language to provide the specific saturated evaporating temperature and entering dry-bulb temperature conditions to be used for cooler/dock and freezer applications. Specifically, for cooler/dock it would require a +25°F saturated evaporator temperature and +35°F entering dry-bulb temperature, and for freezers ratings would be at a -20°F saturated evaporator temperature and -10°F entering air temperature. These rating conditions are consistent with the AHRI-420 Performance Rating of Forced-circulation

Free-delivery Unit Coolers for Refrigeration standard for use with Ammonia and CO2 refrigerant evaporators which is referenced in the proposed code language providing equipment manufacturers a detailed standard to ensure consistency.

Halocarbon refrigerants, which are less common for the statewide area of refrigerated warehouse facilities, are not suitable to follow the 2016 AHRI-420 as those refrigerants being used today and, in the future, have 'glide' which that standard does not support. AHRI-1250 Standard for Performance Rating of Walk-in Coolers and Freezers focuses on matched systems (evaporator + compressor system), and the minimum publishing requirements do not support users in calculating the evaporator specific efficiency. However, the included test procedure provided in the normative appendix C would be applicable for developing the required inputs for the specific efficiency calculations. The primary difference for Halocarbon refrigerant applications is including procedures to account for the glide the refrigerant typical would have. AHRI-420 is more industrial equipment focused and there is a unit cooler certification program available associated with that standard. Further development of the AHRI-420 standard is recommended to support future Title 24 code cycles which would allow certified ratings of refrigerated warehouse evaporators using a common standard reference for all applications.

This mandatory code change would impact refrigerated warehouses. The code change would be applicable to refrigerated warehouses that are greater than or equal to 3,000 square feet and refrigerated spaces with a total of 3,000 square feet or more that are served by the same refrigeration system. Refrigerated spaces less than 3,000 square feet or refrigeration systems that serve a total of less than 3,000 square feet of refrigerated space shall meet the requirements of the Appliance Efficiency Regulations for walk-in coolers or freezers contained in the Appliance Efficiency Regulations (California Code of Regulations, Title 20).

Table 3 summarizes the scope of the proposed code change, which is applicable to new construction, additions, and alterations. There are no proposed acceptance testing requirements and there are no proposed updates to the compliance software.

For additional information, see Section 4.1 in the CASE Report.

Table 3: Scope of Code Change Proposal

Evaporator Specific Efficiency	
Type of Requirement	Mandatory
Applicable Climate Zones	All
Modified Section(s) of Title 24, Part 6	120.6(a)
Modified Title 24, Part 6 Appendices	N/A
Would Compliance Software Be Modified	No
Modified Compliance Document(s)	No

2.3 Energy Savings

2.3.1 Energy Savings Methodology

The Statewide CASE Team used the same methodology, prototype buildings, and simulation software that were used in the CASE Report. Please refer to section 4.3.2 of the CASE Report for details. Table 4 presents information about the refrigerated warehouse prototypes used in the analysis. Table 5 presents modifications made to the Standard Design to simulate the impacts of the proposed code change.

Table 4: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype	Number of Stories	Impacted Floor Area (Square Feet)	Description
NH3-LO-CLR	1	52,000	Ammonia Liquid Overfeed for Coolers and Docks
NH3-DX-CLR	1	16,000	Ammonia DX for Coolers and Docks
HFC-DX-CLR	1	16,000	HFC DX for Coolers and Docks
NH3-LO-FZR	1	40,000	Ammonia Liquid Overfeed for Freezers
NH3-DX-FZR	1	10,000	Ammonia DX for Freezers
HFC-DX-FZR	1	10,000	HFC DX for Freezers

Table 5: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype	Climate Zone	Objects Modified	Parameter Name	Standard Design Parameter Value (Btuh/Watt)	Proposed Design Parameter Value (Btuh/Watt)
NH3-LO-CLR	All	Evaporators	Fan Power	34	50
NH3-DX-CLR	All	Evaporators	Fan Power	20	35
HFC-DX-CLR	All	Evaporators	Fan Power	34	45
NH3-LO-FZR	All	Evaporators	Fan Power	34	45
NH3-DX-FZR	All	Evaporators	Fan Power	20	25
HFC-DX-FZR	All	Evaporators	Fan Power	34	40

The proposed code change was evaluated in all California climate zones. The Statewide CASE Team used 2025 weather files and the 2025 Long-Term Systematic Cost (LSC) factors in the analyses for this addendum.

Refrigerated warehouses predominately use ammonia as a refrigerant and secondarily use halocarbon refrigerant, such as hydrofluorocarbon (HFC) refrigerants. Because the market share for carbon dioxide refrigerants is still relatively small, the energy analysis was not completed for refrigerated warehouses using carbon dioxide. The proposed mandatory requirements are still included for CO2 refrigeration applications as the efficiency levels are similar to Halocarbon systems.

2.3.2 Energy Savings Results

The expected energy savings, peak demand reductions, source energy savings, and energy cost savings from the proposed code change are presented in Table 6 through Table 9. Savings are presented per square foot of refrigerated warehouse for each prototype and climate zone.

Table 6: First Year Electricity Savings (kWh) Per Square Foot by Climate Zone (CZ) – RWH Evaporator Efficiency

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NH3-LO-CLR	0.61	0.72	0.67	0.71	0.67	0.72	0.72	0.76	0.74	0.77	0.76	0.76	0.78	0.74	0.83	0.64
NH3-DX-CLR	1.99	2.43	2.23	2.39	2.21	2.38	2.37	2.53	2.50	2.58	2.50	2.49	2.56	2.46	2.83	2.15
HFC-DX-CLR	0.63	0.73	0.69	0.73	0.69	0.73	0.72	0.77	0.76	0.78	0.77	0.77	0.78	0.75	0.87	0.65
NH3-LO-FZR	0.45	0.48	0.48	0.48	0.48	0.48	0.47	0.48	0.48	0.48	0.48	0.48	0.48	0.47	0.49	0.46
NH3-DX-FZR	0.87	0.90	0.86	0.93	0.83	0.85	0.86	0.91	0.91	0.92	0.90	0.88	0.90	0.93	0.94	0.86
HFC-DX-FZR	0.36	0.40	0.39	0.40	0.39	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.41	0.42	0.40

Table 7: First Year Peak Demand Reduction (kW) Per Square Foot by Climate Zone (CZ) – RWH Evaporator Efficiency

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NH3-LO-CLR	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.07	0.08	0.08	0.08	0.08	0.07	0.08	0.07
NH3-DX-CLR	0.20	0.25	0.24	0.23	0.23	0.24	0.23	0.25	0.25	0.25	0.24	0.24	0.24	0.24	0.27	0.22
HFC-DX-CLR	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.07	0.08	0.08	0.07	0.08	0.06
NH3-LO-FZR	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
NH3-DX-FZR	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.08
HFC-DX-FZR	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04

Table 8: First Year Source Energy Savings (kBtu) Per Square Foot by Climate Zone (CZ) – RWH Evaporator Efficiency

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NH3-LO-CLR	1.00	1.16	1.09	1.15	1.09	1.17	1.17	1.22	1.19	1.25	1.24	1.23	1.26	1.20	1.34	1.05
NH3-DX-CLR	3.21	3.91	3.67	3.83	3.62	3.89	3.82	4.09	4.00	4.10	3.96	3.96	4.06	3.89	4.47	3.51
HFC-DX-CLR	1.01	1.17	1.11	1.16	1.11	1.17	1.15	1.22	1.20	1.23	1.22	1.22	1.24	1.19	1.36	1.04
NH3-LO-FZR	0.73	0.77	0.77	0.77	0.77	0.78	0.76	0.78	0.77	0.77	0.77	0.77	0.77	0.77	0.79	0.74
NH3-DX-FZR	1.35	1.37	1.39	1.45	1.35	1.38	1.37	1.42	1.40	1.39	1.37	1.33	1.36	1.39	1.43	1.31
HFC-DX-FZR	0.59	0.63	0.63	0.63	0.63	0.63	0.65	0.63	0.64	0.64	0.64	0.63	0.64	0.64	0.66	0.64

Table 9: First Year Long-term Systemwide Cost Savings (2026 PV$) Per Square Foot – RWH Evaporator Efficiency

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NH3-LO-CLR	3.38	3.93	3.70	3.89	3.70	3.99	4.00	4.16	4.08	4.27	4.18	4.16	4.25	4.06	4.57	3.56
NH3-DX-CLR	10.90	13.40	12.41	13.03	12.20	13.17	13.05	13.94	13.72	14.13	13.60	13.61	13.93	13.47	15.49	11.92
HFC-DX-CLR	3.44	4.00	3.78	4.00	3.79	4.03	3.97	4.20	4.16	4.27	4.20	4.20	4.28	4.13	4.75	3.57
NH3-LO-FZR	2.48	2.62	2.62	2.61	2.62	2.67	2.60	2.65	2.65	2.64	2.61	2.61	2.62	2.61	2.69	2.54
NH3-DX-FZR	4.65	4.81	4.66	5.03	4.53	4.65	4.89	4.91	4.94	4.95	4.80	4.70	4.81	4.98	5.06	4.64
HFC-DX-FZR	1.98	2.17	2.14	2.18	2.13	2.16	2.21	2.17	2.20	2.20	2.20	2.18	2.21	2.23	2.28	2.18

2.4 Cost and Cost Effectiveness

2.4.1 Incremental First Cost

The Statewide CASE Team reviewed the incremental cost information using data from equipment manufacturers. The 2022 cost data, along with 2026 LSC factors were used to recalculate cost effectiveness as it was determined the pricing per specific efficiency was inconclusive from the sampling of pricing.

In the CASE Report Section 4.4.3, cost data was obtained from multiple evaporator manufacturers as part of the market study. From this large database of evaporator models, first cost of the evaporator was plotted against specific efficiency ratings to determine a correlation of the incremental cost per unit increase of specific efficiency. Based on the results of the database analysis, there was no strong correlation between the cost provided by the manufacturer and the corresponding specific efficiency of the evaporator. There were multiple instances where models of similar capacity and similar cost had differences in specific efficiency by 20 percent or more. Therefore, the incremental first cost could be assumed to be zero, as there are usually models available in the market for similar cost but improved specific efficiency.

However, to not understate the cost of the proposed measure, the Statewide CASE Team developed a simplified methodology for the CASE Report described in Section 4.4.3 for determining the incremental cost of a more efficient evaporator. First, a representative unit with standard specific efficiency is assumed to have fan motors with variable frequency drives, per Title 24, Part 6 requirements. A fan speed was calculated to determine at what percent fan speed does the standard unit achieve the proposed specific efficiency value. This is possible because while capacity varies linearly with airflow across the coil (i.e., fan speed), power has a cubic relationship with fan speed. Subtracting the reduced fan speed value from 100 percent represents the percent increase to the coil surface area that would be necessary to achieve the full capacity of the standard unit. Using a simplifying assumption that incremental cost varies linearly with coil surface area, the incremental cost can be approximated to be the percent increase in surface area required. A standard evaporator with capacities between 20TR and 113TR was estimated to cost between $17,000 and $38,000. These cost values were multiplied by the total number of evaporators in each prototype to determine the assumed Standard Design first cost of evaporators. See Table 10 and Table 11 below.

See Section 4.4 of the CASE Report for additional information on the cost-effectiveness methodology used.

Table 10: Reduced Fan Speeds Required to Achieve Proposed Efficiency

Prototype ID	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value	Reduced Fan Speed of Standard Unit That Achieves Proposed Design Efficiency (%)	Assumed % Evaporator Incremental Cost
Small Refrigerated Warehouse	All	DX Halocarbon Specific Efficiency –Cooler Air Units	34 Btuh/W	45 Btuh/W	87%	13%
	All	DX Halocarbon Specific Efficiency –Freezer Air Units	34 Btuh/W	40 Btuh/W	92%	8%
	All	DX Ammonia Specific Efficiency –Cooler Air Units	20 Btuh/W	35 Btuh/W	76%	24%
	All	DX Ammonia Specific Efficiency –Freezer Air Units	20 Btuh/W	25 Btuh/W	89%	11%
Large Refrigerated Warehouse	All	Flooded/Recirc Ammonia Specific Efficiency –Cooler Air Units	34 Btuh/W	50 Btuh/W	82%	18%
	All	Flooded/Recirc Ammonia Specific Efficiency – Freezer Air Units	34 Btuh/W	45 Btuh/W	87%	13%

Table 11: Incremental First Cost Assumptions

Prototype ID	Climate Zone	Parameter Name	Assumed Standard Design Cost per Prototype ($)	Assumed % Evaporator Incremental Cost	Evaporator Incremental Cost per Prototype ($)	Evaporator Incremental Cost per ft2 ($/ft2)
Small Refrigerated Warehouse	All	DX Halocarbon Specific Efficiency –Cooler Air Units	$137,577	13%	$17,915	$0.69
	All	DX Halocarbon Specific Efficiency –Freezer Air Units	$98,854	8%	$7,682	$0.30
	All	DX Ammonia Specific Efficiency –Cooler Air Units	$197,219	24%	$48,135	$1.85
	All	DX Ammonia Specific Efficiency –Freezer Air Units	$142,857	11%	$15,082	$0.58
Large Refrigerated Warehouse	All	Flooded/Recirc Ammonia Specific Efficiency –Cooler Air Units	$250,719	18%	$43,971	$0.48
	All	Flooded/Recirc Ammonia Specific Efficiency – Freezer Air Units	$228,820	13%	$29,923	$0.33

2.4.2 Cost Effectiveness

The proposed code change is cost effective in every climate zone as indicated by a benefit-to-cost (B/C) ratio greater than one. Table 12 and Table 13 present the benefits, cost, and the B/C ratios for each system type for both new construction and alterations. Long-term Systemwide Cost (LSC) predominantly make up the benefits. The benefits and costs have other present value (PV) cost as described below. These values are weighted averages by the fraction of new construction and alterations statewide.

Table 12: 30-Year Cost-Effectiveness Summary Per Square Foot – New Construction/Additions

Prototype	Benefits LSC Savings + Other PV Savings [a] (2026 PV$/ft^2)	Costs Total Incremental PV Costs [b] (2026 PV$/ft^2)	Benefit-to-Cost Ratio
NH3-LO-CLR	4.07	0.48	8.5
NH3-DX-CLR	13.45	1.84	7.3
HFC-DX-CLR	4.12	0.69	6.0
NH3-LO-FZR	2.62	0.32	8.1
NH3-DX-FZR	4.80	0.58	8.3
HFC-DX-FZR	2.18	0.30	7.4
Total	5.08	0.67	7.5

a. **Benefits: Long-term Systemwide Cost Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis if PV of proposed costs is greater than PV of current costs. Costs are discounted at a real (inflation-adjusted) three percent rate. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

Table 13: 30-Year Cost-Effectiveness Summary Per Square Foot – Alterations

Prototype	Benefits LSC Savings + Other PV Savings [a] (2026 PV$)	Costs Total Incremental PV Costs [b] (2026 PV$)	Benefit-to-Cost Ratio
NH3-LO-CLR	4.12	0.48	8.6
NH3-DX-CLR	13.59	1.84	7.4
HFC-DX-CLR	4.16	0.69	6.0
NH3-LO-FZR	2.62	0.32	8.1
NH3-DX-FZR	4.79	0.58	8.3
HFC-DX-FZR	2.19	0.30	7.4
Total	4.79	0.63	7.5

a. **Benefits: Long-term Systemwide Cost Savings + Other PV Savings:** Benefits include LSC savings over the period of analysis (California Energy Commission 2022, 51-53). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost, incremental PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs, and incremental residual value if proposed residual value is greater than current residual value at end of CASE analysis period.
b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis if PV of proposed costs is greater than PV of current costs. Costs are discounted at a real (inflation-adjusted) three percent rate. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

Table 14 and Table 15 present the B/C ratios for every prototype and climate zone. Note that the B/C ratios are well above one for all climate zones and system types. This demonstrates that this measure is cost-effective for all system types in all climate zones.

Table 14: New Construction Benefit-Cost Ratio by Climate Zone for Each System Type

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NH3-LO-CLR	7.1	8.2	7.8	8.2	7.8	8.4	8.4	8.7	8.6	9.0	8.8	8.7	8.9	8.5	9.6	7.5
NH3-DX-CLR	5.9	7.3	6.7	7.1	6.6	7.1	7.1	7.6	7.4	7.7	7.4	7.4	7.6	7.3	8.4	6.5
HFC-DX-CLR	5.0	5.8	5.5	5.8	5.5	5.9	5.8	6.1	6.0	6.2	6.1	6.1	6.2	6.0	6.9	5.2
NH3-LO-FZR	7.6	8.1	8.1	8.1	8.1	8.2	8.0	8.2	8.2	8.2	8.1	8.1	8.1	8.1	8.3	7.8
NH3-DX-FZR	8.0	8.3	8.1	8.7	7.8	8.1	8.5	8.5	8.6	8.6	8.3	8.1	8.3	8.6	8.8	8.0
HFC-DX-FZR	6.7	7.3	7.2	7.4	7.2	7.3	7.5	7.4	7.4	7.5	7.4	7.4	7.5	7.6	7.7	7.4

Table 15: Alterations Benefit-Cost Ratio by Climate Zone for Each System Type

Prototype	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
NH3-LO-CLR	7.1	8.2	7.8	8.2	7.8	8.4	8.4	8.7	8.6	9.0	8.8	8.7	8.9	8.5	9.6	7.5
NH3-DX-CLR	5.9	7.3	6.7	7.1	6.6	7.1	7.1	7.6	7.4	7.7	7.4	7.4	7.6	7.3	8.4	6.5
HFC-DX-CLR	5.0	5.8	5.5	5.8	5.5	5.9	5.8	6.1	6.0	6.2	6.1	6.1	6.2	6.0	6.9	5.2
NH3-LO-FZR	7.6	8.1	8.1	8.1	8.1	8.2	8.0	8.2	8.2	8.2	8.1	8.1	8.1	8.1	8.3	7.8
NH3-DX-FZR	8.0	8.3	8.1	8.7	7.8	8.1	8.5	8.5	8.6	8.6	8.3	8.1	8.3	8.6	8.8	8.0
HFC-DX-FZR	6.7	7.3	7.2	7.4	7.2	7.3	7.5	7.4	7.4	7.5	7.4	7.4	7.5	7.6	7.7	7.4

2.5 First Year Statewide Impacts

The Statewide CASE Team revised calculations for the statewide savings impacts based on the revised new construction forecast for refrigerated warehouses. The construction forecast indicates a significantly lower trend in new construction in the year 2026 compared to 2023. The statewide new construction forecast for 2026 is presented in Appendix B. Statewide impacts each system configuration type was calculated by multiplying the per-square foot savings presented in Section 2.3, by the assumptions about the percentage of newly constructed that would be impacted by the proposed code and assumptions on the prevalence of each system type.

In general, the refrigerated warehouse market is impacted by both federal and state regulations around acceptable refrigerants to be used in new refrigerated warehouses buildings. These requirements would drive most facilities to use natural refrigerants, primarily being ammonia and carbon dioxide. Synthetic hydrofluorocarbon (HFC) refrigerants are still expected to be used in small facilities but require multiple systems to stay within the refrigerant regulations.

Alterations of existing systems do include some triggers of the refrigerant regulation as well, leading to some switching from hydrochlorofluorocarbons (HCFC) or HFC refrigerants to ammonia or carbon dioxide. However, most of the existing refrigerated warehouse systems use ammonia, and any alterations of existing spaces would have those spaces continue to use ammonia as the refrigerant.

Table 16 summarizes the assumptions of new construction and alterations.

Table 16: 2026 Statewide Construction System Type Assumptions

System Type	New Construction and Additions (Percent Square Footage)	Alterations (Percent Square Footage)
Cooler/Dock Ammonia Liquid Overfeed	30%	1.5%
Cooler/Dock Ammonia DX	15%	0.6%
Cooler/Dock HFC DX	3%	0.25%
Cooler/Dock CO2 Liquid Overfeed	3%	0.05%
Cooler/Dock CO2 DX	9%	0.6%
Freezer Ammonia Liquid Overfeed	20%	1.0%
Freezer Ammonia DX	10%	0.4%
Freezer HFC DX	2%	0.15%
Freezer CO2 Liquid Overfeed	2%	0.05%
Freezer CO2 DX	6%	0.4%
Total	100%	5%

Considering the assumed comparably low effected square footage that would use carbon dioxide as a refrigerant, the 2026 Statewide Impact Analysis used savings for a comparable efficiency HFC refrigerant for projecting the statewide impact of CO_2.

Table 17 and Table 18 present the first-year statewide energy and cost savings by climate zone. Table 19 summarizes the first-year statewide savings. Note that the CEC forecast of construction of refrigerated warehouses expects that no refrigerated warehouses would be constructed or expanded in Climate Zones 1, 2, 7, and 11. Material impacts were not updated with this report. See CASE Report Section 4.5.4 for additional details.

Table 17: Statewide Energy and Energy Cost Impacts – New Construction and Additions

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Square Feet)	First-Year [a] Electricity Savings (kWh)	First-Year Peak Electrical Demand Reduction (kW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	-	-	-	-	-	$0.00
2	-	-	-	-	-	$0.00
3	60,980	52.471	5.316	-	0.085	$0.29
4	50,670	46.109	4.485	-	0.074	$0.25
5	14,310	12.230	1.226	-	0.020	$0.07
6	22,040	19.920	1.980	-	0.032	$0.11
7	-	-	-	-	-	$0.00
8	6,830	6.477	0.636	-	0.010	$0.04
9	13,220	12.396	1.211	-	0.020	$0.07
10	38,740	37.357	3.622	-	0.059	$0.20
11	-	-	-	-	-	$0.00
12	68,490	64.343	6.339	-	0.102	$0.35
13	118,100	113.354	10.985	-	0.180	$0.62
14	7,633	7.108	0.692	-	0.011	$0.04
15	7,893	8.193	0.790	-	0.013	$0.04
16	5,170	4.295	0.429	-	0.007	$0.02
Total	414,076	384.250	37.711	-	0.615	$2.10

a. First-year savings from all buildings completed statewide in 2026.

Table 18: Statewide Energy and Energy Cost Impacts – Alterations

Climate Zone	Statewide New Construction & Additions Impacted by Proposed Change in 2026 (Square Feet)	First-Year [a] Electricity Savings (kWh)	First-Year Peak Electrical Demand Reduction (kW)	First-Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
1	236	0.17	0.017	-	0.000	$0.00
2	22,780	19.43	1.927	-	0.031	$0.11
3	45,520	36.64	3.705	-	0.059	$0.20
4	10,615	9.02	0.879	-	0.014	$0.05
5	19,315	15.46	1.548	-	0.025	$0.08
6	22,830	19.30	1.920	-	0.031	$0.11
7	1,167	0.98	0.097	-	0.002	$0.01
8	21,065	18.64	1.830	-	0.030	$0.10
9	39,325	34.42	3.368	-	0.055	$0.19
10	32,605	29.34	2.852	-	0.047	$0.16
11	13,145	11.59	1.136	-	0.018	$0.06
12	107,300	94.22	9.299	-	0.150	$0.51
13	195,350	175.16	17.029	-	0.279	$0.96
14	9,210	8.01	0.782	-	0.013	$0.04
15	9,695	9.39	0.907	-	0.015	$0.05
16	7,220	5.61	0.560	-	0.009	$0.03
Total	557,378	487.39	47.858	-	0.779	$2.67

a. First-year savings from all buildings completed statewide in 2026.

Table 19: Statewide Energy and Energy Cost Impacts – New Construction, Additions, and Alterations

Construction Type	First-Year [a] Electricity Savings (MWh)	First-Year Peak Electrical Demand Reduction (kW)	First -Year Natural Gas Savings (Million Therms)	First-Year Source Energy Savings (Million kBtu)	30-Year Present Valued LSC Savings (Million 2026 PV$)
New Construction & Additions	0.384	37.711	-	0.61	2.10
Alterations	0.487	47.858	-	0.78	2.67
Total	0.872	85.569	-	1.39	4.77

a. First-year savings from all alterations completed statewide in 2026.

3. Proposed Revisions to Code Language

3.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2022 documents are marked with red underlining (new language) and ~~strikethroughs~~ (deletions).

3.2 Standards

SECTION 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES

Nonresidential~~, high-rise residential,~~ and hotel/motel buildings shall comply with the applicable requirements of Sections 120.6(a) through 120.6(g).

(a) Mandatory Requirements for Refrigerated Warehouses

Refrigerated warehouses that are greater than or equal to 3,000 square feet and refrigerated spaces with a sum total of 3,000 square feet or more that are served by the same refrigeration system shall meet the requirements of Section 120.6(a).

Refrigerated spaces that are less than 3,000 square feet shall meet the requirements of the Appliance Efficiency Regulations for walk-in coolers or freezers contained in the Appliance Efficiency Regulations (California Code of Regulations, Title 20, Sections 1601 through 1608).

…

3. **Evaporators.** New fan-powered evaporators used in coolers and freezers shall conform to the following:

A. Single phase fan motors less than 1 hp and less than 460 Volts in newly installed evaporators shall be electronically commutated motors or shall have a minimum motor efficiency of 70 percent when rated in accordance with NEMA Standard MG 1-2006 at full load rating conditions.

B. Evaporator fans served either by a suction group with multiple compressors, or by a single compressor with variable capacity capability shall be variable speed and the speed shall be controlled in response to space temperature or humidity.

EXCEPTION 1 to Section 120.6(a)3B: Addition, alteration or replacement of less than all of the evaporators in an existing refrigerated space that does not have speed-controlled evaporators.

EXCEPTION 2 to Section 120.6(a)3B: Coolers within refrigerated warehouses that maintain a Controlled Atmosphere for which a licensed engineer has certified that the types of products stored will require constant operation at 100 percent of the design airflow.

EXCEPTION 3 to Section 120.6(a)3B: Areas within refrigerated warehouses that are designed solely for the purpose of quick chilling/freezing of products, including but not limited to spaces with design cooling capacities of greater than 240 Btu/hr-ft² (2 tons per 100 ft²).

C. Evaporator fans served by a single compressor that does not have variable capacity shall utilize controls to reduce airflow by at least 40 percent for at least 75 percent of the time when the compressor is not running.

EXCEPTION to Section 120.6(a)3C: Areas within refrigerated warehouses that are designed solely for the purpose of quick chilling/freezing of products (space with design cooling capacities of greater than 240 Btu/hr-ft² (2 tons per 100 ft²)).

D. Fan-powered evaporators utilizing volatile refrigerants shall meet the applicable efficiency requirements listed in TABLE 120.6-F.

Evaporator specific efficiency is defined as the gross total refrigeration capacity (Btu/h) divided by the electrical input power at 100 percent fan speed at rating conditions listed in Table 120.6-F following the test procedure listed in Table 120.6-F.

EXCEPTION to Section 120.6(a)3D: Evaporators designed solely for the purpose of quick chilling/freezing of products, including but not limited to spaces with design cooling capacities of greater than 240 Btu/hr-ft² (2 tons per 100 ft²).

TABLE 120.6-F FAN-POWERED EVAPORATORS - MINIMUM SPECIFIC EFFICIENCY REQUIREMENTS

Evaporator Type[1][2]	***Size Category***	***Rating Condition***	***Efficiency***	***Test Procedure[3]***
Direct Expansion, Ammonia Refrigerant, Cooler/Dock	All Capacities	Dry coil +25°F saturated evaporating temp +35°F entering drybulb temp 0 in. water static pressure	35 *Btuh/Watt*	AHRI 420
Direct Expansion, Ammonia Refrigerant, Freezer	All Capacities	Dry coil -20°F saturated evaporating temp -10°F entering drybulb temp 0 in. water static pressure	25 *Btuh/Watt*	AHRI 420
Liquid Overfeed, Ammonia Refrigerant, Cooler/Dock	All Capacities	Dry coil +25°F saturated evaporating temp +35°F entering drybulb temp 0 in. water static pressure	50 *Btuh/Watt*	AHRI 420
Liquid Overfeed, Ammonia Refrigerant, Freezer	All Capacities	Dry coil -20°F saturated evaporating temp -10°F entering drybulb temp 0 in. water static pressure	45 *Btuh/Watt*	AHRI 420
Direct Expansion, CO2 Refrigerant, Cooler/Dock	All Capacities	Dry coil +25°F saturated evaporating temp +35°F entering drybulb temp 0 in. water static pressure	35 *Btuh/Watt*	AHRI 420
Direct Expansion, CO2 Refrigerant,	All Capacities	Dry coil -20°F saturated evaporating temp	25 *Btuh/Watt*	AHRI 420

Freezer		-10°F entering drybulb temp 0 in. water static pressure		
Liquid Overfeed, CO_2 Refrigerant, Cooler/Dock	All Capacities	Dry coil +25°F saturated evaporating temp +35°F entering drybulb temp 0 in. water static pressure	50 *Btuh/Watt*	AHRI 420
Liquid Overfeed, CO_2 Refrigerant, Freezer	All Capacities	Dry coil -20°F saturated evaporating temp -10°F entering drybulb temp 0 in. water static pressure	45 *Btuh/Watt*	AHRI 420
Direct Expansion, Halocarbon Refrigerant, Cooler/Dock	All Capacities	Dry coil +25°F saturated evaporating dew point temp +35°F entering air drybulb temp 0 in. water static pressure	45 *Btuh/Watt*	AHRI 1250
Direct Expansion, Halocarbon Refrigerant, Freezer	All Capacities	Dry coil -20°F saturated evaporating dew point temp -10°F entering drybulb temp 0 in. water static pressure	40 *Btuh/Watt*	AHRI 1250

E. The applied static pressure drop for evaporators shall not exceed 0.5 in. water.

EXCEPTION to Section 120.6(a)3E: Areas within refrigerated warehouses that are designed solely for the purpose of quick chilling/freezing of products (space with design cooling capacities of greater than 240 Btu/hr-ft² (2 tons per 100 ft²)).

[1] Direct Expansion: Evaporator in which leaving refrigerant vapor is superheated.

[2] Liquid Overfeed: Evaporator in which refrigerant liquid is supplied at a recirculation rate greater than 1.

[3] Applicable test procedure and reference year are provided under the definitions.

3.3 Reference Appendices

There are no proposed changes to the Reference Appendices.

3.4 ACM Reference Manual

There are no proposed changes to the ACM Reference Manual.

3.5 Compliance Forms

Compliance documents NRCC-PRC-E would need to be revised. A new table would be added to the compliance form that would allow the design team to add information related to the evaporators, resulting in an automatic calculation of the evaporator specific efficiency, and whether it is code compliant based on the space temperature application, liquid feed type and refrigerant.

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Appendix A: Costs in Nominal Dollars

The CEC requested energy cost savings over the 30-year period of analysis in both 2026 present value dollars (2026 PV$) and nominal dollars. The cost-effectiveness analysis uses energy cost values in 2026 PV$. Costs and cost effectiveness using and 2026 PV$ are presented in Section 2.4 - Cost and Cost Effectiveness. Table 20 and Table 21 presents energy cost savings in nominal dollars for new construction and additions, and alterations, respectively.

Table 20: Nominal Life Cycle Energy Cost Savings Over 30-Year Period of Analysis – Per Square Foot – New Construction – Refrigerated Warehouse

Climate Zone	30-Year Life Cycle Electricity Cost Savings (Nominal $)	30-Year Life Cycle Natural Gas Cost Savings (Nominal $)	Total 30-Year Life Cycle Energy Cost Savings (Nominal $)
1	$0.00	$0.00	$0.00
2	$0.00	$0.00	$0.00
3	$10.71	$0.00	$10.71
4	$11.21	$0.00	$11.21
5	$10.61	$0.00	$10.61
6	$11.26	$0.00	$11.26
7	$0.00	$0.00	$0.00
8	$11.76	$0.00	$11.76
9	$11.62	$0.00	$11.62
10	$11.93	$0.00	$11.93
11	$0.00	$0.00	$0.00
12	$11.58	$0.00	$11.58
13	$11.82	$0.00	$11.82
14	$11.51	$0.00	$11.51
15	$12.82	$0.00	$12.82
16	$10.34	$0.00	$10.34

Table 21: Nominal Life Cycle Energy Cost Savings Over 30-Year Period of Analysis – Per Square Foot – Alterations – Refrigerated Warehouse

Climate Zone	30-Year Life Cycle Electricity Cost Savings (Nominal $)	30-Year Life Cycle Natural Gas Cost Savings (Nominal $)	Total 30-Year Life Cycle Energy Cost Savings (Nominal $)
1	$9.13	$0.00	$9.13
2	$10.55	$0.00	$10.55
3	$10.01	$0.00	$10.01
4	$10.47	$0.00	$10.47
5	$9.93	$0.00	$9.93
6	$10.53	$0.00	$10.53
7	$10.50	$0.00	$10.50
8	$10.97	$0.00	$10.97
9	$10.85	$0.00	$10.85
10	$11.13	$0.00	$11.13
11	$10.87	$0.00	$10.87
12	$10.83	$0.00	$10.83
13	$11.05	$0.00	$11.05
14	$10.76	$0.00	$10.76
15	$11.96	$0.00	$11.96
16	$9.66	$0.00	$9.66

Appendix B: 2026 Construction Forecast

Table 22 documents the construction forecast in 2026 and the impacted square footage by climate zone.

Table 22: Estimated New Construction and Existing Building Stock in 2026, by Climate Zone for Refrigerated Warehouses

Climate Zone	New Constructions or Additions in 2026 (Square Feet)	Existing Building Stock in 2026 (Square Feet)
1	0	4,721
2	0	455,600
3	60,980	910,400
4	50,670	212,300
5	14,310	386,300
6	22,040	456,600
7	0	23,340
8	6,830	421,300
9	13,220	786,500
10	38,740	652,100
11	0	262,900
12	68,490	2,146,000
13	118,100	3,907,000
14	7,633	184,200
15	7,893	193,900
16	5,170	144,400
Total	414,076	11,147,561

Table 23 summarizes how the mandatory requirements impact the above square footage by climate zone. The requirements would impact all refrigerant types and system configurations in 2026 for new construction and additions therefore all square footage is impacted. Evaporators have a nominal useful life of 15 years, but many evaporators effectively operate for additional years. It is assumed that existing evaporators would have a 20-year useful life, assuming five percent of the existing evaporators are replaced each year.

Table 23: Percent of New Construction and/or Additions Impacts by RWH Evaporator Specific Efficiency, by Climate Zone

Climate Zone	New Constructions and Additions (Percent of Square Footage Impacted)	Existing Building Stock (Alterations) (Percent of Square Footage Impacted)
1	100%	5%
2	100%	5%
3	100%	5%
4	100%	5%
5	100%	5%
6	100%	5%
7	100%	5%
8	100%	5%
9	100%	5%
10	100%	5%
11	100%	5%
12	100%	5%
13	100%	5%
14	100%	5%
15	100%	5%
16	100%	5%

Attachment: 2022 Refrigeration System Opportunities CASE Report

Codes and Standards Enhancement (CASE) Initiative 2022 California Energy Code

Refrigeration System Opportunities

2022-NR-COV-PROC2-F | Nonresidential, Covered Processes

FINAL CASE REPORT

Prepared by VaCom Technologies

October 2020

Please submit comments to info@title24stakeholders.com.

Document Information

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Authors:	Trevor Bellon and Doug Scott (VaCom Technologies)
Prime Contractor	Energy Solutions
Project Management:	California Statewide Utility Codes and Standards Team: Pacific Gas and Electric Company, Southern California Edison, San Diego Gas & Electric Company, Los Angeles Department of Water and Power, Sacramento Municipal Utility District.

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Executive Summary

This document presents recommended code changes that the California Energy Commission will be considering for adoption in 2021. If you have comments or suggestions prior to the adoption, please email info@title24stakeholders.com. Comments will not be released for public review or will be anonymized if shared.

Introduction

The Codes and Standards Enhancement (CASE) Initiative presents recommendations to support the California Energy Commission's (Energy Commission) efforts to update the California Energy Code (Title 24, Part 6) to include new requirements or to upgrade existing requirements for various technologies. Three California Investor Owned Utilities (IOUs) – Pacific Gas and Electric Company, San Diego Gas and Electric, and Southern California Edison – and two Publicly Owned Utilities – Los Angeles Department of Water and Power and Sacramento Municipal Utility District (herein referred to as the Statewide CASE Team when including the CASE Author) – sponsored this effort. The program goal is to prepare and submit proposals that will result in cost-effective enhancements to improve energy efficiency and energy performance in California buildings. This report and the code change proposals presented herein are a part of the effort to develop technical and cost-effectiveness information for proposed requirements on building energy-efficient design practices and technologies.

The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2022 Title 24 website for information about the rulemaking schedule and how to participate in the process: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

The overall goal of this Final CASE Report is to present a code change proposal for refrigeration systems utilized in refrigerated warehouses and commercial applications (supermarkets). The report contains pertinent information supporting the code change.

Measure Description

Background Information

Submeasure A: Design and Control Requirements for Transcritical CO_2 Systems

Transcritical CO_2 refrigeration systems are a growing technology alternative for owners seeking low global warming potential (GWP) refrigeration systems utilized in commercial refrigeration and refrigerated warehouses. Due to its low critical point of 87°F CO_2 as a refrigerant requires unique design and control requirements compared to other refrigeration systems with more common refrigerant types (ammonia, halocarbons). The proposed code changes provide the first code requirements in Title 24, Part 6 for these system types to clarify best practices for designers and owners.

Submeasure B: Minimum Air-Cooled Condenser Sizing and Specific Efficiency for Packaged Refrigeration Systems

Packaged refrigeration systems combine all the components of a refrigeration system into modular units that can be distributed around a building to replace large centralized systems. They typically use ammonia as the refrigerant but avoid the need for a large single charge, thus providing refrigerated warehouse owners an option for a low GWP refrigeration system.

A market study was conducted to understand how current code requirements originally designed for large central systems affect the design and cost effectiveness of packaged systems. The proposed code changes would reduce the minimum size requirement for air cooled condensers for these systems to make them more cost effective.

Submeasure C: Evaporator Specific Efficiency

In a mechanical refrigeration system, the evaporator is the component that absorbs heat from the air inside the space being cooled. Evaporator efficiency is based on the amount of heat it can absorb divided by the amount of power that must be consumed by the fan motors which are used to evenly distribute the cool air throughout the space. A market study was conducted to understand the efficiency of available products, and a cost-effectiveness analysis was performed to establish reasonable minimum evaporator specific efficiency thresholds that result in statewide energy savings.

Submeasure D: Automatic Door Closers

The proposed code changes add requirements for automatic door closers for refrigerated warehouses to further reduce infiltration. Infiltration occurs when warmer air enters the space being cooled and can account for up to 30 percent of refrigeration loads in refrigerated warehouses. High amounts of infiltration load place a higher load on mechanical refrigeration systems and thus result in wasted energy.

Submeasure E: Acceptance Testing for Commercial Refrigeration

Requirements for commercial refrigeration systems have been included in Title 24, Part 6 since 2013. However, acceptance testing for key energy savings requirements has not yet been included in the reference appendices. Without acceptance testing procedures, installations in California may not be in full compliance resulting in an increase in statewide energy usage. This Final CASE Report proposes acceptance testing procedures to improve future compliance.

Proposed Code Changes

Submeasure A: Design and Control Requirements for Transcritical CO_2 Systems

The proposed code changes would result in the following requirements for transcritical CO_2 refrigeration systems utilized in commercial refrigeration and refrigerated warehouses:

- Restrictions on air-cooled gas coolers in high ambient temperature climate zones to reduce the number of supercritical operating hours. Alternatives to air cooled gas coolers include water cooled condensers connected to a cooling tower, adiabatic gas coolers, and evaporative gas coolers.
    - Restricted Climate Zones for Refrigerated Warehouses: Climate Zone 9, 10, 11, 12, 13, 14, and 15
    - Restricted Climate Zones for Commercial Refrigeration: Climate Zone 10, 11, 12, 13, 14, and 15
- Minimum air-cooled and adiabatic gas cooler sizing and specific efficiency. This is to ensure cost-effective design of the refrigeration system's heat rejection equipment, balancing first cost of the equipment and the additional energy savings that are achieved with larger heat exchanger surfaces.
- Supercritical optimized head pressure control, which allows for the head pressure setpoint to be reset in response to ambient conditions
- Ambient temperature reset control strategy to control head pressure during subcritical operation
- Minimum saturated condensing temperature of 60°F for systems with design saturated suction temperatures of less than 30°F (otherwise 70°F)
- Heat recovery for transcritical CO_2 systems in supermarkets. Refrigeration equipment in supermarkets creates a heating load to maintain comfortable space temperatures for shoppers. As a result, supermarkets require heating for more hours than most occupancies. In most climate zones, waste heat from the refrigeration system can be recovered to provide it more efficiently. Heat recovery is already required for other refrigeration technologies, but heat recovery equipment for high pressure CO_2 systems have different costs and savings.

Submeasure B: Minimum Air-Cooled Condenser Sizing and Specific Efficiency for Packaged Refrigeration Systems

The proposed code change would decrease the minimum sizing and specific efficiency requirements for air cooled condensers that are integrated into a large packaged refrigeration system as summarized in the table below.

Table 1: Packaged Refrigeration System Code Change Summary

	Existing Requirement	Proposed Requirement
Freezer Systems (Sizing)	10°F	15°F
Cooler/Dock Systems (Sizing)	15°F	20°F
All Systems Types (Specific Efficiency)	75 Btuh/Watt (Ammonia)	60 Btuh/Watt
All Systems Types (Specific Efficiency)	65 Btuh/Watt (Halocarbon)	60 Btuh/Watt

The code language would also exempt packaged units below a certain compressor horsepower, similar to the existing exemption for condensing units below a certain size.

Submeasure C: Evaporator Specific Efficiency

The proposed code change would set a minimum evaporator specific efficiency in non-process cooling/freezing applications in refrigerated warehouses. After an extensive market study of costs and efficiency of evaporators, only units with efficiencies in the top 60th percentile would be allowed (i.e., 40 percent of current products would not be not compliant). The proposed thresholds are summarized below.

Table 2: Evaporator Specific Efficiency Proposed Thresholds

Evaporator Application	Liquid Feed Type	Refrigerant Type	Minimum Efficiency
Freezer	Direct Expansion	Halocarbon	40 Btuh/Watt
Freezer	Direct Expansion	Ammonia	25 Btuh/Watt
Freezer	Flooded/Recirculated Liquid	Ammonia	45 Btuh/Watt
Cooler	Direct Expansion	Halocarbon	45 Btuh/Watt
Cooler	Direct Expansion	Ammonia	35 Btuh/Watt
Cooler	Flooded/Recirculated Liquid	Ammonia	50 Btuh/Watt

Submeasure D: Automatic Door Closers

The proposed code change would require two types of automatic door closers to be installed on doors in refrigerated warehouses that separate a colder freezer, cooler, or dock space from a warmer temperature space or the outside. These two door types are an automatic hinge that closes the door from an open position, as well as a tight sealing mechanism that closes the door completely if slightly ajar (approximately one inch opened).

Submeasure E: Acceptance Testing for Commercial Refrigeration

The proposed acceptance testing procedures for commercial refrigeration add new language added to the Nonresidential Appendix NA7 to cover the following measures:

- Condensers and Condenser Fan Motor Variable Speed Control (air cooled, evaporative cooled, and adiabatic)
- Compressor Floating Suction Controls
- Liquid Subcooling
- Refrigerated Display Case Lighting (motion sensor and automatic time switch controls)
- Refrigeration Heat Recovery

Scope of Code Change Proposal

summarizes the scope of the proposed changes and which sections of Standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manual, and compliance documents that would be modified as a result of the proposed change(s).

Table 3: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Section(s) of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Would ACM Reference Manual Be Modified	Modified Compliance Document(s)
Design and Control Requirements for Transcritical CO_2 Systems	Mandatory	Section 100.1; Section 120.6(a); Section 120.6(b)	Nonresidential Appendix NA7	No	NRCC-PRC-E
Minimum Air-Cooled Condenser Sizing Requirements for Packaged Refrigeration Systems	Mandatory	Section 120.6(a)4	N/A	No	NRCC-PRC-E
Minimum Evaporator Specific Efficiency Requirements	Mandatory	Section 120.6(a)3	N/A	No	NRCC-PRC-E
Automatic Door Closer Requirements	Mandatory	Section 120.6(a)7 (currently Section 120.6(a)6)	N/A	No	NRCC-PRC-E
Acceptance Testing Procedures for Commercial Refrigeration	Mandatory	N/A	Nonresidential Appendix NA7	No	NRCA-PRC

Market Analysis and Regulatory Assessment

Because all of the proposed code changes impact the commercial/industrial refrigeration market, the market structure is similar across all submeasures. Key market actors include manufacturers, distributors/sales representatives, design engineers, installation contractors, and end users. Refrigeration equipment is typically specified by design engineers or design build contractors and supplied by multiple original equipment manufacturers (OEMs).

Overall, the proposed code changes are not expected to have significant market or technical barriers as multiple suppliers offer equipment of various sizes and technologies.

Compliance for the proposed code changes is expected to follow similar procedures that already occur for ensuring compliance of existing code language for refrigerated warehouses and commercial refrigeration.

Cost Effectiveness

The code changes are being proposed to only those climate zones where they are found to be cost effective. code change was found to be cost effective for all climate zones where it is proposed to be required. The benefit-to-cost (B/C) ratio compares the benefits or cost savings to the costs over the 15-year period of analysis. Proposed code changes that have a B/C ratio of 1.0 or greater are cost effective. The larger the B/C ratio, the faster the measure pays for itself from energy cost savings. The B/C ratios for the qualifying equipment or climate zones after accounting for exceptions for each submeasure are summarized in the table below. See Sections 2.4, 3.4, 4.4, 5.4, and 6.4 for the methodology, assumptions, and results of the cost-effectiveness analysis.

Table 4: Benefit-to-Cost Ratio Range Summary

Submeasure Name	Prototype	Description	Minimum B/C Ratio	Maximum B/C Ratio	Excluded Climate Zones
Design and Control Requirements for Transcritical CO_2 Systems	Large Refrigerated Warehouse	Air-cooled gas cooler restriction	1.11	3.29	1, 2, 3, 4, 5, 6, 7, 8, 16
Design and Control Requirements for Transcritical CO_2 Systems	Large Refrigerated Warehouse	Gas Cooler Sizing (6F Approach)	1.02	3.49	2,4,8
Design and Control Requirements for Transcritical CO_2 Systems	Large Refrigerated Warehouse	Supercritical Optimized Head Pressure Control with Modulating Fan Speed	1.07	4.93	All
Design and Control Requirements for Transcritical CO_2 Systems	Large Supermarket	Air-cooled gas cooler restriction	1.14	4.66	1, 2, 3, 4, 5, 6, 7, 8, 9, 16
Design and Control Requirements for Transcritical CO_2 Systems	Large Supermarket	Gas Cooler Sizing (6F Approach)	1.52	9.27	N/A
Design and Control Requirements for Transcritical CO_2 Systems	Large Supermarket	Supercritical Optimized Head Pressure Control with Modulating Fan Speed	1.08	1.76	All
Design and Control Requirements for Transcritical CO_2 Systems	Large Supermarket	Heat Recovery	1.02	2.50	15
Minimum Air-Cooled Condenser Sizing Requirements for Packaged Refrigeration Systems	Large Refrigerated Warehouse	Revised minimum gas cooler sizing requirement (15-20F)	1.04	2.48	N/A
Minimum Evaporator Specific Efficiency Requirements	Small Refrigerated Warehouse	Cooler/Dock Evaporators – DX Halocarbon	2.21	3.21	N/A
Minimum Evaporator Specific Efficiency Requirements	Small Refrigerated Warehouse	Freezer Evaporators – DX Halocarbon	3.02	3.59	N/A
Minimum Evaporator Specific Efficiency Requirements	Small Refrigerated Warehouse	Cooler/Dock Evaporators – DX Ammonia	2.57	3.88	N/A
Minimum Evaporator Specific Efficiency Requirements	Small Refrigerated Warehouse	Freezer Evaporators – DX Ammonia	3.21	4.66	N/A
Minimum Evaporator Specific Efficiency Requirements	Large Refrigerated Warehouse	Cooler/Dock Evaporators – Flooded/Recirc Ammonia	3.36	6.18	N/A

Submeasure Name	Prototype	Description	Minimum B/C Ratio	Maximum B/C Ratio	Excluded Climate Zones
Minimum Evaporator Specific Efficiency Requirements	Large Refrigerated Warehouse	Freezer Evaporators – Flooded/Recirc Ammonia	3.50	7.85	N/A
Automatic Door Closer Requirements	Large Refrigerated Warehouse	Automatic door closers	1.26	1.61	16
Acceptance Testing Procedures for Commercial Refrigeration	Large Supermarket	N/A	3.10	22.00	N/A

Statewide Energy Impacts: Energy, Water, and Greenhouse Gas (GHG) Emissions Impacts

Table 5 presents the estimated energy and demand impacts of the proposed code change that would be realized statewide during the first 12 months that the 2022 Title 24, Part 6 requirements are in effect. First-year statewide energy impacts are represented by the following metrics: electricity savings in gigawatt-hours per year (GWh/yr), peak electrical demand reduction in megawatts (MW), natural gas savings in million therms per year (MMTherms /yr), and time dependent valuation (TDV) energy savings in kilo British thermal units per year (TDV kBtu/yr). See Sections 2.5.1, 3.5, 4.5.1, 5.5.1, and 6.5 for more details on the first-year statewide impacts calculated by the Statewide CASE Team. Sections 2.3.2.3, 3.3, 4.3.2.3, 5.3.2.3, and 6.3 contains details on the per-unit energy savings calculated by the Statewide CASE Team.

For Submeasure A (Design and Control Requirements for Transcritical CO_2 Systems), the Statewide CASE Team's goal is to clarify best practices. Therefore, not all of the proposed code language results in incremental statewide savings or GHG impacts. In Table 5 and Table 6 below, first-year statewide energy savings does not include electricity or natural gas savings from the following submeasures, as they are either already assumed to be standard practice or already interpreted to be a requirement:

- Submeasure A: Minimum SCT of 60°F (standard practice)
- Submeasure A: Ambient following head pressure control during subcritical operation (standard practice)
- Submeasure A: Gas Cooler Optimized Head Pressure Control without fan speed modulation (standard practice)
- Submeasure A: Gas Cooler Specific Efficiency (standard practice)
- Submeasure A: Adiabatic Gas Cooler Sizing (standard practice)
- Submeasure A: Heat Recovery (already interpreted to be a requirement in Section 120.6(b), although never explicitly analyzed in previous CASE Reports)

First-year statewide energy savings for Submeasure A include restriction on air cooled gas coolers and air-cooled gas cooler sizing.

Table 5: First-Year Statewide Energy and Impacts

Measure	Electricity Savings (GWh/yr)	Peak Electrical Demand Reduction (MW)	Natural Gas Savings (MMTherms/yr)	TDV Energy Savings (million TDV kBtu/yr)
Design and Control Requirements for Transcritical CO_2 Systems (Total)	**1.51**	**1.13**	**0**	**7.02**
New Construction	1.51	1.13	0	7.02
Additions and Alterations	N/A	N/A	N/A	N/A
Minimum Air-Cooled Condenser Sizing and Specific Efficiency of Package Refrigeration Systems	**N/A**	**N/A**	**N/A**	**N/A**
Evaporator Specific Efficiency (Total)	**6.64**	**1.94**	**0**	**186.7**
New Construction	2.13	0.63	0	60.0
Additions and Alterations	4.51	1.31	0	126.7
Automatic Door Closers (Total)	**0.36**	**0.00**	**0**	**10.4**
New Construction	0.11	0.00	0	3.1
Additions and Alterations	0.25	0.00	0	7.2
Acceptance Testing for Commercial Refrigeration	**N/A**	**N/A**	**N/A**	**N/A**
TOTAL	**8.51**	**3.07**	**0**	**204.1**

Overall, the proposed code language associated with Submeasure A is expected to reduce the energy consumption of refrigerated warehouses and large supermarkets by 10 percent and 5 percent respectively per prototype. Submeasure B does not result in an increase to the stringency of the energy code, and therefore no statewide savings are reported. Submeasure C is expected to reduce the energy consumption for refrigerated warehouses by 3-9 percent per prototype depending on the selected refrigeration system and refrigerant. Submeasure D is expected to reduce the energy consumption for refrigerated warehouse by 1 percent. Submeasure E does not result in an increase to the stringency of the energy code, and therefore no statewide savings are reported.

Table 6 presents the estimated avoided GHG emissions associated with the proposed code change for the first year the standards are in effect. Avoided GHG emissions are measured in metric tons of carbon dioxide equivalent (metric tons CO_2e). Assumptions used in developing the GHG savings are provided in Sections 2.5.2, 4.5.2, 5.5.2 and Appendix F of this report. The monetary value of avoided GHG emissions is included in TDV cost factors and is thus included in the cost-effectiveness analysis.

Table 6: First-Year Statewide GHG Emissions Impacts

Measure	Avoided GHG Emissions (Metric Tons CO_2e/yr)	Monetary Value of Avoided GHG Emissions ($2023)
Design and Control Requirements for Transcritical CO_2 Systems	140	$14,848
Minimum Air-Cooled Condenser Sizing and Specific Efficiency of Package Refrigeration Systems	N/A	N/A
Evaporator Specific Efficiency	380	$40,277
Automatic Door Closers	19	$2,040
Acceptance Testing for Commercial Refrigeration	N/A	N/A
Total	**539**	**$57,165**

Water and Water Quality Impacts

The proposed measure is not expected to have any impacts on water quality, excluding impacts that occur at power plants. Water use may increase due to the proposed measure of restricting air-cooled gas coolers for transcritical CO_2 systems (Submeasure A). The average expected incremental annual water usage per refrigerated warehouse prototype and large supermarket prototype is 890,000 gallons per year and 456,000 gallons per year respectively assuming the use of adiabatic gas coolers.

Compliance and Enforcement

Overview of Compliance Process

The Statewide CASE Team worked with stakeholders to develop a recommended compliance and enforcement process and to identify the impacts this process would have on various market actors. The compliance process is described in Sections 2.1.5, 3.1.5, 4.1.5, 5.1.5, and 6.1.5. Impacts that the proposed measure would have on market actors is described in Appendix F. The key issues related to compliance and enforcement are summarized below:

- Evaporator manufacturers would be required to provide new information as part of their typical equipment submittal documentation (input power and capacity at particular rating conditions).
- Individuals that perform acceptance testing would need to be trained on how to perform new acceptance testing procedures related to commercial refrigeration and transcritical CO_2 systems.
- There currently does not exist any compliance mechanisms related to Title 24, Part 6 that are able to confirm published evaporator ratings to actual evaporator performance. Exploration of requiring evaporator manufacturers to provide certified ratings was explored but cannot be recommended at this time due to multiple competing standards and ongoing discussions in the industry as to which standard is most applicable.

Field Verification and Acceptance Testing

Submeasure A: Design and Control Requirements for Transcritical CO_2 Systems

The only requirement that would require developing new acceptance testing would be for gas cooler control. The testing would be like the condenser acceptance test procedures already developed for refrigerated warehouses.

Compliance for the gas cooler sizing and specific efficiency requirements, restriction of air-cooled gas coolers, and minimum saturated condensing temperature (SCT) requirement would not require additional acceptance testing. Compliance would be achieved through initial permit review of the selected refrigeration equipment, and simple field verification of the minimum SCT setpoint and installed gas cooler type. The existing compliance form used for refrigerated warehouses and commercial refrigeration would be modified for the designer to indicate the page of the construction documents where the particular feature is specified and a checkbox to prompt the building inspector to verify the requirements.

Submeasure B: Minimum Air-Cooled Condenser Sizing and Specific Efficiency for Packaged Refrigeration Systems

Compliance for the revised minimum air-cooled condenser sizing and specific efficiency requirement for packaged refrigeration systems would not require additional acceptance testing. Compliance would be achieved through initial permit review of the selected refrigeration equipment, a completed certificate of installation by the installing contractor and building department inspection of the installed air-cooled condenser. The existing compliance form used for refrigerated warehouses would be modified to prompt the building inspector to verify the requirements and fill out check boxes accordingly.

Submeasure C: Evaporator Specific Efficiency

Compliance for the proposed minimum evaporator specific efficiency requirements would not require additional acceptance testing. Compliance would be achieved through initial permit review of the selected refrigeration equipment, a completed certificate of installation that confirming that the specified efficiency of evaporators were installed and building department inspection of the installed evaporators. The existing compliance form used for refrigerated warehouses would be modified to prompt the building inspector to verify the requirements and fill out check boxes accordingly. Evaporator manufactures would be required to provide rated input power requirements (kW), which is currently not typically provided as part of equipment submittal documentation.

Submeasure D: Automatic Door Closers

Compliance for the proposed automatic door closer requirements would not require additional acceptance testing. Compliance would be achieved through initial permit review of the equipment specified in the door schedule of plan drawings, and building department inspection that the automatic door closer hardware is installed.

Submeasure E: Acceptance Testing for Commercial Refrigeration

This proposed submeasure would add acceptance testing procedures to existing code requirements.

1. Introduction

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The Statewide CASE Team submits code change proposals to the Energy Commission, the state agency that has authority to adopt revisions to Title 24, Part 6. The Energy Commission will evaluate proposals submitted by the Statewide CASE Team and other stakeholders. The Energy Commission may revise or reject proposals. See the Energy Commission's 2022 Title 24 website for information about the rulemaking schedule and how to participate in the process: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

The overall goal of this Final CASE Report is to present a code change proposal for Refrigeration System Opportunities which consists of five main submeasure:

- *Submeasure A: Design and control requirements for transcritical CO_2 systems*
- *Submeasure B: Minimum air-cooled condenser sizing and specific efficiency for packaged refrigeration systems*
- *Submeasure C: Evaporator specific efficiency requirements for refrigerated warehouses*
- *Submeasure D: Automatic door closer requirements for refrigerated warehouses*
- *Submeasure E: Acceptance testing language for existing commercial refrigeration requirements*

The report contains pertinent information supporting the code change.

When developing the code change proposal and associated technical information presented in this report, the Statewide CASE Team worked with a number of industry stakeholders including manufacturers, engineers, facility owners/end users, and others involved in the code compliance process. The proposal incorporates feedback received during a public stakeholder workshop that the Statewide CASE Team held on November 7, 2019 and April 2, 2020.

The following is a brief summary of the contents of this report:

- Section 1 – Submeasure A: Design and Control Requirements for Transcritical CO_2 Systems
- Section 3 – Submeasure B: Air-Cooled Condenser Minimum Sizing and Specific Efficiency Requirements for Packaged Refrigeration Systems
- Section 4 – Submeasure C: Evaporator Specific Efficiency Requirements for Refrigerated Warehouses
- Section 5 – Submeasure D: Automatic Door Closer Requirements for Refrigerated Warehouses
- Section 6 – Submeasure E: Acceptance Testing Language for Existing Commercial Refrigeration Requirements
- Section 7 – Proposed Revisions to Code Language concludes the report with specific recommendations with ~~strikeout~~ (deletions) and <u>underlined</u> (additions) language for the Standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manual, Compliance Manual, and compliance documents.
- Bibliography presents the resources that the Statewide CASE Team used when developing this report.
- Appendix A: Statewide Savings Methodology presents the methodology and assumptions used to calculate statewide energy impacts.
- Appendix B: Embedded Electricity in Water Methodology presents the methodology and assumptions used to calculate the electricity embedded in water use (e.g., electricity used to draw, move, or treat water) and the energy savings resulting from reduced water use.
- Appendix C: Nominal Energy Cost Savings presents TDV cost savings for each submeasure in terms of nominal dollars.
- Appendix D: Environmental Impacts Methodology presents the methodologies and assumptions used to calculate impacts on GHG emissions and water use and quality.

- Appendix E: California Building Energy Code Compliance (CBECC) Software Specification presents relevant proposed changes to the compliance software (if any).
- Appendix F: Impacts of Compliance Process on Market Actors presents how the recommended compliance process could impact identified market actors.
- Appendix G : Summary of Stakeholder Engagement documents the efforts made to engage and collaborate with market actors and experts.
- Appendix H: Simulation Assumptions for Building Prototypes summarizes the simulation assumptions used in the DOE2.2R simulation software to calculate energy impacts per measure

In each section discussing individual submeasure (Sections 2 through 6), the following information is provided:

- Section X.1 – Measure Description provides a description of the measure and its background. This section also presents a detailed description of how this code change is accomplished in the various sections and documents that make up the Title 24, Part 6 Standards.
- Section X.2 – In addition to the Market Analysis section, this section includes a review of the current market structure. Section X.2.2 describes the feasibility issues associated with the code change, including whether the proposed measure overlaps or conflicts with other portions of the building standards, such as fire, seismic, and other safety standards, and whether technical, compliance, or enforceability challenges exist.
- Section X.3 – Energy Savings presents the per-unit energy, demand reduction, and energy cost savings associated with the proposed code change. This section also describes the methodology that the Statewide CASE Team used to estimate per-unit energy, demand reduction, and energy cost savings.
- Section X.4 – This section includes a discussion and presents analysis of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs, i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.
- Section X.5 – First Year Statewide Impacts presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2022 code takes effect. This includes the amount of energy that would be saved by California building owners and tenants and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic by the state of California. Statewide water consumption impacts are also reported.

2. Submeasure A: Design and Control Requirements for Transcritical CO_2 Systems

2.1 Measure Description

2.1.1 Measure Overview

This code change proposal includes minimum design and control requirements for carbon dioxide (CO_2) transcritical refrigeration systems for both refrigerated warehouses (Section 120.6(a)) and commercial refrigeration systems (Section 120.6(b)). These requirements include the following:

- Air-cooled gas cooler restriction, which restricts the use of this type of gas cooler in high ambient temperature climate zones in order to reduce the number of supercritical operating hours. Available options include water-cooled condensers connected to a cooling tower, adiabatic gas coolers, and evaporative gas coolers.
- Minimum air-cooled and adiabatic gas cooler sizing and specific efficiency. This is to ensure cost-effective design of the refrigeration system's heat rejection equipment, balancing first cost of the equipment and the additional energy savings that are achieved with larger heat exchanger surfaces.
- Supercritical optimized head pressure control, which allows for the head pressure setpoint to be reset in response to ambient conditions.
- Subcritical ambient temperature reset control strategy, which aligns the head pressure control strategy of CO_2 systems during subcritical operation with existing code language.
- Minimum saturated condensing temperature setpoint of 60°F
- Heat recovery for transcritical CO_2.

This mandatory code change would impact refrigerated warehouses and retail food stores that intend to use CO_2 transcritical refrigeration system. The code change would be applicable to refrigerated warehouses that are greater than or equal to 3,000 square feet and refrigerated spaces with a sum total of 3,000 square feet or more that are served by the same refrigeration system, and to retail food stores with 8,000 square foot or more conditioned area. The change would also apply to healthcare facilities with refrigerated spaces meeting any of the above criteria. Refrigerated spaces (in warehouses) that are less than 3,000 square feet shall meet the requirements of the Appliance Efficiency Regulations for walk-in coolers or freezers contained in the Appliance Efficiency Regulations (California Code of Regulations, Title 20).

The code change is applicable to new construction, additions, and alterations, but only for newly installed refrigeration systems.

There are no updates to the compliance software as a part of this proposal.

Acceptance testing procedures will be proposed for the optimized head pressure control measure.

2.1.2 Measure History

Transcritical CO_2 refrigeration systems are different from usual refrigeration systems in that the working fluid (CO_2) exceeds its critical point after the vapor compression stage of the refrigeration cycle (outlet of compressor) during times of higher ambient temperatures (above approximately 75°F). This is known as supercritical operation, and results in a decrease in overall system efficiency whenever operating in this mode. During lower ambient conditions when CO_2 is below the critical point after the vapor compression stage, the system is said to be operating subcritically and operates very similarly to other refrigeration systems.

Because of the unique characteristics of CO_2 systems during supercritical operation and because these system types are relatively new to the California market, mandatory requirements for these systems have so far been excluded from Title 24, Part 6. However, the market share for transcritical CO_2 systems has been increasing, both in part to innovations in technology and controls as well as increasing regulatory requirements that may limit future refrigerant alternatives with high global warming potential (GWP) (Avinash 2020). With more systems being installed, requirements on sizing of gas coolers (heat rejection) and head pressure control strategies are expected to improve CO_2 system performance for new installations resulting in statewide energy savings. In addition, these code change proposals would provide clarity for California business owners interested in the technology and looking to minimize their greenhouse gas emissions.

A typical transcritical CO_2 booster system is shown in Figure 1 below. The system consists of two suction groups – booster and high stage. The compressors in the booster suction group serve low temperature (LT) loads and discharge into the suction of the high stage suction group. The compressors in the high stage suction group serve the medium temperature (MT) loads, as well as compress the gas from the booster suction group and the intermediate pressure vessel to high pressures. Heat is rejected from the high-pressure gas in the gas cooler (GC) when the system is operating in the supercritical mode. The discharge pressure is commonly controlled by a hold back valve in combination with the gas cooler fans. When operating in the subcritical mode the gas cooler operates as a condenser, analogous to other common refrigeration systems. The gas or liquid from the gas cooler/condenser expands in the intermediate pressure vessel / flash tank. The gas from the flash tank is compressed by the high stage compressors (noted as MT compressors in the figure below), and the liquid from the flash tank is supplied to medium temperature and low temperature evaporators (loads). The evaporated gas in the evaporators is compressed by its respective suction group compressors.

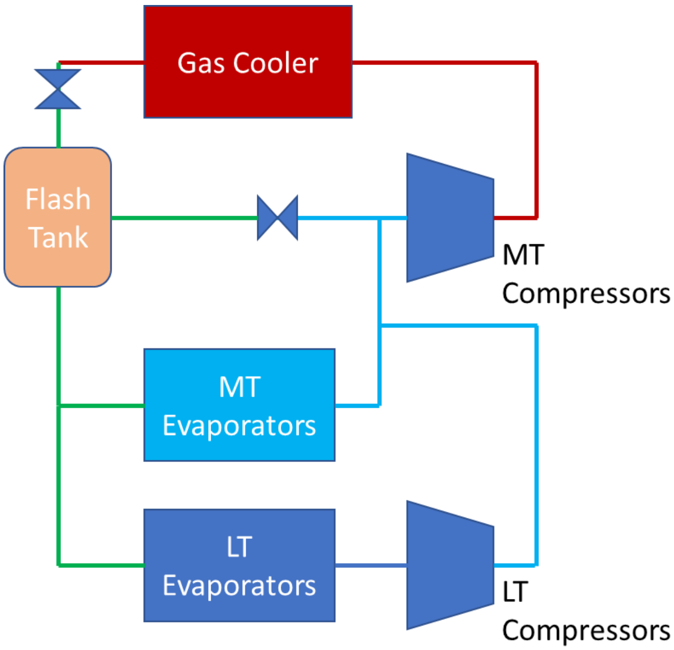

Figure 1: Transcritical CO_2 booster refrigeration system diagram.

Commercial and industrial refrigeration systems use a significant amount of energy, so the efficiency of the CO_2 transcritical systems will be a key factor in annual energy usage of newly installed refrigeration systems that use CO_2 as refrigerant.

As CO_2 transcritical systems increased in popularity in Europe and the United States (U.S.), multiple technologies have been developed that are designed to improve system efficiency during supercritical operating hours or reduce the total number of supercritical operating hours. These technologies consist of gas ejectors, parallel compression configuration, and expanders. While these technologies were explored as part of the CASE proposal, due to low market adoption and limited suppliers, these technologies are not recommended to be a mandatory code requirement at this time.

2.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, ACM Reference Manuals, and compliance documents would be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

2.1.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of Title 24, part 6 as shown below. See Section 7.2 of this report for marked-up code language.

SECTION 120.6 – Mandatory Requirements for Covered Processes

Section 120.6(a)4 – The purpose of the change to this subsection is to clarify that transcritical CO_2 refrigeration systems are exempt from the previously developed condenser sizing, specific efficiency, and controls requirements. New requirements for CO_2 systems were developed as a part of the proposed code language.

New Section 120.6(a)5 – Gas Coolers for Transcritical CO_2 Systems in Refrigerated Warehouses

120.6(a)5A – The purpose of this addition is to specify for which climate zones air-cooled gas coolers shall be prohibited. This is necessary to make clear the requirements of this section.

120.6(a)5B – The purpose of this addition is to communicate a design requirement for air-cooled gas coolers in new transcritical CO_2 refrigeration systems. This is necessary to make clear the requirements of this section.

120.6(a)5C – The purpose of this addition is to communicate a design requirement for adiabatic gas coolers in new transcritical CO_2 refrigeration systems. This is necessary to make clear the requirements of this section.

120.6(a)5D – The purpose of this addition is to communicate a design requirement for fan controls in new transcritical CO_2 refrigeration systems. This is necessary to make clear the requirements of this section.

120.6(a)5E – The purpose of this addition is to communicate the gas cooler pressure controls requirement when the system is operating below the critical point. This is necessary to make clear the requirements of this section.

120.6(a)5F – The purpose of this addition is to communicate the gas cooler pressure controls requirement when the system is operating above the critical point. This is necessary to make clear the requirements of this section.

120.6(a)5G – The purpose of this addition is to communicate a control setpoint requirement for the minimum condensing temperature setpoint for various gas cooler designs. This is necessary to make clear the requirements of this section.

120.6(a)5G – The purpose of this exception is to increase the minimum condensing temperature requirement for suction groups that will be operating at higher suction pressure setpoints and cannot operate at the required minimum saturated condensing temperature setpoint (e.g. parallel compressors). This is necessary to make clear the requirements of this section.

120.6(a)5H – The purpose of this addition is to present Table 120.6F This is necessary to make clear the requirements of this section.

Table 120.6-F – The purpose of this table is to list the gas cooler (condenser) efficiency requirements for air-cooled and adiabatic units in 120.6(a). This is necessary to make clear the requirements of this section.

Section 120.6(a)6 – Compressors

120.6(a)6A – The purpose of this addition is to describe the minimum saturated condensing setpoint requirement for CO_2 compressors. This is necessary to make clear the requirements of this section.

120.6(a)6B – The purpose of this addition is to distinguish between the minimum saturated condensing setpoint requirement of CO_2 compressors versus non-CO_2 compressors. This is necessary to make clear the requirements of this section.

New Section 120.6(b)2 – Transcritical CO_2 Gas Coolers in Commercial Refrigeration

120.6(b)2A through 120.6(b)2G and Table 120.6-H – The purpose and necessity of each of these additions for commercial refrigeration are the same, respectively, as those for Section 120.6(a)5 above for refrigerated warehouses.

New Section 120.6(b)3 – Compressor Systems

Section 120.6(b)3B – The purpose of the change to this subsection is to clarify that liquid subcooling requirements do not apply to CO_2 systems, as liquid subcooling was not a proposed measure for this CASE Report.

Section 120.6(b)3C – The purpose of the change to this subsection was to add the requirement that compressors must be able to operate at the mandatory minimum saturated condensing temperature setpoint. This maintains consistency with the proposed changes outlined in 120.6(b)2.

Section 120.6(b)5 – Refrigeration Heat Recovery

Section 120.6(b)5A – The purpose of this change is to specify an exemption for heat recovery for stores below a design total heat of rejection value. This change is necessary because heat recovery was found to not be cost effective in stores below this threshold.

2.1.3.2 Summary of Changes to the Reference Appendices

The proposed code change would add a new acceptance test procedure for optimized head pressure control in the Nonresidential Appendix NA7. Language for the NA7

Reference Appendix is still under development for acceptance test for supercritical optimized head pressure control (without modulating fan speed requirement), so marked-up language is not provided in this Final CASE Report.

2.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

The proposed code change would not modify the ACM Reference Manual

2.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change would modify the following section of the Nonresidential Compliance Manual:

- **Chapter 10 of the Nonresidential Compliance Manual** – New Section on Transcritical CO_2 compliance

See Section 7.5 of this report for the detailed proposed revisions to the text of the Compliance Manuals.

2.1.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify the compliance documents listed below. Examples of the revised documents are presented in Section 7.6.

- NRCC-PRC-E – Add new tables to allow for people to fill in gas cooler size, head pressure control, etc.

2.1.4 Regulatory Context

2.1.4.1 Existing Requirements in the California Energy Code

The existing code language explicitly exempts transcritical CO_2 systems from the condenser requirements outlined in Section 120.6(a)4 and Section 120.6(b)1, including gas cooler sizing, gas cooler efficiency, head pressure control, and minimum condensing pressure. Gas coolers are currently required to have variable speed fan control and operate their fans in unison per Section 120.6(a)4D and Section 120.6(b)1A.

2.1.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements in other parts of the California Building Code.

2.1.4.3 Relationship to Local, State, or Federal Laws

There are no relevant local, state, or federal laws.

2.1.4.4 Relationship to Industry Standards

Relevant industry standards include American Society of Heating, Refrigerating and Air-Conditioning Engineers Standard 15 - Safety Standard for Refrigeration Systems and

Designation and Safety Classification of Refrigerants (ASHRAE 15) and the International Institute of International Institute of Ammonia Refrigeration (IIAR) CO_2 Handbook.

2.1.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced. This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix F presents how the proposed changes could impact various market actors.

The activities that need to occur during each phase of the project are described below:

- **Design Phase:** Design engineers, contractors, and owners collaborate to develop refrigeration system design loads and select the best system configuration and pieces of equipment to supply adequate cooling. All parties involved should be aware of the proposed code changes as it relates to selecting their gas cooler for ultimate heat rejection, understand how the gas cooler will be controlled, and determine if there are other design options that will allow them to limit their supercritical mode operation or improve its efficiency (i.e., adiabatic condensers, parallel compression, gas ejectors). Design engineers will need to specify the rated temperature difference between the gas cooler outlet temperature and design ambient temperature at a specified design pressure in their equipment schedules, and will also need to show the gas cooler specific efficiency at the rating conditions in the proposed code language.
- **Permit Application Phase:** Typically, a contractor will develop a set of stamped engineering plan drawings on the owner's behalf, that will include refrigeration system design and equipment. The drawings can also be developed by an independent engineering firm and are used as the basis for contractors to supply bids for the project. This set of plan drawings should incorporate information on how the selected gas cooler and overall transcritical CO_2 system complies with Title 24, Part 6. If the selected equipment does not comply with Title 24, Part 6, the authority having jurisdiction should provide plan check comments to correct this before providing any building permits.
- **Construction Phase:** Contractors install the refrigeration system as described in the approved plan drawings, with oversight from the owner and authority having jurisdiction. The installed equipment should match what was approved and specified. This is documented by the installing contractor on the installation certificate where they are certifying that the equipment specified on the compliance documentation is installed.

- **Inspection Phase:** After construction, the owner or contractor have the responsibility to have the building and its various mechanical systems inspected by the authority having jurisdiction. This inspection phase should include an examination of the refrigeration system to verify the compliant equipment described in the plan drawings matches what was physically installed. Acceptance testing should be completed by installing contractor to verify operational requirements such as head pressure control and gas cooler fan control.

The compliance process described above is very similar to the process that currently exists for measures related to refrigerated warehouses and commercial refrigeration. Revised compliance document requirements are anticipated for designers, owners, and contractors to provide evidence on their design drawings that the proposed equipment complies with Title 24, Part 6. These compliance document revisions are expected to be analogous to the condenser sizing and efficiency documents that currently exist in the NRCC-PRC-E form for current commercial and refrigerated warehouse requirements. Additional acceptance testing related to head pressure control is also expected to be required to ensure compliance, although there are still barriers to acceptance testing for refrigeration that may limit the viability of implementing such tests at this time. Primarily, control strategies for head pressure control during supercritical operation are typically proprietary and a uniform test would need to be flexible enough to consider small differences in strategy. One possible solution to this is to require the field technician to test the specific sequence of operations provided by the individual manufacturer to ensure proper control. The primary requirement of pressure setpoint reset based on ambient conditions would be common to all sequence of operations.

2.2 Market Analysis

2.2.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during two public stakeholder meetings that the Statewide CASE Team held on November 7, 2019 and April 2, 2020.

The market structure for CO_2 refrigeration systems is like the overall market structure for other refrigeration systems and consist of the following key market actors: original equipment manufacturers (OEMs), rack manufacturers, distributors/sales representatives, design engineers, installation contractors, and end users. The major components required to build a transcritical CO_2 refrigeration system, such as the compressors, gas coolers, vessels, and valves are supplied by five to eight major OEMs. These OEMs are well established and provide refrigeration equipment for multiple types of refrigeration systems and are not necessarily restricted to just CO_2 equipment. These major components are sold to rack manufactures who design, specify, and construct complete refrigeration rack systems like other supermarket parallel rack refrigeration systems. There are approximately four to five major rack manufacturers located in the U.S. and Canada that supply systems throughout the U.S. Some rack manufacturers are represented by distributors or sales representatives located locally in California who connect customers or contractors with the equipment suppliers and sell the equipment at a marked-up price. Design engineering firms or design/build contractors may also specify the rack equipment required to meet design load of a new construction facility and supply the specifications to the rack manufacturers in order to get pricing. Once equipment is specified, refrigeration contractors will typically purchase, resell, and install the equipment as part of a new construction project on behalf of the building owner.

The number of CO_2 transcritical systems installed in the U.S. is low compared to the total number of installed refrigeration systems. According to a market study published in 2017, 290 transcritical systems have been installed in the U.S. (Ona 2017). However, an increasing number of CO_2 transcritical systems are being installed due to market and regulatory pressures (Ona 2017). Because equipment is supplied by well established companies that have decades of experience in the refrigeration industry, there are no major market barriers in the supply of CO_2 systems.

2.2.2 Technical Feasibility, Market Availability, and Current Practices

In order to understand the technical and market feasibility of implementing the proposed code language, as well as get an understanding of current practices for transcritical CO_2 system designers, a questionnaire was developed and sent to multiple manufacturers that posed basic questions on design and control of existing transcritical CO_2 systems. The key takeaways from the questionnaire are listed below:

- There are two main strategies for head pressure control during supercritical mode operation, one where gas cooler fans run at a fixed speed of 100 percent, and one where gas cooler fans modulate their speed to maintain a fixed approach temperature between the gas cooler outlet temperature and the ambient air
- Gas cooler sizing practices vary from 2°F approach temperature between the gas

cooler outlet temperature and ambient temperature to 10℉

- Though currently exempted, almost all CO_2 systems are utilizing dry bulb following or wet bulb following head pressure control when operating subcritical as outlined in the existing Title 24, Part 6 code for other systems.
- Almost all CO_2 systems are being installed in compliance with proposed code by utilizing gas cooler fan variable speed control.
- There are few installations that utilize parallel compression (less than 15 percent)
- There are few installations that utilize gas ejectors (less than 5 percent)
- Adiabatic condensers are somewhat prevalent throughout the current installation base

Based on this feedback, the proposed code language for gas cooler sizing is not expected to have any market barriers as there is already a strong market supply of gas coolers of various sizes. One technical barrier to the gas cooler sizing measure is consensus on how to define gas cooler size. Most designers utilize the approach temperature, where the size is based on a certain temperature difference between the ambient air and the gas cooler outlet temperature. However, because pressure is a semi-independent variable during transcritical system operation and affects gas cooler performance, the rating to establish gas cooler size should also specify the pressure (Fang 1999). The Statewide CASE Team is currently proposing that the rating pressure be defined at 1400 psig for air cooled gas coolers and 1100 psig for adiabatic gas coolers. The proposed rated temperature conditions for determining specific efficiency are 90℉ dry bulb temperature and 100℉ leaving gas temperature. These values were selected in part due to the availability of data related to adiabatic gas coolers, where performance data was not available for ambient conditions above 90℉ dry bulb temperature in dry mode operation as adiabatic gas coolers are normally utilizing their precooling pads at these conditions. The rated temperatures were selected to maintain consistency between air cooled and adiabatic gas cooler rating conditions.

The proposed code language for the transcritical head pressure control is not expected to have any market barriers as almost all manufacturers in the market have indicated the use of controls that utilize some type of optimized head pressure control. However, one technical barrier to code implementation is how to characterize optimized head pressure control in the code language. System and controls manufacturers utilize their own proprietary software to control the fans and valves that determine system head pressure. Specifying the exact relationship to be used to determine the optimal head pressure may be dependent on multiple variables beyond ambient air temperature, including the operating saturated suction temperature, system configuration, gas cooler technology type, and current load. It may be possible that future building codes or future appliance standards may specify a performance target for transcritical gas cooler/condensers. However, now, it is sufficient that the speed of fans is controlled in unison and that the controls manufacturer has a considered the trade-off between fan energy and compressor energy in developing a pressure and fan control that is responsive to environmental and system conditions. The Statewide CASE Team is currently proposing code language that would encompass multiple optimization algorithms while mandating that pressure varies in response to system conditions in order to maximize system efficiency. There are no market or technical barriers associated with wet bulb or dry bulb following head pressure control during subcritical mode operation as this is in line with current practices.

There are no market barriers associated with adiabatic gas coolers/condensers as there are multiple manufacturers supplying products of various sizes. Technical barriers for including adiabatic condensers in the proposed code language include sizing definitions as discussed more generally for air cooled gas coolers above.

There exist both market and technical barriers for mandating gas ejectors, with only one major manufacturer providing the technology and very few installations. The Statewide CASE Team is currently proposing that gas ejectors not be included in the proposed code language but may be important for future study.

In general, CO_2 systems need special skillset as they operate at high pressures (approximately 1,100 psi and above), compared to the ammonia or halocarbon systems. Thus, the number of contractors with the CO_2 system experience is expected to be limited. The understanding on various equipment and their controls is also limited, as the market is still developing. The proposed measure would help owners in understanding the baseline CO_2 design and efficiency, so the barrier for CO_2 systems to market adoption is expected to decrease. The proposed CO_2 measures would give persistent savings as long as the controls were properly implemented and maintained.

2.2.3 Market Impacts and Economic Assessments

2.2.3.1 Impact on Builders

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California's construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 7).[1] In 2018, total payroll was $80 billion. Nearly 17,000 establishments and 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

Table 7: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establishments	Employment	Annual Payroll (billions $)
Residential	**59,287**	**420,216**	**$23.3**
Residential Building Construction Contractors	22,676	115,777	$7.4
Foundation, Structure, & Building Exterior	6,623	75,220	$3.6
Building Equipment Contractors	14,444	105,441	$6.0
Building Finishing Contractors	15,544	123,778	$6.2
Commercial	**17,273**	**343,513**	**$27.8**
Commercial Building Construction	4,508	75,558	$6.9
Foundation, Structure, & Building Exterior	2,153	53,531	$3.7
Building Equipment Contractors	6,015	128,812	$10.9
Building Finishing Contractors	4,597	85,612	$6.2
Industrial, Utilities, Infrastructure, & Other	**4,103**	**96,550**	**$9.2**
Industrial Building Construction	299	5,864	$0.5
Utility System Construction	1,643	47,619	$4.3
Land Subdivision	952	7,584	$0.9
Highway, Street, and Bridge Construction	770	25,477	$2.4
Other Heavy Construction	439	10,006	$1.0

Source: (State of California, Employment Development Department n.d.)

The proposed change related to Submeasure A would likely affect commercial and industrial builders but would not impact firms that focus on construction and retrofit of utility systems, public infrastructure, or other heavy construction. The effects on the commercial building and industrial building industry would not be felt by all firms and

[1] Average total monthly employment in California in 2018 was 18.6 million; the construction industry represented 4.5 percent of 2018 employment.

workers, but rather would be concentrated in specific industry subsectors. Table 8 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 2.2.4.

Table 8: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard

Construction Subsector	Establishments	Employment	Annual Payroll (billions $)
Nonresidential plumbing and HVAC contractors	2,394	52,977	$4.47

Source: (State of California, Employment Development Department n.d.)

2.2.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 9 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for Submeasure A to affect firms that focus on supermarket and refrigerated warehouse construction.

There is not a North American Industry Classification System (NAICS)[2] code specific for energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of

[2] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

residential and nonresidential buildings.[3] It is not possible to determine which business establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 9 provides an upper bound indication of the size of this sector in California.

Table 9: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
Architectural Services [a]	3,704	29,611	$2.9
Building Inspection Services [b]	824	3,145	$0.2

Source: (State of California, Employment Development Department n.d.)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

The proposed code language would provide new information to building designers and energy consultants when designing and proposing transcritical CO_2 refrigeration systems. These professionals should fully understand how this impacts their recommendations for selected equipment and control strategies. Impacts are not expected to be beyond typical continuous learning required by building designers and energy consultant professionals.

2.2.3.3 Impact on Occupational Safety and Health

The proposed code language is not expected to have a significant impact on occupational safety and health.

2.2.3.4 Impact on Building Owners and Occupants

The commercial building sector includes a wide array of building types, including offices, restaurants and lodging, retail, and mixed-use establishments, and warehouses (including refrigerated) (Kenney 2019). Energy use by occupants of commercial

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[3] Establishments in this sector include businesses primarily engaged in evaluating a building's structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

buildings also varies considerably with electricity used primarily for lighting, space cooling and conditioning, and refrigeration. Natural gas consumed primarily for heating water and for space heating. According to information published in the 2019 California Energy Efficiency Action Plan, there is more than 7.5 billion square feet of commercial floor space in California and consumes 19 percent of California's total annual energy use (Kenney 2019). The diversity of building and business types within this sector creates a challenge for disseminating information on energy and water efficiency solutions, as does the variability in sophistication of building owners and the relationships between building owners and occupants.

Building owners and occupants would benefit from lower energy bills. As discussed in Section 2.2.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2022 code cycle to impact building owners or occupants adversely.

2.2.3.5 Impact on Building Component Retailers (Including Manufacturers and Distributors)

The proposed code language would require building component retailers to ensure that the equipment they are specifying and providing to building owners is compliant with the proposed mandatory measures.

2.2.3.6 Impact on Building Inspectors

Table 10 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections other than learning how to plan check this new requirement on submitted plans.

Table 10: Employment in California State and Government Agencies with Building Inspectors

Sector	Govt.	Establishments	Employment	Annual Payroll (millions $)
Administration of Housing Programs[a]	State	17	283	$29.0
Administration of Housing Programs[a]	Local	36	2,882	$205.7
Urban and Rural Development Admin[b]	State	35	552	$48.2
Urban and Rural Development Admin[b]	Local	52	2,446	$186.6

Source: (State of California, Employment Development Department n.d.)

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.
b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

2.2.3.7 Impact on Statewide Employment

As described in Sections 2.2.3.1 through 2.2.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 2.2.4, the Statewide CASE Team estimated the proposed change in Submeasure A would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors.

2.2.4 Economic Impacts

For the 2022 code cycle, the Statewide CASE Team used the IMPLAN model software, along with economic information from published sources, and professional judgement to develop estimates of the economic impacts associated with each of the proposed code changes.[4] While this is the first code cycle in which the Statewide CASE Team develops estimates of economic impacts using IMPLAN, it is important to note that the economic

[4] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

impacts developed for this report are only estimates and are based on limited and to some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the Statewide CASE Team believes the economic impacts presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the commercial/industrial building industry, architects, energy consultants, and building inspectors. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2022 code cycle regulations would result in additional spending by those businesses.

Table 11: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income (millions $)	Total Value Added (millions)	Output (millions $)
Direct Effects (Additional spending by Commercial Builders)	3	$0.19	$0.25	$0.41
Indirect Effect (Additional spending by firms supporting Commercial Builders)	1	$0.05	$0.07	$0.14
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	1	$0.07	$0.13	$0.20
Total Economic Impacts	**5**	**$0.30**	**$0.45**	**$0.76**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

2.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team’s proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in this section would lead to modest changes in employment of existing jobs.

2.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 2.2.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to transcritical CO_2 refrigeration system design and control which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

2.2.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes would apply to all businesses incorporated in California, regardless of whether the business is incorporated inside or outside of the state.[5] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

2.2.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[6] As Table 12 shows, between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, with an average of 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

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[5] Gov. Code, § 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR § 2003(a)(3) Competitive advantages or disadvantages for California businesses currently doing business in the state.

[6] Net private domestic investment is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

Table 12: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits
2015	$609.3	1,740.4	35%
2016	$456.0	1,739.8	26%
2017	$509.3	1,813.6	28%
2018	$618.3	1,843.7	34%
2019	$580.9	1,827.0	32%
		5-Year Average	**31%**

Source: (Federal Reserve Economic Data n.d.)

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy. Nevertheless, the Statewide CASE Team can derive a reasonable estimate of the change in investment by California businesses by multiplying the sum of Business Income estimated in Table 12 above by 31 percent.

2.2.4.5 Effects on the State General Fund, State Special Funds, and Local Governments

The proposed code language is not expected to have a significant impact on the state general fund, state special funds, or local governments.

2.2.4.6 Impacts on Specific Persons

The proposed code language is not expected to have a significant impact on specific persons.

2.3 Energy Savings

2.3.1 Key Assumptions for Energy Savings Analysis

The energy and cost analysis presented in this report used the final TDV factors that the Energy Commission released in June 2020 which use 20-year global warming potential (GWP) values instead of 100-year GWP values used in previous TDV factors. The 20-year GWP values increased the TDV factors slightly. The electricity TDV factors include the 15 percent retail adder. The natural gas TDV factors include the impact of methane leakage on the building site.

The energy savings analysis was performed using two prototypical buildings. The first prototype is the Large Refrigerated Warehouse (LRWH) prototype. This prototype was previously developed and utilized for refrigeration CASE Reports in the 2008, 2013, and 2019 Title 24, Part 6 code cycles. The prototype was updated to represent typical refrigerated warehouses conforming to 2019 Title 24, Part 6 Standards, which includes envelope and lighting. Refrigeration system equipment and controls for the prototype were developed as part of the market analysis and stakeholder outreach to reflect industry common practice for transcritical CO_2 refrigeration systems. Design loads and operating schedules were assumed to represent industry-standard practice and typical warehouse operation. This prototype was used to develop the energy savings for the proposed code language related to Section 120.6(a) Refrigerated Warehouses.

The assumptions for the CO_2 transcritical system for the Large Refrigerated Warehouse prototype are detailed in Table 143 in Appendix H.

Cooling loads in each refrigerated space were calculated in each climate zone for the prototypical refrigerated warehouses. Then refrigeration equipment (evaporators, compressors and condensers) was sized according to the calculated loads. Loads included envelope transmission loads, exterior and inter-zonal air infiltration, forklift and pallet-lift traffic, employee traffic, evaporator fan motor heat, evaporator defrost heat, lighting heat gain, and product respiration and pull-down load. A 1.15 safety factor was used in the equipment selection process. Load calculation assumptions are available upon request.

The second prototype used was the Large Supermarket Prototype (LSM). This prototype was previously developed and utilized for refrigeration CASE Reports in the 2013 and 2019 Title 24, Part 6 code cycles. The prototype represents a typical large supermarket building and the associated refrigerated display cases, walk-ins, and other loads. Refrigeration system equipment and controls for the prototype were developed as part of the market analysis and stakeholder outreach to reflect industry common practice for transcritical CO_2 refrigeration systems. This prototype is used to develop the energy savings for the proposed code language related to Section 120.6(b) Commercial Refrigeration.

The assumptions for the CO_2 transcritical system for the Large Supermarket prototype are described in detail in Table 144 in Appendix H.

2.3.2 Energy Savings Methodology

2.3.2.1 Energy Savings Methodology per Prototypical Building

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings.

The prototype models used in this analysis were developed to represent typical refrigerated warehouses conforming to 2019 Title 24, Part 6 Standards, which includes envelope and lighting requirements. System types, design loads, and operating schedules were assumed to represent industry-standard practice for transcritical CO_2 systems and typical warehouse operation. In addition, a supermarket prototype model was developed conforming to 2019 Title 24, Part 6 Standards. The prototypes used are summarized in Table 13.

Table 13: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (square feet)
Large Refrigerated Warehouse	1	92,000
Large Supermarket	1	60,000

The building layout for both large warehouse and large supermarket prototypes are shown in the figures below.

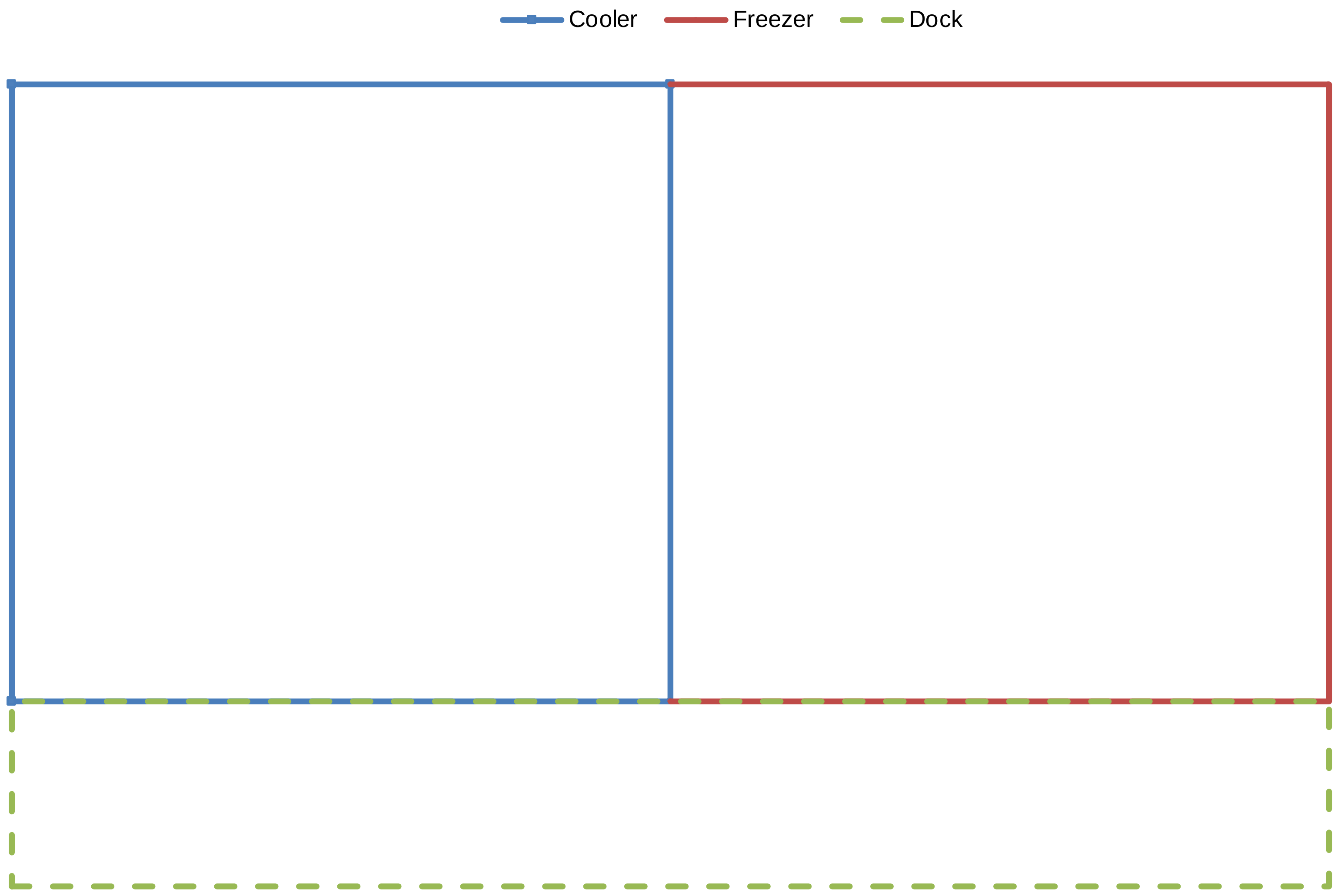

Figure 2. Large refrigerated warehouse prototype layout.

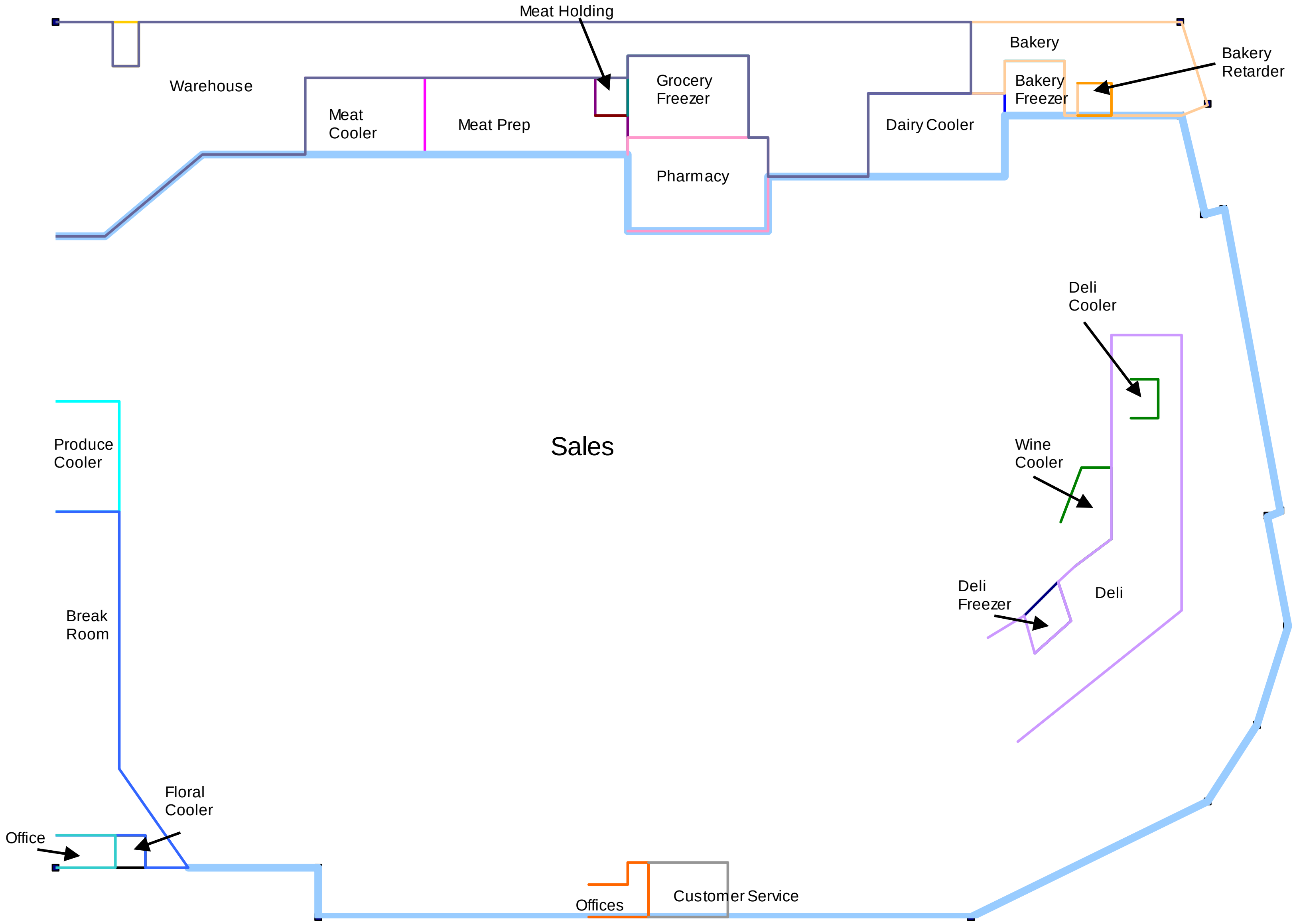

Figure 3. Large supermarket prototype layout.

The Statewide CASE Team estimated energy and demand impacts by simulating the proposed code change using DOE2.2R energy simulation software. The DOE2 version used (2.2R) is a sophisticated component-based energy simulation program that can accurately model the interaction between the building envelope, building loads, and refrigeration systems. The DOE-2.2R version is specifically designed to include refrigeration systems, and uses refrigerant properties, mass flow and component models to accurately describe refrigeration system operation and controls system effects.

Key updates to DOE2.2R were made in order to allow for the simulation of transcritical CO_2 systems. These key updates include the following:

- Addition of a supercritical CO_2 thermophysical properties library (sourced from the National Institute of Standards and Technology REFPROP software)
- Ability for users to provide sperate compressor performance curves (power and mass flow at various suction and discharge pressure conditions) for supercritical operation
- Ability for users to provide separate gas cooler performance curves (heat rejection capacity at various approach temperatures and head pressure conditions) for supercritical operation
- Addition of an expansion/flash tank model that reflects the intermediate pressure vessel commonly used for transcritical CO_2 systems

Model Validation

Model validation was performed to verify that system mass flows and corresponding power consumption of the various refrigeration components were consistent with manufacturer performance data. Table 14 compares the expected power/mass flow based on the manufacturer data to the simulated power/mass flow for the high stage suction group at different subcritical and supercritical operating conditions. Note that the comparison is between the expected operation of a compressor and the simulated operation of a suction group, which comprises multiple compressors, so the magnitude of simulated power and mass flow may be higher.

Table 15 compares the expected power/mass flow based on the manufacturer data to the simulated power/mass flow for the booster suction group at different subcritical and supercritical operating conditions.

Table 14: CO_2 Model Validation - High Stage Suction Group

Mode	Day and Hour	Climate Zone	SST °F	Discharge Pressure psia	Simulated Power kW	Simulated Mass Flow lb./h	Simulated kW/lb./h	Expected Power kW	Expected Mass Flow lb./h	Expected kW/lb./h
Supercritical	7/10 15:00	12	22	1,549	266.0	25,140	0.0105	50.7	4,788	0.0106
Subcritical	7/1 17:00	12	22	949 (80F)	33.6	5,613	0.0060	33.8	5,497	0.0061
Supercritical	8/17 16:00	2	22	1,270	259.5	30,503	0.0085	43.6	5,133	0.0085
Subcritical	11/11 11:00	2	22	846 (70F)	74.0	14,394	0.0051	29.3	5,635	0.0052

Table 15: CO_2 Model Validation - Booster Suction Group

Mode	Day and Hour	Climate Zone	SST °F	Discharge Pressure psia	Simulated Power kW	Simulated Mass Flow lb./h	Simulated kW/lb./h	Expected Power kW	Expected Mass Flow lb./h	Expected kW/lb./h
Subcritical	2/10 2:00	5	-23	435 (22F)	20.2	3,325	0.0061	9.12	1,498	0.0061
Subcritical	10/6 24:00	14	-23	435 (22F)	34.4	5,640	0.0061	9.12	1,498	0.0061

Table 16: CASE Report vs. ORNL Study COP Comparison

City in ORNL Study	COP in ORNL Study	Climate Zone in CASE Report	Booster kWh in CASE Report	Booster MBtu Load in CASE Report	High Stage kWh in CASE Report	High Stage MBH Load in CASE Report	COP in CASE Report	%Difference in COP
San Francisco	3.27	CZ3[a]	78,181	1,356	537,073	5,784	3.40	4%
Los Angeles	2.90	CZ9	79,153	1,372	621,596	5,874	3.03	4%

a. The COP for Climate Zone 4 is 3.25, which is 1 percent lower than the ORNL study. San Francisco is close to San Jose and Oakland, which represent Climate Zone 4 and 3, respectively.

An additional level of modeling validation was performed by comparing results of the Standard Design transcritical CO_2 system with another energy study performed for supermarket transcritical CO_2 systems. The name of the study is “Comparative Analysis of Various CO_2 Configurations in Supermarket Refrigeration Systems”, which was carried out by Oak Ridge National Laboratory (ORNL) and published in the International Journal of Refrigeration in 2014. The study included seven different refrigeration system configurations with CO_2 as refrigerant, including the transcritical booster configuration. The study provided the yearly average system coefficient of performance (COP) in sixteen cities across the U.S, including Los Angeles and San Francisco. The COP was defined as the ratio of the booster and high stage loads, and the booster and high stage compressor power.

The system configurations for the ORNL study and the Final CASE Report are almost identical barring the following exceptions:

1. The ORNL study included the suction line heat exchanger that cools the gas coming out of the gas cooler using the booster discharge gas.
2. The optimum discharge pressure formula in the ORNL study was slightly different than the Final CASE Report.
3. The ambient following TD for the subcritical operation was 18°F in the ORNL study. The same TD was used in the Final CASE Report simulation for the comparison below.
4. The minimum condensing temperature setpoint of 50°F was used. The Final CASE Report uses a minimum condensing temperature setpoint of 60°F regardless of climate zone.

Table 16 gives a comparison of the COP in the ORNL study to the COP of the Final CASE Report Standard Case.

The difference between the ORNL and the Final CASE Report COP values is reasonable as the ORNL study used slightly different parameters than the Final CASE Report, as described above.

Proposed Versus Standard Design

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 17 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Because the number supercritical mode operating hours is dependent on ambient temperatures, Submeasure A was analyzed using all climate zones in California. Comparing the energy impacts of the Standard Design to the Proposed Design reveals the impacts of the proposed code change relative to a building that is minimally compliant with the 2019 Title 24, Part 6 requirements as it relates to the building envelope, lighting, and follows industry typical practices as it relates to transcritical CO_2 design and operation.

Table 17: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Submeasure Name	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
LRWH and LSM	All	Air Cooled Gas Cooler Restriction	Gas Cooler Type	Air Cooled	Adiabatic
LRWH and LSM	All	Minimum Air-Cooled Gas Cooler Sizing and Specific Efficiency	Gas Cooler Size (Rated approach temperature)	8F	Multiple, parametric analysis (4F, 5F, 6F and 7F)
LRWH and LSM	All	Supercritical Optimized Head Pressure Control	Supercritical Head Pressure Control	Optimized head pressure control, fans operate at 100% speed	Optimized head pressure control, fans modulate to maintain fixed TD

DOE2.2R calculates whole-building energy consumption for every hour of the year and sums the values to provide kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). It then applies the 2022 time dependent valuation (TDV) factors to calculate annual energy use in kilo British thermal units per year (TDV kBtu/yr) and annual peak electricity demand reductions measured in kilowatts (kW).

The energy impacts of the proposed code change were expected to vary by climate zone. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone specific TDV factors when calculating energy and energy cost impacts.

Per-unit energy impacts for nonresidential buildings are presented in savings per square foot. Annual energy and peak demand impacts for each prototype building were translated into impacts per square foot by dividing by the floor area of the prototype building. This step allows for an easier comparison of savings across different building types and enables a calculation of statewide savings using the construction forecast that is published in terms of floor area by building type.

Heat Recovery

The energy savings associated with heat recovery for supermarket CO_2 systems was calculated outside of the DOE2.2R simulation model in a separate spreadsheet analysis, utilizing key information from the prototype model as reference. First, the balance point temperature was determined for each climate zone. The balance point temperature for a building is the outdoor dry bulb temperature at which the heat gains of the building are equal to the heat losses, that is, no mechanical heating is required. An example of the balance temperature assessment for Climate Zone 3 is given below; where the plot shows the sales area heating requirement taken from the DOE2.2R prototype model vs. the ambient dry bulb temperature (DBT) for 8,760 hours of the year.

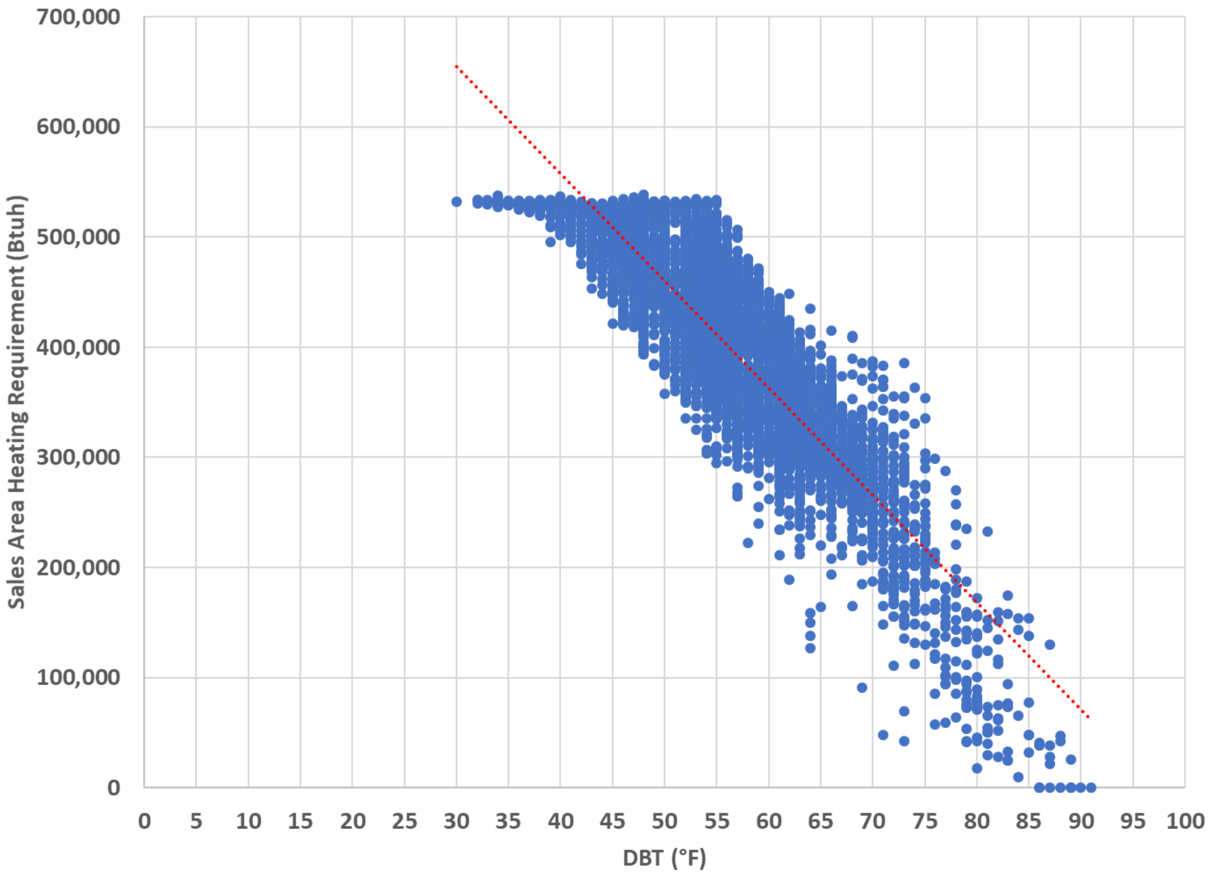

Figure 4. Balance point temperature for Climate Zone 3.

The x-intercept, i.e., the point when the heating requirement is zero, was found to be approximately 80 to 85°F. However, because the opportunity for heat recovery is low at such small heating loads, the balance point temperature in the analysis when heat recovery would be utilized was assumed to be the average ambient dry bulb temperature when heating loads were at 200,000 Btuh. This corresponded to a balance point temperature of 70°F and was found to be similar in all climate zones. The lowering of the balance point decreases the assumed hours of operation of heat recovery, thereby providing a lower and more conservative estimate of the natural gas savings while recognizing the potential impracticalities associated with operating at such low heating loads.

Other key assumptions for the heat recovery savings analysis included the following:

- Cost estimates for additional equipment were based on an indirect heat recovery system, with a 1HP glycol recirculation pump providing glycol to heat recovery CO_2 brazed plate heat exchangers and out to the main heat recovery coil installed in the central air handling unit.
- Refrigeration system is operating subcritically, due to the ambient balance point temperature being below the ambient temperature that would cause the CO_2 system to operate supercritically (~75°F).
- The average saturation condensing temperature (SCT) is estimated to be between 60°F and 70°F.
- The heat recovery heat exchanger was sized for the design 25 percent total heat of rejection requirement per existing Title 24, Part 6 code language. It was determined that CO_2 can achieve this heat load via only de-superheating the refrigerant vapor (i.e., no holdback valve needed to artificially increase the condensing temperature of the refrigerant to utilize latent heat for heat recovery). The enthalpy values to determine the amount of heat rejected via de-superheating are summarized in the table below.

Table 18: CO_2 Enthalpy Values for De-superheating

Saturation Condensing Temperature (°F)	Saturated Vapor Enthalpy (Btu/lbm)	Saturated Liquid Enthalpy (Btu/lbm)	Discharge Temperature (°F)	Superheated Vapor Enthalpy (Btu/lbm)	% THR in de-superheating
70F	174.41	111.74	146.7	210.87	37
65F	176.88	107.7	136.3	209.12	32
60F	178.89	103.96	126.1	207.50	28

- The HVAC system is estimated to have 25,000 CFM supply air flow with 25 percent outside air flow.
- The HVAC system is assumed to have CO_2 based demand control ventilation system that reduces the outside air flow when the occupant load is low. The estimated outside air schedule is visualized in the figure below.

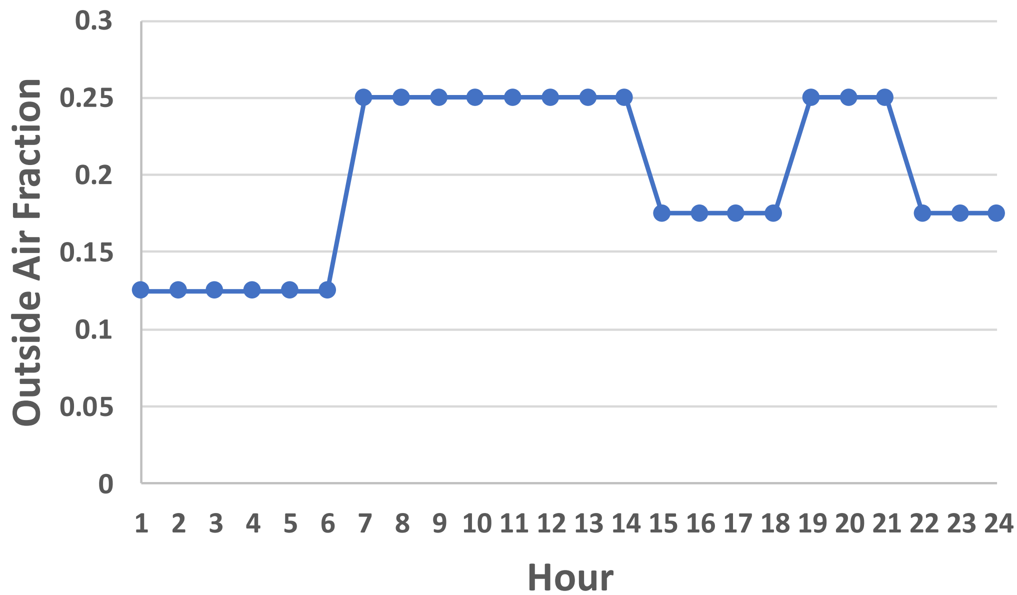

Figure 5. Percent outside air schedule during typical day.

- A 0.5 inch WC fan penalty was applied to the central air handling unit due to the increase in pressure drop when a heat recovery coil is installed, resulting in 14,000 kWh energy penalty.
- Natural gas savings was calculated for various heat recovery heat exchanger sizes based on different assumed design total heat of rejection until most climate zones were found to be cost effective.
- If the hourly dry bulb temperature was less than the balance point temperature, and the heating requirement was greater than 200,000 Btuh, then heat recovery was assumed to take place.
- The high stage suction group loading factor was included in the calculations to account for the average partial loading (estimated 55 percent of design THR) of the suction group, compared to the 100 percent loading used in the THR calculations. The de-superheating factor (percent of THR associated with just de-superheating the CO_2 vapor) was also included in the calculations. For example:
    1. The prototype retail food store sales area has a heating requirement of 376,000 Btuh for the first hour of January 1 in Climate Zone 3, which is greater than the threshold of 200,000 Btuh. The DBT for that hour is 52°F, which is lower than the balance point temperature. (If one of the two conditions are not met in an hour, the heat recovery is assumed to be zero for that hour).
    2. The possible heat recovery was calculated for the first hour of January 1 in

Climate Zone 3 is:

   a. 150MBH (Design THR) x 55 percent (suction group loading at average SCT conditions) x de-superheating factor (37 percent) = 30.5 MBH. The possible heat recovery was calculated for each hour of the year.

   b. The possible heat recovery calculated in step 2a was compared with the heating requirement in step 1. The actual heat recovery was estimated to be equal to the smaller of the two numbers. In case of the 150 MBH heat recovery (30.5 MBH possible heat recovery), the possible heat recovery was always less than the 200,000 Btuh threshold, so the actual heat recovery was equal to the possible heat recovery. However, this may not be the case when the heat recovery calculation iterations are done for other THR thresholds.

3. The actual heat recovery per hour was added to determine the yearly heat recovery potential in therms.

2.3.2.2 Statewide Energy Savings Methodology

The per-unit energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission 2020). The Statewide Construction Forecasts estimate new construction that will occur in 2023, the first year that the 2022 Title 24, Part 6 requirements are in effect. It also estimates the size of the total existing building stock in 2023, which the Statewide CASE Team used to approximate savings from building alterations. The construction forecast provides construction (new construction and existing building stock) by building type and climate zone. The Statewide CASE Team utilized the Refrigerated Warehouse and Grocery construction forecast for this measure to determine the statewide impacts. An additional reduction is applied to the Statewide Construction Forecast to estimate the impacted square footage that is relevant to Submeasure A. It is expected that only 30 percent of new grocery stores and 10 percent of new refrigerated warehouses will utilize transcritical CO_2 technology.

Appendix A presents additional information about the methodology and assumptions used to calculate statewide energy impacts.

2.3.2.3 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per-unit are presented in Table 22 through Table 28 for new construction. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. A discussion of each submeasure is summarized below:

Air-Cooled Gas Cooler Restriction

Large Refrigerated Warehouse

Annual savings for the first year for the 92,000 ft^2 prototypical refrigerated warehouse are expected to range from -112,000 to 436,000 kWh/yr (-1.22 to 4.74 kWh/ft^2-yr) depending upon climate zone. Demand reductions are expected to range between 25 and 260 kW depending on climate zone.

Overall the adiabatic condenser/gas cooler measure was found to result in -8 percent to 18 percent kWh savings compared to the total prototype annual energy consumption when operating with an air-cooled condenser. The reduced head pressure achieved by the adiabatic precooling of the ambient air resulted in fewer supercritical operating hours and overall improvement in refrigeration system performance for most climate zones. The increase in energy in Climate Zones 1, 3, 5 and 7 was due to lower ambient temperatures on average where the impact of air precooling is reduced with more hours running in dry mode. Because adiabatic gas coolers are sized smaller than air cooled gas coolers, climate zones with reduced number of precooling hours will have a larger energy penalty due to the reduced coil surface area. Additionally, adiabatic gas coolers due incur a fan power penalty due to the increased pressure drop across the precooling pad. These energy penalties will outweigh the benefits of adiabatic gas coolers if the number of precool operating hours is not sufficiently high.

A summary of the number of operating hours in the supercritical mode for the air cooled and adiabatic gas coolers for the refrigerated warehouse prototype are given below.

Table 19: Supercritical Hours (Air Cooled Versus Adiabatic, RWH)

Climate Zone	Air Cooled (Base Case)	Adiabatic (EEM1)
1	13	4
2	777	96
3	185	3
4	943	161
5	286	18
6	749	235
7	382	61
8	1,500	262
9	1,523	149
10	1,822	305
11	1,837	328
12	1,327	207
13	2,189	481
14	2,091	163
15	4,143	940
16	450	0

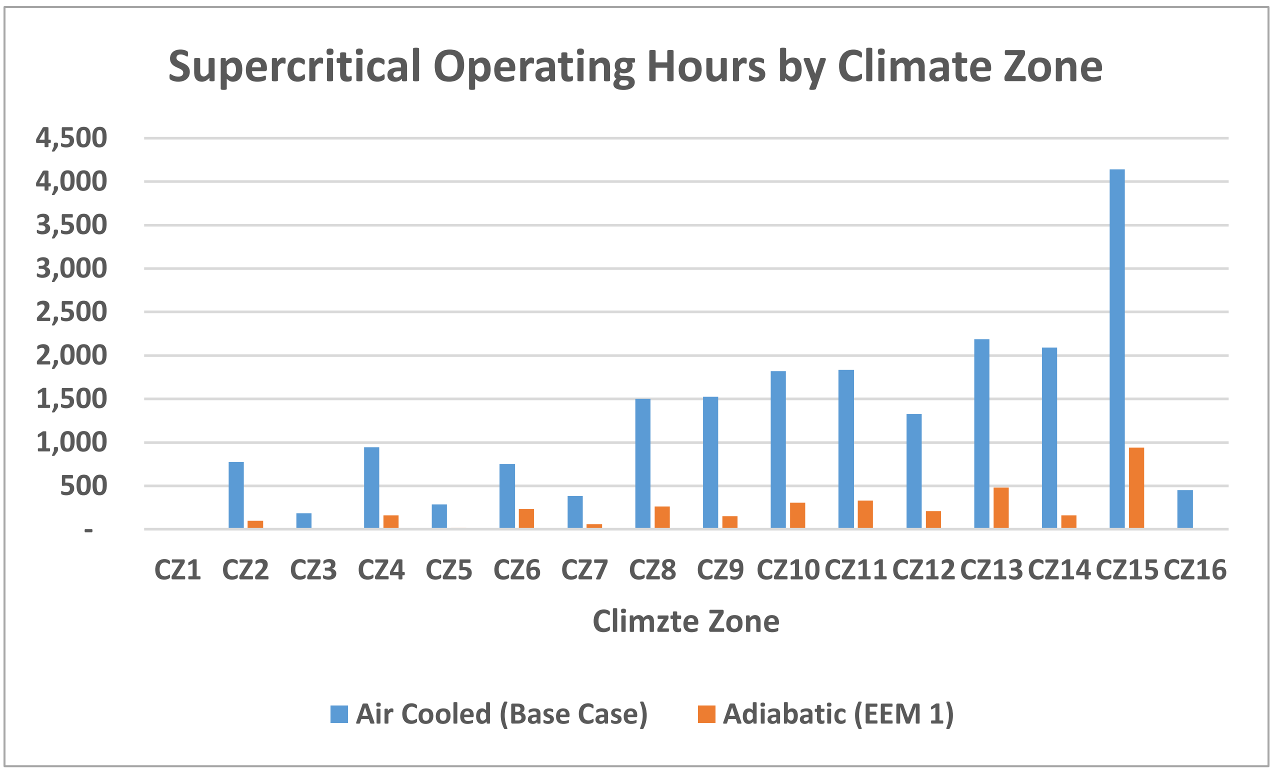

Figure 6. Supercritical hours (air cooled vs. adiabatic, RWH).

The number of hours in transcritical mode are naturally higher in the hot climate zones such as Climate Zone 15, and the hours are lower in the mild or cold climate zones such as Climate Zone 1.

Large Supermarket

Annual savings for the 60,000 ft^2 prototypical supermarket for the first year are expected to range from -116,000 to 274,000 kWh/yr (-1.94 to 4.58 kWh/ft^2) depending upon climate zone. Demand reductions are expected to range between 10 and 201 kW depending on climate zone.

The Large Supermarket prototype saves kWh in Climate Zone 8 through 15, and the kWh consumption increases for all other climate zones.

The supermarket prototype has slightly higher number of hours in the transcritical mode, as it has a different load profile than the refrigerated warehouse prototype.

Table 20: Supercritical Hours (Air Cooled vs. Adiabatic, Supermarket)

Climate Zone	Air Cooled (Base Case)	Adiabatic (EEM1)
1	11	10
2	936	340
3	234	126
4	1,166	595
5	327	102
6	921	1169
7	467	703
8	1,730	862
9	1,790	594
10	2,104	759
11	2,185	736
12	1,541	628
13	2,518	1,043
14	2,305	392
15	4,383	1,307
16	527	17

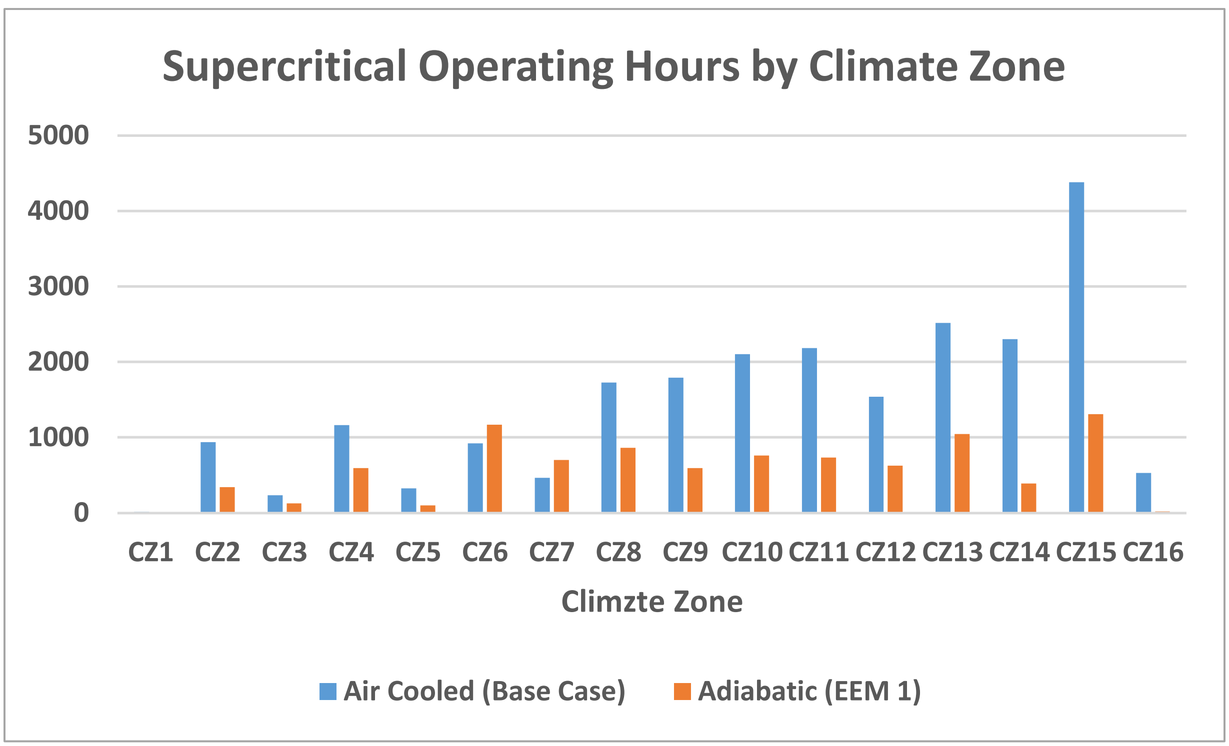

Figure 7. Supercritical hours (air cooled vs. adiabatic, LSM).

Minimum Air-Cooled and Adiabatic Gas Cooler Sizing and Specific Efficiency

The proposed values for air-cooled and adiabatic gas cooler specific efficiency are considered standard practice and do not incur any additional cost or energy savings. Therefore, this measure only attributes incremental savings based on the increase in gas cooler size for air-cooled gas coolers.

Large Refrigerated Warehouse (Air-Cooled Gas Cooler Sized at 6°F Approach)

Annual savings for the large refrigerated warehouse prototype for the first year are expected to range from -8,634 to 15,057 kWh/yr (-0.1 to 0.16 kWh/ft^2) depending upon climate zone. Demand reductions range between -5 and 16 kW depending on climate zone.

Overall, the gas cooler sized at 6°F approach resulted in approximately 1 percent kWh savings compared incrementally to the Standard Design of 8°F approach in the climate zones where there are positive kWh savings.

Large Supermarket (Air-Cooled Gas Cooler Sized at 6°F Approach)

Annual savings for the first year are expected to range from 1,919 to 16,289 kWh/yr (0.03 to 0.27 kWh/ft^2) depending upon climate zone. Demand reductions range between -2.2 to 3.4 kW depending on climate zone.

Overall, the gas cooler sized at 6°F approach resulted in approximately 1 percent kWh savings compared incrementally to the Standard Design of 8°F approach.

Supercritical Optimized Head Pressure Control

Large Refrigerated Warehouse

Annual savings for the 92,000 ft^2 refrigerated warehouse prototype for the first year are expected to range from 267 to 92,600 kWh/yr (0 to 1.01 kWh/ft^2) depending upon climate zone. Demand reductions are expected to range between -64 and 16 kW depending on climate zone.

Overall, the optimized head pressure control with modulating fan speeds resulted in 0 percent to 4 percent kWh savings compared to the total prototype annual kWh consumption when operating with 100 percent fan speed during supercritical operating hours.

Large Supermarket

Annual savings for the 60,000 ft^2 large supermarket prototype for the first year are expected to vary widely over a range from 98 to 22,700 kWh/yr (0 to 0.38 kWh/ft^2) depending upon climate zone. Demand reductions are expected to range between -24.6 and 9 kW depending on climate zone.

The gas cooler fans run at full speed in the Standard Case, so the gas cooler leaving temperature is as low as possible, compared to Proposed Case in which the gas cooler fans modulate speed to maintain a constant approach temperature (difference between the leaving gas temperature and dry bulb temperature). An example is given in Table 21.

The gas leaving the gas cooler is at a higher temperature and enthalpy in the Proposed Case compared to the Base Case. The leaving gas expands into the intermediate pressure vessel at 40°F (568 psia) saturation. After expansion, a higher percent mass fraction of the entering refrigerant is flash gas due to its higher enthalpy in the Proposed Case compared to the Standard Case. This additional flash gas increases the high stage mass flow as the compressors working in the high stage compress the gas in the intermediate pressure vessel. This increase in compressor demand offsets the decrease in condenser fan power, resulting in an overall net increase in demand.

Table 21: Operational Comparison for Optimized Head Pressure Control

Run	Climate Zone	Day and Hour	Discharge Pressure (psia)	Leaving Gas Cooler Temperature (°F)	Leaving Gas Enthalpy (Btu/lb)	Condenser Power (kW)	HS Mass Flow (lb/h)	HS Compressor Power (kW)	Total Power (kW)
Standard Case	9	9/1 17:00	1,530.4	109	137.75	36.9	18,342	234.0	270.9
Proposed Case	9	9/1 17:00	1,530.4	112.2	142.18	14.7	20,530	261.8	276.5

Subcritical Ambient Temperature Reset Control Strategy

This proposed code change is considered standard practice and would incur no incremental cost or energy savings.

Minimum Saturated Condensing Temperature Setpoint of 60℉

This proposed code change is considered standard practice and would incur no incremental cost or energy savings.

Heat Recovery (Large Supermarket)

Annual natural gas savings associated with a heat recovery heat exchanger sized for 25 percent of a minimum design total heat of rejection of 500 MBH are expected to range from 3,000 therms/yr to 11,000 therms/year (0.05 to 0.18 therms/ft^2) depending on the climate zone.

Table 22: First-Year Energy Impacts Per Square Foot – Large Refrigerated Warehouse Prototype Building – Air-Cooled Gas Cooler Restriction

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)[a]	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(1.22)	0.00	0.00	(34.05)
2	0.73	0.00	0.00	32.26
3	(0.75)	0.00	0.00	6.40
4	0.81	0.00	0.00	27.41
5	(0.42)	0.00	0.00	(15.67)
6	0.90	0.00	0.00	23.17
7	(0.18)	0.00	0.00	(9.36)
8	1.49	0.00	0.00	32.99
9	1.67	0.00	0.00	51.60
10	2.17	0.00	0.00	62.58
11	2.60	0.00	0.00	125.17
12	1.72	0.00	0.00	62.25
13	1.86	0.00	0.00	73.55
14	2.16	0.00	0.00	73.81
15	4.74	0.00	0.00	167.70
16	0.42	0.00	0.00	9.76

a. Demand savings rounds to zero on a per square foot basis. Reference in-text description for total prototype demand savings/increases.

Table 23: First-Year Energy Impacts Per Square Foot – Large Refrigerated Warehouse Prototype Building – Air Cooled Gas Cooler Sized at 6°F

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)[a]	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)[b]
1	0.15	0.00	0.00	3.99
2	0.07	0.00	0.00	0.46
3	0.09	0.00	0.00	2.64
4	0.10	0.00	0.00	0.96
5	0.11	0.00	0.00	3.11
6	0.16	0.00	0.00	3.61
7	0.15	0.00	0.00	3.65
8	0.08	0.00	0.00	0.77
9	0.06	0.00	0.00	0.35
10	0.06	0.00	0.00	0.36
11	(0.00)	(0.00)	0.00	(1.28)
12	0.05	0.00	0.00	(0.02)
13	(0.01)	0.00	0.00	(1.49)
14	(0.02)	0.00	0.00	(1.71)
15	(0.09)	0.00	0.00	(3.04)
16	0.06	0.00	0.00	1.53

a. Demand savings rounds to zero on a per square foot basis. Reference in-text description for total prototype demand savings/increases.

b. Larger gas coolers with the same specific efficiency will have higher fan power. Because the Standard Case assumes 100% fan speed during supercritical operation, it is possible to have negative TDV energy savings due to high condenser fan power during peak periods where the TDV factors are higher, even if the total annual energy savings are slightly positive.

Table 24: First-Year Energy Impacts Per Square Foot – Large Refrigerated Warehouse Prototype Building – Supercritical Optimized Head Pressure Control (with Modulating Fan Speeds)

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)[a]	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	0.00	(0.00)	0.00	0.12
2	0.16	(0.00)	0.00	8.05
3	0.04	(0.00)	0.00	4.12
4	0.23	(0.00)	0.00	11.97
5	0.09	0.00	0.00	2.23
6	0.22	0.00	0.00	10.36
7	0.13	0.00	0.00	4.59
8	0.37	(0.00)	0.00	14.26
9	0.37	0.00	0.00	14.54
10	0.41	(0.00)	0.00	15.08
11	0.46	(0.00)	0.00	14.59
12	0.27	(0.00)	0.00	10.48
13	0.53	(0.00)	0.00	16.31
14	0.55	(0.00)	0.00	18.37
15	1.01	(0.00)	0.00	18.55
16	0.16	0.00	0.00	4.02

a. Demand savings rounds to zero on a per square foot basis. Reference in-text description for total prototype demand savings/increases.

Table 25. First-Year Energy Impacts Per Square Foot – Large Supermarket Prototype Building – Air-Cooled Gas Cooler Restriction

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)[a]	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)[b]
1	(1.94)	0.00	0.00	(53.84)
2	(0.42)	0.00	0.00	5.24
3	(1.20)	0.00	0.00	(24.86)
4	(0.39)	0.00	0.00	12.43
5	(1.03)	0.00	0.00	(30.69)
6	(0.33)	0.00	0.00	(5.02)
7	(0.78)	0.00	0.00	(22.64)
8	0.16	0.00	0.00	17.71
9	0.32	0.00	0.00	26.47
10	0.83	0.00	0.00	41.34
11	1.42	0.00	0.00	67.01
12	0.45	0.00	0.00	36.42
13	1.42	0.00	0.00	67.64
14	1.38	0.00	0.00	54.21
15	4.58	0.00	0.00	170.72
16	(0.36)	0.00	0.00	(9.33)

a. Demand savings rounds to zero on a per square foot basis. Reference in-text description for total prototype demand savings/increases.

b. Because this measure was analyzed assuming adiabatic gas coolers which are designed to result in peak energy savings, it is possible to have positive TDV energy savings due to energy savings during times when TDV factors are comparatively very high, even if the total annual energy savings are slightly negative.

Table 26: First-Year Energy Impacts Per Square Foot – Large Supermarket Prototype Building – Air Cooled Gas Cooler Sized at 6°F

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)[a]	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	0.27	(0.00)	0.00	7.06
2	0.14	0.00	0.00	3.76
3	0.19	(0.00)	0.00	5.11
4	0.22	(0.00)	0.00	5.39
5	0.21	(0.00)	0.00	6.03
6	0.27	0.00	0.00	7.18
7	0.24	(0.00)	0.00	6.66
8	0.17	(0.00)	0.00	5.10
9	0.17	0.00	0.00	4.33
10	0.16	(0.00)	0.00	4.64
11	0.08	(0.00)	0.00	1.63
12	0.15	(0.00)	0.00	3.78
13	0.13	(0.00)	0.00	2.89
14	0.07	(0.00)	0.00	1.36
15	0.03	0.00	0.00	0.82
16	0.11	(0.00)	0.00	2.81

a. Demand savings rounds to zero on a per square foot basis. Reference in-text description for total prototype demand savings/increases.

Table 27: First-Year Energy Impacts Per Square Foot – Large Supermarket Prototype Building – Supercritical Optimized Head Pressure Control (with Modulating Fan Speeds)

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)[a]	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	0.00	0.00	0.00	0.05
2	0.10	0.00	0.00	3.50
3	0.03	0.00	0.00	2.87
4	0.14	0.00	0.00	4.32
5	0.05	0.00	0.00	1.44
6	0.12	(0.00)	0.00	4.54
7	0.08	0.00	0.00	3.45
8	0.17	0.00	0.00	5.15
9	0.18	(0.00)	0.00	5.32
10	0.19	0.00	0.00	5.11
11	0.20	0.00	0.00	5.48
12	0.13	(0.00)	0.00	3.60
13	0.21	(0.00)	0.00	4.79
14	0.23	0.00	0.00	7.04
15	0.38	(0.00)	0.00	5.55
16	0.09	0.00	0.00	2.36

a. Demand savings rounds to zero on a per square foot basis. Reference in-text description for total prototype demand savings/increases.

Table 28. First-Year Energy Impacts Per Square Foot – Large Supermarket Prototype Building –Heat Recovery for CO_2

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)[a]	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	(0.35)	0.00	0.18	2.52
2	(0.33)	0.00	0.14	1.71
3	(0.35)	0.00	0.16	2.18
4	(0.33)	0.00	0.13	1.64
5	(0.34)	0.00	0.17	2.19
6	(0.33)	0.00	0.13	1.65
7	(0.34)	0.00	0.12	1.43
8	(0.33)	0.00	0.11	1.16
9	(0.32)	0.00	0.11	1.18
10	(0.32)	0.00	0.10	1.08
11	(0.31)	0.00	0.10	1.14
12	(0.32)	0.00	0.11	1.20
13	(0.31)	0.00	0.10	1.03
14	(0.31)	0.00	0.10	1.13
15	(0.29)	0.00	0.05	0.27
16	(0.33)	0.00	0.14	1.71

a. Demand savings rounds to zero on a per square foot basis. Reference in-text description for total prototype demand savings/increases.

2.4 Cost and Cost Effectiveness

2.4.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 2.3.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). In this case, the period of analysis used is 15 years. The TDV energy cost impacts are presented in nominal dollars and in 2023 present value dollars and represent the energy cost savings realized over 15 years.

This code change proposal is only applicable to newly constructed refrigeration systems (both new construction and alteration). Because the energy savings does not differ between new construction and alterations, the energy cost savings analysis described below only reference new construction.

2.4.2 Energy Cost Savings Results

Per-square foot energy cost savings for newly constructed buildings and alterations that are realized over the 15-year period of analysis are presented in nominal dollars in the Final CASE Report in Appendix C. Energy cost savings in 2023 present valued (PV) dollars are presented in Section 2.4.5 below in the cost effectiveness tables. The only benefit to the proposed measures is electricity cost savings. Therefore, the benefits presented in Section 2.4.5 are equivalent to the PV TDV electricity cost savings in PV 2023$.

The TDV methodology allows peak electricity savings to be valued more than electricity savings during non-peak periods. The code change proposal with the most significant impact on peak savings is the restriction on air-cooled gas coolers. The peak savings attributed to adiabatic gas coolers for the refrigerated warehouse prototype in all climate zones are given in the table below. Note savings values in parentheses are negative values and reflect increased energy consumption and increased energy cost.

Climate Zone 3 has cost savings during the peak hours and increase in energy cost during most of the remaining hours, so its peak hour cost savings percentage is higher than 100 percent. The peak hour savings are high in Climate Zone 2, 3, 6, 14 and 15. The savings are more evenly spread out in the remaining climate zones.

Table 29: Contribution of Peak Savings - Adiabatic Gas Coolers

Climate Zone	Peak Hours	Average $/TDV	Peak $/TDV	Peak Hour Savings (TDV $)	Total Savings (TDV $)	Peak Hour Savings %	Average Peak Hour Savings (TDV $)	Average Savings per Hour (TDV $)
1	Aug 27, 28, 29: 5pm to 8pm	2.51	37.73	(1,140)	(278,784)	0.4	(127)	(31.8)
2	Jun 28, 29, 30: 5pm to 8pm	2.49	297.53	36,319	264,170	13.7	4,035	30.16
3	Oct 1, 2, 3: 5pm to 8pm	2.50	260.25	149,805	52,418	285.8	16,645	5.98
4	Jun 28, 29, 30: 5pm to 8pm	2.51	206.92	33,752	224,406	15.0	3,750	25.62
5	Oct 1, 2, 3: 5pm to 8pm	2.52	77.70	4,600	(128,272)	(3.6)	511	(14.64)
6	Oct 1, 2, 3: 5pm to 8pm	2.50	137.64	21,532	189,698	11.4	2,392	21.65
7	Sep 2, 3, 4: 2pm to 5pm	2.50	90.50	2,447	(76,637)	(3.2)	272	(8.87)
8	Sep 3, 4, 5: 2pm to 5pm	2.51	98.23	15,361	270,144	5.7	1,707	30.84
9	Jun 28, 29, 30: 2pm to 5pm	2.51	184.41	10,684	422,508	2.5	1,187	48.23
10	Jun 28, 29, 30: 2pm to 5pm	2.50	81.70	12,573	512,392	2.5	1,397	58.49
11	Jun 7, 8, 9:2pm to 5pm	2.50	192.50	109,694	1,024,868	10.7	12,188	116.99
12	Jun 28, 29, 30: 2pm to 5pm	2.50	187.97	32,090	509,720	6.3	3,566	58.19
13	Jun 28, 29, 30: 2pm to 5pm	2.49	276.76	53,778	602,266	8.9	5,975	68.75
14	Jun 28, 29, 30: 2pm to 5pm	2.50	218.48	61,327	604,337	10.1	6,814	68.99
15	Jun 28, 29, 30: 2pm to 5pm	2.50	225.50	193,205	1,373,096	14.1	21,467	156.75
16	Feb 2, 3, 4: 5pm to 8pm	2.55	141.65	84	79,908	0.11	9.32	9.12

2.4.3 Incremental First Cost

Incremental first cost is the initial cost to adopt more efficient equipment or building practices when compared to the cost of an equivalent baseline project. Therefore, it was important that the Statewide CASE Team consider first costs in evaluating overall measure cost effectiveness. Incremental first costs are based on data available today and can change over time as markets evolve and professionals become familiar with new technology and building practices.

Air-Cooled Gas Cooler Restriction

The incremental cost for restricting air-cooled gas coolers was estimated by assuming the use of adiabatic gas coolers. Pricing data from multiple manufacturers for an air-cooled gas cooler at a nominal 8°F rated approach temperature between gas cooler outlet temperature and ambient dry bulb temperature was compared to pricing data for an adiabatic gas cooler at a nominal 15°F rated approach temperature between gas cooler outlet temperature and ambient dry bulb temperature, assuming the adiabatic gas cooler was operating in dry mode. This sizing approach is analogous to the current minimum sizing practices for adiabatic condensers that is currently in Title 24, Part 6. The price difference between the air cooled and adiabatic gas coolers was used to determine a percent cost increase that was then applied to each climate zone simulation for each prototype. The incremental cost was found to be approximately 30 percent more for adiabatic.

In addition to the equipment cost, an incremental $3,000 was assumed to cover the cost of water piping and installation. Taxes were assumed to be 7.5 percent and a contingency of 10 percent was used. In total the estimated incremental cost was assumed to be approximately $83,000 and $34,000 for the LRWH and LSM prototypes respectively across all climate zones.

Minimum Air-Cooled and Adiabatic Gas Cooler Sizing and Specific Efficiency

Incremental cost for gas cooler sizing was developed by developing a database of air-cooled gas coolers and establishing an average cost per unit of heat rejection capacity ($/MBH). The incremental size increase associated with a change in the rated temperature difference between the gas cooler outlet temperature and the design ambient air temperature was converted to a corresponding increasing in MBH, and thus a corresponding increase to the expected cost of the incrementally larger gas cooler. The incremental first cost was estimated to be $5,000 per degree of approach temperature when selecting a larger gas cooler for large refrigerated warehouses, and $2,500 per degree temperature difference when selecting a larger gas cooler for large supermarkets.

Supercritical Optimized Head Pressure Control

The incremental cost for optimized head pressure control with modulating fan speeds (as opposed to fan speeds at 100% speed during supercritical operation) was developed by accounting for both incremental equipment costs, installation costs, and commissioning costs. General optimized head pressure control is already standard practice for transcritical CO_2 systems, with the key differences in fan speed control. The incremental cost associated with going from 100 percent fan speed control during supercritical mode to modulating fan speed control was assumed to be 90 hours of additional programming and commissioning time per prototype. Commissioning time consists of fine tuning the operating approach temperature setpoint, and validation that fan speeds modulate to maintain a fixed approach temperature for each transcritical CO_2 rack/condenser. A labor rate of $120/hr was used, and a 10 percent contingency factor was applied to calculate the total incremental cost. The total incremental first cost was estimated to be $10,800 per prototype.

Subcritical Ambient Temperature Reset Control Strategy

This proposed code change is considered standard practice and would incur no incremental cost or energy savings.

Minimum Saturated Condensing Temperature Setpoint of 60℉

This proposed code change is considered standard practice and would incur no incremental cost or energy savings.

Heat Recovery (Large Supermarket)

The incremental first cost estimate for indirect CO_2 heat recovery is as follows:

Table 30: Incremental First Cost (Heat Recovery)

Cost Category	**Amount (2023 PV)**
Equipment (brazed plate glycol/CO_2 HX, glycol air coil, recirculation pump)	$13,195
Materials – piping, ductwork, additional refrigerant etc.	$10,563
Installation and Commissioning	$13,350
Taxes, Permits, Contingency and Others	$13,915
Total	$51,023

The installation and commissioning labor hours were estimated to be as follows:

- Piping installation labor – 70 hours at $75 per hour
- Additional electrical and controls work – 20 hours at $75 per hour
- Labor to install coil in duct or air handler – 40 hours at $75 per hour
- Engineering and planning – 40 hours at $90 per hour

7.5 percent was added for taxes and permits, and 30 percent contingency was included.

2.4.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 15-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows:

$$PresentValueofMaintenanceCost = MaintenanceCost \times [\frac{1}{1+d}]^n$$

Air-Cooled Gas Cooler Restriction

Adiabatic gas coolers need additional maintenance due to the pre-cooling pads, as they are wetted by water. The pre-cooling pads need to be cleaned periodically. Additionally, the adiabatic condensers switch between dry mode and wet mode depending upon the ambient dry bulb temperature. The control strategy needs periodic checks to make sure that it is working optimally. The maintenance cost was estimated to be $64,000 and $32,000 for the large warehouse and large supermarket prototype, respectively. The maintenance costs for the 15 years include the 3 percent discount rate.

The replacement cost was considered for adiabatic gas coolers. The pre-cooling pads were estimated to be replaced three times during the 15-year analysis period. The cost of pre-cooling pad replacement was estimated to be $120,000 and $60,000 for the large warehouse and large supermarket, respectively.

Lastly, water usage and sewer costs were included on an annual basis. 21 different water districts were sampled to develop estimated per unit cost impacts. The estimated average water and sewer costs were each $0.006/gallon. Water usage varied by climate zone resulting in different water and sewer costs. These costs are summarized in Table 31 below.

Table 31: 15 Year Present Value Water and Sewer Costs for Adiabatic Gas Coolers

Climate Zone	15 Year Water and Sewer Costs (PV 2023$) - LRWH	15 Year Water and Sewer Costs (PV 2023$) - LSM
1	$6,339	$3,580
2	$61,286	$31,541
3	$31,194	$17,134
4	$46,954	$24,707
5	$32,335	$17,542
6	$116,323	$62,247
7	$65,063	$35,755
8	$122,452	$63,663
9	$111,594	$57,961
10	$112,035	$56,892
11	$93,445	$47,220
12	$85,787	$44,003
13	$108,065	$53,104
14	$93,880	$46,849
15	$149,813	$68,549
16	$25,474	$15,021

Minimum Air-Cooled and Adiabatic Gas Cooler Sizing and Specific Efficiency

There is no incremental maintenance cost associated with this measure.

Supercritical Optimized Head Pressure Control

The optimized head pressure control needs periodic checks to make sure fan modulation in response to the temperature difference between the ambient dry bulb temperature and the leaving gas cooler temperature is working optimally. The maintenance cost was estimated to be $17,000 and $8,500 for the large warehouse and large supermarket prototype, respectively. The maintenance costs for the 15 years include the 3 percent discount rate.

Subcritical Ambient Temperature Reset Control Strategy

This proposed code change is considered standard practice and would incur no incremental cost or energy savings.

Minimum Saturated Condensing Temperature Setpoint of 60℉

This proposed code change is considered standard practice and would incur no incremental cost or energy savings.

Heat Recovery (Large Supermarket)

The incremental maintenance cost was calculated as the present value (PV) for $800 per year at 3 percent discount rate for 15 years. The estimated labor hours and hourly labor rate were estimated to be 8 and $100 per hour, respectively. The total Maintenance cost over 15 years was calculated to be $9,550.

2.4.5 Cost Effectiveness

This measure proposes a mandatory requirement. As such, a cost analysis is required to demonstrate that the measure is cost effective over the 15-year period of analysis.

The Energy Commission establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 15-year period of analysis were included. The TDV energy cost savings from electricity savings were also included in the evaluation.

Design costs were not included nor were the incremental costs of code compliance verification.

According to the Energy Commission's definitions, a measure is cost effective if the benefit-to-cost (B/C) ratio is greater than 1.0. The B/C ratio is calculated by dividing the cost benefits realized over 15 years by the total incremental costs, which includes maintenance costs for 15 years. The B/C ratio was calculated using 2023 PV costs and cost savings.

Results of the per-square foot cost-effectiveness analyses are presented in Table 32. through

Table 38 for new construction. Alterations are not considered for this proposed measure.

Table 32: 15-Year Cost-Effectiveness Summary Per Square Foot – New Construction – Large Refrigerated Warehouse – Air-Cooled Gas Cooler Restriction

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	($3.03)	$2.98	(1.02)
2	$2.87	$3.57	0.80
3	$0.57	$3.25	0.18
4	$2.44	$3.42	0.71
5	($1.39)	$3.26	(0.43)
6	$2.06	$4.17	0.49
7	($0.83)	$3.62	(0.23)
8	$2.94	$4.24	0.69
9	$4.59	$4.12	1.11
10	$5.57	$4.13	1.35
11	$11.14	$3.92	2.84
12	$5.54	$3.84	1.44
13	$6.55	$4.08	1.60
14	$6.57	$3.93	1.67
15	$14.92	$4.54	3.29
16	$0.87	$3.19	0.27

Table 33: 15-Year Cost-Effectiveness Summary Per Square Foot – New Construction – Large Refrigerated Warehouse – Gas Cooler Sized at 6°F

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$0.36	$0.10	3.49
2	$0.04	$0.15	0.27
3	$0.23	$0.14	1.74
4	$0.09	$0.15	0.58
5	$0.28	$0.14	2.00
6	$0.32	$0.15	2.21
7	$0.32	$0.14	2.33
8	$0.07	$0.16	0.44
9	$0.03	$0.16	0.20
10	$0.03	$0.17	0.19
11	($0.11)	$0.17	(0.68)
12	($0.00)	$0.16	(0.01)
13	($0.13)	$0.16	(0.81)
14	($0.15)	$0.17	(0.92)
15	($0.27)	$0.19	(1.45)
16	$0.14	$0.13	1.02

Table 34: 15-Year Cost-Effectiveness Summary Per Square Foot – New Construction – Large Refrigerated Warehouse – Supercritical Optimized Head Pressure Control (with Modulating Fan Speeds)

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$0.01	$0.335	0.03
2	$0.72	$0.335	2.14
3	$0.37	$0.335	1.10
4	$1.07	$0.335	3.18
5	$0.20	$0.335	0.59
6	$0.92	$0.335	2.75
7	$0.41	$0.335	1.22
8	$1.27	$0.335	3.79
9	$1.29	$0.335	3.87
10	$1.34	$0.335	4.01
11	$1.30	$0.335	3.88
12	$0.93	$0.335	2.79
13	$1.45	$0.335	4.34
14	$1.64	$0.335	4.89
15	$1.65	$0.335	4.93
16	$0.36	$0.335	1.07

Table 35: 15-Year Cost-Effectiveness Summary Per Square Foot – New Construction – Large Supermarket – Air-Cooled Gas Cooler Restriction

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	($4.79)	$2.18	(2.20)
2	$0.47	$2.64	0.18
3	($2.21)	$2.40	(0.92)
4	$1.11	$2.53	0.44
5	($2.73)	$2.41	(1.13)
6	($0.45)	$3.16	(0.14)
7	($2.01)	$2.71	(0.74)
8	$1.58	$3.18	0.50
9	$2.36	$3.08	0.76
10	$3.68	$3.07	1.20
11	$5.96	$2.91	2.05
12	$3.24	$2.85	1.14
13	$6.02	$3.00	2.00
14	$4.83	$2.90	1.66
15	$15.19	$3.26	4.66
16	($0.83)	$2.37	(0.35)

Table 36: 15-Year Cost-Effectiveness Summary Per Square Foot – New Construction – Large Supermarket – Gas Cooler Sized at 6°F

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$0.63	$0.07	9.27
2	$0.33	$0.07	4.52
3	$0.46	$0.07	6.60
4	$0.48	$0.07	6.77
5	$0.54	$0.07	7.85
6	$0.64	$0.07	9.10
7	$0.59	$0.07	8.79
8	$0.45	$0.07	6.08
9	$0.39	$0.08	5.11
10	$0.41	$0.08	5.24
11	$0.15	$0.08	1.82
12	$0.34	$0.08	4.34
13	$0.26	$0.08	3.32
14	$0.12	$0.08	1.52
15	$0.07	$0.09	0.83
16	$0.25	$0.07	3.72

Table 37. 15-Year Cost-Effectiveness Summary Per Square Foot – New Construction – Large Supermarket – Supercritical Optimized Head Pressure Control (with Modulating Fan Speeds)

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$0.00	$0.36	0.01
2	$0.31	$0.36	0.88
3	$0.26	$0.36	0.72
4	$0.38	$0.36	1.08
5	$0.13	$0.36	0.36
6	$0.40	$0.36	1.14
7	$0.31	$0.36	0.86
8	$0.46	$0.36	1.29
9	$0.47	$0.36	1.33
10	$0.46	$0.36	1.28
11	$0.49	$0.36	1.37
12	$0.32	$0.36	0.90
13	$0.43	$0.36	1.20
14	$0.63	$0.36	1.76
15	$0.49	$0.36	1.39
16	$0.21	$0.36	0.59

Table 38. 15-Year Cost-Effectiveness Summary Per Square Foot – New Construction – Large Supermarket – Heat Recovery

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$2.52	$1.01	2.50
2	$1.71	$1.01	1.69
3	$2.18	$1.01	2.16
4	$1.64	$1.01	1.62
5	$2.19	$1.01	2.17
6	$1.65	$1.01	1.63
7	$1.43	$1.01	1.42
8	$1.16	$1.01	1.15
9	$1.18	$1.01	1.17
10	$1.08	$1.01	1.07
11	$1.14	$1.01	1.13
12	$1.20	$1.01	1.19
13	$1.03	$1.01	1.02
14	$1.13	$1.01	1.12
15	$0.27	$1.01	(0.27)
16	$1.71	$1.01	1.69

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

2.4.6 Response to Stakeholder Comments

One major comment was received from stakeholders after the release of the Draft CASE Report related to Submeasure A. This comment requested that technologies such as parallel compression, ejectors, or mechanical subcooling be considered as an alternative to air cooled gas cooler restriction in the code requirements.

In response to this comment two CO_2 refrigeration systems were modeled to determine whether or not parallel compression would achieve similar savings to the cost-effective air cooled gas cooler restriction measure. The first refrigeration system (System 1) uses adiabatic gas coolers and the second refrigeration system (System 2) uses air-cooled gas coolers and parallel compression with an SST setpoint of 30°F. Other system parameters were not changed between the two systems. The two systems were compared with a Base Case system that uses air-cooled gas cooler with no parallel compression. The comparison was done for Climate Zone 10, as this climate zone has a benefit cost ratio of 1.35, which is marginally above 1.

The table below summarizes the results.

Table 39: Parallel Compression vs. Air Cooled Gas Cooler Restriction

Run	Total kWh	kWh Savings	Total TDV	TDV Savings
Base Case (air cooled gas cooler)	1,981,267	NA	57,903	NA
System 1 with adiabatic gas cooler	1,781,213	200,000	52,146	5,757
System 2 with air cooled gas cooler (Base Case) and parallel compression	1,935,113	46,100	56,488	1,416

Although parallel compression reduces the compressor energy of the refrigeration system, it results in only approximately 23 percent of the savings achieved by the restriction of air cooled gas coolers. Therefore, it is not considered an energy neutral alternative to the air cooled gas cooler restriction measure. Due to modeling limitations and timing constraints, gas ejectors were not analyzed. It should be noted that inherent in the design of a booster transcritical CO_2 system is the intermediate flash tank, which acts as a flash subcooler which feeds lower temperature liquid to medium temperature and low temperature loads.

2.5 First-Year Statewide Impacts

2.5.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction by multiplying the per-square foot savings, which are presented in Section 2.4.2, by assumptions about the percentage of newly constructed buildings that would be impacted by the proposed code. The statewide new construction forecast for 2023 is presented in Appendix A as are the Statewide CASE Team's assumptions about the percentage of new construction that would be impacted by the proposal (by climate zone and building type).

Because transcritical CO_2 is an emerging technology, and ammonia is still the dominant refrigerant of choice for refrigerated warehouses in the state of California, only 5 percent of new construction square footage is assumed to be transcritical CO_2 systems.

The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2023. The 15-year energy cost savings represent the energy cost savings over the entire 15-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account. Table 40 through Table 43 present the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone. While supercritical optimized head pressure control with modulating fan speeds was shown to be cost effective in some climate zones, the Statewide CASE Team at this time is not recommending this measure for adoption due to two main reasons: the magnitude of savings is small on a per prototype basis (~ one percent) and the Statewide CASE Team does not want to limit innovation in control strategies. The proposed specific efficiency threshold for air-cooled gas coolers combined with the restriction of air-cooled gas coolers in warm ambient climate zones ensures that the 100% fan speed control strategy during supercritical operation would not result in excess energy consumption provided that the head pressure is still adjusted based on ambient conditions. Thus, this measure is not included in the statewide savings estimates.

Table 40: Statewide Energy and Energy Cost Impacts – New Construction – Large Refrigerated Warehouse – Air-Cooled Gas Cooler Restriction

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (nonresidential: million square feet)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	15-Year Present Valued Energy Cost Savings (2023 PV$)
1	0.0000	0.000	0.00	0	$0
2	0.0000	0.000	0.00	0	$0
3	0.0000	0.000	0.00	0	$0
4	0.0000	0.000	0.00	0	$0
5	0.0000	0.000	0.00	0	$0
6	0.0000	0.000	0.00	0	$0
7	0.0000	0.000	0.00	0	$0
8	0.0000	0.000	0.00	0	$0
9	0.0172	0.029	0.01	0	$78,961
10	0.0108	0.023	0.01	0	$60,090
11	0.0090	0.023	0.03	0	$100,006
12	0.0298	0.051	0.04	0	$165,206
13	0.0235	0.044	0.02	0	$153,806
14	0.0037	0.008	0.00	0	$24,622
15	0.0021	0.010	0.01	0	$32,068
16	0.0000	0.000	0.00	0	$0
TOTAL	**0.0962**	**0.1888**	**0.1131**	**0**	**$614,759**

a. First-year savings from all buildings completed statewide in 2023.

Table 41: Statewide Energy and Energy Cost Impacts – New Construction – Large Refrigerated Warehouse – Gas Cooler Sized at 6°F

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (nonresidential: million square feet)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	15-Year Present Valued Energy Cost Savings (2023 PV$)
1	0.0008	0.000	0.00	0	$280
2	0.0000	0.000	0.00	0	$0
3	0.0238	0.002	0.00	0	$5,584
4	0.0000	0.000	0.00	0	$0
5	0.0024	0.000	0.00	0	$675
6	0.0081	0.001	0.00	0	$2,613
7	0.0015	0.000	0.00	0	$500
8	0.0000	0.000	0.00	0	$0
9	0.0000	0.000	0.00	0	$0
10	0.0000	0.000	0.00	0	$0
11	0.0000	0.000	0.00	0	$0
12	0.0000	0.000	0.00	0	$0
13	0.0000	0.000	0.00	0	$0
14	0.0000	0.000	0.00	0	$0
15	0.0000	0.000	0.00	0	$0
16	0.0024	0.000	0.00	0	$327
TOTAL	**0.0391**	**0.0042**	**0.0017**	**0**	**$9,980**

a. First-year savings from all buildings completed statewide in 2023.

Table 42: Statewide Energy and Energy Cost Impacts – New Construction – Large Supermarket – Air-Cooled Gas Cooler Restriction

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (nonresidential: million square feet)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	15-Year Present Valued Energy Cost Savings (2023 PV$)
1	0.0000	0.000	0.00	0	$0
2	0.0000	0.000	0.00	0	$0
3	0.0000	0.000	0.00	0	$0
4	0.0000	0.000	0.00	0	$0
5	0.0000	0.000	0.00	0	$0
6	0.0000	0.000	0.00	0	$0
7	0.0000	0.000	0.00	0	$0
8	0.0000	0.000	0.00	0	$0
9	0.0000	0.000	0.00	0	$0
10	0.2951	0.245	0.21	0	$1,085,668
11	0.0718	0.102	0.08	0	$428,471
12	0.3035	0.136	0.41	0	$983,723
13	0.1544	0.220	0.20	0	$929,238
14	0.0663	0.091	0.06	0	$319,712
15	0.0482	0.220	0.16	0	$731,886
16	0.0000	0.000	0.00	0	$0
TOTAL	**0.9392**	**1.015**	**1.12**	**0**	**$4,478,698**

a. First-year savings from all buildings completed statewide in 2023.

Table 43: Statewide Energy and Energy Cost Impacts – New Construction – Large Supermarket – Gas Cooler Sized at 6°F

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (nonresidential: million square feet)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	15-Year Present Valued Energy Cost Savings (2023 PV$)
1	0.0108	0.003	(0.00)	0	$6,781
2	0.0641	0.009	0.00	0	$21,450
3	0.2674	0.050	(0.01)	0	$121,683
4	0.1356	0.029	(0.00)	0	$65,026
5	0.0287	0.006	(0.00)	0	$15,407
6	0.1938	0.052	0.01	0	$123,784
7	0.1624	0.038	(0.01)	0	$96,201
8	0.2738	0.047	(0.01)	0	$124,395
9	0.4185	0.069	0.02	0	$161,153
10	0.0000	0.000	0.00	0	$0
11	0.0000	0.000	0.00	0	$0
12	0.0000	0.000	0.00	0	$0
13	0.0000	0.000	0.00	0	$0
14	0.0000	0.000	0.00	0	$0
15	0.0000	0.000	0.00	0	$0
16	0.0233	0.003	(0.00)	0	$5,841
TOTAL	**1.58**	**0.31**	**0.01**	**0.00**	**$741,721**

a. First-year savings from all buildings completed statewide in 2023.

2.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion. Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42). See Appendix D for additional details on the methodology used to calculate GHG emissions. In short, this analysis assumes an average electricity emission factor of 240.4 metric tons CO_2e per GWh based on the average emission factors for the CACX EGRID subregion.

Table 44 and Table 45 present the estimated first-year avoided GHG emissions of the proposed code change; the avoided GHG emissions of different measures cannot be added as multiple measures address the same equipment (gas cooler). Note that GHG emission calculated here are the indirect GHG reductions associated energy savings. Another side benefit of transcritical CO_2 systems is the reduction in direct emissions of high GWP (global warming potential) refrigerants such as might be used in supermarket refrigeration systems. The energy efficiency measures described here are comparing a transcritical CO_2 baseline system against a high efficiency transcritical CO_2 system and thus there are no direct emissions reductions resulting from refrigerant choice.

Table 44: First-Year Statewide GHG Emissions Impacts – Large Refrigerated Warehouse

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO_2e)	Total Reduced CO_2e Emissions[a,b] (Metric Tons CO_2e)
Air-Cooled Gas Cooler Restriction	0.189	15.4	15.4
Air-Cooled Gas Cooler Sized at 6°F	0.004	0.4	0.4
TOTAL	**0.19**	**38**	**15.8**

a. First-year savings from all buildings completed statewide in 2023.

b. Assumes the following emission factors: 227.9 $MTCO_2e$/GWh

Table 45: First-Year Statewide GHG Emissions Impacts – Large Supermarket

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO_2e)	Natural Gas Savings[a] (MMTherms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO_2e)	Total Reduced CO_2e Emissions[a,b] (Metric Tons CO_2e)
Air-Cooled Gas Cooler Restriction	1.02	95.4	0	0	95.4
Air-Cooled Gas Cooler Sized at 6°F	0.31	29.2	0	0	29.2
TOTAL	**1**	**124.6**	**0**	**0**	**124.6**

a. First-year savings from all buildings completed statewide in 2023.

b. Assumes the following emission factors: 227.9 $MTCO_2e$/GWh.

2.5.3 Statewide Water Use Impacts

The proposed code change would not result in water savings. Water usage is expected to increase due to the restriction of air-cooled gas coolers in multiple climate zones.

Impacts on water use are presented in Table 46. It was assumed that all incremental water usage occurred outdoors, and the embedded electricity value was 3,565 kWh/million gallons of water. The embedded electricity estimate was derived from a 2015 CPUC study that quantified the embedded electricity savings from IOU programs that save both water and energy (CPUC 2015). See in Appendix B additional information on the embedded electricity savings estimates.

Table 46: Impacts on Water Use and Embedded Electricity in Water

Impact	On-Site Indoor Water Savings (gallons/yr)	On-site Outdoor Water Savings (gallons/yr)	Embedded Electricity Savings[a] (kWh/yr)
Per Square Foot Impacts (LRWH)	0	(13)	(0.047)
Per Square Foot Impacts (LSM)	0	(9)	(0.033)
First-Year[b] Statewide Impacts	0	(10,264,833)	(36,594)

a. Assumes embedded energy factor of 4,848kWh per million gallons of water for indoor use and 3,565 kWh per million gallons of water for outdoor water use (CPUC 2015).

2.5.4 Statewide Material Impacts

The proposed code change would require additional material for some submeasures.

The use of adiabatic gas coolers in place of air-cooled gas coolers would probably decrease the material (steel) use, as the adiabatic gas coolers are sized with higher approach (lower capacity) compared to the air-cooled gas coolers in the Standard Case. The pre-cooler pad material would be additional material type in the adiabatic gas coolers. The industry uses a variety of materials for pre-cooling pads; cellulose based pads are considered in this material impact analysis.

Supercritical and subcritical optimized head pressure control and minimum SCT setpoint of 60°F would not have any impact on material used as these measures just change the equipment control.

The increase in gas cooler size compared to the Standard Case, i.e., gas coolers sized at 6°F compared to 8°F in the Base Case, would increase the material (steel) used, as the gas coolers would need more material to reject the same amount of heat at a lower approach. The increase in the material usage is estimated based on the gas cooler manufacturer data.

Table 47: First-Year Statewide Impacts on Material Use – Large Refrigerated Warehouse – Air-Cooled Gas Cooler Restriction

Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/year)	
		Per-Unit Impacts	First-Year[b] Statewide Impacts
Cellulose or other type of pre-cooling pad materials	I	0.06	9,825

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).
b. First-year savings from all buildings completed statewide in 2023.

Table 48: First-Year Statewide Impacts on Material Use – Large Refrigerated Warehouse – Gas Cooler Sized at 6°F

Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/year)	
		Per-Unit Impacts	First-Year[b] Statewide Impacts
Steel	I	0.0077	523

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).
b. First-year savings from all buildings completed statewide in 2023.

Table 49: First-Year Statewide Impacts on Material Use – Large Supermarket – Air-Cooled Gas Cooler Restriction

Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/year)	
		Per-Unit Impacts	First-Year[b] Statewide Impacts
Cellulose or other type of pre-cooling pad materials	I	0.046	115,811

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).
b. First-year savings from all buildings completed statewide in 2023.

Table 50: First-Year Statewide Impacts on Material Use – Large Supermarket – Gas Cooler Sized at 6°F

Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/year)	
		Per-Unit Impacts	First-Year[b] Statewide Impacts
Steel	I	0.0041	10,557

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).
b. First-year savings from all buildings completed statewide in 2023.

2.5.5 Other Non-Energy Impacts

Non-energy benefits associated with the proposed measures includes improved education and understanding of transcritical CO_2 system operations. As the state of California continues to seek reduction in greenhouse gas emissions, all low GWP refrigerants would present an opportunity for market actors to adopt decisions that are consistent with statewide goals.

3. Submeasure B: Minimum Air-Cooled Condenser Sizing and Specific Efficiency for Packaged Refrigeration Systems

3.1 Measure Description

3.1.1 Measure Overview

The Statewide CASE Team proposes that the minimum size requirement for air cooled condensers for packaged refrigeration systems utilized in refrigerated warehouses be decreased to enable cost-effective installations. Condenser size is defined by the temperature difference (TD) between the design dry bulb temperature and saturated condensing temperature. The larger the temperature difference, the smaller the condenser. The existing requirement is 10°F TD for freezer systems and 15°F TD for cooler systems. The proposed requirement is 15°F TD for freezer systems and 20°F TD for cooler systems. Specific efficiency, which is related to condenser sizing, would also be modified from 65 Btuh/W to 60 Btuh/W. This would modify an existing code requirement that was developed without consideration of the package refrigeration system technology type, while also providing a limitation such that condensers are not routinely undersized.

As part of this submeasure proposal, the standard has been revised to eliminate confusion around condenser requirement exemptions for packaged units and condensing units. As part of a code language cleanup effort in 2019, condenser sizing, specific efficiency, and condenser fins per inch requirements which were previously exempted for condensing units was inadvertently interpreted to be required without the requisite cost-effective analysis. These requirements are proposed to be exempt for units with compressor horsepower less than 100HP.

The code change is applicable to new construction only.

There is no proposed acceptance testing associated with this proposed measure.

There are no proposed updates to the compliance software for this proposed measure.

Because the proposed code change does not result in statewide energy savings, a full energy savings and cost effectiveness analysis has not been performed.

3.1.2 Measure History

Packaged refrigeration systems are a growing alternative to the traditional built up refrigeration systems that are used to provide cooling for refrigerated warehouses. Instead of a centrally located engine room with large compressors and vessels that provide cooling to all spaces throughout the warehouse, multiple packaged systems can be installed on the roof or on grade outside with each providing cooling to a dedicated space or zone. These packaged systems utilize the same principles of the vapor compression refrigeration cycle and utilize the same refrigerant types (ammonia, HFCs). However, these products integrate all major components of a refrigeration system, including the compressors, condensers, vessels, and evaporators, into a unit that can be prefabricated, shipped, and installed.

Packaged systems can offer multiple benefits including lower system charge, increased footprint available for productive spaces as they eliminate the need for an engine room, reduced pressure drop in the suction piping due to shorter piping runs, and reduced installation costs in some cases. Because they can offer systems with reduced charge, they can help eliminate potential market barriers for low GWP refrigerants such as ammonia where regulatory and compliance costs coupled with safety concerns would eliminate ammonia as an option with high charge central systems.

Many of the main packaged system manufacturers provide equipment that meets most of the current Title 24, Part 6 requirements for refrigerated warehouse. However, stakeholder feedback has indicated that the air-cooled condenser sizing requirement is currently limit the adoption of this technology. Because these systems are pre-packaged and designed to be installed on the roof within a single base frame, current minimum condenser size requirements result in a cascade of cost impacts that extend beyond a larger condenser surface area, including transportation logistics, overall package size and weight, structural support requirements, etc. Additionally, the air-cooled minimum condenser size requirement was implemented into Title 24, Part 6 utilizing a prototype model that assumed a central system configuration, making the cost effectiveness results not comparable.

The existing code requirements for refrigerated warehouses in Title 24, Part 6 Section 120.6(a) were originally drafted and adopted as part of the 2008 code cycle, including the minimum condenser size requirement for air-cooled condensers. During this time packaged systems were not widely available in the market, and the prototype energy model used to develop the statewide energy savings and cost effectiveness calculations utilized assumptions associated with a central system as was standard practice in the industry.

3.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents would be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

3.1.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of Title 24, Part 6 as shown below. See Section 7.2 of this report for marked-up code language.

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

Section 100.1(b) – Definitions

This change adds definitions for condensing units and packaged refrigeration systems. The reason for adding them is that these terms are used frequently in Section 120.6(a). The necessity is to improve Title 24, Part 6's compliance with the clarity and consistency criteria of California Government Code Sections 11349 and 11349.1, and California Code of Regulations, Title 1, Section 16.

SECTION 120.6 Mandatory Requirements for Covered Processes

120.6(a)4 – Condensers

Section 120.6(a)4A –The purpose of this change is to clarify the exception to this requirement by defining what is considered a quick chilling or freezing load. It is necessary to improve Title 24, Part 6's compliance with the clarity and consistency criteria of California Government Code Sections 11349 and 11349.1, and California Code of Regulations, Title 1, Section 16.

Section 120.6(a)4B – The purpose of this change is to add the specific condenser sizing requirements related to condensing units and packaged systems. It is necessary because these requirements do not exist in the current code language.

Section 120.6(a)4B – Separately from the above, this change removes the exemption of sizing requirements for condensing units under 100HP. The reason is that it is later included at the end of Section 120.6(a)4. This change is necessary to improve Title 24, Part 6's compliance with the clarity and consistency criteria of California Government Code Sections 11349 and 11349.1, and California Code of Regulations, Title 1, Section 16.

Section 120.6(a)4B – The purpose of this change is to make the second exception to this section the only one, and to clarify the design cooling load that apply to quick chilling or freezing. It is necessary to improve Title 24, Part 6's compliance with the clarity and consistency criteria of California Government Code Sections 11349 and 11349.1, and California Code of Regulations, Title 1, Section 16.

Section 120.6(a)4C – The purpose of this change is to clarify the design cooling load that apply to quick chilling or freezing. It is necessary to improve Title 24, Part 6's compliance with the clarity and consistency criteria of California Government Code Sections 11349 and 11349.1, and California Code of Regulations, Title 1, Section 16.

Section 120.6(a)4 – The purpose of this change is to add the exemptions for condensing units and packaged units under 100HP related to sizing, specific efficiency, and fins per inch requirements. The reason is to improve clarity and include packaged units (condensing units are already exempted). This change is necessary to improve Title 24, Part 6's compliance with the clarity and consistency criteria of California Government Code Sections 11349 and 11349.1, and California Code of Regulations, Title 1, Section 16.

Table 120.6-E – The purpose of the change to this table is to add the specific efficiency requirements for packaged units and condensing units greater than or equal to 100HP and to specify the rating conditions for determining specific efficiency. This change is necessary to make the table consistent with the rest of Sections 120.6(a)4.

3.1.3.2 Summary of Changes to the Reference Appendices

The proposed code change would not modify the Reference Appendices.

3.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

The proposed code change would not modify the ACM Reference Manual.

3.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change would modify Section 10.6.3.3 Condensers of the Nonresidential Compliance Manual. See Section 7.5 of this report for the detailed proposed revisions to the text of the Compliance Manuals.

3.1.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify the compliance documents listed below. Examples of the revised documents are presented in Section 7.6.

- NRCC-PRC-E – revised to include a table section that allows for the design temperature difference for air cooled condensers associated with packaged units.

3.1.4 Regulatory Context

3.1.4.1 Existing Requirements in the California Energy Code

The existing requirements in Title 24, Part 6 for minimum sizing of air-cooled condensers for refrigerated warehouse is a 10℉ temperature difference between design dry bulb temperature and saturated condensing temperature for systems serving freezers and 15℉ for systems serving coolers. There currently exist two exemptions for condensing units below 100HP and for systems serving quick chilling/freezing process loads.

3.1.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements in other parts of the California Building Code.

3.1.4.3 Relationship to Local, State, or Federal Laws

There are no relevant local, state, or federal laws.

3.1.4.4 Relationship to Industry Standards

There are no relevant industry standards.

3.1.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced. This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix E presents how the proposed changes could impact various market actors.

The activities that need to occur during each phase of the project are described below:

- **Design Phase:** Design engineers, contractors, and owners collaborate to develop refrigeration system design loads and select the best system configuration and pieces of equipment to supply adequate cooling. All parties involved should be aware of the proposed code changes as it relates to sizing air cooled condensers if a packaged system is selected to meet the loads.
- **Permit Application Phase:** Typically, a contractor would develop a set of stamped engineering plan drawings on the owner's behalf, that would include refrigeration system design and equipment schedules. The drawings can also be developed by an independent engineering firm and are used as the basis for contractors to supply bids for the project. This set of plan drawings should incorporate information on the packaged refrigeration units and the related condenser design specifications. If the selected equipment does not comply with Title 24, Part 6, the authority having jurisdiction should provide plan check comments to correct this before providing any building permits.
- **Construction Phase:** Contractors install the refrigeration system as described in the approved plan drawings, with oversight from the owner and authority having jurisdiction. The installed equipment should match what was approved and specified in the equipment schedule. This is documented by the Covered Process Certificate of Installation and signed by the responsible party – typically the licensed mechanical contractor.

- **Inspection Phase:** After construction, the owner or contractor have the responsibility to have the building and its various mechanical systems inspected by the authority having jurisdiction. This inspection phase should include an examination of the refrigeration system to verify the compliant equipment described in the plan drawings matches what was physically installed.

The compliance process described above is very similar to the process that currently exists for measures related to refrigerated warehouses and commercial refrigeration. Updates to the existing refrigerated warehouse certificate of compliance document (NRCC-PRC-E) are anticipated in order for designers, owners, and contractors to provide evidence on their design drawings that the proposed equipment complies with Title 24, Part 6. These compliance documents updates are expected to be analogous to the existing air-cooled condenser sizing section already included in NRCC-PRC-E. No additional acceptance testing is expected to be required as this an equipment specification and not a control specification.

3.2 Market Analysis

3.2.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during public stakeholder meetings that the Statewide CASE Team held on November 7, 2019 and April 2, 2020.

The packaged market is comprised of the following key market actors: package manufacturers, distributors/sales representatives, design engineers, installation contractors, and end users. The packaged systems used in refrigerated warehouses are supplied by multiple original equipment manufacturers (OEMs) with approximately five to eight major manufacturers. Packaged systems come in a variety of capacity ranges from approximately 40 tons of refrigeration (TR) capacity to 900 TR, with multiple refrigerant options including ammonia and HFCs (R134a). Most available packages include ambient dry bulb following control with variable speed condenser fans that are controlled in unison per current Title 24, Part 6 requirements. Other energy efficiency options are available including floating suction pressure control and variable speed control of the compressors. Most packaged utilize air cooled condensers, with some market options available with water cooled condensers connected to a cooling tower.

In order to determine what type and what size package should be installed at existing refrigerated warehouses or new refrigerated warehouses, design engineers or design build contractors are hired by the end users to provide equipment specifications. There are on the order of 10-15 major design build contractors throughout the state of California with experience in industrial refrigeration that assist end users in selecting equipment. There are multiple items for consideration whenever packages are specified. These considerations range from energy efficiency, design capacity, installation cost, first cost, application type (freezer vs. cooler vs. process load), and materials of construction. Once the packaged units are selected, contractors purchase the equipment through manufacturers directly or through distribution representatives and resell the equipment to the end user at a marked-up price. End users may have the option to purchase equipment directly from a distributor, but this is not common practice. The population of end users in the market for industrial refrigeration equipment are facility owners ranging from cold storage, food and beverage processing, dairy processing, and agricultural product processors. Based on a Lawrence Berkeley National Laboratory study conducted in 2012 for Demand Response potential in California Refrigerated Warehouses, a sample population of approximately 300 facilities were surveyed. This sample population is estimated to be approximately two-thirds of the entire statewide facility population, indicating an estimated end user market of over 500 facilities.

3.2.2 Technical Feasibility, Market Availability, and Current Practices

A market study was conducted to understand the availability of packaged systems, the current design options available to end users, and how these options related to the existing Title 24, Part 6 code language. The table below summarizes the findings of the market study.

Table 51: Package System Market Summary

Manufacturer	Capacity Available (TR)	Refrigerant Options	Condenser Type Options	Typical Air-Cooled Condenser Sizing	Condenser Fan Variable Speed Control	Minimum 70F SCT	Head Pressure Control with Air Cooled Condenser
Manufacturer A	Up to 350	Ammonia	Air Cooled	15-20°F	Yes	Yes	Temperature reset (i.e., floating head pressure)
Manufacturer B	Up to 150	Ammonia	Water Cooled	N/A	N/A	Yes	N/A
Manufacturer C	Up to 900	Ammonia	Water Cooled	N/A	N/A	Yes	N/A
Manufacturer D	Up to 200	R134a	Air Cooled	15°F – 20°F	Yes	Yes	Temperature reset (i.e., floating head pressure)
Manufacturer E	Up to 400	Ammonia	Air Cooled, Water Cooled	15°F	Yes	Yes	Temperature reset (i.e., floating head pressure)

Overall, there are three main manufacturers that utilize air cooled condensers as part of their package system design. While Title 24, Part 6 requirements like head pressure control, minimum SCT, and condenser fan control are met with the current available products in the market, air cooled condensers are typically sized smaller than what is required for central systems.

The proposed code change proposal would allow for smaller air-cooled condensers to be installed as part of the packaged systems. Design practices would simply be modified to accommodate higher design saturated condensing temperatures from the existing code language requiring 10-15°F temperature difference to 20°F. Package manufacturers would still be compelled to size their condensers sufficiently large to keep the compressors within the compressor manufacturer recommended operating envelope without excessively high head pressures. Additionally, because condensers are sized for the highest annual ambient temperatures and design loads, typical operating points would still be at reduced head pressures throughout the year, and would still be utilizing variable fan speed control, which would limit the impact of higher energy consumption.

3.2.3 Market Impacts and Economic Assessments

3.2.3.1 Impact on Builders

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California's construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 52).[7] In 2018, total payroll was $80 billion. Nearly 17,000 establishments and 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

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[7] Average total monthly employment in California in 2018 was 18.6 million; the construction industry represented 4.5 percent of 2018 employment.

Table 52: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establishments	Employment	Annual Payroll (billions $)
Residential	**59,287**	**420,216**	**$23.3**
Residential Building Construction Contractors	22,676	115,777	$7.4
Foundation, Structure, & Building Exterior	6,623	75,220	$3.6
Building Equipment Contractors	14,444	105,441	$6.0
Building Finishing Contractors	15,544	123,778	$6.2
Commercial	**17,273**	**343,513**	**$27.8**
Commercial Building Construction	4,508	75,558	$6.9
Foundation, Structure, & Building Exterior	2,153	53,531	$3.7
Building Equipment Contractors	6,015	128,812	$10.9
Building Finishing Contractors	4,597	85,612	$6.2
Industrial, Utilities, Infrastructure, & Other	**4,103**	**96,550**	**$9.2**
Industrial Building Construction	299	5,864	$0.5
Utility System Construction	1,643	47,619	$4.3
Land Subdivision	952	7,584	$0.9
Highway, Street, and Bridge Construction	770	25,477	$2.4
Other Heavy Construction	439	10,006	$1.0

Source: (State of California, Employment Development Department n.d.)

The proposed change related to Submeasure B would likely affect commercial and industrial builders but would not impact firms that focus on construction and retrofit of utility systems, public infrastructure, or other heavy construction. The effects on the commercial building and industrial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 53 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 3.2.4.

Table 53: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard

Construction Subsector	Establishments	Employment	Annual Payroll (billions $)
Nonresidential plumbing and HVAC contractors	2,394	52,977	$4.5

Source: (State of California, Employment Development Department n.d.)

3.2.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 54 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for Submeasure B to affect firms that focus on refrigerated warehouse construction.

There is not a North American Industry Classification System (NAICS)[8] code specific for energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[9] It is not possible to determine which business

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[8] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

[9] Establishments in this sector include businesses primarily engaged in evaluating a building’s structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 54 provides an upper bound indication of the size of this sector in California.

Table 54: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
Architectural Services [a]	3,704	29,611	$2.9
Building Inspection Services [b]	824	3,145	$0.2

Source: (State of California, Employment Development Department n.d.)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

The proposed code language is expected to eliminate a key market barrier for packaged systems. As such, building designers and energy consultants may recognize the technology as a more viable option for their customers/end users. Building designers and energy consultants should be made aware of the revised air-cooled condenser minimum sizing requirement such that new designs are compliant with the revised code language.

3.2.3.3 Impact on Occupational Safety and Health

The proposed code language is expected to eliminate a key market barrier for packaged systems. If packaged systems are increasingly adopted instead of built up central refrigeration systems because of the decrease in the minimum size for air cooled condensers, new facilities with packaged systems would be expected to have comparatively lower refrigerant charge. An overall reduction in refrigerant charge would reduce the health and safety impact of a potential refrigerant leak, which is particularly important when applied to ammonia refrigeration systems. Additionally, since packaged systems are installed on the roof, the impact of a refrigerant leak is less likely to impact personnel inside the facility.

3.2.3.4 Impact on Building Owners and Occupants

The commercial building sector includes a wide array of building types, including offices, restaurants and lodging, retail, and mixed-use establishments, and warehouses (including refrigerated) (Kenney 2019). Energy use by occupants of commercial buildings also varies considerably with electricity used primarily for lighting, space cooling and conditioning, and refrigeration. Natural gas consumed primarily for heating water and for space heating. According to information published in the 2019 California Energy Efficiency Action Plan, there is more than 7.5 billion square feet of commercial floor space in California and consumes 19 percent of California's total annual energy use (Kenney 2019). The diversity of building and business types within this sector creates a challenge for disseminating information on energy and water efficiency solutions, as does the variability in sophistication of building owners and the relationships between building owners and occupants.

Building owners and occupants would benefit from lower energy bills. As discussed in Section 3.2.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2022 code cycle to impact building owners or occupants adversely.

3.2.3.5 Impact on Building Component Retailers (Including Manufacturers and Distributors)

The proposed code language is expected to eliminate a key market barrier for packaged systems. Therefore, manufacturers and distributors involved in the packaged system market may see a greater demand for their products, leading to increased revenue and increased sales tax revenue for the state of California.

3.2.3.6 Impact on Building Inspectors

Table 55 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 55: Employment in California State and Government Agencies with Building Inspectors

Sector	Govt.	Establishments	Employment	Annual Payroll (millions $)
Administration of Housing Programs[a]	State	17	283	$29.0
Administration of Housing Programs[a]	Local	36	2,882	$205.7
Urban and Rural Development Admin[b]	State	35	552	$48.2
Urban and Rural Development Admin[b]	Local	52	2,446	$186.6

Source: (State of California, Employment Development Department n.d.)

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.
b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

3.2.3.7 Impact on Statewide Employment

As described in Sections 3.2.3.1 through 3.2.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 3.2.4, the Statewide CASE Team estimated the proposed change in Submeasure B would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in Submeasure B would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

3.2.4 Economic Impacts

For the 2022 code cycle, the Statewide CASE Team used the IMPLAN model software, along with economic information from published sources, and professional judgement to develop estimates of the economic impacts associated with each of the proposed code changes.[10] While this is the first code cycle in which the Statewide CASE Team develops estimates of economic impacts using IMPLAN, it is important to note that the economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the Statewide CASE Team believes the economic impacts presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the commercial/industrial building industry, architects, energy consultants, and building inspectors. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2022 code cycle regulations would result in additional spending by those businesses.

There is no incremental cost associated with this measure, and thus no economic impact calculation for increased spending throughout the California economy.

3.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in this section would lead to modest changes in employment of existing jobs.

3.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 3.2.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed

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[10] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

change represents a modest change to packaged system design and control which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

3.2.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes would apply to all businesses incorporated in California, regardless of whether the business is incorporated inside or outside of the state.[11] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

3.2.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[12] As Table 56 shows, between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, with an average of 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

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[11] Gov. Code, § 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR § 2003(a)(3) Competitive advantages or disadvantages for California businesses currently doing business in the state.

[12] Net private domestic investment is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

Table 56: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits
2015	609.3	1,740.4	35%
2016	456.0	1,739.8	26%
2017	509.3	1,813.6	28%
2018	618.3	1,843.7	34%
2019	580.9	1,827.0	32%
		5-Year Average	**31%**

Source: (Federal Reserve Economic Data n.d.)

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy.

3.2.4.5 Effects on the State General Fund, State Special Funds, and Local Governments

The proposed code language is not expected to have an effect on the state general fund, state special fund, or local governments.

3.2.4.6 Impacts on Specific Persons

The proposed code language is not expected to have an impact on specific persons.

3.3 Energy Savings

The code change proposal would not increase the stringency of the existing Title 24, Part 6, so there would be no savings on a per-square foot basis. Section X.3 of the Final CASE Reports, which typically presents the methodology, assumptions, and results of the per-square foot energy impacts, has been truncated for this measure. Although this measure does not result in electricity or gas savings, the measure would promote additional options for low charge, low GWP refrigerant systems for refrigerated warehouse end users in the state of California. This aligns with other statewide goals related to reducing statewide GHG emissions via reducing refrigerant emissions.

3.4 Cost and Cost Effectiveness

The code change proposal would not increase the stringency of the existing Title 24, Part 6, so the Energy Commission does not need a complete cost-effectiveness analysis to approve the proposed change. Section X.4 of the Final CASE Reports typically presents a detailed cost-effectiveness analysis. For this proposed change, the

Statewide CASE Team is presenting information on the cost implications in lieu of a full cost-effectiveness analysis.

Overall, the proposed code change proposal is expected to reduce the first cost of air-cooled packaged systems for refrigerated warehouses between $300-700/TR based on feedback from manufacturers. A high level analysis was conducted utilizing assumptions from the Large Refrigerated Warehouse prototype described in Appendix H of the Final CASE Report to estimate the cost effectiveness of the existing 10-15°F sizing requirement compared to the proposed 15-20°F sizing requirement. The analysis utilized the following assumptions:

Design loads on the Freezer, Cooler and Dock spaces were estimated to be as follows:

Table 57: Design Load Assumptions

Space	Design Load (TR)
Freezer	113
Cooler	86
Dock	56

The respective packaged systems selected for the design load were as follows:

Table 58: Package Quantity Assumptions

Space	Design Load (TR)
Freezer	(2) 60 TR units
Cooler	(1) 100 TR unit
Dock	(1) 60 TR unit

The average hourly load was estimated to be 39 percent of design load for Freezer systems and 33 percent for Cooler systems based on the load profiles utilized in the Large Refrigerated Warehouse prototype.

The kW/TR for the packaged system serving Freezer, Cooler and Dock was estimated to be 1.61, 0.71 and 0.65, respectively. The conditions for the kW/TR calculation were estimated using an average saturated condensing temperature of 80°F, and design saturated suction temperatures of -23°F, 22°F and 27°F

The estimated kWh and TDV increase are given in the table below. A factor of 0.0286 was used to convert the kWh increase to TDV increase, based on the correlation between the kWh savings and TDV savings for the Submeasure C. A factor of $89/MBTU TDV was used to convert the TDV energy to cost ($, 15-year present value). The cost savings associated with lower condenser sizing was estimated using a factor of $450/TR for cooler and dock systems and $600/TR for freezer systems. The incremental kWh was estimated factoring in both the decrease in condenser surface area as well as an increase in fan power ratings due to the change in specific efficiency.

Table 59: Benefit-to-Cost Ratio Summary

System	kWh Increase	TDV Increase (MBTU)	TDV $ Increase (Cost Increase)	Cost Saved (Benefit)	Benefit/ Cost Ratio
Freezer	27,228	777	$69,206	$72,000	1.04
Cooler	7,151	204	$18,175	$45,000	2.48
Dock	4,305	123	$10,941	$27,000	2.47

For all three package system applications, the reduced air-cooled condenser minimum sizing requirement was shown to be cost effective.

3.5 First-Year Statewide Impacts

The code change proposal would not increase the stringency of the existing Title 24, Part 6, so the savings associated with this proposed change are minimal. Typically, the Statewide CASE Team presents a detailed analysis of statewide energy and cost savings associated with the proposed change in Section 3.6 of the Final CASE Report. As discussed in Section 3.4, although the measure is associated with slightly negative energy savings, the code change proposal would enable a cost-effective option for low GWP, low charge refrigeration systems that could be utilized to aid in statewide GHG emission reduction goals, as well as improve the safety and health of refrigerated warehouse workers due to reduced ammonia refrigerant charge inside occupied spaces. Assuming 10 percent of 2023 refrigerated warehouse new construction adopts packaged refrigeration technology, the first year statewide energy impact is an increase of 68,958 kWh (0.42 kWh/square foot, 164,000 square feet of forecasted construction).

4. Submeasure C: Evaporator Specific Efficiency

4.1 Measure Description

4.1.1 Measure Overview

A minimum specific efficiency is proposed for all non-process cooling/freezing evaporators used in refrigerated warehouses. Evaporator specific efficiency is defined as cooling capacity of the evaporator (Btu/hr) divided by the power input (Watts) required for the fan motors at rated temperature conditions at 100 percent fan speed. The rated capacity is defined at 10°F of temperature difference between the incoming air temperature and the saturated evaporating temperature of the refrigerant, assuming a dry coil. This metric is similar to what is used currently in Title 24, Part 6 for comparing the efficiency of refrigeration condensers.

The following values are proposed for different evaporator applications, types and refrigerants.

Table 60: Proposed Evaporator Specific Efficiency Values

Evaporator Application	Liquid Feed Type	Refrigerant Type[a]	Minimum Efficiency
Freezer	Direct Expansion	Halocarbon	40 Btuh/Watt
Freezer	Direct Expansion	Ammonia	25 Btuh/Watt
Freezer	Flooded/ Recirculated Liquid	Ammonia	45 Btuh/Watt
Cooler	Direct Expansion	Halocarbon	45 Btuh/Watt
Cooler	Direct Expansion	Ammonia	35 Btuh/Watt
Cooler	Flooded/ Recirculated Liquid	Ammonia	50 Btuh/Watt

a. A stakeholder comment was received that energy efficiency metrics for CO_2 evaporators should be included in the proposed measure due to increasing market adoption and the possibility of high GWP refrigerant regulations that would further increase CO_2 market share. While the Statewide CASE team agrees that this would be valuable study effort for the proposed measure, current resources do not allow for a complete cost-effective analysis and market research.

Evaporators that use a penthouse configuration have additional static pressure drop, resulting in higher fan power draw. To account for this, evaporators in penthouse configurations would be required to submit capacity and power ratings assuming 0” water column (WC) in order to compare to the proposed specific efficiency thresholds in the table above.

This mandatory code change would impact refrigerated warehouses. The code change would be applicable to refrigerated warehouses that are greater than or equal to 3,000 square feet and refrigerated spaces with a sum total of 3,000 square feet or more that are served by the same refrigeration system. Refrigerated spaces less than 3,000 square feet shall meet the requirements of the Appliance Efficiency Regulations for walk-in coolers or freezers contained in the Appliance Efficiency Regulations (California Code of Regulations, Title 20).

The code change is applicable to new construction, additions and alterations.

There is no proposed acceptance testing associated with this proposed measure.

There are no proposed updates to the compliance software for this proposed measure.

4.1.2 Measure History

Evaporators are heat exchangers used in vapor compression refrigeration systems that allow heat transfer from the air inside a refrigerated space to the refrigerant, thus providing cooling to the air. Fans are integrated as part of the evaporator in order to draw air across the heat exchanger surface area, as well as provide adequate mixing to avoid temperature stratification. As discussed in the section above, specific efficiency is a metric defined as the capacity of the evaporator divided by the input power requirement. The higher the specific efficiency of the evaporator, the less fan power is required to achieve the necessary cooling, thus resulting in both direct energy savings from the fan motor as well as indirect compressor energy savings. This is because the heat produced by the fans will eventually be removed from the refrigerated spaces and is thus added load on the refrigeration system.

2019 Title 24, Part 6 does not currently have a minimum efficiency requirement for evaporators. Evaporator specific efficiency was initially considered in the 2013 Title 24, Part 6 CASE Report, but the measure was ultimately not adopted because the research on evaporator ratings revealed challenges in getting the evaporator capacity and applied fan motor power at rated conditions.

In recent years, more information has become available on evaporators as almost all manufacturers have product selection software, and the capacity ratings are becoming more standardized. Some manufacturers are now providing certified ratings in their product catalogues to provide more confidence in the capacity of the equipment being sold. Additionally, some manufacturers provide the applied fan power at the operating conditions.

Evaporators use significant amount of energy in refrigerated warehouses. Therefore, the efficiency of evaporators is a key factor in annual energy usage of refrigerated warehouses, even with the 2019 Title 24, Part 6 mandatory requirement of variable speed control of evaporator fans.

The market research conducted by the Statewide CASE Team showed a large variation in efficiency of evaporator models available in the market. The proposed code change is expected to save significant energy by prohibiting the installation of low efficiency units.

4.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents would be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

4.1.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of Title 24, Part 6 as shown below. See Section 7.2 of this report for marked-up code language.

SECTION 120.6 – Mandatory Requirements for Covered Processes

120.6(a)3 – Evaporators

120.6(a)3D – The purpose of this change is to introduce Tables 120.6-B through 120.6-D. This is necessary because these rating conditions and minimum evaporator specific efficiencies do not exist in the current code language.

120.6(a)3D – The purpose of this change is to add an exception for evaporators designed solely for quick chilling/freezing processes. This is necessary to make clear the requirements for this section.

Table 120.6-B – The purpose of this new table is to provide the rating conditions for determining the specific efficiency of evaporators depending on the evaporator application (Freezer vs. Cooler/Dock). This is necessary to make clear the requirements for this section.

Table 120.6-C – The purpose of this new table is to provide the mandatory minimum evaporator specific efficiency values for a variety of refrigerants used in freezer applications. This is necessary to make clear the requirements of this section.

Table 120.6-D – The purpose of this new table is to provide the mandatory minimum evaporator specific efficiency values for a variety of refrigerants used in cooler/dock applications. This is necessary to make clear the requirements of this section.

120.6(a)3E – The purpose of this new subsection is to specify the maximum static pressure drop for evaporators installed in refrigerated warehouses. This is necessary because fan power consumption and therefore evaporator specific efficiency are impacted by static pressure drop imparted by ducts or penthouse configurations. Therefore, a maximum allowable pressure drop is specified to avoid high energy penalties of undersized ductwork. An exemption is included for quick chilling/freezing applications to be consistent with other exemptions in 120.6(a).

4.1.3.2 Summary of Changes to the Reference Appendices

The proposed code change would not modify the Reference Appendices.

4.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

The proposed code change would not modify the ACM Reference Manual.

4.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change would modify Section 10.6.3.2 Evaporators t of the Nonresidential Compliance Manual. See Section 7.5 of this report for the detailed proposed revisions to the text of the Compliance Manuals.

4.1.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify the compliance documents listed below. Examples of the revised documents are presented in Section 7.6.

- NRCC-PRC-E – revised to include a table section that allows for the calculation of specific efficiency of the evaporator and determine if the proposed equipment is compliant

4.1.4 Regulatory Context

4.1.4.1 Existing Requirements in the California Energy Code

There are no relevant existing requirements in the California Energy Code.

4.1.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements in other parts of the California Building Code.

4.1.4.3 Relationship to Local, State, or Federal Laws

There are no relevant local, state, or federal laws.

4.1.4.4 Relationship to Industry Standards

Relevant industry standards for determining evaporator efficiency and for evaporator efficiency requirements include:

- AHRI 410: Standard for Forced-Circulation Air Cooling and Air-Heating Coils
- AHRI 420: Performance Rating of Forced-Circulation Free-Delivery Unit Coolers

for Refrigeration

- AHRI 1250: Performance Rating of Walk-In Coolers and Freezers
- ASHRAE 33: Methods of Testing Forced-Circulation Air-Cooling and Air-Heating Coils

4.1.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced. This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix E presents how the proposed changes could impact various market actors.

The activities that need to occur during each phase of the project are described below:

- **Design Phase:** Design engineers, contractors, and owners collaborate to develop refrigeration system design loads and select the best system configuration and pieces of equipment to supply adequate cooling. All parties involved should be aware of the proposed code changes as it relates to selecting evaporators for each refrigerated space and ensure that the calculated specific efficiency at rated conditions meets the minimum requirements.
- **Permit Application Phase:** Typically, a contractor would develop a set of stamped engineering plan drawings on the owner's behalf, that would include refrigeration system design and equipment schedules. The drawings can also be developed by an independent engineering firm and are used as the basis for contractors to supply bids for the project. This set of plan drawings should incorporate information on the selected evaporators for the refrigerated spaces. If the selected equipment does not comply with Title 24, Part 6, the authority having jurisdiction should provide plan check comments to correct this before providing any building permits.
- **Construction Phase:** Contractors install the refrigeration system as described in the approved plan drawings, with oversight from the owner and authority having jurisdiction. The installed equipment should match what was approved and specified in the equipment schedule.
- **Inspection Phase:** After construction, the owner or contractor have the responsibility to have the building and its various mechanical systems inspected by the authority having jurisdiction. This inspection phase should include an examination of the refrigeration system to verify the compliant equipment described in the plan drawings matches what was physically installed.

The compliance process described above is very similar to the process that currently exists for measures related to refrigerated warehouses and commercial refrigeration. Updates to the existing refrigerated warehouse certificate of compliance document (NRCC-PRC-E) are anticipated in order for designers, owners, and contractors to provide evidence on their design drawings that the proposed equipment complies with Title 24, Part 6. These compliance documents updates are expected to be analogous to the condenser specific efficiency section already included in NRCC-PRC-E. No additional acceptance testing is expected to be required.

To ensure compliance, evaporator manufacturers would have to be able to provide rated input power at rated motor conditions as well as provide ratings that are based on the rating definition included in the proposed code language. To avoid all potential compliance issues, acceptance testing could be proposed to perform spot power measures of the evaporators at 100 percent fan speed. However, at this time, the Statewide CASE Team is not recommending this approach as it may provide an undue burden on building inspectors, and because power ratings are becoming more widely available directly from the manufacturer.

4.2 Market Analysis

4.2.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during public stakeholder meetings that the Statewide CASE Team held on November 7, 2019 and April 2, 2020.

The evaporator market is well established and comprised of the following key market actors: manufacturers, distributors/sales representatives, design engineers, installation contractors, and end users. The evaporators used in refrigerated warehouses are supplied by multiple original equipment manufacturers (OEMs) with approximately five to eight major manufacturers. Evaporators come in a range of sizes and profiles with differing number of fans, fan HP per motor, number of circuits, number of passes, and liquid feed types. In order to determine what type and what size evaporators should be installed at existing refrigerated warehouses or new refrigerated warehouses, design engineers or design build contractors are hired by the end users to provide equipment specifications. There are on the order of 10-15 major design build contractors throughout the state of California with experience in industrial refrigeration that assist end users in selecting equipment. There are multiple items for consideration whenever evaporators are specified. These considerations range from energy efficiency, design capacity, installation cost, first cost, application type (freezer vs. cooler vs. process load), and materials of construction. Once the evaporators are selected, contractors purchase the equipment through distributors or sales representatives, and resell the equipment to the end user at a marked-up price. End users may have the option to purchase equipment directly from a distributor, but this is not common practice. The population of end users in the market for industrial refrigeration evaporators are facility owners ranging from cold storage, food and beverage processing, dairy processing, and agricultural product processors. Based on a Lawrence Berkeley National Laboratory study conducted in 2012 for Demand Response potential in California Refrigerated Warehouses, a sample population of approximately 300 facilities were surveyed. This sample population is estimated to be approximately two-thirds of the entire statewide facility population, indicating an estimated end user market of over 500 facilities.

4.2.2 Technical Feasibility, Market Availability, and Current Practices

The evaporator market is well established. The evaporator data studied during the market study was collected from three major manufacturers that make their evaporator performance data widely available for a wide variety of model types. The database was comprised of over 1,000 unique evaporator models. This data showed a wide range of specific efficiency values, with multiple options above the proposed specific efficiency threshold. Therefore, there are no known market barriers for this measure.

Some technical considerations need attention. The evaporator performance data provided by manufacturers must be rated at similar rating conditions, using similar rating methodologies. The manufacturer testing methods have historically not been consistent, but the testing by manufacturers has improved and most manufacturers primarily publish one of two types of ratings – DTM and DT1. The DTM rating takes the air temperature as the mean room temperature for capacity calculations. The DT1 rating takes the air temperature at the inlet of the evaporator, as per AHRI 420 Standard, for capacity calculations. The proposed code language defines the evaporator capacity at 10℉ temperature difference between the inlet air of the evaporator and the saturated evaporating temperature, similar to DT1 rating type.

One potential solution is to require certified evaporator capacity ratings that align with an approved test methodology, such as AHRI 420. However, stakeholder feedback from multiple major evaporator manufacturers has indicated that other standards would be more applicable to industrial refrigeration, such as ASHRAE Standard 33 and AHRI Standard 410. Therefore, the Statewide CASE Team is currently not proposing required certified ratings based on AHRI 420 but may be a source for future work. Instead of proposing a specific certified test methodology, the code language will include a detailed description of the rating condition assumptions that each manufacturer can use to design their own test method or adjust their statistical/engineering models that are used in equipment performance ratings accordingly. It should be noted that the rating conditions for evaporator specific efficiency align with the suction pressure, return air temperature, and dry coil conditions specified in AHRI 420 for freezers and coolers.

The motor power published by manufacturers also needs improvement in order to assist in determining the accurate specific efficiency for each evaporator. Most manufacturers publish nominal motor power, while the input power at rated conditions is required for the specific efficiency calculations. In order to overcome this challenge, manufacturers are expected to provide rated input power based on the detailed rating conditions defined in the code language. Similar to DOE requirements for performance ratings for evaporators in walk in coolers and freezers, this rated power can be based on lab validated statistical/engineering models, which eliminates the requirement for testing each individual model that is provided by the manufacturer.

Another technical challenge is the use of glide refrigerants. Glide refrigerants are unique in that they evaporate at a range of temperatures instead of a single temperature. Ratings from the manufacturers can be provided at a temperature difference between the inlet air and the dew point temperature or between the inlet air and the midpoint temperature. The Statewide CASE Team originally proposed to mandate the ratings of glide refrigerant be defined as the temperature difference between the inlet air and the midpoint temperature, as this provides a more accurate basis of comparison when comparing glide halocarbon refrigerants (R-407A, etc.) to a non-glide halocarbon refrigerant (R-404A). After further stakeholder engagement, the Statewide CASE Team is now proposing to define the rating of glide refrigerants be based on the dewpoint temperature as opposed to the midpoint temperature to better align with other industry standard rating practices. Additionally, this rating condition also eliminates possible confusion associated with rating evaporators with high glide refrigerants, where a 10°F temperature difference based on midpoint is insufficient to allow for full refrigerant evaporation plus a nominal amount of superheat.

The measure is expected save significant amount of energy without affecting the evaporator installation and maintenance techniques or available product storage space. Moreover, the measure would give persistent savings as the specific efficiency is not affected by equipment age as long as the regular equipment maintenance is carried out.

4.2.3 Market Impacts and Economic Assessments

4.2.3.1 Impact on Builders

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California's construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 61).[13] In 2018, total payroll was $80 billion. Nearly 17,000 establishments and 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

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[13] Average total monthly employment in California in 2018 was 18.6 million; the construction industry represented 4.5 percent of 2018 employment.

Table 61: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establishments	Employment	Annual Payroll (billions $)
Residential	**59,287**	**420,216**	**$23.3**
Residential Building Construction Contractors	22,676	115,777	$7.4
Foundation, Structure, & Building Exterior	6,623	75,220	$3.6
Building Equipment Contractors	14,444	105,441	$6.0
Building Finishing Contractors	15,544	123,778	$6.2
Commercial	**17,273**	**343,513**	**$27.8**
Commercial Building Construction	4,508	75,558	$6.9
Foundation, Structure, & Building Exterior	2,153	53,531	$3.7
Building Equipment Contractors	6,015	128,812	$10.9
Building Finishing Contractors	4,597	85,612	$6.2
Industrial, Utilities, Infrastructure, & Other	**4,103**	**96,550**	**$9.2**
Industrial Building Construction	299	5,864	$0.5
Utility System Construction	1,643	47,619	$4.3
Land Subdivision	952	7,584	$0.9
Highway, Street, and Bridge Construction	770	25,477	$2.4
Other Heavy Construction	439	10,006	$1.0

Source: (State of California, Employment Development Department n.d.)

The proposed change related to Submeasure C would likely affect commercial and industrial builders but would not impact firms that focus on construction and retrofit of utility systems, public infrastructure, or other heavy construction. The effects on the commercial building and industrial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 62 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 4.2.4.

Table 62: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard

Construction Subsector	Establishments	Employment	Annual Payroll (billions $)
Nonresidential plumbing and HVAC contractors	2,394	52,977	$4.47

Source: (State of California, Employment Development Department n.d.)

4.2.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 63 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for Submeasure C to affect firms that focus on refrigerated warehouse construction.

There is not a North American Industry Classification System (NAICS)[14] code specific for energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[15] It is not possible to determine which business

[14] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

[15] Establishments in this sector include businesses primarily engaged in evaluating a building's structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 63 provides an upper bound indication of the size of this sector in California.

Table 63: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
Architectural Services [a]	3,704	29,611	$2.9
Building Inspection Services [b]	824	3,145	$0.2

Source: (State of California, Employment Development Department n.d.)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

The proposed code language would require building designers and energy consultants to be aware of the adjusted baseline requirement for evaporators specific efficiency and take this into account when providing design specifications and estimated energy savings.

4.2.3.3 Impact on Occupational Safety and Health

Because higher specific efficiency evaporators result in lower fan motor power, the noise generated by the fan motors is expected to reduce. Reduction in noise generation may have an overall positive effect on the safety and health of individuals working in refrigerated warehouses. Lower noise volumes result in improved ability for workers to communicate with each other (including communication related to safety while performing job tasks) and reduced risk of physical damage to the ear.

4.2.3.4 Impact on Building Owners and Occupants

The commercial building sector includes a wide array of building types, including offices, restaurants and lodging, retail, and mixed-use establishments, and warehouses (including refrigerated) (Kenney 2019). Energy use by occupants of commercial buildings also varies considerably with electricity used primarily for lighting, space cooling and conditioning, and refrigeration. Natural gas consumed primarily for heating water and for space heating. According to information published in the 2019 California Energy Efficiency Action Plan, there is more than 7.5 billion square feet of commercial floor space in California and consumes 19 percent of California’s total annual energy use (Kenney 2019). The diversity of building and business types within this sector creates a challenge for disseminating information on energy and water efficiency solutions, as does the variability in sophistication of building owners and the relationships between building owners and occupants.

Building owners and occupants would benefit from lower energy bills. As discussed in Section 4.2.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2022 code cycle to impact building owners or occupants adversely.

4.2.3.5 Impact on Building Component Retailers (Including Manufacturers and Distributors)

Manufacturers and distributors are expected to see a reduction in sales for evaporator models that do not meet the specific efficiency requirements, while also seeing an increase in sales for higher efficiency models.

4.2.3.6 Impact on Building Inspectors

Table 64 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 64: Employment in California State and Government Agencies with Building Inspectors

Sector	Govt.	Establishments	Employment	Annual Payroll (millions $)
Administration of Housing Programs[a]	State	17	283	$29.0
Administration of Housing Programs[a]	Local	36	2,882	$205.7
Urban and Rural Development Admin[b]	State	35	552	$48.2
Urban and Rural Development Admin[b]	Local	52	2,446	$186.6

Source: (State of California, Employment Development Department n.d.)

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.

b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

4.2.3.7 Impact on Statewide Employment

As described in Sections 4.2.3.1 through 4.2.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 4.2.4, the Statewide CASE Team estimated the proposed change in Submeasure C would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in Submeasure C would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

4.2.4 Economic Impacts

For the 2022 code cycle, the Statewide CASE Team used the IMPLAN model software, along with economic information from published sources, and professional judgement to develop estimates of the economic impacts associated with each of the proposed code changes.[16] While this is the first code cycle in which the Statewide CASE Team develops estimates of economic impacts using IMPLAN, it is important to note that the economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the Statewide CASE Team believes the economic impacts presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

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[16] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the commercial/industrial building industry, architects, energy consultants, and building inspectors. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2022 code cycle regulations would result in additional spending by those businesses.

Table 65: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions $)
Direct Effects (Additional spending by Commercial Builders)	2	$0.11	$0.15	$0.24
Indirect Effect (Additional spending by firms supporting Commercial Builders)	0	$0.03	$0.04	$0.08
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	1	$0.04	$0.07	$0.12
Total Economic Impacts	**3**	**$0.18**	**$0.26**	**$0.44**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

4.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team’s proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in this section would lead to modest changes in employment of existing jobs.

4.2.4.2 Creation or Elimination of Businesses in California

As stated in Section4.2.4.1, the Statewide CASE Team’s proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to evaporator requirements which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

4.2.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes would apply to all businesses incorporated in California, regardless of whether the business is incorporated inside or outside of the state.[17] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

4.2.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[18] As Table 66 shows, between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, with an average of 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

Table 66: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits
2015	609.3	1,740.4	35%
2016	456.0	1,739.8	26%
2017	509.3	1,813.6	28%
2018	618.3	1,843.7	34%
2019	580.9	1,827.0	32%
		5-Year Average	**31%**

Source: (Federal Reserve Economic Data n.d.)

[17] Gov. Code, § 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR § 2003(a)(3) Competitive advantages or disadvantages for California businesses currently doing business in the state.

[18] Net private domestic investment is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in investment by California businesses by multiplying the sum of Business Income estimated in Table 65 above by 31 percent.

4.2.4.5 Effects on the State General Fund, State Special Funds, and Local Governments

The proposed code language is not expected to have an effect on the state general fund, state special fund, or local governments.

4.2.4.6 Impacts on Specific Persons

The proposed code language is not expected to have an impact on specific persons.

4.3 Energy Savings

4.3.1 Key Assumptions for Energy Savings Analysis

The energy and cost analysis presented in this report used the final TDV factors that the Energy Commission released in June 2020 which use 20-year global warming potential (GWP) values instead of 100-year GWP values used in previous TDV factors. The 20-year GWP values increased the TDV factors slightly. The electricity TDV factors include the 15 percent retail adder. The natural gas TDV factors include the impact of methane leakage on the building site.

The energy savings analysis was performed using two prototypical buildings. The first prototype is the Large Refrigerated Warehouse prototype. This prototype was previously developed and utilized for refrigeration CASE Reports in the 2008, 2013, and 2019 Title 24, Part 6 code cycles. The prototype represents a typical large refrigerated warehouse that utilizes a central ammonia refrigeration system with recirculated liquid feed evaporators. This prototype was used to model the energy savings related to the minimum specific efficiency requirements of flooded/recirculated ammonia evaporators. The base case and proposed evaporator specific efficiency values are summarized in Table 69 in the section below.

The assumptions for the Large Refrigerated Warehouse prototype are described in detail in Table 145 in Appendix H.

The second prototype is the Small Refrigerated Warehouse prototype. This prototype was previously developed and utilized for refrigeration CASE Reports in the 2008, 2013, and 2019 Title 24, Part 6 code cycles. The prototype represents a typical small refrigerated warehouse that utilizes reciprocating compressor rack refrigeration systems with direct expansion (DX) liquid feed evaporators. This prototype was used to model the energy savings related to the minimum specific efficiency requirements of halocarbon/ammonia DX evaporators. The base case and proposed evaporator specific efficiency values are summarized in Table 69 in the section below.

The assumptions for the Small Refrigerated Warehouse prototype are described in detail in Table 146 in Appendix H.

Cooling loads in each refrigerated space were calculated in each climate zone for the prototypical refrigerated warehouses. Then refrigeration equipment (evaporators, compressors and condensers) was sized according to the calculated loads. Loads included envelope transmission loads, exterior and inter-zonal air infiltration, forklift and pallet-lift traffic, employee traffic, evaporator fan motor heat, evaporator defrost heat, lighting heat gain, and product respiration and pull-down load. A 1.15 safety factor was used in the equipment selection process. Load calculation assumptions are available upon request.

4.3.2 Energy Savings Methodology

4.3.2.1 Energy Savings Methodology per Prototypical Building

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings. The prototype buildings that the Statewide CASE Team used in the analysis are summarized in Table 67 and Table 68 below. Evaporator capacities varied only slightly between each climate. The average single evaporator sizes for the Small Refrigerated Warehouse prototype were 28TR (28 tons of refrigeration capacity), 35TR, and 20TR for the cooler, freezer, and dock spaces respectively. The average single evaporator sizes for the Large Refrigerated Warehouse prototype were 85TR, 113TR, and 56TR for the cooler, freezer, and dock spaces accordingly.

The prototype models used in this analysis were developed to represent typical refrigerated warehouses conforming to 2019 Title 24, Part 6 Standards, which includes envelope, lighting, and refrigeration system requirements. Design loads and operating schedules were assumed to represent industry-standard practice and typical warehouse operation.

Table 67: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (ft^2)
Large Refrigerated Warehouse	1	92,000
Small Refrigerated Warehouse	1	26,000

Table 68: Refrigerated Space Breakdown of Prototypes

Prototype	35°F Cooler (ft^2, Air Unit Qty)	-10°F Freezer (ft^2, Air Unit Qty)	40°F Dock (ft^2, Air Unit Qty)	Total (ft^2, Air Unit Qty)
Large Refrigerated Warehouse	40,000; 6	40,000; 6	12,000; 6	92,000; 18
Small Refrigerated Warehouse	10,000; 4	10,000; 4	6,000; 4	26,000; 12

The building layout for both large and small warehouse prototypes is shown in the figure below.

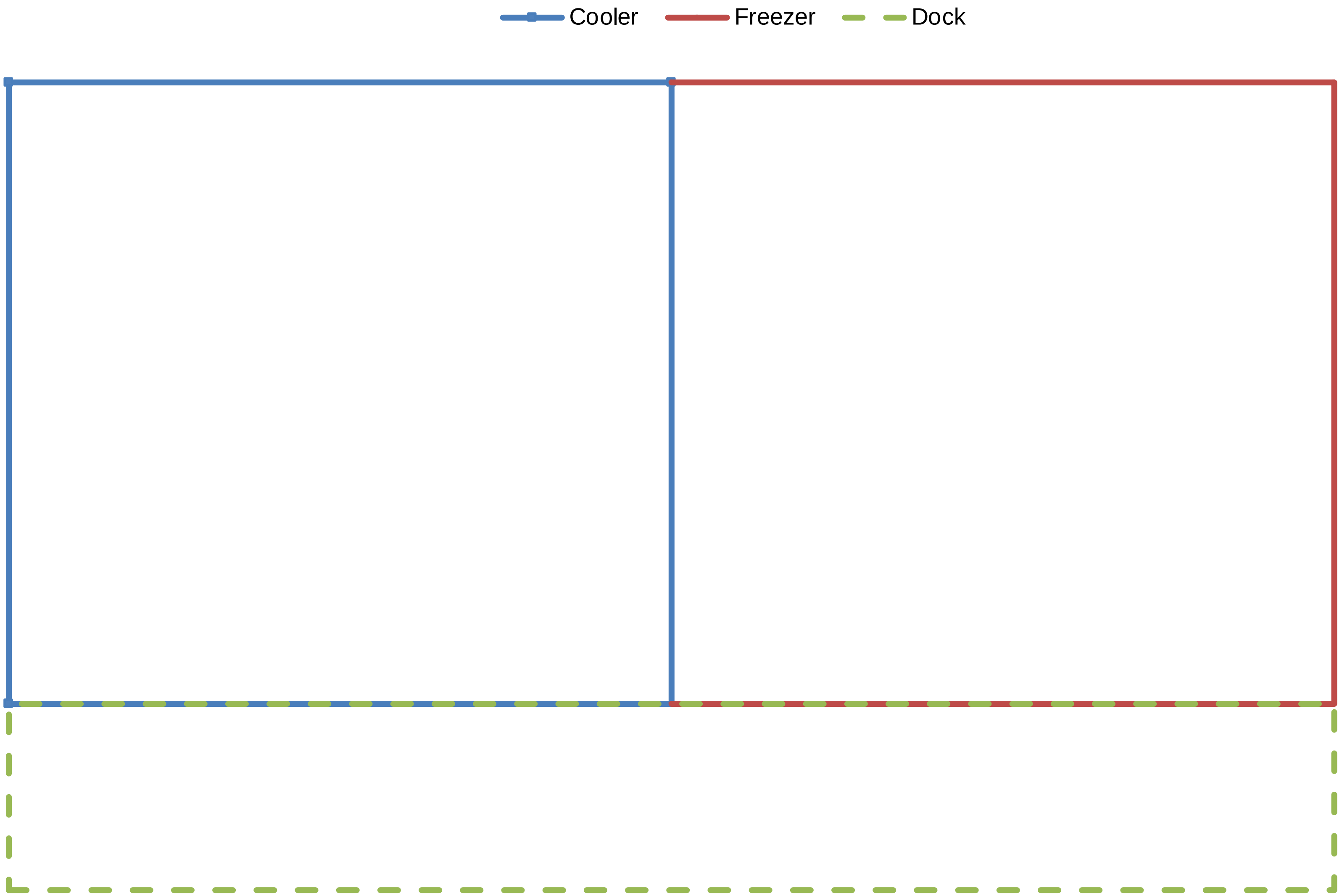

Figure 8. Large and small refrigerated warehouse prototype layout.

The energy usage for each measure in each prototype was modeled using DOE2.2R energy simulation software. The DOE2 version used (2.2R) is a sophisticated component-based energy simulation program that can accurately model the interaction between the building envelope, building loads, and refrigeration systems. The DOE-2.2R version is specifically designed to include refrigeration systems, and uses refrigerant properties, mass flow and component models to accurately describe refrigeration system operation and controls system effects.

Submeasure C was evaluated in all climate zones in California.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 69 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design.

Table 69. Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
Small Refrigerated Warehouse	All	DX Halocarbon Specific Efficiency – Cooler Air Units	34 Btuh/W	45 Btuh/W
Small Refrigerated Warehouse	All	DX Halocarbon Specific Efficiency – Freezer Air Units	34 Btuh/W	40 Btuh/W
Small Refrigerated Warehouse	All	DX Ammonia Specific Efficiency – Cooler Air Units	20 Btuh/W	35 Btuh/W
Small Refrigerated Warehouse	All	DX Ammonia Specific Efficiency – Freezer Air Units	20 Btuh/W	25 Btuh/W
Large Refrigerated Warehouse	All	Flooded/Recirc Ammonia Specific Efficiency – Cooler Air Units	34 Btuh/W	50 Btuh/W
Large Refrigerated Warehouse	All	Flooded/Recirc Ammonia Specific Efficiency – Freezer Air Units	34 Btuh/W	45 Btuh/W

Comparing the energy impacts of the Standard Design to the Proposed Design reveals the impacts of the proposed code change relative to a building that is minimally compliant with the 2019 Title 24, Part 6 requirements.

DOE2.2R calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). It then applies the 2022 time dependent valuation (TDV) factors to calculate annual energy use in kilo British thermal units per year (TDV kBtu/yr) and annual peak electricity demand reductions measured in kilowatts (kW).

The energy impacts of the proposed code change does vary by climate zone. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone specific TDV factors when calculating energy and energy cost impacts.

Per-square foot energy impacts for nonresidential buildings are presented in savings per square foot. Annual energy and peak demand impacts for each prototype building were translated into impacts per square foot by dividing by the floor area of the prototype building. This step allows for an easier comparison of savings across different building types and enables a calculation of statewide savings using the construction forecast that is published in terms of floor area by building type.

4.3.2.2 Statewide Energy Savings Methodology

The per-square foot energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission 2020). The Statewide Construction Forecasts estimate new construction that will occur in 2023, the first year that the 2022 Title 24, Part 6 requirements are in effect. It also estimates the size of the total existing building stock in 2023 that the Statewide CASE Team used to approximate savings from building alterations. The construction forecast provides construction (new construction and existing building stock) by building type and climate zone. The Statewide CASE Team utilized the Refrigerated Warehouse construction forecast for this measure to determine the statewide impacts.

Appendix A presents additional information about the methodology and assumptions used to calculate statewide energy impacts.

4.3.2.3 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per unit are presented in Table 70 through Table 77 and are applicable to both new construction and alterations. The per-square foot energy savings figures do not account for naturally occurring market adoption or compliance rates. Annual savings for the first year are expected to range from 0.37 to 2.83 kWh/ft^2 depending upon climate zone and depending on the evaporator refrigerant/liquid feed type. Demand reductions are expected to range between 0.00012 kW/ft^2 and 0.00107 kW/ft^2 depending on climate zone and depending on the evaporator refrigerant/liquid feed type.

The energy savings impact per unit was shown to be approximately 30-300 percent higher for the proposed cooler minimum specific efficiency values compared to freezer minimum specific efficiency values. This is due to the higher recommended minimum efficiency values for coolers as compared to freezers, as well as coolers representing slightly more of the total square footage of the prototypical warehouse compared to freezer square footage. Savings results across all climate zones are predictably close in overall magnitude, with small differences shown due to the impact climate has on the overall refrigeration system efficiency. Low ambient temperature climate zones were shown on average to have slightly lower energy savings impact per unit. This is because the incremental reduction in heat load that occurs when fan power is decreased has a greater savings impact on refrigeration systems operating in higher ambient temperature areas where they will operate at higher discharge pressures on average, and thus lower efficiency. Overall, the freezer and cooler requirements combined result in 6 to 13 percent of total energy savings for a typical refrigerated warehouse.

The proposed measure also reduces peak demand for refrigerated warehouses by approximately 5 percent. Peak refrigeration loads typically coincide with higher ambient temperature hours during the year, which also coincides with peak grid hours. Evaporator fans may ramp up their speed to 100 percent during the high load hours, contributing to peak electrical power consumption. With the proposed minimum specific efficiency requirements, effects of evaporators ramping up their fan speeds in response to larger loads have a reduced impact on the peak electrical power consumption for a refrigerated warehouse and may lead to improved grid management. One important note to consider is recent trend for refrigerated warehouse to participate in load shifting. Load shifting is where refrigerated warehouses turn off their refrigeration systems during peak hours to avoid high demand charges, and “catch-up” by running the system heavily loaded during the night. This trend has caused peak electrical demand from refrigerated warehouse to be less coincident with overall peaks in grid demand. Thus, the demand savings could have somewhat less impact on overall grid health and operation than the magnitude of savings implies.

Table 70: First-Year Energy Impacts Per Square Foot – Flooded/Recirc Ammonia Evaporators for Coolers - Large Refrigerated Warehouse Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	0.61	0.00	0	33.07
2	0.72	0.00	0	19.84
3	0.67	0.00	0	18.61
4	0.71	0.00	0	19.94
5	0.67	0.00	0	18.43
6	0.72	0.00	0	20.04
7	0.72	0.00	0	19.79
8	0.76	0.00	0	21.41
9	0.74	0.00	0	20.95
10	0.78	0.00	0	21.79
11	0.76	0.00	0	21.28
12	0.76	0.00	0	21.18
13	0.78	0.00	0	21.68
14	0.74	0.00	0	20.56
15	0.83	0.00	0	23.22
16	0.65	0.00	0	17.94

Table 71: First-Year Energy Impacts Per Square Foot – Flooded/Recirc Ammonia Evaporators for Freezers - Large Refrigerated Warehouse Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	0.45	0.00	0	28.57
2	0.48	0.00	0	13.21
3	0.48	0.00	0	13.20
4	0.48	0.00	0	13.45
5	0.48	0.00	0	13.07
6	0.48	0.00	0	13.41
7	0.47	0.00	0	12.85
8	0.48	0.00	0	13.68
9	0.48	0.00	0	13.62
10	0.48	0.00	0	13.50
11	0.48	0.00	0	13.29
12	0.48	0.00	0	13.28
13	0.48	0.00	0	13.32
14	0.47	0.00	0	13.21
15	0.49	0.00	0	13.70
16	0.46	0.00	0	12.73

Table 72: First-Year Energy Impacts Per Square Foot – DX Ammonia Evaporators for Coolers - Small Refrigerated Warehouse Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	1.95	0.00	0	53.20
2	2.42	0.00	0	67.36
3	2.26	0.00	0	62.72
4	2.38	0.00	0	67.66
5	2.24	0.00	0	62.03
6	2.41	0.00	0	67.00
7	2.38	0.00	0	65.37
8	2.51	0.00	0	71.08
9	2.49	0.00	0	71.29
10	2.58	0.00	0	72.05
11	2.50	0.00	0	70.37
12	2.51	0.00	0	70.40
13	2.56	0.00	0	71.99
14	2.46	0.00	0	68.20
15	2.83	0.00	0	80.29
16	2.18	0.00	0	61.83

Table 73: First-Year Energy Impacts Per Square Foot – DX Ammonia Evaporators for Freezers - Small Refrigerated Warehouse Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	0.76	0.00	0	20.84
2	0.90	0.00	0	26.04
3	0.89	0.00	0	24.65
4	0.92	0.00	0	27.83
5	0.86	0.00	0	23.44
6	0.86	0.00	0	24.80
7	0.83	0.00	0	24.00
8	0.91	0.00	0	26.84
9	0.91	0.00	0	25.46
10	0.91	0.00	0	24.92
11	0.92	0.00	0	29.50
12	0.89	0.00	0	25.53
13	0.90	0.00	0	27.16
14	0.92	0.00	0	24.97
15	0.94	0.00	0	30.23
16	0.86	0.00	0	23.58

Table 74: First-Year Energy Impacts Per Square Foot – DX Halocarbon Evaporators for Coolers - Small Refrigerated Warehouse Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	0.63	0.00	0	17.08
2	0.73	0.00	0	20.56
3	0.69	0.00	0	19.28
4	0.73	0.00	0	20.75
5	0.69	0.00	0	18.99
6	0.73	0.00	0	20.49
7	0.72	0.00	0	19.71
8	0.77	0.00	0	21.98
9	0.76	0.00	0	21.67
10	0.78	0.00	0	21.99
11	0.77	0.00	0	21.66
12	0.77	0.00	0	21.61
13	0.78	0.00	0	22.15
14	0.75	0.00	0	21.20
15	0.87	0.00	0	24.82
16	0.65	0.00	0	18.01

Table 75: First-Year Energy Impacts Per Square Foot – DX Halocarbon Evaporators for Freezers - Small Refrigerated Warehouse Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	0.37	0.00	0	10.03
2	0.40	0.00	0	11.23
3	0.39	0.00	0	10.90
4	0.40	0.00	0	11.38
5	0.39	0.00	0	10.72
6	0.40	0.00	0	11.01
7	0.40	0.00	0	10.92
8	0.40	0.00	0	11.31
9	0.40	0.00	0	11.64
10	0.40	0.00	0	11.37
11	0.41	0.00	0	11.53
12	0.40	0.00	0	11.30
13	0.40	0.00	0	11.34
14	0.41	0.00	0	11.37
15	0.42	0.00	0	11.93
16	0.39	0.00	0	10.71

4.4 Cost and Cost Effectiveness

4.4.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 4.3.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). In this case, the period of analysis used is 15 years. The TDV cost impacts are presented in nominal dollars and in 2023 present value dollars and represent the energy cost savings realized over 15 years.

The recommended code change applies to new construction, alterations, and additions. The cost savings are assumed to be similar on a square foot basis for all categories.

4.4.2 Energy Cost Savings Results

Per-square foot energy cost savings for newly constructed buildings and alterations that are realized over the 15-year period of analysis are presented in nominal dollars in the Final CASE Report in Appendix C. Energy cost savings in 2023 present valued (PV) dollars are presented in Section 4.4.5 below in the cost effectiveness tables. The only benefit to the proposed measures is electricity cost savings. Therefore, the benefits presented in Section 4.4.5 are equivalent to the PV TDV electricity cost savings in PV 2023$.

4.4.3 Incremental First Cost

Cost data was obtained from multiple evaporator manufacturers as part of the market study described in Section 4.2. From this large database of evaporator models, first cost of the evaporator was plotted against specific efficiency ratings to determine a correlation of the incremental cost per unit increase of specific efficiency. Based on the results of the database analysis, there was no strong correlation to be made between the cost provided by the manufacturer and the corresponding specific efficiency of the evaporator. There were multiple instances where models of similar capacity and similar cost had differences in specific efficiency by 20 percent or more. Therefore, the incremental first cost could be assumed to be zero, as there are usually models available in the market for similar cost but improved specific efficiency. However, in order to not understate the cost of the proposed measure, the Statewide CASE Team developed a simplified methodology for determining the incremental cost of a more efficient evaporator. First, a representative unit with standard specific efficiency is assumed to have fan motors with variable frequency drives, per Title 24, Part 6 requirements. A fan speed was calculated to determine at what percent fan speed does the standard unit achieve the proposed specific efficiency value. This is possible because while capacity varies linearly with airflow across the coil (i.e., fan speed), power has a cubic relationship with fan speed. Subtracting the reduced fan speed value from 100 percent represents the percent increase to the coil surface area that would be necessary to achieve the full capacity of the standard unit. Using a simplifying assumption that incremental cost varies linearly with coil surface area, the incremental cost can be approximated to be the percent increase in surface area required. A standard evaporator with capacities between 20TR and 113TR was estimated to cost between $17,000 and $38,000. These cost values were multiplied by the total number of evaporators in each prototype to determine the assumed standard design first cost of evaporators. See Table 76 and

Table 77 below.

Table 76: Reduced Fan Speeds Required to Achieve Proposed Efficiency

Prototype ID	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value	Reduced Fan Speed of Standard Unit That Achieves Proposed Design Efficiency (%)	Assumed % Evaporator Incremental Cost
Small Refrigerated Warehouse	All	DX Halocarbon Specific Efficiency – Cooler Air Units	34 Btuh/W	45 Btuh/W	87%	13%
Small Refrigerated Warehouse	All	DX Halocarbon Specific Efficiency – Freezer Air Units	34 Btuh/W	40 Btuh/W	92%	8%
Small Refrigerated Warehouse	All	DX Ammonia Specific Efficiency – Cooler Air Units	20 Btuh/W	35 Btuh/W	76%	24%
Small Refrigerated Warehouse	All	DX Ammonia Specific Efficiency – Freezer Air Units	20 Btuh/W	25 Btuh/W	89%	11%
Large Refrigerated Warehouse	All	Flooded/Recirc Ammonia Specific Efficiency – Cooler Air Units	34 Btuh/W	50 Btuh/W	82%	18%
Large Refrigerated Warehouse	All	Flooded/Recirc Ammonia Specific Efficiency – Freezer Air Units	34 Btuh/W	45 Btuh/W	87%	13%

Table 77: Incremental First Cost Assumptions

Prototype ID	Climate Zone	Parameter Name	Assumed Standard Design Cost per Prototype ($)	Assumed % Evaporator Incremental Cost	Evaporator Incremental Cost per Prototype ($)	Evaporator Incremental Cost per ft2 ($/ft2)
Small Refrigerated Warehouse	All	DX Halocarbon Specific Efficiency – Cooler Air Units	$137,577	13%	$17,915	$ 0.69
Small Refrigerated Warehouse	All	DX Halocarbon Specific Efficiency – Freezer Air Units	$98,854	8%	$7,682	$0.30
Small Refrigerated Warehouse	All	DX Ammonia Specific Efficiency – Cooler Air Units	$197,219	24%	$48,135	$1.85
Small Refrigerated Warehouse	All	DX Ammonia Specific Efficiency – Freezer Air Units	$142,857	11%	$15,082	$0.58
Large Refrigerated Warehouse	All	Flooded/Recirc Ammonia Specific Efficiency – Cooler Air Units	$250,719	18%	$43,971	$0.48
Large Refrigerated Warehouse	All	Flooded/Recirc Ammonia Specific Efficiency – Freezer Air Units	$228,820	13%	$29,923	$0.33

4.4.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 15-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows:

$$PresentValueofMaintenanceCost = MaintenanceCost \times [\frac{1}{1+d}]^n$$

The effective useful life for an evaporator is estimated to be 15 years. Therefore, replacement costs are not considered for the 15-year period cost benefit analysis. Additionally, there is no additional maintenance required for evaporators with higher specific efficiency compared to lower specific efficiency as the main equipment components and operation is nearly identical, with the exception of reduced fan power.

4.4.5 Cost Effectiveness

This measure proposes a mandatory requirement. As such, a cost analysis is required to demonstrate that the measure is cost effective over the 15-year period of analysis.

The Energy Commission establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 15-year period of analysis were included. The TDV energy cost savings from electricity savings were also included in the evaluation.

Design costs were not included nor were the incremental costs of code compliance verification.

According to the Energy Commission's definitions, a measure is cost effective if the B/C ratio is greater than 1.0. The B/C ratio is calculated by dividing the cost benefits realized over 15 years by the total incremental costs, which includes maintenance costs for 15 years. The B/C ratio was calculated using 2023 PV costs and cost savings.

Results of the per-square foot cost-effectiveness analyses are presented in

Table 83 for new construction and alterations.

The proposed specific efficiency thresholds were determined in part by what is reasonably available in the marketplace, without excessive restriction of market options. The proposed thresholds exclude approximately 40 percent of the models collected in the evaporator database described in previous sections. Using the incremental cost assumptions developed in the section above, the proposed thresholds were found to be cost effective for every evaporator type in every climate zone, with ratios ranging from approximately 2.2 to 4.5. In general, the cost effectiveness increased when the difference between the standard value and proposed value were smaller.

Table 78: 15-Year Cost-Effectiveness Summary Per Square Foot – Flooded/Recirc Ammonia Cooler - New Construction, Alterations, Additions

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$2.94	$0.48	6.18
2	$1.77	$0.48	3.71
3	$1.66	$0.48	3.48
4	$1.78	$0.48	3.73
5	$1.64	$0.48	3.45
6	$1.78	$0.48	3.75
7	$1.76	$0.48	3.70
8	$1.91	$0.48	4.00
9	$1.86	$0.48	3.92
10	$1.94	$0.48	4.08
11	$1.89	$0.48	3.98
12	$1.89	$0.48	3.96
13	$1.93	$0.48	4.05
14	$1.83	$0.48	3.85
15	$2.07	$0.48	4.34
16	$1.60	$0.48	3.36

Table 79: 15-Year Cost-Effectiveness Summary Per Square Foot – Flooded/Recirc Ammonia Freezer - New Construction, Alterations, Additions

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$2.54	$0.32	7.85
2	$1.18	$0.32	3.63
3	$1.17	$0.32	3.63
4	$1.20	$0.32	3.70
5	$1.16	$0.32	3.59
6	$1.19	$0.32	3.68
7	$1.14	$0.32	3.53
8	$1.22	$0.32	3.76
9	$1.21	$0.32	3.74
10	$1.20	$0.32	3.71
11	$1.18	$0.32	3.65
12	$1.18	$0.32	3.65
13	$1.19	$0.32	3.66
14	$1.18	$0.32	3.63
15	$1.22	$0.32	3.76
16	$1.13	$0.32	3.50

Table 80: 15-Year Cost-Effectiveness Summary Per Square Foot – DX Ammonia Cooler - New Construction, Alterations, Additions

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$4.73	$1.84	2.57
2	$6.00	$1.84	3.25
3	$5.58	$1.84	3.03
4	$6.02	$1.84	3.27
5	$5.52	$1.84	2.99
6	$5.96	$1.84	3.23
7	$5.82	$1.84	3.16
8	$6.33	$1.84	3.43
9	$6.34	$1.84	3.44
10	$6.41	$1.84	3.48
11	$6.26	$1.84	3.40
12	$6.27	$1.84	3.40
13	$6.41	$1.84	3.48
14	$6.07	$1.84	3.29
15	$7.15	$1.84	3.88
16	$5.50	$1.84	2.98

Table 81: 15-Year Cost-Effectiveness Summary Per Square Foot – DX Ammonia Freezer - New Construction, Alterations, Additions

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$1.85	$0.58	3.21
2	$2.32	$0.58	4.01
3	$2.19	$0.58	3.80
4	$2.48	$0.58	4.29
5	$2.09	$0.58	3.61
6	$2.21	$0.58	3.82
7	$2.14	$0.58	3.70
8	$2.39	$0.58	4.14
9	$2.27	$0.58	3.92
10	$2.22	$0.58	3.84
11	$2.63	$0.58	4.54
12	$2.27	$0.58	3.93
13	$2.42	$0.58	4.18
14	$2.22	$0.58	3.85
15	$2.69	$0.58	4.66
16	$2.10	$0.58	3.63

Table 82: 15-Year Cost-Effectiveness Summary Per Square Foot – DX Halocarbon Cooler - New Construction, Alterations, Additions

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$1.52	$0.69	2.21
2	$1.83	$0.69	2.66
3	$1.72	$0.69	2.49
4	$1.85	$0.69	2.68
5	$1.69	$0.69	2.45
6	$1.82	$0.69	2.65
7	$1.75	$0.69	2.55
8	$1.96	$0.69	2.84
9	$1.93	$0.69	2.80
10	$1.96	$0.69	2.84
11	$1.93	$0.69	2.80
12	$1.92	$0.69	2.79
13	$1.97	$0.69	2.86
14	$1.89	$0.69	2.74
15	$2.21	$0.69	3.21
16	$1.60	$0.69	2.33

Table 83: 15-Year Cost-Effectiveness Summary Per Square Foot – DX Halocarbon Freezer - New Construction, Alterations, Additions

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$0.89	$0.30	3.02
2	$1.00	$0.30	3.38
3	$0.97	$0.30	3.28
4	$1.01	$0.30	3.43
5	$0.95	$0.30	3.23
6	$0.98	$0.30	3.31
7	$0.97	$0.30	3.29
8	$1.01	$0.30	3.41
9	$1.04	$0.30	3.51
10	$1.01	$0.30	3.42
11	$1.03	$0.30	3.47
12	$1.01	$0.30	3.40
13	$1.01	$0.30	3.42
14	$1.01	$0.30	3.42
15	$1.06	$0.30	3.59
16	$0.95	$0.30	3.22

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

4.4.6 Response to Stakeholder Comments

A stakeholder recommended using dew point temperature instead of midpoint temperature for rating the evaporator specific efficiency to better align with AHRI 1250: Performance Rating of Walk-In Coolers and Freezers.

After reviewing the stakeholder's request to align with DOE standards for evaporator capacity ratings conditions, the Statewide CASE Team agrees to propose that the evaporator capacity rating condition for glide refrigerants shall be based on dew point rather than midpoint temperature for determining specific efficiency. This will also eliminate possible confusion associated with rating evaporators with high glide refrigerants, where a 10℉ temperature difference based on midpoint is insufficient to allow for full refrigerant evaporation plus a nominal amount of superheat. For typical coil configurations, using the dewpoint temperature as the basis for the rating will result in approximately a 20+% rated increase in capacity without changing the configuration of the coil as compared to utilizing the midpoint as the rating basis. This is because dew point rating definitions have lower operating pressures, and thus have a larger temperature difference with the inlet air through the coil. As a result, unless the specific efficiency values are changed, allowable fan power would also rise proportionately. Evaporator specific efficiency has a benefit to cost to benefit ratio in excess of 3 to 1 and impacts less than 40% of the evaporator market. Adjusting the specific ratio upwards proportionately would be reasonable for high glide refrigerants so the same coil and fan configuration would hold. However, this would not be the case for non-glide refrigerants. As a result, the Statewide CASE Team incrementally increased the specific efficiency threshold for halocarbon evaporator efficiency thresholds.

Another stakeholder comment was submitted related to how the specific efficiency requirements would impact equipment regulated under the federal walk-in cooler and freezer code requirements. The Statewide CASE Team clarified that equipment subject to federal equipment standards (defined as refrigerated spaces less than 3,000 square feet served by a dedicated condensing unit and unit cooler) must comply only to those standards, and that the proposed evaporator specific efficiency requirements would not apply.

4.5 First-Year Statewide Impacts

4.5.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction by multiplying the per-square foot savings, which are presented in Section 4.3.2.3, by assumptions about the percentage of newly constructed buildings that would be impacted by the proposed code. The statewide new construction forecast for 2023 is presented in Appendix A as are the Statewide CASE Team's assumptions about the percentage of new construction that would be impacted by the proposal (by climate zone and building type).

A literature review of recently constructed refrigerated warehouse was conducted by referencing a database of Savings By Design refrigerated warehouse new construction incentive analyses from VaCom Technologies. Based on this literature review and experience in the refrigeration industry, the statewide savings impact was more heavily weighted towards large refrigerated warehouses with central ammonia systems. It was assumed that 70 percent of the new construction square footage would utilize flooded/recirculated ammonia evaporators. 10 percent of the new construction square footage assumed the use of DX halocarbon evaporators, and 10 percent of new construction square footage was assumed to utilize ammonia DX evaporators as it is still considered an emerging technology. The other 10 percent of new construction was assumed to be a system type other than what was listed above, such as transcritical CO_2 systems.

While evaporators have a nominal effective useful life of 15 years, evaporators will often operate for much longer. Therefore, it is estimated that only 5 percent of the existing building stock will be subject to the proposed code changes.

The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2023. The 15-year energy cost savings represent the energy cost savings over the entire 15-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account. Table 84 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone. Table 85 presents first-year statewide savings from new construction, additions, and alterations.

Table 84: Statewide Energy and Energy Cost Impacts – New Construction

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (nonresidential million square feet)	First-Year[a] Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	15-Year Present Valued Energy Cost Savings (million 2023 PV$)
1	0.0071	0.009	0.00	0	$0.04
2	0.0421	0.060	0.02	0	$0.15
3	0.2142	0.292	0.08	0	$0.72
4	0.1086	0.154	0.05	0	$0.39
5	0.0219	0.030	0.01	0	$0.07
6	0.0731	0.104	0.03	0	$0.26
7	0.0139	0.020	0.01	0	$0.05
8	0.1058	0.156	0.05	0	$0.39
9	0.1547	0.225	0.07	0	$0.57
10	0.0971	0.145	0.04	0	$0.36
11	0.0808	0.119	0.04	0	$0.30
12	0.2684	0.394	0.12	0	$0.98
13	0.2115	0.316	0.10	0	$0.79
14	0.0337	0.049	0.01	0	$0.12
15	0.0193	0.031	0.01	0	$0.08
16	0.0216	0.028	0.01	0	$0.07
TOTAL	**1.4738**	**2.13**	**0.63**	**0**	**$5.34**

a. First-year savings from all buildings completed statewide in 2023.

Table 85: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions

Construction Type	First-Year Electricity Savings (GWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (MMTherms)	15-Year Present Valued Energy Cost Savings (million 2023 PV$)
New Construction	2.13	0.63	0	$5.34
Additions and Alterations	4.506	1.31	0	$11.28
TOTAL	**6.64**	**1.94**	**0.00**	**$16.62**

a. First-year savings from all alterations completed statewide in 2023.

4.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion. Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42). See Appendix F for additional details on the methodology used to calculate GHG emissions. In short, this analysis assumes an average electricity emission factor of 240.4 metric tons CO_2e per GWh based on the average emission factors for the CACX EGRID subregion.

Table 86 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 370 metric tons of carbon dioxide equivalents (metric tons CO_2e) would be avoided.

Table 86: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings[a] (GWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO_2e)	Natural Gas Savings[a] (MMTherms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO_2e)	Total Reduced CO_2e Emissions[a, b] (Metric Tons CO_2e)
Flooded/Recirculated Ammonia Evaporator Specific Efficiency - Cooler	2.52	152	0	0	152
Flooded/Recirculated Ammonia Evaporator Specific Efficiency - Freezer	1.63	98	0	0	98
DX Halocarbon Evaporator Specific Efficiency - Cooler	0.40	21	0	0	21
DX Halocarbon Evaporator Specific Efficiency - Freezer	0.15	12	0	0	12
DX Ammonia Evaporator Specific Efficiency - Cooler	1.26	72	0	0	72
DX Ammonia Evaporator Specific Efficiency - Freezer	0.67	25	0	0	25
TOTAL	**6.64**	**380**	**0**	**0**	**380**

a. First-year savings from all buildings completed statewide in 2023.

b. Assumes the following emission factors: 0.0002279 $MTCO_2e/kWh$

4.5.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

4.5.4 Statewide Material Impacts

The proposed code change would mandate the use of more efficient evaporators. Based on the evaporator data collected for this study from various manufacturers, there is no direct correlation between the material usage and efficiency. Multiple variables affect the evaporator efficiency, such as circuit design, air volume, fan efficiency, motor efficiency, surface area, circulation, fins per inch, etc. However, as a general rule, and assuming all other variables are equal, more coil surface area is required in order to increase the capacity of an evaporator without changing the required input fan motor power, thereby increasing the specific efficiency.

The weight difference between an evaporator with baseline efficiency and proposed efficiency was determined via manufacturer equipment data averaged over multiple representative models. The increase in weight per evaporator was then applied to the entire prototype model based on the number of assumed evaporators in each space. The statewide construction forecast was then used to determine the first-year statewide material impact.

The materials used by different manufacturers vary (e.g., steel, aluminum), as the material of construction is a design choice by the manufacturers.

Table 87: First-Year Statewide Impacts on Material Use

Measure	Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/year)	
			Per-Unit Impacts	First-Year[b] Statewide Impacts
Flooded/Recirculated Ammonia Evaporator Specific Efficiency - Cooler	Steel/ Aluminum	I	0.010	9,282
Flooded/Recirculated Ammonia Evaporator Specific Efficiency - Freezer	Steel/ Aluminum	I	0.016	14,851
DX Halocarbon Evaporator Specific Efficiency - Cooler	Steel/ Aluminum	I	0.0146	1,936
DX Halocarbon Evaporator Specific Efficiency - Freezer	Steel/ Aluminum	I	0.0055	727
DX Ammonia Evaporator Specific Efficiency - Cooler	Steel/ Aluminum	I	0.0252	3,342
DX Ammonia Evaporator Specific Efficiency - Freezer	Steel/ Aluminum	I	0.0086	1,140
TOTAL	Steel/ Aluminum	I		31,278

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).

b. First-year savings from all buildings completed statewide in 2023.

4.5.5 Other Non-Energy Impacts

Non-energy benefits may include overall quieter evaporators inside refrigerated spaces due to the reduced fan power required to achieve the same amount of refrigeration cooling capacity. Lower noise inside refrigerated warehouses could improve overall occupant comfort and reduce the likelihood of ear damage of the occupants due to exposure to high volume levels.

5. Submeasure D: Automatic Door Closers

5.1 Measure Description

5.1.1 Measure Overview

Automatic door closers are mandatory for walk-in coolers and freezers with less than 3,000 square feet, as per the Code of Federal Regulations (CFR 431.306(a)). California Title 20 also mandates automatic door closers on walk-in coolers and freezers with less than 3,000 square foot area. This proposed submeasure would add similar mandatory automatic door closing requirements for refrigerated spaces 3,000 square feet and over to better align with the best practices outlined in the current federal standards for smaller refrigerated spaces.

There are two types of automatic door closers: the first is a mechanism that automatically closes the door from a standing-open position. Applicable hardware includes cam hinge or spring hinge. The second closer type is a mechanism that tightly seals the door to the door frame to eliminate air leakage. Applicable hardware includes snap type door closers or magnetic gaskets.

The proposed measure would apply to new construction, additions, and alterations (i.e., when doors are replaced) to existing facilities, including healthcare facilities. It would not require any updates to the compliance software or additional acceptance tests.

Small modifications are expected to be required to the compliance document NRCC-PRC-E to update the Infiltration Barriers section for refrigerated warehouses.

Based on the cost effectiveness analysis and statewide savings analysis described in Sections 5.4 and 5.5 below, this measure was found to be cost effective in all climate zones except Climate Zone 16, with an average B/C ratio of 1.44 and a 15 year present value statewide savings of approximately $282,000.

5.1.2 Measure History

Infiltration barriers reduce cooling loads by preventing warmer air from entering refrigerated spaces and are one of the most cost-effective ways to save energy in grocery stores and refrigerated warehouses. One very important infiltration barrier is automatic door closers. People may forget to close doors behind them, or they may close them without achieving a tight seal.

Automatic door closers are mandatory for walk-in coolers and freezers with less than 3,000 square feet, as per the Code of Federal Regulations (CFR 431.306(a)). California Title 20 also previously mandated automatic door closers on walk-in coolers and freezers with less than 3,000 square foot area. Excerpt of the federal code language is provided below:

(a) Each walk-in cooler or walk-in freezer manufactured on or after January 1, 2009, shall—

(1) Have automatic door closers that firmly close all walk-in doors that have been closed to within 1 inch of full closure, except that this paragraph shall not apply to doors wider than 3 feet 9 inches or taller than 7 feet;

(2) Have strip doors, spring hinged doors, or other method of minimizing infiltration when doors are open;

An overview of federal and state standards related to automatic door closers and other infiltration barriers is summarized in the table below.

Table 88: Summary of History and Proposed Requirements for Automatic Door Closers

Size	Federal	CA Title 20	CA Title 24, Part 6 existing	CA Title 24, Part 6 proposed
Less than 3,000ft^2	Automatic Door Closers required	Automatic Door Closers required	Title 24, Part 6 does not apply, references federal standards	No additional Title 24, Part 6 code proposals
3,000ft^2 and over	No federal standards	Does not apply	Option for automatic door closer, air curtain or strip curtains	Required automatic door closers for personnel doors

5.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents would be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

5.1.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of the Title 24, Part 6 as shown below. See Section 7.2 of this report for marked-up code language.

SECTION 120.6 – COVERED PROCESSES

Section 120.6(a)8 – Automatic Door Closers

A summary of the purpose of change for each section and table affected by Submeasure D is summarized in the paragraphs below.

120.6(a)8 – The purpose of this addition is communicate the automatic door closer requirements associated with this measure and specify when they apply. This is necessary to make clear the requirements of this section.

5.1.3.2 Summary of Changes to the Reference Appendices

The proposed code change would not modify the Reference Appendices

5.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

The proposed code change would not modify the ACM Reference Manual.

5.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change would modify Section 10.6.2.3 Infiltration Barriers of the Nonresidential Compliance Manual. See Section 7.5 of this report for the detailed proposed revisions to the text of the Compliance Manuals.

5.1.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify the compliance documents listed below. Examples of the revised documents are presented in Section 7.6.

- NRCC-PRC-E - Small modifications are expected to be required to update the Infiltration Barriers section for refrigerated warehouses.

5.1.4 Regulatory Context

5.1.4.1 Existing Requirements in the California Energy Code

The existing requirements in Title 24, Part 6 require infiltration barriers for passageways between freezers and higher temperature spaces and coolers and non-refrigerated spaces. Infiltration barrier options include air curtains, automatically closing doors, and strip curtains. Automatic door closers are not defined and there is no distinction between passageway types.

5.1.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements in other parts of the California Building Code.

5.1.4.3 Relationship to Local, State, or Federal Laws

Automatic door closers are mandatory for walk-in coolers and freezers with less than 3,000 square feet, as per the Code of Federal Regulations (CFR 431.306(a)). California Title 20 also previously mandated automatic door closers on walk-in coolers and freezers with less than 3,000 square foot area. Excerpt of the federal code language is provided below:

(a) Each walk-in cooler or walk-in freezer manufactured on or after January 1, 2009, shall—

(1) Have automatic door closers that firmly close all walk-in doors that have been closed to within 1 inch of full closure, except that this paragraph shall not apply to doors wider than 3 feet 9 inches or taller than 7 feet;

(2) Have strip doors, spring hinged doors, or other method of minimizing infiltration when doors are open;

5.1.4.4 Relationship to Industry Standards

There are no relevant industry standards.

5.1.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced. This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix E presents how the proposed changes could impact various market actors.

The activities that need to occur during each phase of the project are described below:

- **Design Phase:** Design engineers, architects, contractors, and owners collaborate to develop refrigerated warehouse design specifications. During this phase, it will be important for all parties to be aware of the new requirement and ensure automatic door refrigeration system design loads and select the best system configuration and pieces of equipment to supply adequate cooling. All parties involved should be aware of the proposed code changes as it relates to automatic door closers. Designers and architects should note in the door schedules associated with their drawings that calls out automatic door closer specifications.
- **Permit Application Phase:** Typically, a contractor or designer would develop a set of stamped engineering plan drawings on the owner's behalf, that would include refrigeration system design and equipment. The drawings can also be developed by an independent engineering firm and are used as the basis for contractors to supply bids for the project. This set of plan drawings should incorporate notes on automatic door closer types being specified for the refrigerated warehouse passageways. If this is not specified, the authority having jurisdiction should provide plan check comments to correct this before providing any building permits.

- **Construction Phase:** Contractors should be mindful of the door schedule in the design drawings, and order and install the automatic door closers accordingly.
- **Inspection Phase:** After construction, the owner or contractor have the responsibility to have the building and its various mechanical systems inspected by the authority having jurisdiction. This inspection phase should include an examination of the infiltration barriers for the refrigerated warehouse passageways. This can be a visual inspection only. No acceptance testing is expected to be required.

The compliance process described above does not significantly differ from the normal compliance process in place for existing code language on infiltration barriers. Small updates to the compliance documents are expected to be needed to clarify the mandatory requirement, but overall verification and compliance would be conducted in a similar manner.

5.2 Market Analysis

5.2.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during public stakeholder meetings that the Statewide CASE Team held on November 7, 2019 and April 2, 2020.

The overall market for automatic door closers is driven primarily by the following market actors: architects, engineers/designers, general construction contractors, and end users. Whenever a new refrigerated warehouse is planned for construction, it first needs to be designed. Engineering design firms that are comprised of architects and engineers develop detailed plan sets that specify the facility layout, materials of construction, electrical design, and mechanical design. These plan sets are heavily influenced by federal and state codes and standards to ensure that the facility design will be compliant with regulations and will be permitted for construction. Commonly included in the plan set are door schedules which list a variety of door types found throughout the facility and quantity of each door type. Detailed notes are included that specify specific door hardware to be used for each door type. Once the project is approved for construction, general contractors utilize the plans to determine what hardware is needed to be purchased. Contractors thus are the primary purchasers for equipment such as automatic door closers and will review the available options in the market in order to select specific automatic door closer manufacturers. The automatic door closers of different types are supplied by multiple manufacturers. The use of automatic door closers is mandatory for commercial walk-in coolers and freezers as per the Federal Walk-in Standard, resulting in a market that is already well established with limited barriers. The same type of door closers can be used for the manual doors used for people-movement in and out of the freezers and coolers in refrigerated warehouses. Some door closer manufacturers are Kason, Kawneer, and Orange Energizing Solutions.

End users may also play an important role in the overall market structure. Energy conscious end users may specifically request that the design team or contractors install automatic door closers. Other end users may only do what is required by code in order to reduce the initial first cost of construction.

5.2.2 Technical Feasibility, Market Availability, and Current Practices

The door closer market is well established. The door closer data studied during the market study showed that multiple manufacturers produce different types of door closers. Many supermarkets already use the two types of door closers suggested in this measure due to the existing federal standards. Therefore, there are no known market barriers for this measure. Photos of the three types of automatic door closing mechanisms are shown below for reference.

Figure 9. Spring type door closer example.

Figure 10. Cam type door closer example.

Figure 11. Snap type door closer example.

There are no technical issues that limit the ability to implement the proposed measure. However, there are some technical considerations related to effectiveness of door closers that may require additional attention. First, the effectiveness of door closers in reducing the infiltration is not studied and published. A literature review of published information provided by the major door closer manufacturers did not show any studies on infiltration reduction. The studies on infiltration for doors that do not use automatic door closers are also not readily available. Assumptions on door usage (number of openings per day, stand open time, etc.) were developed based on previous experience of the Stakeholder CASE Team in performing energy audits and extensive modeling of California refrigerated warehouses over multiple years. The Stakeholder CASE Team recommends that future laboratory research be conducted on door closer effectiveness to supplement the current level of field experience in observing how doors are utilized in existing refrigerated warehouses.

Current practice for automatic door closers for personnel doors was determined by a design plan review of available plan drawings from Savings By Design projects that were previously undertaken by members of the Stakeholder CASE Team, as well as input from design group stakeholders. Based on this review, common practice was determined to be the use of some form of hinge type automatic closure for man doors, particularly for freezer personnel doors. There was also found to be hardware that allowed for a tight seal of the door against the door frame. However, this type of hardware did not automatically provide a tight seal and required the user to ensure the door was snapped closed.

The savings from this measure should persist for the analysis period of 15 years, provided the regular maintenance of door closers are done on time.

5.2.3 Market Impacts and Economic Assessments

5.2.3.1 Impact on Builders

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California's construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 89).[19] In 2018, total payroll was $80 billion. Nearly 17,000 establishments and 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

[19] Average total monthly employment in California in 2018 was 18.6 million; the construction industry represented 4.5 percent of 2018 employment.

Table 89: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establishments	Employment	Annual Payroll (billions $)
Residential	**59,287**	**420,216**	**$23.3**
Residential Building Construction Contractors	22,676	115,777	$7.4
Foundation, Structure, & Building Exterior	6,623	75,220	$3.6
Building Equipment Contractors	14,444	105,441	$6.0
Building Finishing Contractors	15,544	123,778	$6.2
Commercial	**17,273**	**343,513**	**$27.8**
Commercial Building Construction	4,508	75,558	$6.9
Foundation, Structure, & Building Exterior	2,153	53,531	$3.7
Building Equipment Contractors	6,015	128,812	$10.9
Building Finishing Contractors	4,597	85,612	$6.2
Industrial, Utilities, Infrastructure, & Other	**4,103**	**96,550**	**$9.2**
Industrial Building Construction	299	5,864	$0.5
Utility System Construction	1,643	47,619	$4.3
Land Subdivision	952	7,584	$0.9
Highway, Street, and Bridge Construction	770	25,477	$2.4
Other Heavy Construction	439	10,006	$1.0

Source: (State of California, Employment Development Department n.d.)

The proposed change related to Submeasure D would likely affect commercial and industrial builders but would not impact firms that focus on construction and retrofit of utility systems, public infrastructure, or other heavy construction. The effects on the commercial building and industrial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 90 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 5.2.4.

Table 90: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard

Construction Subsector	Establishments	Employment	Annual Payroll (billions $)
Nonresidential plumbing and HVAC contractors	2,394	52,977	$4.5

Source: (State of California, Employment Development Department n.d.)

5.2.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 91 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for Submeasure D to affect firms that focus on supermarket and refrigerated warehouse construction.

There is not a North American Industry Classification System (NAICS)[20] code specific for energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[21] It is not possible to determine which business

[20] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

[21] Establishments in this sector include businesses primarily engaged in evaluating a building's structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 91 provides an upper bound indication of the size of this sector in California.

Table 91: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
Architectural Services [a]	3,704	29,611	$2.9
Building Inspection Services [b]	824	3,145	$0.2

Source: (State of California, Employment Development Department n.d.)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

Building designers and energy consultants would be required to specify the required automatic door closer hardware types based on the proposed code language in their future refrigerated warehouse plan sets.

5.2.3.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Division of Occupational Safety and Health (Cal/OSHA). All existing health and safety rules would remain in place. Complying with the proposed code change is not anticipated to have adverse impacts on the safety or health of occupants or those involved with the construction, commissioning, and maintenance of the building.

5.2.3.4 Impact on Building Owners and Occupants

The commercial building sector includes a wide array of building types, including offices, restaurants and lodging, retail, and mixed-use establishments, and warehouses (including refrigerated) (Kenney 2019). Energy use by occupants of commercial buildings also varies considerably with electricity used primarily for lighting, space cooling and conditioning, and refrigeration. Natural gas consumed primarily for heating water and for space heating. According to information published in the 2019 California Energy Efficiency Action Plan, there is more than 7.5 billion square feet of commercial floor space in California and consumes 19 percent of California's total annual energy use (Kenney 2019). The diversity of building and business types within this sector creates a challenge for disseminating information on energy and water efficiency solutions, as does the variability in sophistication of building owners and the relationships between building owners and occupants.

Building owners and occupants would benefit from lower energy bills. As discussed in Section 5.2.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2022 code cycle to impact building owners or occupants adversely.

Building owners for newly constructed refrigerated warehouses would need to ensure that the design team and general contractors responsible for constructing the new facility and appropriately specifying the correct type of hardware as specified by the proposed code language. Building owners would also be impacted by the additional cost of the hardware but would be the beneficiary of improved energy efficiency of their buildings. The economics of this measure and the full impact on building owners is discussed in later sections.

5.2.3.5 Impact on Building Component Retailers (Including Manufacturers and Distributors)

The Statewide CASE Team anticipates the proposed change would have no material impact on California component retailers.

5.2.3.6 Impact on Building Inspectors

Table 92 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 92: Employment in California State and Government Agencies with Building Inspectors

Sector	Govt.	Establishments	Employment	Annual Payroll (millions $)
Administration of Housing Programs[a]	State	17	283	$29.0
Administration of Housing Programs[a]	Local	36	2,882	$205.7
Urban and Rural Development Admin[b]	State	35	552	$48.2
Urban and Rural Development Admin[b]	Local	52	2,446	$186.6

Source: (State of California, Employment Development Department n.d.)

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.
b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

The proposed code language is not expected to have a significant impact on building inspectors, as infiltration barriers are already included in Title 24, Part 6.

5.2.3.7 Impact on Statewide Employment

As described in Sections 5.2.3.1 through 5.2.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 5.2.4, the Statewide CASE Team estimated the proposed change in Submeasure D would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in Submeasure D would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

5.2.4 Economic Impacts

For the 2022 code cycle, the Statewide CASE Team used the IMPLAN model software, along with economic information from published sources, and professional judgement to develop estimates of the economic impacts associated with each of the proposed code changes.[22] While this is the first code cycle in which the Statewide CASE Team develops estimates of economic impacts using IMPLAN, it is important to note that the economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the Statewide CASE Team believes the economic impacts presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the commercial/industrial building industry, architects, energy consultants, and building inspectors. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2022 code cycle regulations would result in additional spending by those businesses.

[22] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

Table 93: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions $)
Direct Effects (Additional spending by Commercial Builders)	1	$0.05	$0.06	$0.11
Indirect Effect (Additional spending by firms supporting Commercial Builders)	0	$0.01	$0.02	$0.04
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	0	$0.02	$0.03	$0.05
Total Economic Impacts	**1**	**$0.08**	**$0.12**	**$0.20**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

5.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team’s proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in this section would lead to modest changes in employment of existing jobs.

5.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 5.2.4.1, the Statewide CASE Team’s proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to evaporator requirements which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

5.2.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes would apply to all businesses incorporated in California, regardless of whether the business is incorporated inside or outside of the state.[23] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

5.2.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[24] As Table 94 shows, between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, with an average of 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

Table 94: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits
2015	609.3	1,740.4	35%
2016	456.0	1,739.8	26%
2017	509.3	1,813.6	28%
2018	618.3	1,843.7	34%
2019	580.9	1,827.0	32%
		5-Year Average	**31%**

Source: (Federal Reserve Economic Data n.d.)

[23] Gov. Code, § 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR § 2003(a)(3) Competitive advantages or disadvantages for California businesses currently doing business in the state.

[24] Net private domestic investment is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in investment by California businesses by multiplying the sum of Business Income estimated in Table 93 above by 31 percent.

5.2.4.5 Effects on the State General Fund, State Special Funds, and Local Governments

The proposed code language is not expected to have an effect on the state general fund, state special funds, or local governments.

5.2.4.6 Impacts on Specific Persons

The proposed code language is not expected to have an impact on specific persons.

5.3 Energy Savings

5.3.1 Key Assumptions for Energy Savings Analysis

The energy and cost analysis presented in this report used the final TDV factors that the Energy Commission released in June 2020 which use 20-year global warming potential (GWP) values instead of 100-year GWP values used in previous TDV factors. The 20-year GWP values increased the TDV factors slightly. The electricity TDV factors include the 15 percent retail adder. The natural gas TDV factors include the impact of methane leakage on the building site.

The assumptions for analyzing this measure are summarized in detail in Table 147 in Appendix H.

5.3.2 Energy Savings Methodology

5.3.2.1 Energy Savings Methodology per Prototypical Building

The Energy Commission directed the Statewide CASE Team to model the energy impacts using specific prototypical building models that represent typical building geometries for different types of buildings. The prototype buildings that the Statewide CASE Team used in the analysis are summarized in Table 95 and Table 96 below. The prototype models used in this analysis were developed to represent typical refrigerated warehouses conforming to 2019 Title 24, Part 6 Standards, which includes envelope, lighting, and refrigeration system requirements. Design loads and operating schedules were assumed to represent industry-standard practice and typical warehouse operation.

Table 95: Prototype Buildings Used for Energy, Demand, Cost, and Environmental Impacts Analysis

Prototype Name	Number of Stories	Floor Area (ft^2)
Large Refrigerated Warehouse	1	92,000
Small Refrigerated Warehouse	1	26,000

Table 96: Refrigerated Space Breakdown of Prototypes

Prototype	35°F Cooler (ft^2)	-10°F Freezer (ft^2)	40°F Dock (ft^2)	Total (ft^2)
Large Refrigerated Warehouse	40,000	40,000	12,000	92,000
Small Refrigerated Warehouse	10,000	10,000	6,000	26,000

The building layout for both large and small warehouse prototypes is shown in the figure below.

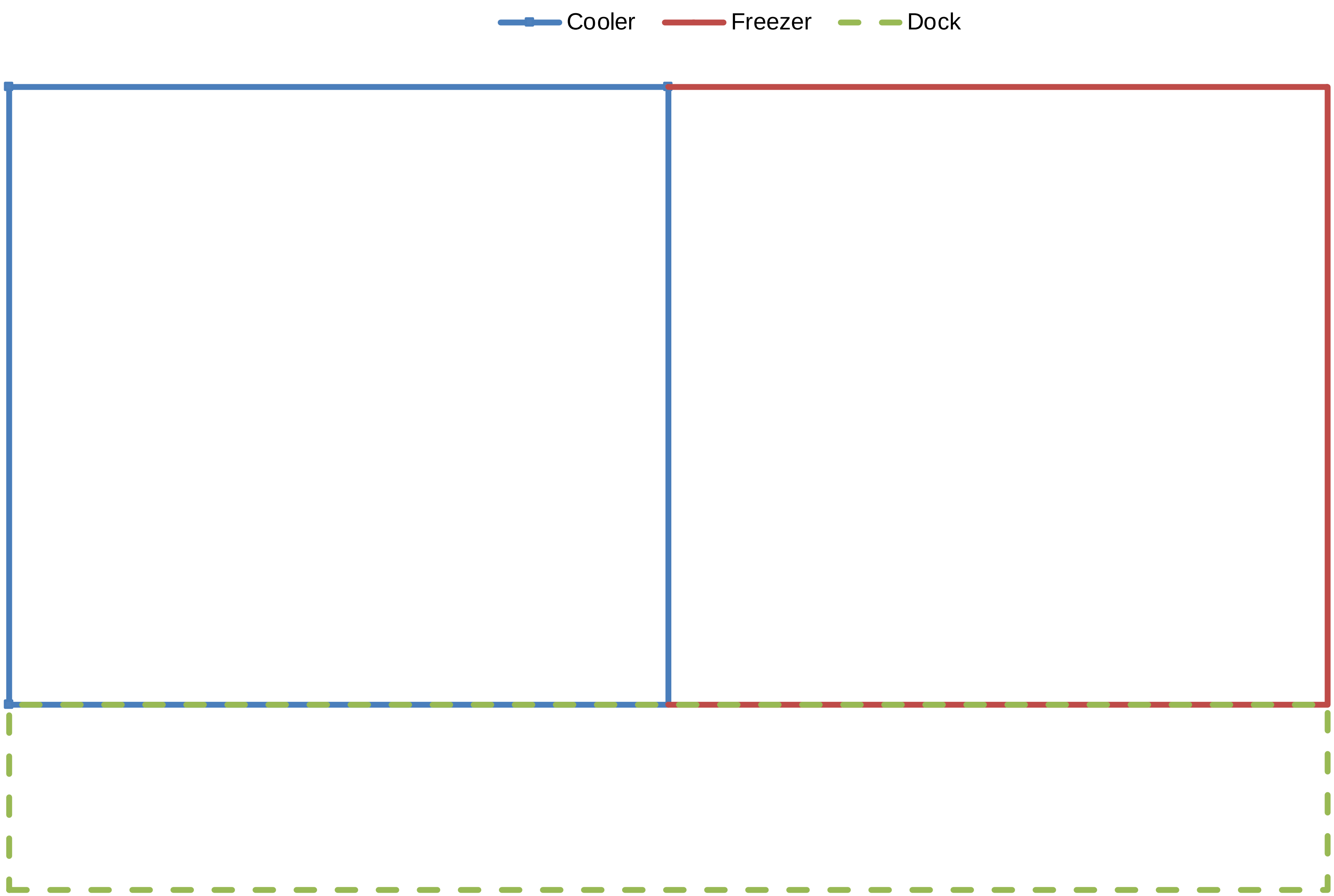

Figure 12. Large and small refrigerated warehouse prototype layout.

The energy usage for each submeasure in each prototype was modeled using DOE2.2R energy simulation software. The DOE2 version used (2.2R) is a sophisticated component-based energy simulation program that can accurately model the interaction between the building envelope, building loads, and refrigeration systems. The DOE-2.2R version is specifically designed to include refrigeration systems, and uses refrigerant properties, mass flow and component models to accurately describe refrigeration system operation and controls system effects.

Submeasure D was evaluated in all climate zones in California.

The Proposed Design was identical to the Standard Design in all ways except for the revisions that represent the proposed changes to the code. Table 97 presents precisely which parameters were modified and what values were used in the Standard Design and Proposed Design. Comparing the energy impacts of the Standard Design to the Proposed Design reveals the impacts of the proposed code change relative to a building that is minimally compliant with the 2019 Title 24, Part 6 requirements.

Table 97: Modifications Made to Standard Design in Each Prototype to Simulate Proposed Code Change

Prototype ID	Climate Zone	Parameter Name	Standard Design Parameter Value	Proposed Design Parameter Value
Large Refrigerated Warehouse, Small Refrigerated Warehouse	All	Infiltration for each exterior door	50 CFM	40 CFM
Large Refrigerated Warehouse, Small Refrigerated Warehouse	All	Passage time per door opening	5 seconds	4 seconds
Large Refrigerated Warehouse, Small Refrigerated Warehouse	All	Stand-open time per hour for each interior door	60 seconds	0 seconds
Large Refrigerated Warehouse, Small Refrigerated Warehouse	All	Leakage when door is closed	5% of the maximum flow through the door	0% of the maximum flow through the door

DOE2.2R calculates whole-building energy consumption for every hour of the year measured in kilowatt-hours per year (kWh/yr) and therms per year (therms/yr). It then applies the 2022 time dependent valuation (TDV) factors to calculate annual energy use in kilo British thermal units per year (TDV kBtu/yr) and annual peak electricity demand reductions measured in kilowatts (kW). California Building Energy Code Compliance for

Commercial/Nonresidential Buildings Software (CBECC-Com/Res) also generates TDV energy cost savings values measured in 2023 present value dollars (2023 PV$) and nominal dollars.

The energy impacts of the proposed code change vary by climate zone. The Statewide CASE Team simulated the energy impacts in every climate zone and applied the climate-zone specific TDV factors when calculating energy and energy cost impacts.

Per-square foot energy impacts for nonresidential buildings are presented in savings per square foot. Annual energy and peak demand impacts for each prototype building were translated into impacts per square foot by dividing by the floor area of the prototype building. This step allows for an easier comparison of savings across different building types and enables a calculation of statewide savings using the construction forecast that is published in terms of floor area by building type.

5.3.2.2 Statewide Energy Savings Methodology

The per-square foot energy impacts were extrapolated to statewide impacts using the Statewide Construction Forecasts that the Energy Commission provided (California Energy Commission 2020). The Statewide Construction Forecasts estimate new construction that will occur in 2023, the first year that the 2022 Title 24, Part 6 requirements are in effect. It also estimates the size of the total existing building stock in 2023 that the Statewide CASE Team used to approximate savings from building alterations. The construction forecast provides construction (new construction and existing building stock) by building type and climate zone. The Statewide CASE Team utilized the Refrigerated Warehouse construction forecast for this measure to determine the statewide impacts. Appendix A presents additional information about the methodology and assumptions used to calculate statewide energy impacts.

5.3.2.3 Per-Unit Energy Impacts Results

Energy savings and peak demand reductions per unit are presented in Table 98 for new construction. The per-unit energy savings figures do not account for naturally occurring market adoption or compliance rates. Annual savings for the first year are expected to range from 0.037 to 0.073 kWh/ft^{2}and no corresponding natural gas savings. There are no expected demand reductions from the measure for any climate zone.

Savings estimates are considered conservative, as they do not consider forgetting to close the door for periods longer than 60 seconds. Savings were shown to be significantly less in Climate Zone 16 primarily due to overall cooler temperatures. Lower ambient temperatures translate to more efficient refrigeration system operation. The more efficiently the refrigeration system is operating, the less impact infiltration reduction will have on overall savings.

Table 98: First-Year Energy Impacts Per Square Foot – Large Refrigerated Warehouse Prototype Building

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Reductions (kW)	Natural Gas Savings (therms/yr)	TDV Energy Savings (TDV kBtu/yr)
1	0.07	0.00	0	1.87
2	0.07	0.00	0	1.91
3	0.07	0.00	0	2.02
4	0.07	0.00	0	2.04
5	0.07	0.00	0	1.97
6	0.08	0.00	0	2.19
7	0.07	0.00	0	2.05
8	0.07	0.00	0	2.00
9	0.07	0.00	0	1.94
10	0.07	0.00	0	1.89
11	0.06	0.00	0	1.84
12	0.07	0.00	0	1.88
13	0.06	0.00	0	1.89
14	0.06	0.00	0	1.71
15	0.07	0.00	0	1.97
16	0.04	0.00	0	1.10

5.4 Cost and Cost Effectiveness

5.4.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates that were derived using the methodology described in Section 5.3.2. TDV is a normalized metric to calculate energy cost savings that accounts for the variable cost of electricity and natural gas for each hour of the year, along with how costs are expected to change over the period of analysis (30 years for residential measures and nonresidential envelope measures and 15 years for all other nonresidential measures). In this case, the period of analysis used is 15 years. The TDV cost impacts are presented in nominal dollars and in 2023 present value dollars and represent the energy cost savings realized over 15 years.

The recommended code change applies to new construction, alterations, and additions. The cost savings are assumed to be similar on a square foot basis for all categories.

5.4.2 Energy Cost Savings Results

Per-square foot energy cost savings for newly constructed buildings and alterations that are realized over the 15-year period of analysis are presented in nominal dollars in the Final CASE Report in Appendix C. Energy cost savings in 2023 present valued (PV) dollars are presented in Section 5.4.5 below in the cost effectiveness tables. The only benefit to the proposed measures is electricity cost savings. Therefore, the benefits presented in Section 5.4.5 are equivalent to the PV TDV electricity cost savings in PV 2023$.

5.4.3 Incremental First Cost

The incremental first cost for the proposed mandatory automatic door closing measure was developed by reviewing publicly available pricing for cam hinge, spring hinge, and snap close type mechanisms. Labor cost was estimated to be approximately one hour of additional installation time per door at a labor rate of $60/hr. The equipment and labor cost per door were then multiplied by the number of people passageway doors that were modeled in the Large Refrigerated Warehouse prototype. Then the total cost was divided by the square footage of the Large Refrigerated Warehouse prototype. A table summarizing the incremental first cost assumptions and calculations are shown below.

Table 99: Incremental First Cost Per Door

Cost Component	Cost ($)	Notes
Snap Closer Mechanism	$103	Online retail suppliers for walk in coolers and freezers
Spring/Cam Hinge Mechanism	$448	Online retail suppliers for walk in coolers and freezers
Installation Labor	$60	Assumes $60/hr
Taxes, Permits and Contingency Costs	$96	7.5% for taxes and permits 10% for contingency
Total	$707	

Table 100: Incremental First Cost Per Square Foot

	Description	Value	Notes
1	# of Doors per Prototype	10	
2	Incremental Cost per Door	$707	
3	Incremental Cost per Prototype	$7,070	[3] = [1] * [2]
4	Prototype Square Footage	92,000	
5	Incremental Cost Per Square Footage	$0.077	[5] = [3] / [4]

5.4.4 Incremental Maintenance and Replacement Costs

Incremental maintenance cost is the incremental cost of replacing the equipment or parts of the equipment, as well as periodic maintenance required to keep the equipment operating relative to current practices over the 15-year period of analysis. The present value of equipment maintenance costs (savings) was calculated using a three percent discount rate (d), which is consistent with the discount rate used when developing the 2022 TDV. The present value of maintenance costs that occurs in the n^{th} year is calculated as follows:

$$PresentValueofMaintenanceCost = MaintenanceCost \times \left[\frac{1}{1+d}\right]^n$$

It was assumed that half of the doors would require hardware replacement during the 15 year analysis period, resulting in an additional present value incremental cost of $0.044/ft^2. Additional feedback is requested for operational experience with door closers to confirm the effective useful life assumption.

5.4.5 Cost Effectiveness

This measure proposes a mandatory requirement. As such, a cost analysis is required to demonstrate that the measure is cost effective over the 15-year period of analysis.

The Energy Commission establishes the procedures for calculating cost effectiveness. The Statewide CASE Team collaborated with Energy Commission staff to confirm that the methodology in this report is consistent with their guidelines, including which costs were included in the analysis. The incremental first cost and incremental maintenance costs over the 15-year period of analysis were included. The TDV energy cost savings from electricity savings were also included in the evaluation.

Design costs were not included nor were the incremental costs of code compliance verification.

According to the Energy Commission's definitions, a measure is cost effective if the B/C ratio is greater than 1.0. The B/C ratio is calculated by dividing the cost benefits realized over 15 years by the total incremental costs, which includes maintenance costs for 15 years. The B/C ratio was calculated using 2023 PV costs and cost savings.

Results of the per-square foot cost-effectiveness analyses are presented in Table 101 for new construction, additions, and alterations.

The Submeasure D was found to be cost effective in all climate zones except for Climate Zone 16.

Table 101: 15-Year Cost-Effectiveness Summary Per Square Foot – New Construction, Additions, Alterations

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[a] (2023 PV$)	Costs Total Incremental PV Costs[b] (2023 PV$)	Benefit-to-Cost Ratio
1	$0.17	$0.12	1.37
2	$0.17	$0.12	1.40
3	$0.18	$0.12	1.48
4	$0.18	$0.12	1.50
5	$0.18	$0.12	1.45
6	$0.19	$0.12	1.61
7	$0.18	$0.12	1.51
8	$0.18	$0.12	1.47
9	$0.17	$0.12	1.43
10	$0.17	$0.12	1.39
11	$0.16	$0.12	1.35
12	$0.17	$0.12	1.38
13	$0.17	$0.12	1.39
14	$0.15	$0.12	1.26
15	$0.18	$0.12	1.45
16	$0.10	$0.12	0.80

a. **Benefits: TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (Energy + Environmental Economics 2020). Other savings are discounted at a real (nominal – inflation) three percent rate. Other PV savings include incremental first-cost savings if proposed first cost is less than current first cost. Includes PV maintenance cost savings if PV of proposed maintenance costs is less than PV of current maintenance costs.

b. **Costs: Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Costs are discounted at a real (inflation-adjusted) three percent rate and if PV of proposed maintenance costs is greater than PV of current maintenance costs. If incremental maintenance cost is negative, it is treated as a positive benefit. If there are no total incremental PV costs, the B/C ratio is infinite.

5.5 First-Year Statewide Impacts

5.5.1 Statewide Energy and Energy Cost Savings

The Statewide CASE Team calculated the first-year statewide savings for new construction, additions, and alterations by multiplying the per-square foot savings, which are presented in Section 5.3.3, by assumptions about the percentage of newly constructed buildings that would be impacted by the proposed code. The statewide new construction forecast for 2023 is presented in Appendix A as are the Statewide CASE Team's assumptions about the percentage of new construction that would be impacted by the proposal (by climate zone and building type).

For Submeasure D, because all refrigerated warehouses utilize doors between refrigerated spaces and non-refrigerated spaces, this measure is assumed to affect 100 percent of new construction refrigerated warehouses.

The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2023. The 15-year energy cost savings represent the energy cost savings over the entire 15-year analysis period. The statewide savings estimates do not take naturally occurring market adoption or compliance rates into account.

Table 102 presents the first-year statewide energy and energy cost savings from newly constructed buildings by climate zone.

Table 103 presents first-year statewide savings from new construction, additions, and alterations. It was estimated that square footage related to additions and alterations will equal 5 percent of the current existing building stock in 2023.

Table 102: Statewide Energy and Energy Cost Impacts – New Construction

Climate Zone	Statewide New Construction Impacted by Proposed Change in 2023 (nonresidential: million ft^2)	First-Year[a] Electricity Savings (kWh)	First-Year Peak Electrical Demand Reduction (MW)	First-Year Natural Gas Savings (MMTherms)	15-Year Present Valued Energy Cost Savings (2023 PV$)
1	0.008	532	0	0	$1,312
2	0.047	3,127	0	0	$7,970
3	0.238	17,128	0	0	$42,718
4	0.121	8,484	0	0	$21,904
5	0.024	1,712	0	0	$4,283
6	0.081	6,206	0	0	$15,838
7	0.015	1,115	0	0	$2,813
8	0.118	8,129	0	0	$20,943
9	0.172	11,512	0	0	$29,725
10	0.108	7,077	0	0	$18,172
11	0.090	5,741	0	0	$14,706
12	0.298	19,508	0	0	$49,959
13	0.235	15,244	0	0	$39,485
14	0.037	2,214	0	0	$5,714
15	0.021	1,465	0	0	$3,767
16	0.000	0	0	0	$0
TOTAL	**1.614**	**109,194**	**0**	**0**	**$279,309**

a. First-year savings from all buildings completed statewide in 2023.

Table 103: Statewide Energy and Energy Cost Impacts – New Construction, Alterations, and Additions

Construction Type	First-Year Electricity Savings[a] (kWh)	First-Year Peak Electrical Demand Reduction (MW)	First -Year Natural Gas Savings (MMTherms)	15-Year Present Valued Energy Cost Savings (2023 PV$)
New Construction	109,194	0	0	$279,309
Additions and Alterations	252,107	0	0	$645,183
TOTAL	**361,301**	**0**	**0**	**$924,491**

a. First-year savings from all alterations completed statewide in 2023.

5.5.2 Statewide Greenhouse Gas (GHG) Emissions Reductions

The Statewide CASE Team calculated avoided GHG emissions assuming the emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion. Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42). See Appendix C for additional details on the methodology used to calculate GHG emissions. In short, this analysis assumes an average electricity emission factor of 240.4 metric tons CO_2e per GWh based on the average emission factors for the CACX EGRID subregion.

Table 104 presents the estimated first-year avoided GHG emissions of the proposed code change. During the first year, GHG emissions of 20 metric tons of carbon dioxide equivalents (metric tons CO_2e) would be avoided, utilizing a GHG factor of 0.0002279 metric tons CO_2e/kWh.

Table 104: First-Year Statewide GHG Emissions Impacts

Measure	Electricity Savings[a] (kWh/yr)	Reduced GHG Emissions from Electricity Savings[a] (Metric Tons CO_2e)	Natural Gas Savings[a] (MMTherms/yr)	Reduced GHG Emissions from Natural Gas Savings[a] (Metric Tons CO_2e)	Total Reduced CO_2e Emissions[a,b] (Metric Tons CO_2e)
New Construction	108,646	6	0	0	6
Additions and Alterations	250,983	13	0	0	13
TOTAL	**359,629**	**19**	**0**	**0**	**19**

a. First-year savings from all buildings completed statewide in 2023.

b. Assumes the following emission factors: 0.0002279 MTCO_2e/kWh.

5.5.3 Statewide Water Use Impacts

The proposed code change would not result in water savings.

5.5.4 Statewide Material Impacts

The proposed code change would require new devices, i.e., door closers to be installed on each door used for man movement. The use of door closers would increase the usage of steel as the door closers are mostly made of steel.

Table 105: First-Year Statewide Impacts on Material Use

Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/year)	
		Per-Unit Impacts	First-Year[b] Statewide Impacts
Steel	I	0.0013 pounds / ft^2	1,724

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).
b. First-year savings from all buildings completed statewide in 2023.

5.5.5 Other Non-Energy Impacts

With reduced infiltration between spaces, there is expected to be less frost build up around the doors, which may reduce the possibility of frost melting and contributing to slipping hazards for personnel.

6. Submeasure E: Acceptance Testing for Commercial Refrigeration

6.1 Measure Description

6.1.1 Measure Overview

This proposed submeasure would add acceptance testing language to the Nonresidential Reference Appendix NA7 – Installation and Acceptance Requirements for Nonresidential Buildings and Covered Processes. The referenced code requirements are found in Section 120.6(b) Commercial Refrigeration and include the following measures:

- Condensers and Condenser Fan Motor Variable Speed Control (air cooled, evaporative cooled, and adiabatic)
- Compressor Floating Suction Controls
- Liquid Subcooling
- Refrigerated Display Cases Lighting (motion sensor and automatic time switch controls)
- Refrigeration Heat Recovery

This proposal would affect the acceptance testing preformed for new construction commercial refrigeration system (e.g., supermarkets). There would be no changes to the adopted energy efficiency standards or the compliance software, but nonresidential appendices would be updated. Additional NRCA compliance documents are expected to be required to support the adoption of the new acceptance test language.

6.1.2 Measure History

Acceptance testing is a critical step to ensure code compliance and by extension energy savings. Currently, there are five key code requirements listed in Section 120.6(b) of Title 24, Part 6 for commercial refrigeration systems. However, there are currently no acceptance testing methods to help end users and regulators understand if a system is meeting them.

The performance of commercial refrigeration systems and their compliance with code depend heavily on how well they are commissioned. This is because even if a system is built using the appropriate individual components, it will only operate efficiently if the control system is functioning properly.

Commercial refrigeration code requirements were adopted as part of the 2013 Title 24, Part 6 code language. There was no associated acceptance testing language at that time. During the 2019 code change proposal cycle, acceptance testing language was drafted but was introduced too late to be accepted.

For the 2022 Title 24, Part 6 code change proposal cycle, the Statewide CASE Team is including the previously drafted acceptance test language. The construction inspection and functional testing methods described in the acceptance test language are expected to improve understanding of how commercial refrigeration systems should operate and provide step by step instructions for field technicians to verify proper installation of equipment and controls.

6.1.3 Summary of Proposed Changes to Code Documents

The sections below summarize how the standards, Reference Appendices, Alternative Calculation Method (ACM) Reference Manuals, and compliance documents would be modified by the proposed change. See Section 7 of this report for detailed proposed revisions to code language.

6.1.3.1 Summary of Changes to the Standards

The proposed code change would not modify the standards.

6.1.3.2 Summary of Changes to the Reference Appendices

This proposal would modify the sections of the Reference Appendices identified below. See Section 7.3 of this report for the detailed proposed revisions to the text of the reference appendices.

Reference Appendix NA7 – installation and Acceptance Requirements for Nonresidential Buildings and Covered Processes

NA7.XX (New Section) – Commercial Refrigeration System Acceptance Tests

Condensers and Condenser Fan Motor Variable Speed Control: The proposed acceptance test language would reference existing functional tests used for refrigerated warehouses to verify fan speeds modulating in unison, proper rotation direction, and floating head pressure controls.

Compressor Floating Suction Pressure: The proposed acceptance test language would describe construction inspection tasks to verify accuracy of pressure sensor readings, pressure to saturated temperature conversions, and identification of the cooling circuits designated for floating suction temperature control. Functional tests would be included to verify that the saturated suction temperature setpoint dynamically adjusts in response to lower loads.

Liquid Subcooling: The proposed acceptance test language would describe construction inspection tasks to verify accuracy of pressure sensor readings, liquid temperature sensor readings, and pressure to saturated temperature conversions.

Functional tests would be included to verify that the installed subcooler is providing adequate liquid subcooling through review of trend data and spot measurements.

Refrigerated Display Case Lighting: The proposed acceptance test language would describe construction inspection tasks for both motion sensor control and automatic time switch control to ensure the appropriate control equipment is installed. Functional tests would be included to verify the installed controls are operating correctly.

Refrigeration Heat Recovery: The proposed acceptance test language would describe construction inspection tasks to verify accuracy of pressure and temperature sensor readings for sensors associated with heat recovery equipment. Functional tests would be included that verify that the controls system activates the heat recovery devices, and that there is measurable heat gain to the air or other fluid that is reclaiming the heat from the refrigeration discharge vapor.

6.1.3.3 Summary of Changes to the Nonresidential ACM Reference Manual

The proposed code change would not modify the ACM Reference Manual.

6.1.3.4 Summary of Changes to the Nonresidential Compliance Manual

The proposed code change would modify the following section of the Nonresidential Compliance Manual:

- Table 13-1: Acceptance Documents
- Section 13.4.4 Covered Process Systems and Equipment

See Section 7.5 of this report for the detailed proposed revisions to the text of the Compliance Manuals.

6.1.3.5 Summary of Changes to Compliance Documents

The proposed code change would modify the compliance documents listed below. Examples of the revised documents are presented in Section 7.6.

- NRCA-PRC-XX – Certificate of acceptance for Condensers and Condenser Fan Motor Variable Speed Control (air cooled, evaporative cooled, and adiabatic).
- NRCA-PRC-XX – Certificate of acceptance for Compressor Floating Suction Controls
- NRCA-PRC-XX – Certificate of acceptance for Liquid Subcooling
- NRCA-PRC-XX – Certificate of acceptance for Refrigerated Display Cases Lighting (motion sensor and automatic time switch controls)
- NRCA-PRC-XX – Certificate of acceptance for Refrigeration Heat Recovery

6.1.4 Regulatory Context

6.1.4.1 Existing Requirements in the California Energy Code

The proposed acceptance test language refers to the existing commercial refrigeration requirements in Title 24, Part 6 Section 120.6(b).

6.1.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements in other parts of the California Building Code.

6.1.4.3 Relationship to Local, State, or Federal Laws

There are no relevant local, state, or federal laws.

6.1.4.4 Relationship to Industry Standards

There are no relevant industry standards.

6.1.5 Compliance and Enforcement

When developing this proposal, the Statewide CASE Team considered methods to streamline the compliance and enforcement process and how negative impacts on market actors who are involved in the process could be mitigated or reduced. This section describes how to comply with the proposed code change. It also describes the compliance verification process. Appendix E presents how the proposed changes could impact various market actors.

The activities that need to occur during each phase of the project are described below:

- **Design Phase:** Design engineers, contractors, and owners collaborate to develop refrigeration system design loads and select the best system configuration and pieces of equipment to supply adequate cooling. The design must be compliant with Title 24, Part 6 Section 120.6(b). The proposed acceptance test language does not affect this phase of compliance.
- **Permit Application Phase:** Typically, a contractor will develop a set of stamped engineering plan drawings on the owner's behalf, that will include refrigeration system design and equipment. The drawings can also be developed by an independent engineering firm and are used as the basis for contractors to supply bids for the project. This set of plan drawings should incorporate compliance documents that have already been developed to confirm that the design complies with Title 24, Part 6. If the selected equipment does not comply with Title 24, Part 6, the authority having jurisdiction should provide plan check comments to correct this before providing any building permits. The proposed acceptance test language does not affect this phase of compliance.

- **Construction Phase:** Contractors install the refrigeration system as described in the approved plan drawings, with oversight from the owner and authority having jurisdiction. The installed equipment should match what was approved and specified. The proposed acceptance test language does not affect this phase of compliance.
- **Inspection Phase:** After construction, the owner or contractor have the responsibility to have the building and its various mechanical systems inspected by the authority having jurisdiction. This inspection phase should include an examination of the refrigeration system to verify the compliant equipment described in the plan drawings matches what was physically installed. Acceptance testing should be completed to verify operational requirements such compressor floating suction control and lighting control. The proposed acceptance test language should be used by a field technician as part of the inspection process, and upon passing should provide the owner with Certificate of Installation and Certificate of Acceptance documents.

The compliance process above is identical to the existing compliance process for the Design, Permit Application, and Construction phases. The inspection phase would change as a result of the proposed acceptance testing language. Additional field verification and diagnostic tests would be required that were previously not performed in order for the installed refrigeration system to be accepted.

The Statewide CASE Team has provided detailed step by step instructions in the proposed acceptance test language that should mitigate uncertainty in the methodology of accepting the installed refrigeration system. However, additional training for technicians may be required in order to realize the full benefits of the proposed acceptance test language.

6.2 Market Analysis

6.2.1 Market Structure

The Statewide CASE Team performed a market analysis with the goals of identifying current technology availability, current product availability, and market trends. It then considered how the proposed standard may impact the market in general as well as individual market actors. Information was gathered about the incremental cost of complying with the proposed measure. Estimates of market size and measure applicability were identified through research and outreach with stakeholders including utility program staff, Energy Commission staff, and a wide range of industry actors. In addition to conducting personalized outreach, the Statewide CASE Team discussed the current market structure and potential market barriers during a public stakeholder meeting that the Statewide CASE Team held on November 7, 2019 and April 2, 2020.

The proposed submeasure for acceptance testing language for commercial refrigeration primarily has an impact on the commissioning agent for a new construction project who is responsible for ensuring all building systems are performing according to their design specifications. The acceptance test language can be used as a useful tool to ensure proper compliance by providing step by step instructions for verification.

6.2.2 Technical Feasibility, Market Availability, and Current Practices

There are no major technical barriers to performing the proposed acceptance tests. One of the main market barriers for performing the proposed acceptance tests is a limited number of trained field technicians for refrigeration. The Statewide CASE Team has attempted to mitigate this by providing step by step instructions for acceptance testing for the first time in commercial refrigeration. Publishing the acceptance test language should provide California business owners, commissioning agents, technicians, and building inspectors a clearer understanding of how to properly commission commercial refrigeration systems. This is expected to promote improvement in compliance and an improvement in overall technician education.

6.2.3 Market Impacts and Economic Assessments

6.2.3.1 Impact on Builders

Builders of residential and commercial structures are directly impacted by many of the measures proposed by the Statewide CASE Team for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

California's construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 106).[25] In 2018, total payroll was $80 billion. Nearly 17,000 establishments and 344,000 employees focus on the commercial sector. The remainder of establishments and employees work in industrial, utilities, infrastructure, and other heavy construction (industrial sector).

[25] Average total monthly employment in California in 2018 was 18.6 million; the construction industry represented 4.5 percent of 2018 employment.

Table 106: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establishments	Employment	Annual Payroll (billions $)
Residential	**59,287**	**420,216**	**$23.3**
Residential Building Construction Contractors	22,676	115,777	$7.4
Foundation, Structure, & Building Exterior	6,623	75,220	$3.6
Building Equipment Contractors	14,444	105,441	$6.0
Building Finishing Contractors	15,544	123,778	$6.2
Commercial	**17,273**	**343,513**	**$27.8**
Commercial Building Construction	4,508	75,558	$6.9
Foundation, Structure, & Building Exterior	2,153	53,531	$3.7
Building Equipment Contractors	6,015	128,812	$10.9
Building Finishing Contractors	4,597	85,612	$6.2
Industrial, Utilities, Infrastructure, & Other	**4,103**	**96,550**	**$9.2**
Industrial Building Construction	299	5,864	$0.5
Utility System Construction	1,643	47,619	$4.3
Land Subdivision	952	7,584	$0.9
Highway, Street, and Bridge Construction	770	25,477	$2.4
Other Heavy Construction	439	10,006	$1.0

Source: (State of California, Employment Development Department n.d.)

The proposed change related to Submeasure E would likely affect commercial builders but would not impact firms that focus on construction and retrofit of utility systems, public infrastructure, or other heavy construction. The effects on the commercial building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 107 shows the commercial building subsectors the Statewide CASE Team expects to be impacted by the changes proposed in this report. The Statewide CASE Team's estimates of the magnitude of these impacts are shown in Section 6.2.4.

Table 107: Specific Subsectors of the California Commercial Building Industry Impacted by Proposed Change to Code/Standard

Construction Subsector	Establishments	Employment	Annual Payroll (billions $)
Nonresidential plumbing and HVAC contractors	2,394	52,977	$4.47

Source: (State of California, Employment Development Department n.d.)

6.2.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes practices is within the normal practices of building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training in order to remain compliant with changes to design practices and building codes.

Businesses that focus on residential, commercial, institutional, and industrial building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 108 shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector. The Statewide CASE Team anticipates the impacts for Submeasure E to affect firms that focus on supermarket construction.

There is not a North American Industry Classification System (NAICS)[26] code specific for energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[27] It is not possible to determine which business

[26] NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

[27] Establishments in this sector include businesses primarily engaged in evaluating a building's structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

establishments within the Building Inspection Services sector are focused on energy efficiency consulting. The information shown in Table 108 provides an upper bound indication of the size of this sector in California.

Table 108: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
Architectural Services [a]	3,704	29,611	$2.9
Building Inspection Services [b]	824	3,145	$0.2

Source: (State of California, Employment Development Department n.d.)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures;
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential & nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services.

6.2.3.3 Impact on Occupational Safety and Health

The proposed code change does not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Division of Occupational Safety and Health (Cal/OSHA). All existing health and safety rules would remain in place. Complying with the proposed code change is not anticipated to have adverse impacts on the safety or health of occupants or those involved with the construction, commissioning, and maintenance of the building.

6.2.3.4 Impact on Building Owners and Occupants

The commercial building sector includes a wide array of building types, including offices, restaurants and lodging, retail, and mixed-use establishments, and warehouses (including refrigerated) (Kenney 2019). Energy use by occupants of commercial buildings also varies considerably with electricity used primarily for lighting, space cooling and conditioning, and refrigeration. Natural gas consumed primarily for heating water and for space heating. According to information published in the 2019 California Energy Efficiency Action Plan, there is more than 7.5 billion square feet of commercial floor space in California and consumes 19 percent of California’s total annual energy use (Kenney 2019). The diversity of building and business types within this sector creates a challenge for disseminating information on energy and water efficiency solutions, as does the variability in sophistication of building owners and the relationships between building owners and occupants.

Building owners and occupants would benefit from lower energy bills. As discussed in Section 6.2.4.1, when building occupants save on energy bills, they tend to spend it elsewhere in the economy thereby creating jobs and economic growth for the California economy. The Statewide CASE Team does not expect the proposed code change for the 2022 code cycle to impact building owners or occupants adversely.

6.2.3.5 Impact on Building Component Retailers (Including Manufacturers and Distributors)

There is no expected impact on building component retailers as the acceptance test language does not change current code requirements.

6.2.3.6 Impact on Building Inspectors

Table 109 shows employment and payroll information for state and local government agencies in which many inspectors of residential and commercial buildings are employed. Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The Statewide CASE Team, therefore, anticipates the proposed change would have no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 109: Employment in California State and Government Agencies with Building Inspectors

Sector	Govt.	Establishments	Employment	Annual Payroll (millions $)
Administration of Housing Programs[a]	State	17	283	$29.0
Administration of Housing Programs[a]	Local	36	2,882	$205.7
Urban and Rural Development Admin[b]	State	35	552	$48.2
Urban and Rural Development Admin[b]	Local	52	2,446	$186.6

Source: (State of California, Employment Development Department n.d.)

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.

b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

The proposed acceptance testing language would add additional steps required by building inspectors to verify commercial refrigeration systems have been properly commissioned.

6.2.3.7 Impact on Statewide Employment

As described in Sections 6.2.3.1 through 6.2.3.6, the Statewide CASE Team does not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 6.2.4, the Statewide CASE Team estimated the proposed change in Submeasure E would affect statewide employment and economic output directly and indirectly through its impact on builders, designers and energy consultants, and building inspectors. In addition, the Statewide CASE Team estimated how energy savings associated with the proposed change in Submeasure E would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

There is no expected impact on statewide employment as the acceptance test language does not change current code requirements.

6.2.4 Economic Impacts

For the 2022 code cycle, the Statewide CASE Team used the IMPLAN model software, along with economic information from published sources, and professional judgement to develop estimates of the economic impacts associated with each of the proposed code changes.[28] While this is the first code cycle in which the Statewide CASE Team develops estimates of economic impacts using IMPLAN, it is important to note that the economic impacts developed for this report are only estimates and are based on limited and to some extent speculative information. In addition, the IMPLAN model provides a relatively simple representation of the California economy and, though the Statewide CASE Team is confident that direction and approximate magnitude of the estimated economic impacts are reasonable, it is important to understand that the IMPLAN model is a simplification of extremely complex actions and interactions of individual, businesses, and other organizations as they respond to changes in energy efficiency codes. In all aspect of this economic analysis, the CASE Authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the Statewide CASE Team believes the economic

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[28] IMPLAN (Impact Analysis for Planning) software is an input-output model used to estimate the economic effects of proposed policies and projects. IMPLAN is the most commonly used economic impact model due to its ease of use and extensive detailed information on output, employment, and wage information.

impacts presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the commercial/industrial building industry, architects, energy consultants, and building inspectors. The Statewide CASE Team does not anticipate that money saved by commercial building owners or other organizations affected by the proposed 2022 code cycle regulations would result in additional spending by those businesses.

Table 110: Estimated Impact that Adoption of the Proposed Measure would have on the California Commercial Construction Sector

Type of Economic Impact	Employment (jobs)	Labor Income (millions $)	Total Value Added (millions $)	Output (millions $)
Direct Effects (Additional spending by Commercial Builders)	4	$0.26	$0.34	$0.57
Indirect Effect (Additional spending by firms supporting Commercial Builders)	1	$0.06	$0.10	$0.19
Induced Effect (Spending by employees of firms experiencing “direct” or “indirect” effects)	2	$0.10	$0.17	$0.28
Total Economic Impacts	**7**	**$0.42**	**$0.61**	**$1.04**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

6.2.4.1 Creation or Elimination of Jobs

The Statewide CASE Team does not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new *types* of jobs or the elimination of *existing* types of jobs. In other words, the Statewide CASE Team’s proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in this section would lead to modest changes in employment of existing jobs.

There is no expected impact on the creation or elimination of jobs as the acceptance test language does not change current code requirements.

6.2.4.2 Creation or Elimination of Businesses in California

As stated in Section 6.2.4.1, the Statewide CASE Team's proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to evaporator requirements which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the Statewide CASE Team does not foresee any new businesses being created, nor does the Statewide CASE Team think any existing businesses would be eliminated due to the proposed code changes.

6.2.4.3 Competitive Advantages or Disadvantages for Businesses in California

The proposed code changes would apply to all businesses incorporated in California, regardless of whether the business is incorporated inside or outside of the state.[29] Therefore, the Statewide CASE Team does not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the Statewide CASE Team does not anticipate businesses located outside of California would be advantaged or disadvantaged.

6.2.4.4 Increase or Decrease of Investments in the State of California

The Statewide CASE Team analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[30] As Table 111 shows, between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, with an average of 31 percent. While only an approximation of the proportion of business income used for net capital investment, the Statewide CASE Team believes it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

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[29] Gov. Code, § 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR § 2003(a)(3) Competitive advantages or disadvantages for California businesses currently doing business in the state.

[30] Net private domestic investment is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

Table 111: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits
2015	609.3	1,740.4	35%
2016	456.0	1,739.8	26%
2017	509.3	1,813.6	28%
2018	618.3	1,843.7	34%
2019	580.9	1,827.0	32%
		5-Year Average	**31%**

Source: (Federal Reserve Economic Data n.d.)

The Statewide CASE Team does not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy. Nevertheless, the Statewide CASE Team is able to derive a reasonable estimate of the change in investment by California businesses by multiplying the sum of Business Income estimated in Table 110 above by 31 percent.

6.2.4.5 Effects on the State General Fund, State Special Funds, and Local Governments

There is no expected impact on state general funds, state special funds, or local governments as the acceptance test language does not change current code requirements.

6.2.4.6 Impacts on Specific Persons

There is no expected impact on specific persons as the acceptance test language does not change current code requirements.

6.3 Energy Savings

The code change proposal would not modify the stringency of the existing energy efficiency standards, so there would be no savings on a per-square foot basis. Section X.3 of the Final CASE Reports, which typically presents the methodology, assumptions, and results of the per-square foot energy impacts, has been truncated for this measure. Although this measure does not result in electricity or gas savings, the measure would promote improved compliance for measures already described in Title 24, Part 6 Section 120.6(b). Non-energy benefits include improved clarity and education on how to commission commercial refrigeration systems.

6.4 Cost and Cost Effectiveness

For this proposed change, the Statewide CASE Team is presenting information on the cost implications in lieu of a full cost-effectiveness analysis.

The cost implications for the proposed acceptance testing language includes additional time for a field technician to complete the tests and complete the associated certificate of acceptance forms. The acceptance test language describes commissioning activities that should already be included as a matter of course for building and commissioning new construction projects. However, if these tests are not being performed, the additional cost is estimated to be approximately 60 additional working hours for a technician based on time required to complete the step by step instructions proposed.

Assuming a labor rate of $60/hour and a contingency factor of 25 percent, the cost of acceptance testing is expected to be approximately $4,500 per prototype, or $0.08/ft^2 (based on 60,000 ft^2 large supermarket prototype). Per the energy savings results from the 2013 CASE Report that analyzed the commercial refrigeration measures, the $/ft^2 savings results for Climate Zone 12 are shown below. It is estimated that improved commissioning due to acceptance testing requirements would conservatively result in 5 percent energy improvement compared to existing conditions. The resulting energy savings is shown to be cost effective, with B/C ratios between 3 and 22.

Table 112: Submeasure E Benefit Cost Ratio Summary

Measure	Incremental Cost per Prototype ($)	Incremental Cost per ft^2 ($/ft^2)	Full Measure Benefit ($/ft^2, 2013 CASE, CZ12)	5% Improve-ment ($/ft^2)	Benefit Cost Ratio
Floating Head Pressure, Condenser Control	$900	$0.015	$2.29	$0.11	7.63
Floating Suction Pressure	$900	$0.015	$0.93	$0.05	3.10
Liquid Subcooling	$900	$0.015	$1.00	$0.05	3.33
Display Case Lighting	$900	$0.015	$3.21	$0.16	10.70
Heat Recovery	$900	$0.015	$6.60	$0.33	22.00
TOTAL	**$4,500**	**$0.08**	**$14.03**	**$0.70**	**9.35**

6.5 First-Year Statewide Impacts

The code change proposal would not modify the stringency of the existing Title 24, Part 6, so the savings associated with this proposed change are minimal. Typically, the

Statewide CASE Team presents a detailed analysis of statewide energy and cost savings associated with the proposed change in Section X.5 of the Final CASE Report. As discussed in Section 6.3, although the energy savings are limited, the measure would promote improved compliance and education on commissioning.

7. Proposed Revisions to Code Language

7.1 Guide to Markup Language

The proposed changes to the standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with red <u>underlining</u> (new language) and ~~strikethroughs~~ (deletions).

7.2 Standards

SECTION 100.1 – DEFINITIONS AND RULES OF CONSTRUCTION

(b) Definitions. Terms, phrases, words and their derivatives in Part 6 shall be defined as specified in Section 100.1. Terms, phrases, words and their derivatives not found in Section 100.1 shall be defined as specified in the "Definitions" chapters of Title 24, Parts 1 through 5 of the California Code of Regulations. Where terms, phrases, words and their derivatives are not defined in any of the references above, they shall be defined as specified in Webster's Third New International Dictionary of the English Language, Unabridged (1961 edition, through the 2002 addenda), unless the context requires otherwise.

<u>**CONDENSING UNIT** is a mechanical refrigeration system consisting of a compressor, condenser, liquid receiver, and controls that are packaged as a single product.</u>

<u>**PACKAGED REFRIGERATION SYSTEMS** are mechanical refrigeration systems consisting of compressors, condensers, evaporators and vessels used to provide direct or indirect cooling for refrigerated spaces that have been integrated into a single packaged unit designed to be installed on the roof of a refrigerated warehouse or on grade. Applies to systems with evaporators integrated into the package or with evaporators pre-engineered as a split system.</u>

TRANSCRITICAL CO_2 REFRIGERATION SYSTEM is a type of refrigeration system that uses CO_2 as the refrigerant where the ultimate heat rejection to ambient air can take place above the critical point.

> **TRANSCRITICAL MODE** is a system operating condition for a refrigeration system wherein the refrigerant pressure and temperature leaving the compressor is such that the refrigerant is at or above the critical point. Typically used in reference to CO_2 refrigeration systems.
>
> **SUBCRITICAL MODE** is a system operating condition for a refrigeration system wherein the refrigerant pressure and temperature leaving the compressor is such that the refrigerant is below the critical point. Typically used in reference to CO_2 refrigeration systems.

SECTION 120.6 – MANDATORY REQUIREMENTS FOR COVERED PROCESSES

Nonresidential, high-rise residential, and hotel/motel buildings shall comply with the applicable requirements of Sections 120.6(a) through 120.6(g).

a. Mandatory Requirements for Refrigerated Warehouses. Refrigerated Warehouses that are greater than or equal to 3,000 square feet and refrigerated spaces with a sum total of 3,000 square feet or more that are served by the same refrigeration system shall meet the requirements of Section 120.6(a).

Refrigerated Spaces that are less than 3,000 square feet shall meet the requirements of the Appliance Efficiency Regulations for walk-in coolers or freezers contained in the Appliance Efficiency Regulations (California Code of Regulations, Title 20, Sections 1601 through 1608).

1. **Insulation Requirements.** Exterior surfaces of refrigerated warehouses shall be insulated at least to the R-values in TABLE 120.6-A.

TABLE 120.6-A REFRIGERATED WAREHOUSE INSULATION

SPACE	SURFACE	MINIMUM R-VALUE (°F·hr·sf/Btu)
Freezers	Roof/Ceiling	R-40
	Wall	R-36
	Floor	R-35
	Floor with all heating from productive refrigeration capacity[1]	R-20
Coolers	Roof/Ceiling	R-28
	Wall	R-28

1. All underslab heating is provided by a heat exchanger that provides refrigerant subcooling or other means that result in productive refrigeration capacity on the associated refrigerated system.

2. **Underslab heating.** Electric resistance heat shall not be used for the purposes of underslab heating.

   EXCEPTION to Section 120.6(a)2: Underslab heating systems controlled such that the electric resistance heat is thermostatically controlled and disabled during the summer on-peak period defined by the local electric utility.

3. **Evaporators.** New fan-powered evaporators used in coolers and freezers shall conform to the following:

   A. Single phase fan motors less than 1 hp and less than 460 Volts in newly installed evaporators shall be electronically commutated motors or shall have a minimum motor efficiency of 70 percent when rated in accordance with NEMA Standard MG 1-2006 at full load rating conditions.

   B. Evaporator fans served either by a suction group with multiple compressors, or by a single compressor with variable capacity capability shall be variable speed and the speed shall be controlled in response to space temperature or humidity.

   EXCEPTION 1 to Section 120.6(a)3B: Addition, alteration or replacement of less than all of the evaporators in an existing refrigerated space that does not have speed-controlled evaporators.

   EXCEPTION 2 to Section 120.6(a)3B: Coolers within refrigerated warehouses that maintain a Controlled Atmosphere for which a licensed engineer has certified that the types of products stored will require constant operation at 100 percent of the design airflow.

EXCEPTION 3 to Section 120.6(a)3B: Areas within refrigerated warehouses that are designed solely for the purpose of quick chilling/freezing of products, including but not limited to spaces with design cooling capacities of greater than 240 Btu/hr-ft² (2 tons per 100 ft²).

C. Evaporator fans served by a single compressor that does not have variable capacity shall utilize controls to reduce airflow by at least 40 percent for at least 75 percent of the time when the compressor is not running.

EXCEPTION to Section 120.6(a)3C: Areas within refrigerated warehouses that are designed solely for the purpose of quick chilling/freezing of products (spaces with design cooling capacities of greater than 240 Btu/hr-ft², or 2 tons per 100 ft²).

D. Fan-powered evaporators shall meet the evaporator specific efficiency requirements listed in TABLE 120.6-C and 120.6-D at the conditions listed in TABLE 120.6-B. Evaporator specific efficiency is defined as the total refrigeration capacity (Btu/h) divided by the electrical input power at 100 percent fan speed. Capacity is rated at 10°F of temperature difference between the incoming air temperature and the saturated evaporating temperature. For glide refrigerants, the saturated evaporating temperature is defined as the dewpoint temperature. Input power is rated at 100% fan speed at rated temperature conditions.

EXCEPTION to Section 120.6(a)3D: Evaporators designed solely for the purpose of quick chilling/freezing of products, including but not limited to spaces with design cooling capacities of greater than 240 Btu/hr-ft² (2 tons per 100 ft²).

TABLE 120.6-B EVAPORATOR SPECIFIC EFFICIENCY RATING CONDITIONS

	FREEZER APPLICATION	**COOLER/DOCK APPLICATION**
Saturated evaporating temperature (°F)	-20	25
Entering air temperature (°F)	-10	35
External Static pressure (in. WC)	0	0
Rating type	Dry Coil	Dry Coil

TABLE 120.6-C EVAPORATOR SPECIFIC EFFICIENCY FOR FREEZER APPLICATIONS

LIQUID FEED TYPE	**REFRIGERANT TYPE**	**MINIMUM EFFICIENCY (Btuh/Watt)**
Direct Expansion	Halocarbon	40
	Ammonia	25

Flooded/Recirculated Liquid	Ammonia	45

TABLE 120.6-D EVAPORATOR SPECIFIC EFFICIENCY FOR COOLER APPLICATIONS

EVAPORATOR TYPE	**REFRIGERANT TYPE**	**MINIMUM EFFICIENCY (Btuh/Watt)**
Direct Expansion	Halocarbon	45
	Ammonia	35
Flooded/Recirculated Liquid	Ammonia	50

E. The applied static pressure drop for evaporators installed in refrigerated warehouses shall not exceed 0.5" water column.

EXCEPTION to Section 120.6(a)3E: Evaporators designed solely for the purpose of quick chilling/freezing of products, including but not limited to spaces with design cooling capacities of greater than 240 Btu/hr-ft² (2 tons per 100 ft²).

4. **Condensers.** New fan-powered condensers on all new refrigeration systems shall conform to the following:

A. Design saturated condensing temperatures for evaporative-cooled condensers and water-cooled condensers served by fluid coolers or cooling towers shall be less than or equal to:

i. The design wetbulb temperature plus 20°F in locations where the design wetbulb temperature is less than or equal to 76°F; or

ii. The design wetbulb temperature plus 19°F in locations where the design wetbulb temperature is between 76°F and 78°F; or

iii. The design wetbulb temperature plus 18°F in locations were the design wetbulb temperature is greater than or equal to 78°F.

EXCEPTION 1 to Section 120.6(a)4A: Compressors and condensers on a refrigeration system for which more than 20 percent of the total design refrigeration cooling load is for quick chilling or freezing (space with design cooling capacities of greater than 240 Btu/hr-ft² (2 tons per 100 ft²), or process refrigeration cooling for other than a refrigerated space.

B. Design saturated condensing temperatures for air-cooled condensers shall be less than or equal to the following:

i. Condensing units and packaged refrigeration systems

1. The design dry bulb temperature plus 15°F for systems serving freezers;

2. The design dry bulb temperature plus 20°F for systems serving coolers.

ii. All other refrigeration systems

~~i~~ 1. The design dry bulb temperature plus 10°F for systems serving freezers;

ii 2. The design dry bulb temperature plus 15°F for systems serving coolers.

EXCEPTION 1 to Section 120.6(a)4B: Condensing units with a total compressor horsepower less than 100 HP.

EXCEPTION 2 to Section 120.6(a)4B: Compressors and condensers on a refrigeration system for which more than 20 percent of the total design refrigeration cooling load is for quick chilling or freezing (space with design cooling capacities of greater than 240 Btu/hr-ft² (2 tons per 100 ft²), or process refrigeration cooling for other than a refrigerated space.

C. The saturated condensing temperature necessary for adiabatic condensers to reject the design total heat of rejection of a refrigeration system assuming dry mode performance shall be less than or equal to:

i. The design dry bulb temperature plus 20°F for systems serving freezers;

ii. The design dry bulb temperature plus 30°F for systems serving coolers.

EXCEPTION 1 to Section 120.6(a)4C: Compressors and condensers on a refrigeration system for which more than 20 percent of the total design refrigeration cooling load is for quick chilling or freezing (space with design cooling capacities of greater than 240 Btu/hr-ft² (2 tons per 100 ft²), or process refrigeration cooling for other than a refrigerated space.

D. All condenser fans for air-cooled condensers, evaporative-cooled condensers, adiabatic condensers, gas coolers, air or water fluid coolers or cooling towers shall be continuously variable speed, with the speed of all fans serving a common condenser high side controlled in unison.

E. The minimum condensing temperature setpoint shall be less than or equal to 70°F for air-cooled condensers, evaporative-cooled condensers, adiabatic condensers, gas coolers, air or water-cooled fluid coolers or cooling towers.

F. Condensing temperature reset. The condensing temperature set point of systems served by air-cooled condensers shall be reset in response to ambient dry bulb temperature. The condensing temperature set point of systems served by evaporative-cooled condensers or water-cooled condensers (via cooling towers or fluid coolers) shall be reset in response to ambient wetbulb temperatures. The condensing temperature set point for systems served by adiabatic condensers shall be reset in response to ambient dry bulb temperature while operating in dry mode.

EXCEPTION 1 to Section 120.6(a)4F: Condensing temperature control strategies approved by the Executive Director that have been demonstrated to provide at least equal energy savings.

EXCEPTION 2 to Section 120.6(a)4F: Systems served by adiabatic condensers in Climate Zones 1, 3, 5, 12, 14 and 16.

G. Fan-powered condensers shall meet the condenser efficiency requirements listed in TABLE 120.6-EB. Condenser efficiency is defined as the Total Heat of Rejection (THR) capacity divided by all electrical input power including fan power at 100 percent fan speed, and power of spray pumps for evaporative condensers.

EXCEPTION to Section 120.6(a)4G: Adiabatic condensers with ammonia as refrigerant.

H. Air-cooled condensers shall have a fin density no greater than 10 fins per inch.

EXCEPTION to Section 120.6(a)4H: Micro-channel condensers.

EXCEPTION to Section 120.6(a)4A, 4B, 4C, 4G, and 4H: Condensing units or packaged refrigeration systems with a total compressor horsepower less than or equal to 100 HP.

EXCEPTION to Section 120.6(a)4: Transcritical CO_2 refrigeration systems.

~~**EXCEPTION to Section 120.6(a)1A, 1B, 1C, 1E, 1F and 1G:** Transcritical CO_2 refrigeration systems.~~

TABLE 120.6-E~~B~~ FAN-POWERED CONDENSERS – MINIMUM EFFICIENCY REQUIREMENTS

CONDENSER TYPE	REFRIGERANT TYPE	MINIMUM EFFICIENCY	RATING CONDITION
Outdoor Evaporative-Cooled with THR Capacity > 8,000 MBH	All	350 Btuh/Watt	100°F Saturated Condensing Temperature (SCT), 70°F Outdoor Wetbulb Temperature
Outdoor Evaporative-Cooled with THR Capacity < 8,000 MBH and Indoor Evaporative-Cooled	All	160 Btuh/Watt	
Outdoor Air-Cooled	Ammonia	75 Btuh/Watt	105°F Saturated Condensing Temperature (SCT), 95°F Outdoor Dry bulb Temperature
	Halocarbon	65 Btuh/Watt	
Outdoor Air-Cooled, Packaged Units and Condensing Units with compressor horsepower greater than or equal to 100HP	All	60 Btuh/Watt	105°F Saturated Condensing Temperature (SCT), 95°F Outdoor Dry bulb Temperature
Adiabatic Dry Mode	Halocarbon	45 Btuh/W	105°F Saturated Condensing Temperature (SCT), 95°F Outdoor Dry bulb Temperature
Indoor Air-Cooled	All	Exempt	

5. **Transcritical CO_2 Gas Coolers.** New fan-powered gas coolers on all new transcritical CO_2 refrigeration systems shall conform to the following:

A. Air cooled gas coolers are prohibited in Climate Zones 9 through 15.

B. Design leaving gas temperature for air-cooled gas coolers shall be less than or equal to the design dry bulb temperature plus 6°F.

EXCEPTION to Section 120.6(a)5B: Design leaving gas temperature for air-cooled gas coolers in Climate Zone 2, 4, and 8 shall be less than or equal to the design dry bulb temperature plus 8°F.

C. Design leaving gas temperature for adiabatic gas coolers necessary to reject the design total heat of rejection of a refrigeration system assuming dry mode performance shall be less than or equal to the design dry bulb temperature plus 15°F.

D. All gas cooler fans shall be continuously variable speed, with the speed of all fans serving a common condenser high side controlled in unison.

E. While operating below the critical point, the gas cooler pressure shall be controlled in accordance to 120.6(a)4F.

F. While operating above the critical point, the gas cooler pressure setpoint shall be reset based on ambient conditions such that the system efficiency is maximized.

G. The minimum condensing temperature setpoint shall be less than or equal to 60°F for air-cooled gas coolers, evaporative-cooled gas coolers, adiabatic gas coolers, air or water-cooled fluid coolers or cooling towers.

EXCEPTION to Section 120.6(a)5G: Transcritical CO_2 systems with a design intermediate saturated suction temperature greater than or equal to 30°F shall have a minimum condensing temperature setpoint of 70°F or less.

H. Fan-powered gas coolers shall meet the gas cooler efficiency requirements listed in TABLE 120.6-F. Gas cooler efficiency is defined as the Total Heat of Rejection (THR) capacity divided by all electrical input power (fan power at 100 percent fan speed).

TABLE 120.6-F TRANSCRITICAL CO_2 FAN-POWERED GAS COOLERS – MINIMUM EFFICIENCY REQUIREMENTS

CONDENSER TYPE	REFRIGERANT TYPE	MINIMUM EFFICIENCY	RATING CONDITION
Outdoor Air-Cooled	Transcritical CO_2	160 Btuh/W	1400 psig, 100°F Outlet Gas Temperature, 90°F Outdoor Dry bulb Temperature
Adiabatic Dry Mode	Transcritical CO_2	90 Btuh/W	1100 psig, 100°F Outlet Gas Temperature, 90°F Outdoor Dry bulb Temperature

~~5~~ 6. **Compressors.** Compressor systems utilized in refrigerated warehouses shall conform to the following:

A. Compressors for transcritical CO_2 refrigeration systems shall be designed to operate at a minimum condensing temperature of 60°F or less.

EXCEPTION to Section 120.6(a)6A: Compressors with a design saturated suction temperature greater than or equal to 30°F shall be designed to operate at a minimum condensing temperature of 70°F or less.

~~A~~ B. Compressors serving refrigeration systems that are not transcritical CO_2, shall be designed to operate at a minimum condensing temperature of 70°F or less.

~~B~~ C. New open-drive screw compressors in new refrigeration systems with a design saturated suction temperature (SST) of 28°F or lower that discharges to the system condenser pressure shall control compressor speed in response to the refrigeration load.

EXCEPTION 1 to Section 120.6(a)~~5 B~~ 6C: Refrigeration plants with more than one dedicated compressor per suction group.

EXCEPTION 2 to Section 120.6(a) ~~5 B~~ 6C: Compressors and condensers on a refrigeration system for which more than 20 percent of the total design refrigeration cooling load is for quick chilling or freezing (space with design cooling capacities of greater than 240 Btu/hr-ft² (2 tons per 100 ft²), or process refrigeration cooling for other than a refrigerated space.

~~C~~ D. New screw compressors with nominal electric motor power greater than 150 HP shall include the ability to automatically vary the compressor volume ratio (Vi) in response to operating pressures.

~~6~~ 7. **Infiltration Barriers.** Passageways between freezers and higher-temperature spaces, and passageways between coolers and nonrefrigerated spaces, shall have an infiltration barrier consisting of strip curtains, an automatically-closing door, or an air curtain designed by the manufacturer for use in the passageway and temperature for which it is applied.

EXCEPTION 1 to Section 120.6(a) ~~6~~ 7: Openings with less than 16 square feet of opening area.

EXCEPTION 2 to Section 120.6(a) ~~6~~ 7: Dock doorways for trailers.

8. **Automatic Door Closers**. Doors designed for the passage of people only between freezers and higher-temperature spaces, and between coolers and nonrefrigerated spaces, shall have automatic door closers that automatically close all doors from an open position and firmly close all doors that have been closed to within 1 inch of full closure.

~~7~~ 9. **Refrigeration System Acceptance.** Before an occupancy permit is granted for a new refrigerated warehouse, or before a new refrigeration system serving a refrigerated warehouse is operated for normal use, the following equipment and systems shall be certified as meeting the Acceptance Requirements for Code Compliance, as specified by the Reference Nonresidential Appendix NA7. A Certificate of Acceptance shall be submitted to the enforcement agency that certifies that the equipment and systems meet the acceptance requirements:

A. Electric resistance underslab heating systems shall be tested in accordance with NA7.10.1.

B. Evaporators fan motor controls shall be tested in accordance with NA7.10.2.

C. Evaporative condensers shall be tested in accordance with NA7.10.3.1.

D. Air-cooled condensers shall be tested in accordance with NA7.10.3.2.

E. Adiabatic condensers shall be tested in accordance with NA7.10.3.3

F. Variable speed compressors shall be tested in accordance with NA7.10.4.

120.6 (b) Mandatory Requirements for Commercial Refrigeration

Retail food or beverage stores with 8,000 square feet or more of conditioned floor area, and that utilize either refrigerated display cases, or walk-in coolers or freezers, shall meet all applicable State and federal appliance and equipment standards consistent with Section 110.0 and 110.1 or, for equipment not subject to such standards, the requirements of Subsections 1 through 4.

1. **Condensers serving refrigeration systems.** Fan-powered condensers shall conform to the following requirements:

A. All condenser fans for air-cooled condensers, evaporative-cooled condensers, adiabatic condensers, gas coolers, air or water-cooled fluid coolers or cooling towers shall be continuously variable speed, with the speed of all fans serving a common condenser high side controlled in unison.

B. The refrigeration system condenser controls for systems with air-cooled condensers shall use variable-setpoint control logic to reset the condensing temperature setpoint in response to ambient dry bulb temperature.

C. The refrigeration system condenser controls for systems with evaporative-cooled condensers shall use variable-setpoint control logic to reset the condensing temperature setpoint in response to ambient wetbulb temperature.

D. The refrigeration system condenser controls for systems with adiabatic condensers shall use variable setpoint control logic to reset the condensing temperature setpoint in response to ambient dry bulb temperature while operating in dry mode.

EXCEPTION 1 to Section 120.6(b)1B, C and D: Condensing temperature control strategies approved by the executive director that have been demonstrated to provide equal energy savings.

EXCEPTION 2 to Section 120.6(b)1D: Systems served by adiabatic condensers in Climate Zone 16.

E. The saturated condensing temperature necessary for adiabatic condensers to reject the design total heat of rejection of a refrigeration system assuming dry mode performance shall be less than or equal to:

i. The design dry bulb temperature plus 20°F for systems serving freezers;

ii. The design dry bulb temperature plus 30°F for systems serving coolers.

F. The minimum condensing temperature setpoint shall be less than or equal to 70°F.

G. Fan-powered condensers shall meet the specific efficiency requirements listed in Table 120.6-G~~C~~.

TABLE 120.6-G~~C~~ FAN-POWERED CONDENSERS –SPECIFIC EFFICIENCY REQUIREMENTS

CONDENSER TYPE	MINIMUM SPECIFIC EFFICIENCY[a]	RATING CONDITION
Evaporative-Cooled	160 Btuh/W	100°F Saturated Condensing Temperature (SCT), 70°F Entering Wetbulb Temperature
Air-Cooled	65 Btuh/W	105°F Saturated Condensing Temperature (SCT), 95°F Entering Dry bulb Temperature
Adiabatic Dry Mode	45 Btu/W (halocarbon)	105°F Saturated Condensing Temperature (SCT), 95°F Entering Dry bulb Temperature

[a] See Section 100.1 for definition of condenser specific efficiency.

EXCEPTION 1 to Section 120.6(b)1G: Condensers with a Total Heat Rejection capacity of less than 150,000 Btuh at the specific efficiency rating condition.

EXCEPTION 2 to Section 120.6(b)1G: Stores located in Climate Zone 1.

EXCEPTION 3 to Section 120.6(b)1G: Existing condensers that are reused for an addition or alteration.

H. Air-cooled condensers shall have a fin density no greater than 10 fins per inch.

EXCEPTION 1 to Section 120.6(b)1H: Microchannel condensers.

EXCEPTION 2 to Section 120.6(b)1H: Existing condensers that are reused for an addition or alteration.

EXCEPTION to Section 120.6(b)1B, 1C, 1D, 1E, 1F, 1G: Transcritical CO_2 refrigeration systems.

EXCEPTION to Section 120.6(b)1: New condensers replacing existing condensers when the attached compressor system Total Heat of Rejection does not increase and less than 25 percent of both the attached compressors and the attached display cases are new.

2. **Transcritical CO_2 Gas Coolers.** New fan-powered gas coolers on all new transcritical CO_2 refrigeration systems shall conform to the following:

A. Air cooled gas coolers are prohibited in Climate Zones 10 through 15.

B. Design leaving gas temperature for air-cooled gas coolers shall be less than or equal to the design dry bulb temperature plus 6°F

C. Design leaving gas temperature for adiabatic gas coolers necessary to reject the design total heat of rejection of a refrigeration system assuming dry mode performance shall be less than or equal to the design dry bulb temperature plus 15°F.

D. All gas coolers fans shall be continuously variable speed, with the speed of all fans serving a common condenser high side controlled in unison.

E. While operating below the critical point, the gas cooler pressure shall be controlled in accordance to 120.6(b)1A.

F. While operating above the critical point, the gas cooler pressure setpoint shall be reset based on ambient conditions such that the system efficiency is maximized.

G. The minimum condensing temperature setpoint shall be less than or equal to 60°F for air-cooled gas coolers, evaporative-cooled gas coolers, adiabatic gas coolers, air or water-cooled fluid coolers or cooling towers.

EXCEPTION to Section 120.6(b)2G: Transcritical CO_2 systems with a design intermediate saturated suction temperature greater than or equal to 30°F shall have a minimum condensing temperature setpoint of 70°F or less.

H. Fan-powered gas coolers shall meet the condenser efficiency requirements listed in TABLE 120.6-H. Gas cooler efficiency is defined as the Total Heat of Rejection (THR) capacity divided by all electrical input power (fan power at 100 percent fan speed).

TABLE 120.6-H TRANSCRITICAL CO_2 FAN-POWERED GAS COOLERS – MINIMUM EFFICIENCY REQUIREMENTS

CONDENSER TYPE	REFRIGERANT TYPE	MINIMUM EFFICIENCY	RATING CONDITION
Outdoor Air-Cooled	Transcritical CO_2	160 Btuh/W	1400 psig, 100°F Outlet Gas Temperature, 90°F Outdoor Dry bulb Temperature
Adiabatic Dry Mode	Transcritical CO_2	90 Btuh/W	1100 psig, 100°F Outlet Gas Temperature, 90°F Outdoor Dry bulb Temperature

~~2~~ 3. **Compressor Systems.** Refrigeration compressor systems and condensing units shall conform to the following requirements.

A. Compressors and multiple-compressor suction groups shall include control systems that use floating suction pressure logic to reset the target saturated suction temperature based on the temperature requirements of the attached refrigeration display cases or walk-ins.

EXCEPTION 1 to Section 120.6(b) ~~2~~ 3A: Single compressor systems that do not have continuously variable capacity capability.

EXCEPTION 2 to Section 120.6(b) ~~2~~ 3A: Suction groups that have a design saturated suction temperature of 30°F or higher, or suction groups that comprise the high stage of a two-stage or cascade system or that primarily serve chillers for secondary cooling fluids.

B. Liquid subcooling shall be provided for all low temperature compressor systems with a design cooling capacity equal or greater than 100,000 Btu/hr with a design saturated suction temperature of -10°F or lower, with the subcooled liquid temperature maintained continuously at 50°F or less at the exit of the subcooler, using compressor economizer port(s) or a separate medium or high temperature suction group operating at a saturated suction temperature of 18°F or higher.

EXCEPTION 1 to Section 120.6(b) ~~2~~ 3B: Low temperature cascade systems that condense into another refrigeration system rather than condensing to ambient temperature.

EXCEPTION 2 to Section 120.6(b)3B: Transcritical CO_2 systems.

C. Compressors for Transcritical CO_2 refrigeration systems shall be designed to operate at a minimum condensing temperature of 60°F or less.

EXCEPTION to Section 120.6(b)3C: Compressors with a design saturated suction temperature greater than or equal to 30°F shall be designed to operate at a minimum condensing temperature of 70°F or less.

EXCEPTION to Section 120.6(b)~~2~~3A,~~and~~ ~~2~~3B, and 3C: Existing compressor systems that are reused for an addition or alteration.

~~3~~ 4. **Refrigerated Display Cases.** Lighting in refrigerated display cases, and lights on glass doors installed on walk-in coolers and freezers shall be controlled by one of the following:

A. Automatic time switch controls to turn off lights during nonbusiness hours. Timed overrides for any line-up or walk-in case may only be used to turn the lights on for up to one hour. Manual overrides shall time-out automatically to turn the lights off after one hour.

B. Motion sensor controls on each case that reduce display case lighting power by at least 50 percent within 30 minutes after the area near the case is vacated.

~~4~~ 5. **Refrigeration Heat Recovery.**

A. HVAC systems shall utilize heat recovery from refrigeration system(s) for space heating, using no less than 25 percent of the sum of the design Total Heat of Rejection of all refrigeration systems that have individual Total Heat of Rejection values of 150,000 Btu/h or greater at design conditions.

EXCEPTION 1 to Section 120.6(b) ~~4~~ 5A: Stores located in Climate Zone 15.

EXCEPTION ~~2~~ 3 to Section 120.6(b) ~~4~~ 5A: HVAC systems or refrigeration systems that are reused for an addition or alteration.

EXCEPTION 3 to Section 120.6(b)5A: Stores where the design Total Heat of Rejection of all refrigeration systems is less than 500,000 Btu/h.

B. The increase in hydrofluorocarbon refrigerant charge associated with refrigeration heat recovery equipment and piping shall be no greater than 0.35 lbs per 1,000 Btu/h of heat recovery heating capacity.

7.3 Reference Appendices

Design and Control Requirements for Transcritical CO_2 Systems

NA7.10.5 Transcritical CO2 Gas Cooler and Gas Cooler Fan Motor Variable Speed Control (Refrigerated Warehouses)

The purpose of these tests is to confirm proper operation of gas cooler control, including variable speed fan operation and variable setpoint control logic, which are both important elements of floating head pressure control, with the intent to operate with the lowest total system energy (considering both compressors and gas cooler fan power) through the course of the year.

It is important to note that transcritical CO2 refrigeration systems are unique in that they can operate in one of two modes: subcritical operation and supercritical operation. Subcritical operation generally occurs during periods where ambient conditions are below 75F to 80F, where high pressure CO2 vapor will condense in the gas cooler and the refrigeration system will operate analogous to other mechanical refrigeration systems (rejecting heat at a constant pressure and temperature). Supercritical operation generally occurs during periods where ambient conditions are above 75F to 80F, where the high pressure CO2 vapor will not condense (or partially condense) in the gas cooler, and pressure and temperature can vary semi-independently during the heat rejection process. Because these two modes of operation are based on ambient conditions, it may not be possible for the field technician to observe both subcritical and supercritical control strategies during a single acceptance test. Sufficient to completing the acceptance test, the field technician shall perform either the functional test outlined in 10.4.1.2 or 10.4.1.3 depending on the ambient conditions and resulting system operating mode at the time of the test. The construction inspection must be completed regardless of ambient conditions.

The following test methods are general in nature, with the understanding that refrigeration systems are commonly custom designed, with many design choices, as well as varying load profiles. For all of these reasons, a thorough understanding of both refrigeration system design and refrigeration control system operation is necessary to effectively conduct these tests.

The measurement devices used to verify the refrigeration system controls shall be calibrated to a NIST traceable reference, with a calibration reference dated within the past two years. The calibrated measurement devices to be used in these acceptance tests are called the "standard" and shall have the following measurement tolerances: The temperature measurement devices shall be calibrated to +/- 0.7°F between -30°F and 200°F. The pressure measurement devices shall be calibrated to +/- 7.5 psi between 0 and 1500 psig.

NA7.10.5.1Air-Cooled and Adiabatic Gas Coolers and Gas Cooler Fan Motor Variable Speed Control

Conduct and document the following functional tests on all air-cooled and adiabatic gas coolers.

NA7.10.5.1.1Construction Inspection

Prior to functional testing, document the following:

(a) Verify the control system minimum saturated condensing temperature (SCT) setpoint is at or below 60°F. If the design saturated suction temperature (SST) of the intermediate suction group is greater than or equal to 30°F, verify the control system SCT setpoint is at or below 70°F.

(b) Verify accuracy of refrigerant pressure-temperature conversions and consistent use of either temperature or pressure for the controlled variable setpoint in the control system.

- The condensing temperature has an equivalent pressure during subcritical operation.
- Either pressure or temperature may be used in the control system as the controlled variable to maintain gas cooler pressure (condensing temperature) during subcritical operation, as long as the setpoint value is similarly expressed in pressure or temperature.
- Documentation may be achieved through pictures of control system screens or control system documentation, supported by sample calculations of observed pressures or temperatures and associated conversion values, as available in the control system interface.

(c) Verify the gas cooler outlet temperature sensor reads accurately, using a NIST traceable instrument, including verification of at least two different gas cooler outlet readings. Calibrate if needed. Replace if outside manufacturer's recommended calibration range.

(d) Verify the discharge pressure sensor (or gas cooler pressure if used) reads accurately, using a NIST traceable reference pressure gauge or meter, and with pressure checked for at least two pressures within the typical operating range. Calibrate if needed. Replace if outside manufacturers recommended calibration range.

(e) Verify the ambient dry bulb temperature using a NIST traceable instrument, including verification of at least two different ambient readings. Calibrate if needed. Replace if outside manufacturer's recommended calibration range. If the ambient dry bulb temperature sensor is installed between the adiabatic pad and the gas cooler coil for adiabatic gas coolers, verification must be performed when operating in "dry" mode.

(f) Verify the ambient dry bulb temperature is not mounted in direct sunlight or is provided with a suitable solar shield. The ambient dry bulb temperature sensor may be installed between the adiabatic pad and the gas cooler coil for adiabatic gas coolers and is referred to as the precool air temperature sensor.

(g) Verify that all sensor readings used by the gas cooler controller display correct values at the controller, as well as derived values (e.g., observed pressure is correctly converted saturation temperature for CO2)

(h) Verify that all fan motors are operational and rotating in the correct direction.

(i) Verify that gas cooler fan speed controls are operational and controlling all gas cooler fan motors in unison.

(j) Verify that all speed controls operate automatically in response to changes in pressure, gas cooler outlet temperature, and ambient dry bulb or precool air temperature.

(k) Verify the installation of the gas cooler holdback valve, which may be located near the inlet of the intermediate pressure vessel or near the outlet of the gas cooler.

NA7.10.5.1.2Functional Testing (Option A: Subcritical Operation)

Planning: The system cooling load must be sufficiently high, and ambient conditions sufficiently below the critical point, to operate subcritically with all gas cooler fans in operation and observe controls in average conditions. Be cognizant of weather conditions in scheduling testing and, if necessary and possible, arrange to artificially increase or decrease evaporator loads in order to perform the Functional Testing at typical system conditions.

Step 1: Verify mechanical controls and other strategies will not affect tests

(a) Turn off any heat reclaim controls and any intermittent defrost pressure offset strategies that would affect gas cooler setpoint control.

(b) If testing an adiabatic gas cooler, adjust setpoints to ensure that the gas cooler stays in "dry" mode or "precool" mode consistently throughout the test.

Step 2: Operate in control range and verify stable control

(a) Verify the gas cooler control value is operating in the variable setpoint control range, i.e. above the minimum SCT setpoint and below the maximum SCT setpoint.

- If necessary, increase or decrease the system load.

- If necessary, during low load or low ambient conditions with system observed at the minimum SCT, temporarily adjust the minimum SCT to a lower value, if the refrigeration system design will allow, or increase the control TD to result in a higher control value.

(b) Observe control operation for at least 30 minutes to confirm stable control operation, as shown by gas cooler fan speed varying as compressor capacity changes, and not ranging from maximum to minimum fan speed or constant "hunting". If required, adjust control response setpoints to achieve stable operation. Since gas cooler control settings require fine-tuning over time, this is often accomplished using control system history or visual trends, showing one hourly and daily operation.

Step 3: Identify control TD

(a) Record the current outdoor ambient air dry bulb or precool air temperature and refrigeration system condensing temperature/condensing pressure readings from the control system. Note whether discharge pressure or a dedicated gas cooler pressure sensor is used for gas cooler pressure control.

(b) Document current head pressure control setpoints, including the TD setpoint.

(c) Calculate and record the actual observed temperature difference (TD), defined as the difference between the ambient dry bulb temperature or precool air temperature and the refrigeration system saturated condensing temperature (SCT).

(d) Confirm agreement between the current control system TD setpoint and the observed TD. If values are different, address and correct control system methods.

Step 4: Test adjusted control TD

(a) Enter a smaller TD value into the control system, sufficient to cause an observable response, such as 1-2 degrees smaller, but not small enough to cause system to operate continuously at 100% fan speed. Record this value as TD Test Setpoint 1.

(b) Observe change in control system operation which should include an increase in fan speed and a decrease in condensing temperature.

(c) Allow time for the control system to achieve stable operation.

(d) Document current head pressure control setpoints, including the TD setpoint.

(e) Calculate and record the actual observed temperature difference (TD), defined as the difference between the ambient dry bulb or precool air temperature and the refrigeration system saturated condensing temperature (SCT).

(f) Confirm agreement between the current control system TD setpoint and the observed TD. If values are different, address and correct control system methods.

(g) Perform the above test sequence with a second TD value, recorded as TD Test Setpoint 2, and record the same values above to confirm agreement between the current control system TD setpoint and the observed TD. If needed perform corrective actions and repeat testing until variable setpoint control can be confirmed and documented.

Step 5: Verify and document all fans operate in unison down to minimum SCT

(a) Document that all fans are in operation, fan speed, actual SCT and control system minimum SCT setpoint, by recording control system screens or trends along with observations.

- In cool weather and/or light loads, this may be the observed operation during testing without need to manipulate system setpoints.
- In warmer weather and/or higher loads, the control system minimum SCT value can be increased slowly to a value equal to, and then above, the current operating condition, in order to observe the fans operating in unison and fan speeds dropping as the minimum SCT setpoint is achieved.

Step 6: Restore setpoints

(a) Restore any heat reclaim or defrost functionality that was turned off to allow testing.

(b) Reset the minimum condensing temperature setpoint if it was adjusted during Step 5.

(c) Reset adiabatic mode controls to original values.

NA7.10.5.1.3Functional Testing (Option B: Supercritical Operation)

Planning: Ambient conditions must be sufficiently above the critical point to operate supercritically. Be cognizant of weather conditions in scheduling testing and, if necessary and possible, arrange to artificially increase or decrease evaporator loads in order to perform the Functional Testing at typical system conditions.

Step 1: Verify mechanical controls and other strategies will not affect tests

(a) Turn off any heat reclaim controls and any intermittent defrost pressure offset strategies that would affect gas cooler setpoint control.

(b) If testing an adiabatic gas cooler, adjust setpoints to ensure that the gas cooler stays in “dry” mode or “precool” mode consistently throughout the test.

Step 2: Operate in supercritical mode and verify pressure control

(a) Observe operation for at least 30 minutes or reference control system history or visual trends to verify the gas cooler holdback valve modulates its opening in response to changes in ambient dry bulb or precool air temperature resulting in a change in gas cooler pressure. Fan speeds are allowed to operate fixed at 100% to maximize the temperature reduction of the outlet gas or modulate to maintain a temperature difference between the ambient dry bulb or precool air temperature and the gas cooler outlet temperature. Reference the original equipment manufacturer operating manual or sequence of operation descriptions to confirm the observed variation in the pressure setpoint is consistent with the design control strategy.

Step 3: Restore setpoints

(a) Restore any heat reclaim or defrost functionality that was turned off to allow testing.

(b) Reset adiabatic mode controls to original values.

NA7.XX.X Transcritical CO2 Gas Cooler and Gas Cooler Fan Motor Variable Speed Control (Commercial Refrigeration)

The purpose of these tests is to confirm proper operation of gas cooler control, including variable speed fan operation and variable setpoint control logic, which are both important elements of floating head pressure control, with the intent to operate with the lowest total system energy (considering both compressors and gas cooler fan power) through the course of the year.

It is important to note that transcritical CO2 refrigeration systems are unique in that they can operate in one of two modes: subcritical operation and supercritical operation. Subcritical operation generally occurs during periods where ambient conditions are below 75F to 80F, where high pressure CO2 vapor will condense in the gas cooler and the refrigeration system will operate analogous to other mechanical refrigeration systems (rejecting heat at a constant pressure and temperature). Supercritical operation generally occurs during periods where ambient conditions are above 75F to 80F, where the high pressure CO2 vapor will not condense (or partially condense) in the gas cooler, and pressure and temperature can vary semi-independently during the heat rejection process. Because these two modes of operation are based on ambient conditions, it may not be possible for the field technician to observe both subcritical and supercritical control strategies during a single acceptance test. Sufficient to completing the acceptance test, the field technician shall perform either the functional test outlined in 10.4.1.2 or 10.4.1.3 depending on the ambient conditions and resulting system operating mode at the time of the test. The construction inspection must be completed regardless of ambient conditions.

The following test methods are general in nature, with the understanding that refrigeration systems are commonly custom designed, with many design choices, as well as varying load profiles. For all of these reasons, a thorough understanding of both refrigeration system design and refrigeration control system operation is necessary to effectively conduct these tests.

The measurement devices used to verify the refrigeration system controls shall be calibrated to a NIST traceable reference, with a calibration reference dated within the past two years. The calibrated measurement devices to be used in these acceptance tests are called the "standard" and shall have the following measurement tolerances: The temperature measurement devices shall be calibrated to +/- 0.7°F between -30°F and 200°F. The pressure measurement devices shall be calibrated to +/- 7.5 psi between 0 and 1500 psig.

NA7.XX.X.1Air-Cooled and Adiabatic Gas Coolers and Gas Cooler Fan Motor Variable Speed Control

Conduct and document the following functional tests on all air-cooled and adiabatic gas coolers.

NA7.XX.X.1.1Construction Inspection

Same as RWH (Section NA7.10.4.1.1)

NA7.XX.X.1.2Functional Testing (Option A: Subcritical Operation)

Same as RWH (Section NA7.10.4.1.2)

NA7.XX.X.1.3Functional Testing (Option B: Supercritical Operation)

Same as RWH (Section NA7.10.4.1.3)

Minimum Air-Cooled Condenser Sizing for Packaged Refrigeration Systems

There are no proposed changes to the Reference Appendices.

Evaporator Specific Efficiency

There are no proposed changes to the Reference Appendices.

Automatic Door Closers

There are no proposed changes to the Reference Appendices.

Acceptance Testing for Commercial Refrigeration

NA7.XX Commercial Refrigeration System Acceptance Tests

NA7.XX.1 Condensers and Condenser Fan Motor Variable Speed Control

NA7.XX.1.1 Air-Cooled Condensers and Adiabatic Condenser Fan Motor Variable Speed Control

Conduct and document the following functional tests on all air-cooled and adiabatic condensers.

NA7.XX.1.1.1 Construction Inspection

Same as RWH (Section NA7.10.3.1.1)

NA7.XX.1.1.2 Functional Testing

Same as RWH (Section NA7.10.3.1.2)

NA7.XX.1.2 Evaporative Condensers and Condenser Fan Motor Variable Speed Control

NA7.XX.1.2.1 Construction Inspection

Same as RWH (Section NA7.10.3.2.1)

NA7.XX.1.2.2 Functional Testing

Same as RWH (Section NA7.10.3.2.2)

NA7.XX.2 Compressor Floating Suction Controls

The purpose of this test is to confirm proper operation of compressor floating suction control. This control measure is intended to reduce compressor lift by allowing the suction pressure setpoint to increment higher during periods of low loads.

The following test methods are general in nature, with the understanding that refrigeration systems are commonly custom designed, with many design choices, as well as varying load profiles. Since refrigeration systems generally operate year-round, the subject control methods will apply in all weather, whereas the acceptance tests may need to be applied at a specific time of the year. For all of these reasons, a thorough understanding of both refrigeration system design and refrigeration control system operation is necessary to effectively conduct these tests.

The measurement devices used to verify the refrigeration system controls shall be calibrated to a NIST traceable reference, with a calibration reference dated within the past two years. The calibrated measurement devices to be used in these acceptance tests are called the "standard" and shall have the following measurement tolerances: The temperature measurement devices shall be calibrated to +/- 0.7°F between -30°F and 200°F. The pressure measurement devices shall be calibrated to +/- 2.5 psi between 0 and 500 psig.

NA7.XX.2.1 Construction Inspection

Prior to functional testing, document the following:

(c) Review and document design information for the refrigeration system to determine information, for each applicable suction group, including:

- The design compressor saturated suction temperature (SST) for each suction group
- The cooling circuit(s) designated for use in floating suction temperature control, associated with each suction group, including the manner in which floating suction is maintained if a “float” circuits are in defrost
- Design air temperature for the cooling circuits used for floating suction control
- The floating suction temperature range (defined in SST), designated by the design engineer, for each system
- The methodology used for floating suction group, either direct temperature reading or indirect indication of system load via electronic suction regulator (ESR) position, or other method that results in suction pressure floating before cooling is otherwise reduced for the critical circuit(s)

(d) Verify accuracy of refrigerant pressure-temperature conversions and consistent use of either temperature or pressure for controlling suction setpoint in the control system.

- The saturated suction temperature has an equivalent pressure for a given refrigerant.
- Either pressure or temperature may be used in the control system as the controlled variable to maintain suction pressure (saturated suction temperature), as long as the setpoint value is similarly expressed in pressure or temperature.
- For refrigerants with boiling point transition (glide), verify that SST values derived from pressure, or pressure values derived from SST are

defined using the midpoint temperature, i.e., the average of bubble point and dew point.

- Documentation may be achieved through pictures of control system screens or control system documentation, supported by sample calculations of observed pressures or temperatures and associated conversion values, as available in the control system interface.

(e) Verify the suction pressure sensors read accurately, using a NIST traceable reference pressure gauge or meter, and with pressure checked for at least two pressures within the typical operating range. Calibrate if needed. Replace if outside manufacturers recommended calibration range.

(f) For systems with mechanical evaporator pressure regulators (EPRs) or thermostat and solenoid control, verify that the EPR valves or the solenoid temperature control settings, on the circuit(s) used for floating suction logic, are set below the normal control range (i.e., lower than what would otherwise be required to maintain design temperature) such that these controls do not inhibit floating suction pressure. Note: this refers to the permanent setpoint condition, not a temporary setting for the purpose of compliance testing.

NA7.XX.2.2 Functional Testing

Planning: Floating suction pressure control raises the suction setpoints when the attached circuits are not at design load and cooling can be met with a higher suction temperature. Cooling load is affected by store temperature and operations, with loads significantly higher when cases are stocked and during peak shopping periods. Be cognizant of weather conditions and store operations in scheduling Functional Testing such that the assessment is made during average store conditions and operations, to the extent possible.

Where possible and particularly where graphical trends are available, tests performed on two successive days will often provide greater accuracy by normalizing the effect of store operations, defrosts, etc. Where possible, use control system user interface trends, screen pictures and available history to document the conditions over a full day.

Step 1: Turn off floating suction pressure control and allow at least two hours for system to stabilize at the fixed suction setpoint. Document the following from the control system:

(a) Fixed SST setpoint

(b) Average operating suction pressure and SST

(c) Operating temperature of each float circuit

(d) Note any control circuits that are in defrost

Step 2: Verify the reasonableness of the fixed suction pressure setpoint.

(a) The average operating SST for each system should not normally be more than 5 F below the design SST for the temperature. If the operating SST is lower than a 5 F difference, either:

- Adjust the fixed setpoint to a higher value, if it will still maintain the required circuit temperatures during peak loads
- Document the design variance that requires the fixed setpoint to be lower.
- Record the final fixed SST if changes are made.

Step 3: Restore floating suction pressure control and allow at least two hours for system to stabilize. Record the following data over the two hour period using control system trending if available.

(a) Average SST setpoint

(b) Average operating pressure and SST

(c) Operating temperature of each float circuit

(d) Note if any control circuits that are in defrost

(e) If necessary due to defrost, heavy case stocking, required control system adjustments, or other complicating factors, repeat testing to determine an accurate result for each system.

Step 4: Record floating suction pressure performance by documenting the following:

(a) Design SST (noted in construction inspection)

(b) Design floating suction temperature range (noted in construction inspection)

(c) Calculate average degrees of suction float, based on the average SST determined in Step 3.a minus the final fixed SST in Step 1.a

(d) To the extent possible, include user interface trends or history graphs showing the fixed setpoint and varying floating suction pressure setpoint

(e) Determine if suction pressure setpoint increased during Step 3 and if average degrees of suction float was positive.

(f) Provide a narrative of the floating suction pressure performance in the context of the store conditions and operations during the test period, to provide context with the fact that floating suction varies through the day, week and year.

NA7.XX.3 Liquid Sub-cooling

The purpose of this test is to confirm proper operation of the subcooler.

The measurement devices used to verify the refrigeration system controls shall be calibrated to a NIST traceable reference, with a calibration reference dated within the past two years. The calibrated measurement devices to be used in these acceptance tests are called the "standard" and shall have the following measurement tolerances: The temperature measurement devices shall be calibrated to +/- 0.7°F between -30°F and 200°F. The pressure measurement devices shall be calibrated to +/- 2.5 psi between 0 and 500 psig.

NA7.XX.3.1 Construction Inspection

Prior to functional testing, document the following:

(a) Review and document subcooler design information for each subcooler, including:

- System design condensing temperature (i.e., subcooler entering temperature)
- Design subcooler leaving liquid temperature
- Design subcooler saturated suction temperature

(b) Verify accuracy of refrigerant pressure-temperature conversions and consistent use of either temperature or pressure for the controlled variable setpoint in the control system.

(c) Verify the suction pressure sensors, discharge or condenser pressure sensors, and subcooler entering and leaving temperature sensors read accurately, using NIST traceable instruments, including verification of at least two different ambient readings. Calibrate if needed. Replace if outside manufacturers recommended calibration range.

NA7.XX.3.2 Functional Testing

To the extent possible, include user interface trends or history graphs showing the condensing temperature and subcooled liquid temperature

Step 1: Adjust condensing temperature to increase load

(a) Record current SCT setpoint value

(b) If required based on prevailing ambient conditions and system operation, temporarily increase the system condensing temperature setpoint to a value within ten degrees of the system design SCT and allow system operation to stabilize for at least 30 minutes

Step 2: Verify performance and record subcooler performance at increased load

(a) Measure and record the system saturated condensing temperature (via pressure measurement)

(b) Measure and record the subcooler entering liquid temperature

(c) Measure and record the subcooler leaving liquid temperature

(d) Measure and record the saturated suction temperature (via pressure measurement) at the subcooler suction

(e) Verify each subcooler maintains an average leaving liquid temperature equal to the design value or lower, and maintains subcooling at all times, with temperature control variance within +/-10 F. If required, take corrective action to achieve design leaving temperature and stable temperature control

Step 3: Adjust condensing temperature to decrease load

(a) Set the SCT setpoint to minimum SCT value or the lowest value as weather permits. Record SCT setpoint value and allow system to stabilize for at least 30 minutes.

(b) Turn off circuit loads as necessary to reduce subcooler loads and document the circuit ID(s)

Step 4: Verify performance and record subcooler performance at reduced load

(a) Measure and record the system saturated condensing temperature (via pressure measurement)

(b) Measure and record the subcooler entering liquid temperature

(c) Measure and record the subcooler leaving liquid temperature

(d) Measure and record the saturated suction temperature (via pressure measurement) at the subcooler suction

(e) Verify each subcooler maintains an average leaving liquid temperature equal to the design value or lower, and maintains subcooling at all times, with temperature control variance within +/-10 F. If required, take corrective action to achieve design leaving temperature and stable temperature control

Step 5: Restore SCT to initially recorded value in Step 1a restore circuit loads turned off in Step 3b.

NA7.XX.4 Refrigerated Display Cases Lighting

The purpose of these tests is to confirm proper operation refrigerated display case lighting control.

The measurement devices used to verify lighting power reduction shall be calibrated to a NIST traceable reference, with a calibration reference dated within the past two years. The calibrated measurement devices to be used in these acceptance tests are called the "standard" and shall have the following measurement tolerances: The current measurements shall be calibrated to +/- 1% between 1% and 100% of rated primary current.

NA7.XX.4.1 Motion Sensor based control

NA7.XX.4.1.1 Construction inspection

Prior to functional testing, document the following:

(a) Motion sensor has been located to minimize false signals.

(b) Desired sensor coverage is not blocked by obstructions that could adversely affect performance.

NA7.XX.4.1.2 Functional Testing

For stores with up to a total of five (5) motion sensors controlling refrigerated display cases, all motion sensors shall be tested. For stores with more than a total of five (5) motion sensors controlling refrigerated display cases, sensors can be sampled by creating groups of sensors. Group size cannot be more than 5 motion sensors. If the first sensor in the sample group passes the acceptance test, all sensors and the display cases controlled by them in the sample group also pass. If the first sensor in the sample group fails the acceptance test, the rest of the sensors in that group shall be tested and any failed sensor in the sample group shall be repaired or replaced and retested until the sensor passes the test. Sample sizes should be such that at least five (5) sensors are tested.

Step 1: Simulate motion in area under lights controlled by the sensor. Verify and document the following:

(a) Status indicator operates correctly.

(b) Lights controlled by sensors turn on immediately upon entry into the controlled display cases area.

(c) Signal sensitivity is adequate to achieve desired control.

(d) For stores which dim display case lighting to save power, measure the current drawn by the lighting circuit using an appropriate standard with lights on at 100% lighting level.

Step 2: Simulate no motion in area with lighting controlled by the sensor. Verify and document the following:

(a) At least half the lights controlled by the sensor turn off within a maximum of 30 minutes from the start of an unoccupied condition for stores with no light dimming.

(b) For stores which dim display case lighting to save power, measure the current drawn by the lighting circuit using an appropriate standard with lights at dimmed lighting levels.

(c) For stores which dim display case lighting to save power, lights controlled by the sensor reduce power consumption (confirmed by measuring current using appropriate standard) by at least 50 percent within a maximum of 30 minutes from the start of an unoccupied condition.

(d) The sensor does not trigger a false "on" from movement outside of the controlled area.

(e) Signal sensitivity is adequate to achieve desired control.

NA7.XX.4.2 Automatic Time Switch Control

NA7.XX.4.2.1 Construction Inspection

Prior to functional testing, confirm and document the following:

(a) Verify the automatic scheduling control is installed.

(b) Verify the control is programmed with acceptable schedules (i.e., the lights are scheduled to turn off during non-business hours).

(c) Demonstrate and document for the lighting control programming including both ON schedule and OFF schedule, for weekday, weekend, and holidays (if applicable).

(d) Verify the correct time and date is properly set in the lighting control panel.

NA7.XX.4.2.2 Functional Testing

Verify and document the following:

Step 1: Document all settings on the control system.

(a) Document the schedule used.

(b) Change the time of disabling the lights to a few minutes in the future. Record value as the test time.

(a) Verify that all display case lights or lights on glass doors installed on walk-in coolers/freezers turn off at the test time.

Step 2: Manually override the timer to turn on the lights in line-ups or walk-in cases during a scheduled OFF period.

(a) Verify that lights turn off after one hour.

Step 3: Reset all settings back to earlier conditions as recorded in Step 1.

NA7.XX.5 Refrigeration Heat Recovery

The purpose of these tests is to confirm proper operation of the heat recovery system.

The measurement devices used to verify the refrigeration system controls shall be calibrated to a NIST traceable reference, with a calibration reference dated within the past two years. The calibrated measurement devices to be used in these acceptance tests are called the "standard" and shall have the following measurement tolerances: The temperature measurement devices shall be calibrated to +/- 0.7°F between -30°F and 200°F. The pressure measurement devices shall be calibrated to +/- 2.5 psi between 0 and 500 psig.

NA7.XX.5.1 Construction Inspection

Prior to functional testing, document the following:

(a) Verify that the pump (if any) for heat recovery is functional.

(b) Verify the discharge pressure sensors read accurately, using a NIST traceable reference pressure gauge or meter, and with pressure checked for at least two pressures within the typical operating range. Calibrate if needed. Replace if outside manufacturers recommended calibration range.

(c) Verify the entering and leaving temperature sensors for the heat reclaim coil (direct system) or heat recovery heat exchanger (indirect system) read accurately, using a NIST traceable reference pressure gauge or meter, and with pressure checked for at least two pressures within the typical operating range. Calibrate if needed. Replace if outside manufacturers recommended calibration range.

NA7.XX.5.2 Functional Testing

Step 1: Document initial system setpoints. Change system setpoints if necessary such that HVAC system enters "heating mode". Allow one hour for the system to stabilize.

Step 2: Document the following:

(a) Verify that the control system has activated heat recovery devices.

(b) For a direct heat recovery system, measure the entering air temperature to the heat reclaim coil, or for an indirect heat recovery system, measure the entering fluid temperature entering the heat recovery heat exchanger

(c) For a direct heat recovery system, measure the leaving air temperature to the heat reclaim coil, or for an indirect heat recovery system, measure the leaving fluid temperature entering the heat recovery heat exchanger

(d) Determine if there was a temperature rise in the air or fluid.

Step 3: Restore all settings back to setpoints recorded in Step 1.

7.4 ACM Reference Manual

There are no proposed changes to the ACM Reference Manual.

7.5 Compliance Manuals

Design and Control Requirements for Transcritical CO_2 Systems

Chapter 10 of the Nonresidential Compliance Manual would need to be revised. A new section would be included that discusses what a transcritical CO_2 system is and provide compliance examples relevant to the proposed new code requirements.

Minimum Air-Cooled Condenser Sizing for Packaged Refrigeration Systems

Chapter 10 of the Nonresidential Compliance Manual would need to be revised. Section 10.6.3.3 discusses compliance requirements for condensers installed at refrigerated warehouses in detail. Additional language would be added to this section to specify that the compliance requirements are unique for packaged refrigeration systems. Included would be a definition and diagram of a representative packaged system, and a compliance example for sizing an air-cooled condenser with the revised minimum sizing requirements.

Evaporator Specific Efficiency

Chapter 10 of the Nonresidential Compliance Manual would need to be revised. In particular, in Section 10.6.3.2 Evaporators, the definition of evaporator specific efficiency would be described, along with step by step sample calculations to aid in overall understanding and compliance of the proposed measure. The acceptance test chapter would not need to be revised.

Automatic Door Closers

Chapter 10 of the Nonresidential Compliance Manual would need to be revised. In Section 10.6.2.3 Infiltration Barriers, there would need to be a paragraph describing the automatic door closing types and clarify how the new mandatory requirement affects doors for people passage.

Acceptance Testing for Commercial Refrigeration

Chapter 13 of the Nonresidential Compliance Manual would need to be revised to highlight the new acceptance tests that are typically described in Section 13.4.4. Additionally, Table 13-1 would need to be revised to include the new associated with the new NRCA acceptance documents.

7.6 Compliance Documents

Design and Control Requirements for Transcritical CO_2 Systems

Compliance documents NRCC-PRC-E would need to be revised. New tables would be added for verifying compliance for gas coolers and gas cooler control that is specifically for transcritical CO_2 systems. The additions would be analogous to current condenser requirement sections in the compliance form.

Minimum Air-Cooled Condenser Sizing for Packaged Refrigeration Systems

Compliance document NRCC-PRC-E would need to be revised. The intention of the revision is to allow the user of the form to check whether or not the system is a packaged refrigeration system, and determine if the air cooled condenser associated with the packaged system is compliant based on the revised temperature difference specified in the proposed code language.

Evaporator Specific Efficiency

Compliance document NRCC-PRC-E would need to be revised. A new table would be added to the compliance form that would allow the inspector to add information related to the evaporators, resulting in an automatic calculation of the evaporator specific efficiency, and whether it is code compliant based on the liquid feed type and refrigerant.

Automatic Door Closers

Compliance documents NRCC-PRC-E would need to be revised to update the Infiltration Barriers section for refrigerated warehouses.

Acceptance Testing for Commercial Refrigeration

New compliance documents (NRCA-PRC forms) would need to be developed to aid the construction inspection and functional testing described in the proposed acceptance test language in the reference appendix.

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Appendix A: Statewide Savings Methodology

To calculate first-year statewide savings, the Statewide CASE Team multiplied the per-unit savings by statewide construction estimates for the first year the standards will be in effect (2023). The projected nonresidential new construction forecast and existing statewide building stock that would be impacted by the proposed code change in 2023 is presented in Table 113 through Table 118 below. This section describes how the Statewide CASE Team developed these estimates.

The Energy Commission Building Standards Office provided the nonresidential construction forecast, which is available for public review on the Energy Commission's website: https://www.energy.ca.gov/title24/participation.html.

The Energy Commission's forecast allocated 19 percent of the total square footage of new construction in 2023 to the miscellaneous building type, which is a category for all space types that do not fit well into another building category. It is likely that the Title 24, Part 6 requirements apply to the miscellaneous building types, and savings would be realized from this floorspace. The new construction forecast does not provide sufficient information to distribute the miscellaneous square footage into the most likely building type, so the Statewide CASE Team redistributed the miscellaneous square footage into the remaining building types so that the percentage of building floorspace in each climate zone, net of the miscellaneous square footage, will remain constant. See Table 119 for a sample calculation for redistributing the miscellaneous square footage among the other building types.

After the miscellaneous floorspace was redistributed, the Statewide CASE Team made assumptions about the percentage of newly constructed floorspace that would be impacted by the proposed code change. If a proposed code change does not apply to a specific building type, it is assumed that zero percent of the floorspace would be impacted by the proposal.

Table 113: Submeasure A Air-Cooled Gas Cooler Restriction - New Nonresidential Construction and Existing Building Stock Impacted by Proposed Code Change in 2023, by Climate Zone and Building Type (Million Square Feet)

Climate Zone	New Construction in 2023 (Million Square Feet)			Existing Building Stock in 2023 (Million Square Feet)		
	Grocery	Refrigerated Warehouse	TOTAL	Grocery	Refrigerated Warehouse	TOTAL
1	0.00	0.00	**0.00**	0	0	**0.00**
2	0.00	0.00	**0.00**	0	0	**0.00**
3	0.00	0.00	**0.00**	0	0	**0.00**
4	0.00	0.01	**0.01**	0	0	**0.00**
5	0.00	0.00	**0.00**	0	0	**0.00**
6	0.00	0.00	**0.00**	0	0	**0.00**
7	0.00	0.00	**0.00**	0	0	**0.00**
8	0.00	0.00	**0.00**	0	0	**0.00**
9	0.00	0.00	**0.00**	0	0	**0.00**
10	0.30	0.01	**0.31**	0	0	**0.00**
11	0.07	0.01	**0.08**	0	0	**0.00**
12	0.30	0.03	**0.33**	0	0	**0.00**
13	0.15	0.02	**0.18**	0	0	**0.00**
14	0.07	0.00	**0.07**	0	0	**0.00**
15	0.05	0.00	**0.05**	0	0	**0.00**
16	0.00	0.00	**0.00**	0	0	**0.00**
TOTAL	**0.94**	**0.10**	**1.03**	**0.00**	**0.00**	**0.00**

Climate zones that were shown not to be cost effective for the air-cooled gas cooler restriction measure were excluded from the percent of square footage affected. It was estimated that only 10 percent of new construction will utilize transcritical CO_2 refrigeration systems for refrigerated warehouses and 30 percent of new construction for large supermarkets. Because the proposed code requirement is applicable to only new construction, none of the existing building stock was assumed to be affected by the proposed code requirement.

Table 114: Submeasure A Minimum Air-Cooled Gas Cooler Sizing 6F - New Nonresidential Construction and Existing Building Stock Impacted by Proposed Code Change in 2023, by Climate Zone and Building Type (Million Square Feet)

Climate Zone	New Construction in 2023 (Million Square Feet)			Existing Building Stock in 2023 (Million Square Feet)		
	Grocery	Refrigerated Warehouse	TOTAL	Grocery	Refrigerated Warehouse	TOTAL
1	0.01	0.00	**0.01**	0	0	**0.00**
2	0.06	0.00	**0.06**	0	0	**0.00**
3	0.27	0.02	**0.29**	0	0	**0.00**
4	0.14	0.00	**0.14**	0	0	**0.00**
5	0.03	0.00	**0.03**	0	0	**0.00**
6	0.19	0.01	**0.20**	0	0	**0.00**
7	0.16	0.00	**0.16**	0	0	**0.00**
8	0.27	0.01	**0.29**	0	0	**0.00**
9	0.42	0.00	**0.42**	0	0	**0.00**
10	0.00	0.00	**0.00**	0	0	**0.00**
11	0.00	0.00	**0.00**	0	0	**0.00**
12	0.00	0.00	**0.00**	0	0	**0.00**
13	0.00	0.00	**0.00**	0	0	**0.00**
14	0.00	0.00	**0.00**	0	0	**0.00**
15	0.00	0.00	**0.00**	0	0	**0.00**
16	0.02	0.00	**0.03**	0	0	**0.00**
TOTAL	**1.58**	**0.05**	**1.63**	**0.00**	**0.00**	**0.00**

It was estimated that only 10 percent of new construction will utilize transcritical CO_2 refrigeration systems for refrigerated warehouses and 30 percent of new construction for large supermarkets. Because the proposed code requirement is applicable to only new construction, none of the existing building stock was assumed to be affected by the proposed code requirement.

Table 115: Submeasure C Flooded/Recirculated Ammonia Requirements - New Nonresidential Construction and Existing Building Stock Impacted by Proposed Code Change in 2023, by Climate Zone and Building Type (Million Square Feet)

Climate Zone	New Construction in 2023 (Million Square Feet)		Existing Building Stock in 2023 (Million Square Feet)	
	Refrigerated Warehouse	TOTAL	Refrigerated Warehouse	TOTAL
1	0.01	0.01	0.01	0.01
2	0.03	0.03	0.06	0.06
3	0.17	0.17	0.30	0.30
4	0.08	0.08	0.15	0.15
5	0.02	0.02	0.03	0.03
6	0.06	0.06	0.13	0.13
7	0.01	0.01	0.02	0.02
8	0.08	0.08	0.18	0.18
9	0.12	0.12	0.27	0.27
10	0.08	0.08	0.17	0.17
11	0.06	0.06	0.12	0.12
12	0.21	0.21	0.40	0.40
13	0.16	0.16	0.31	0.31
14	0.03	0.03	0.06	0.06
15	0.02	0.02	0.03	0.03
16	0.02	0.02	0.03	0.03
TOTAL	**1.15**	**1.15**	**2.27**	**2.27**

All climate zones were shown to be cost effective for the minimum evaporator specific efficiency requirements. It was estimated that 70 percent of the refrigerated warehouse new construction will utilize large flooded/recirculated ammonia systems. Only 5 percent of the existing building stock was assumed to be affected for alterations. This is because evaporators have a long useful life, and often are not replaced until 15-20 years (or more) after original installation. Of the 5 percent affected, 3 percent was assumed to be recirculated/flooded ammonia systems and 2 percent was assumed to be halocarbon DX systems. Because ammonia DX is a relatively new technology, the code requirements are not expected to have any impact on existing building stock.

Table 116: Submeasure C DX Ammonia Cooler and Freezer Requirements - Percent of Estimated New Nonresidential Construction and Existing Building Stock Impacted by Proposed Code Change in 2023, by Climate Zone and Building Type (Million Square Feet)

Climate Zone	New Construction in 2023 (Million Square Feet)		Existing Building Stock in 2023 (Million Square Feet)	
	Refrigerated Warehouse	TOTAL	Refrigerated Warehouse	TOTAL
1	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00
3	0.02	0.02	0.00	0.00
4	0.01	0.01	0.00	0.00
5	0.00	0.00	0.00	0.00
6	0.01	0.01	0.00	0.00
7	0.00	0.00	0.00	0.00
8	0.01	0.01	0.00	0.00
9	0.02	0.02	0.00	0.00
10	0.01	0.01	0.00	0.00
11	0.01	0.01	0.00	0.00
12	0.03	0.03	0.00	0.00
13	0.02	0.02	0.00	0.00
14	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00
TOTAL	**0.16**	**0.16**	**0.00**	**0.00**

All climate zones were shown to be cost effective for the minimum evaporator specific efficiency requirements. It was estimated that 10 percent of the refrigerated warehouse new construction will utilize DX ammonia systems as DX ammonia systems are relatively new to the industry. The existing building stock of DX ammonia systems is assumed to be negligible.

Table 117: Submeasure C DX Halocarbon Cooler and Freezer Requirements - Percent of Estimated New Nonresidential Construction and Existing Building Stock Impacted by Proposed Code Change in 2023, by Climate Zone and Building Type (Million Square Feet)

Climate Zone	New Construction in 2023 (Million Square Feet)		Existing Building Stock in 2023 (Million Square Feet)	
	Refrigerated Warehouse	TOTAL	Refrigerated Warehouse	TOTAL
1	0.00	0.00	0.01	0.01
2	0.00	0.00	0.04	0.04
3	0.02	0.02	0.20	0.20
4	0.01	0.01	0.10	0.10
5	0.00	0.00	0.02	0.02
6	0.01	0.01	0.08	0.08
7	0.00	0.00	0.02	0.02
8	0.01	0.01	0.12	0.12
9	0.02	0.02	0.18	0.18
10	0.01	0.01	0.11	0.11
11	0.01	0.01	0.08	0.08
12	0.03	0.03	0.27	0.27
13	0.02	0.02	0.21	0.21
14	0.00	0.00	0.04	0.04
15	0.00	0.00	0.02	0.02
16	0.00	0.00	0.02	0.02
TOTAL	**0.16**	**0.16**	**1.51**	**1.51**

All climate zones were shown to be cost effective for the minimum evaporator specific efficiency requirements. It was estimated that 10 percent of the refrigerated warehouse new construction will utilize DX halocarbon systems due to the widespread industry preference for larger ammonia systems and a trend away from higher GWP refrigerants. Only 5 percent of the existing building stock was assumed to be affected for alterations. This is because evaporators have a long useful life, and often are not replaced until 15-20 years (or more) after original installation. Of the 5 percent affected, 3 percent was assumed to be recirculated/flooded ammonia systems and 2 percent was assumed to be halocarbon DX systems. Because ammonia DX is a relatively new technology, the code requirements are not expected to have any impact on existing building stock.

Table 118: Submeasure D Automatic Door Closer - New Nonresidential Construction and Existing Building Stock Impacted by Proposed Code Change in 2023, by Climate Zone and Building Type (Million Square Feet)

Climate Zone	New Construction in 2023 (Million Square Feet)		Existing Building Stock in 2023 (Million Square Feet)	
	Refrigerated Warehouse	TOTAL	Refrigerated Warehouse	TOTAL
1	0.01	0.01	0.02	0.02
2	0.05	0.05	0.10	0.10
3	0.24	0.24	0.50	0.50
4	0.12	0.12	0.25	0.25
5	0.02	0.02	0.05	0.05
6	0.08	0.08	0.21	0.21
7	0.02	0.02	0.04	0.04
8	0.12	0.12	0.30	0.30
9	0.17	0.17	0.44	0.44
10	0.11	0.11	0.28	0.28
11	0.09	0.09	0.20	0.20
12	0.30	0.30	0.67	0.67
13	0.23	0.23	0.52	0.52
14	0.04	0.04	0.09	0.09
15	0.02	0.02	0.05	0.05
16	0.00	0.00	0.00	0.00
TOTAL	**1.61**	**1.61**	**3.73**	**3.73**

100 percent of new construction is estimated to be impacted by the proposed code change. Only 5 percent of the existing building stock was assumed to be affected for additions and alterations.

Table 119: Example of Redistribution of Miscellaneous Category - 2023 New Construction in Climate Zone 1

Building Type	2020 Forecast (Million Square Feet) [A]	Distribution Excluding Miscellaneous Category [B]	Redistribution of Miscellaneous Category (Million Square Feet) [C] = B × [D = 0.145]	Revised 2020 Forecast (Million Square Feet) [E] = A + C
Small Office	0.036	7%	0.010	0.046
Large Office	0.114	21%	0.031	0.144
Restaurant	0.015	3%	0.004	0.020
Retail	0.107	20%	0.029	0.136
Grocery Store	0.029	5%	0.008	0.036
Non-Refrigerated Warehouse	0.079	15%	0.021	0.101
Refrigerated Warehouse	0.006	1%	0.002	0.008
Schools	0.049	9%	0.013	0.062
Colleges	0.027	5%	0.007	0.034
Hospitals	0.036	7%	0.010	0.046
Hotel/Motels	0.043	8%	0.012	0.055
Miscellaneous **[D]**	0.145	---	0.000	0.145
TOTAL	0.686	100%	0.147	0.83370

Appendix B: Embedded Electricity in Water Methodology

The Statewide CASE Team assumed the following embedded electricity in water values: 4,848 kWh/million gallons of water for indoor water use and 3,565 kWh/million gallons for outdoor water use. Embedded electricity use for indoor water use includes electricity used for water extraction, conveyance, treatment to potable quality, water distribution, wastewater collection, and wastewater treatment. Embedded electricity for outdoor water use includes all energy uses upstream of the customer; it does not include wastewater collection or wastewater treatment. The embedded electricity values do not include on-site energy uses for water, such as water heating and on-site pumping. On-site energy impacts are accounted for in the energy savings estimates presented in Section 4 of this report.

These embedded electricity values were derived from research conducted for CPUC Rulemaking 13-12-011. The CPUC study aimed to quantify the embedded electricity savings associated with IOU incentive programs that result in water savings, and the findings represent the most up-to-date research by the CPUC on embedded energy in water throughout California (California Public Utilities Commission 2015a, California Public Utilities Commission (CPUC) 2015b). The CPUC analysis was limited to evaluating the embedded electricity in water and does not include embedded natural gas in water. For this reason, this CASE Report does not include estimates of embedded natural gas savings associated with water reductions, though the embedded electricity values can be assumed to have the same associated emissions factors as grid-demanded electricity in general.

The specific CPUC embedded electricity values used in the CASE analysis are shown in Table 123. These values represent the average energy intensity by hydrologic region, which are based on the historical supply mix for each region regardless of who supplied the electricity (IOU-supplied and non-IOU- supplied electricity). The CPUC calculated the energy intensity of marginal supply but recommended using the average IOU and non-IOU energy intensity to estimate total statewide average embedded electricity of water use in California.

Table 120: Embedded Electricity in Water by California Department of Water Resources Hydrologic Region (kWh Per Acre Foot (AF))

Region	Extraction, Conveyance, and Treatment	Distribution	Wastewater Collection + Treatment	Outdoor (Upstream of Customer)	Indoor (All Components)
NC	235	163	418	398	816
SF	375	318	418	693	1,111
CC	513	163	418	677	1,095
SC	1,774	163	418	1,937	2,355
SR	238	18	418	255	674
SJ	279	18	418	297	715
TL	381	18	418	399	817
NL	285	18	418	303	721
SL	837	163	418	1,000	1,418
CR	278	18	418	296	714

Hydrologic Region Abbreviations:
NC = North Coast, SF = San Francisco Bay, CC = Central Coast, SC = South Coast, SR = Sacramento River, SJ = San Joaquin River, TL = Tulare Lake, NL = North Lahontan, SL = South Lahontan, CR = Colorado River
Source: Navigant team analysis

Source: (California Public Utilities Commission (CPUC) 2015b).

The Statewide CASE Team used CPUC's indoor and outdoor embedded electricity estimates by hydrologic region (presented in Table 120) and population data by hydrologic region from the U.S. Census Bureau (U.S. Census Bureau, Population Division 2014) to calculate the statewide population-weighted average indoor and outdoor embedded electricity values that were used in the CASE analysis (see Table 28). The energy intensity values presented in Table 120 were converted from kWh per acre foot to kWh per million gallons to harmonize with the units used in the CASE analysis. There are 3.07acre feet per million gallons.

Table 121: Statewide Population-Weighted Average Embedded Electricity in Water

Hydrologic Region	Indoor Water Use (kWh/million gallons)	Outdoor Water Use (kWh/million gallons)	Percent of California Population
North Coast	2,504	1,221	2.1%
San Francisco	3,410	2,127	18.2%
Central Coast	3,360	2,078	3.8%
South Coast	7,227	5,944	44.8%
Sacramento River	2,068	783	8.1%
San Joaquin River	2,194	911	4.7%
Tulare Lake	2,507	1,224	6.3%
North Lahontan	2,213	930	0.1%
South Lahontan	4,352	3,069	5.5%
Colorado River	2,191	908	6.5%
Statewide Population-Weighted Average	4,848	3,565	

Sources: (U.S. Census Bureau, Population Division 2014) and (California Department of Water Resources 2016).

Appendix C: Nominal Energy Cost Savings

In Sections 3.4, 4.4, 5.4, 6.4, and 6.4 the energy cost savings of the proposed code changes over the 15- and 30-year period of analysis are presented in 2023 present value dollars.

This appendix **presents** energy cost savings in nominal dollars. Energy costs are escalating as in the TDV analysis but the time value of money is not included so the results are not discounted.

Table 122: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – New Construction – Large Refrigerated Warehouse Prototype – Air Cooled Gas Cooler Restriction

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	($4.27)	$0.00	($4.27)
2	$4.05	$0.00	$4.05
3	$0.80	$0.00	$0.80
4	$3.44	$0.00	$3.44
5	($1.97)	$0.00	($1.97)
6	$2.91	$0.00	$2.91
7	($1.17)	$0.00	($1.17)
8	$4.14	$0.00	$4.14
9	$6.48	$0.00	$6.48
10	$7.85	$0.00	$7.85
11	$15.71	$0.00	$15.71
12	$7.81	$0.00	$7.81
13	$9.23	$0.00	$9.23
14	$9.26	$0.00	$9.26
15	$21.04	$0.00	$21.04
16	$1.22	$0.00	$1.22

Table 123: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – New Construction – Large Refrigerated Warehouse Prototype Building – Optimized Head Pressure Control with Modulating Fan Speeds

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	$0.02	$0.00	$0.02
2	$1.01	$0.00	$1.01
3	$0.52	$0.00	$0.52
4	$1.50	$0.00	$1.50
5	$0.28	$0.00	$0.28
6	$1.30	$0.00	$1.30
7	$0.58	$0.00	$0.58
8	$1.79	$0.00	$1.79
9	$1.82	$0.00	$1.82
10	$1.89	$0.00	$1.89
11	$1.83	$0.00	$1.83
12	$1.32	$0.00	$1.32
13	$2.05	$0.00	$2.05
14	$2.31	$0.00	$2.31
15	$2.33	$0.00	$2.33
16	$0.50	$0.00	$0.50

Table 124: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – New Construction – Large Refrigerated Warehouse Prototype Building – Gas Cooler Sized at 6°F

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	$0.50	$0.00	$0.50
2	$0.06	$0.00	$0.06
3	$0.33	$0.00	$0.33
4	$0.12	$0.00	$0.12
5	$0.39	$0.00	$0.39
6	$0.45	$0.00	$0.45
7	$0.46	$0.00	$0.46
8	$0.10	$0.00	$0.10
9	$0.04	$0.00	$0.04
10	$0.04	$0.00	$0.04
11	($0.16)	$0.00	($0.16)
12	($0.00)	$0.00	($0.00)
13	($0.19)	$0.00	($0.19)
14	($0.21)	$0.00	($0.21)
15	($0.38)	$0.00	($0.38)
16	$0.19	$0.00	$0.19

Table 125: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – New Construction – Large Supermarket Prototype Building – Air Cooled Gas Cooler Restriction

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	($6.76)	$0.00	($6.76)
2	$0.66	$0.00	$0.66
3	($3.12)	$0.00	($3.12)
4	$1.56	$0.00	$1.56
5	($3.85)	$0.00	($3.85)
6	($0.63)	$0.00	($0.63)
7	($2.84)	$0.00	($2.84)
8	$2.22	$0.00	$2.22
9	$3.32	$0.00	$3.32
10	$5.19	$0.00	$5.19
11	$8.41	$0.00	$8.41
12	$4.57	$0.00	$4.57
13	$8.49	$0.00	$8.49
14	$6.80	$0.00	$6.80
15	$21.42	$0.00	$21.42
16	($1.17)	$0.00	($1.17)

Table 126: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – New Construction – Large Supermarket Prototype Building – Optimized Head Pressure Control with Modulating Fan Speeds

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	$0.01	$0.00	$0.01
2	$0.44	$0.00	$0.44
3	$0.36	$0.00	$0.36
4	$0.54	$0.00	$0.54
5	$0.18	$0.00	$0.18
6	$0.57	$0.00	$0.57
7	$0.43	$0.00	$0.43
8	$0.65	$0.00	$0.65
9	$0.67	$0.00	$0.67
10	$0.64	$0.00	$0.64
11	$0.69	$0.00	$0.69
12	$0.45	$0.00	$0.45
13	$0.60	$0.00	$0.60
14	$0.88	$0.00	$0.88
15	$0.70	$0.00	$0.70
16	$0.30	$0.00	$0.30

Table 127: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – New Construction – Large Supermarket Prototype Building – Gas Cooler Sized at 6°F

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	$0.89	$0.00	$0.89
2	$0.47	$0.00	$0.47
3	$0.64	$0.00	$0.64
4	$0.68	$0.00	$0.68
5	$0.76	$0.00	$0.76
6	$0.90	$0.00	$0.90
7	$0.84	$0.00	$0.84
8	$0.64	$0.00	$0.64
9	$0.54	$0.00	$0.54
10	$0.58	$0.00	$0.58
11	$0.20	$0.00	$0.20
12	$0.47	$0.00	$0.47
13	$0.36	$0.00	$0.36
14	$0.17	$0.00	$0.17
15	$0.10	$0.00	$0.10
16	$0.35	$0.00	$0.35

Table 128: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – Flooded/Recirc Ammonia Cooler - New Construction, Alterations, Additions

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	$4.15	$0.00	$4.15
2	$2.49	$0.00	$2.49
3	$2.34	$0.00	$2.34
4	$2.50	$0.00	$2.50
5	$2.31	$0.00	$2.31
6	$2.51	$0.00	$2.51
7	$2.48	$0.00	$2.48
8	$2.69	$0.00	$2.69
9	$2.63	$0.00	$2.63
10	$2.73	$0.00	$2.73
11	$2.67	$0.00	$2.67
12	$2.66	$0.00	$2.66
13	$2.72	$0.00	$2.72
14	$2.58	$0.00	$2.58
15	$2.91	$0.00	$2.91
16	$2.25	$0.00	$2.25

Table 129: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – Flooded/Recirc Ammonia Freezer - New Construction, Alterations, Additions

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	$3.58	$0.00	$3.58
2	$1.66	$0.00	$1.66
3	$1.66	$0.00	$1.66
4	$1.69	$0.00	$1.69
5	$1.64	$0.00	$1.64
6	$1.68	$0.00	$1.68
7	$1.61	$0.00	$1.61
8	$1.72	$0.00	$1.72
9	$1.71	$0.00	$1.71
10	$1.69	$0.00	$1.69
11	$1.67	$0.00	$1.67
12	$1.67	$0.00	$1.67
13	$1.67	$0.00	$1.67
14	$1.66	$0.00	$1.66
15	$1.72	$0.00	$1.72
16	$1.60	$0.00	$1.60

Table 130: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – DX Ammonia Cooler - New Construction, Alterations, Additions

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	$6.68	$0.00	$6.68
2	$8.45	$0.00	$8.45
3	$7.87	$0.00	$7.87
4	$8.49	$0.00	$8.49
5	$7.78	$0.00	$7.78
6	$8.41	$0.00	$8.41
7	$8.20	$0.00	$8.20
8	$8.92	$0.00	$8.92
9	$8.95	$0.00	$8.95
10	$9.04	$0.00	$9.04
11	$8.83	$0.00	$8.83
12	$8.83	$0.00	$8.83
13	$9.03	$0.00	$9.03
14	$8.56	$0.00	$8.56
15	$10.08	$0.00	$10.08
16	$7.76	$0.00	$7.76

Table 131: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – DX Ammonia Freezer - New Construction, Alterations, Additions

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	$2.61	$0.00	$2.61
2	$3.27	$0.00	$3.27
3	$3.09	$0.00	$3.09
4	$3.49	$0.00	$3.49
5	$2.94	$0.00	$2.94
6	$3.11	$0.00	$3.11
7	$3.01	$0.00	$3.01
8	$3.37	$0.00	$3.37
9	$3.19	$0.00	$3.19
10	$3.13	$0.00	$3.13
11	$3.70	$0.00	$3.70
12	$3.20	$0.00	$3.20
13	$3.41	$0.00	$3.41
14	$3.13	$0.00	$3.13
15	$3.79	$0.00	$3.79
16	$2.96	$0.00	$2.96

Table 132: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – DX Halocarbon Cooler - New Construction, Alterations, Additions

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	$2.14	$0.00	$2.14
2	$2.58	$0.00	$2.58
3	$2.42	$0.00	$2.42
4	$2.60	$0.00	$2.60
5	$2.38	$0.00	$2.38
6	$2.57	$0.00	$2.57
7	$2.47	$0.00	$2.47
8	$2.76	$0.00	$2.76
9	$2.72	$0.00	$2.72
10	$2.76	$0.00	$2.76
11	$2.72	$0.00	$2.72
12	$2.71	$0.00	$2.71
13	$2.78	$0.00	$2.78
14	$2.66	$0.00	$2.66
15	$3.11	$0.00	$3.11
16	$2.26	$0.00	$2.26

Table 133: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – DX Halocarbon Freezer - New Construction, Alterations, Additions

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	$1.26	$0.00	$1.26
2	$1.41	$0.00	$1.41
3	$1.37	$0.00	$1.37
4	$1.43	$0.00	$1.43
5	$1.34	$0.00	$1.34
6	$1.38	$0.00	$1.38
7	$1.37	$0.00	$1.37
8	$1.42	$0.00	$1.42
9	$1.46	$0.00	$1.46
10	$1.43	$0.00	$1.43
11	$1.45	$0.00	$1.45
12	$1.42	$0.00	$1.42
13	$1.42	$0.00	$1.42
14	$1.43	$0.00	$1.43
15	$1.50	$0.00	$1.50
16	$1.34	$0.00	$1.34

Table 134: Nominal TDV Energy Cost Savings Over 15-Year Period of Analysis – Per Square Foot – Door Closers - New Construction, Alterations, Additions

Climate Zone	15-Year TDV Electricity Cost Savings (Nominal $)	15-Year TDV Natural Gas Cost Savings (Nominal $)	Total 15-Year TDV Energy Cost Savings (Nominal $)
1	$0.23	0	$0.23
2	$0.24	0	$0.24
3	$0.25	0	$0.25
4	$0.26	0	$0.26
5	$0.25	0	$0.25
6	$0.27	0	$0.27
7	$0.26	0	$0.26
8	$0.25	0	$0.25
9	$0.24	0	$0.24
10	$0.24	0	$0.24
11	$0.23	0	$0.23
12	$0.24	0	$0.24
13	$0.24	0	$0.24
14	$0.21	0	$0.21
15	$0.25	0	$0.25
16	$0.14	0	$0.14

Appendix D: Environmental Impacts Methodology

Greenhouse Gas (GHG) Emissions Factors

As directed by Energy Commission staff, GHG emissions were calculated making use of the average emissions factors specified in the United States Environmental Protection Agency (U.S. EPA) Emissions & Generation Resource Integrated Database (eGRID) for the Western Electricity Coordination Council California (WECC CAMX) subregion (United States Environmental Protection Agency 2018). This ensures consistency between state and federal estimations of potential environmental impacts. The electricity emissions factor calculated from the eGRID data is 240.4 metric tons CO_2e per GWh. The Summary Table from eGrid 2016 reports an average emission rate of 529.9 pounds CO_2e/MWh for the WECC CAMX subregion. This value was converted metric tons/GWh.

Avoided GHG emissions from natural gas savings attributable to sources other than utility-scale electrical power generation are calculated using emissions factors specified in Chapter 1.4 of the U.S. EPA's Compilation of Air Pollutant Emissions Factors (AP-42) (United States Environmental Protection Agency 1995). The U.S. EPA's estimates of GHG pollutants that are emitted during combustion of one million standard cubic feet of natural gas are: 120,000 pounds of CO_2 (Carbon Dioxide), 0.64 pounds of N_2O (Nitrous Oxide) and 2.3 pounds of CH_4 (Methane). The emission value for N_2O assumed that low NOx burners are used in accordance with California air pollution control requirements. The carbon equivalent values of N_2O and CH_4 were calculated by multiplying by the global warming potentials (GWP) that the California Air Resources Board used for the 2000-2016 GHG emission inventory, which are consistent with the 100-year GWPs that the Intergovernmental Panel on Climate Change used in the fourth assessment report (AR4). The GWP for N_2O and CH_4 are 298 and 25, respectively. Using a nominal value of 1,000 Btu per standard cubic foot of natural gas, the carbon equivalent emission factor for natural gas consumption is 5,454.4 metric tons per million therms.

GHG Emissions Monetization Methodology

The 2022 TDV energy cost factors used in the lifecycle cost-effectiveness analysis include the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs). To demonstrate the cost savings of avoided GHG emissions, the Statewide CASE Team disaggregated the value of avoided GHG emissions from the other economic impacts. The authors used the same monetary values that are used in the TDV factors – $106.20 per metric ton CO2e.

Water Use and Water Quality Impacts Methodology

There are no impacts to water quality. Water use impacts are discussed in Section 2 for Submeasure A.

Appendix E: California Building Energy Code Compliance (CBECC) Software Specification

There are no recommended revisions to the compliance software as a result of this code change proposal.

Appendix F: Impacts of Compliance Process on Market Actors

This appendix discusses how the recommended compliance process, which is described in each submeasure section above, could impact various market actors. Table 135 through Table 139 identifies the market actors who would play a role in complying with the proposed change, the tasks for which they would be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing work flow, and ways negative impacts could be mitigated. The information contained in Table 135 through Table 139 is a summary of key feedback the Statewide CASE Team received when speaking to market actors about the compliance implications of the proposed code changes. Appendix G summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the code change proposal, including gathering information on the compliance process.

Table 135: Roles of Market Actors in the Proposed Compliance Process – Submeasure A

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Engineering Design Firms/Design Build Contractors	• Identify relevant requirements • Perform required calculations for relevant equipment confirm compliance. • Complete compliance document for permit application. • Review submittals during construction. • Coordinate with commissioning agent/field technician as necessary.	• Quickly and easily determine requirements based on scope. • Demonstrate compliance with calculations required for other design tasks. • Clearly communicate system requirements to constructors. • Quickly complete compliance documents. • Easily identify noncompliant substitutions. • Minimize coordination during construction.	• Would need to perform additional calculations for relevant equipment with proposed requirements. • Would need to document compliance with new requirement, not currently being documented.	• Revise compliance document to automate compliance calculations. • Proposed documentation methodology uses materials already produced as part of the design/construction process. No additional documentation necessary.
Plans Examiner	• Identify relevant requirements. • Confirm data on documents is compliant. • Confirm plans/specifications match data on documents. • Provide correction comments if necessary.	• Quickly and easily determine requirements based on scope. • Quickly and easily determine if data in documents meets requirements. • Quickly and easily determine if plans/specs match documents. • Quickly and easily provide correction comments that would resolve issue.	• Would need to verify new calculations are compliant. • Would need to verify existing conditions baseline. • Would need to verify calculations match plans	• Compliance document could auto-verify data is compliant with standards. • Existing conditions documented via as-builts or photos or field technician. Do not require additional field visit by Authority Having Jurisdiction. • Record compliance on documents in a way easily compared to plans.

Table 136: Roles of Market Actors in the Proposed Compliance Process – Submeasure B

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Engineering Design Firms/Design Build Contractors	• Identify relevant requirements • Perform required calculations for relevant equipment confirm compliance. • Complete compliance document for permit application. • Review submittals during construction.	• Quickly and easily determine requirements based on scope. • Demonstrate compliance with calculations required for other design tasks. • Clearly communicate system requirements to constructors. • Quickly complete compliance documents. • Easily identify noncompliant substitutions.	No additional calculations required	• Revise compliance document to automate compliance calculations. • Proposed documentation methodology uses materials already produced as part of the design/construction process. No additional documentation necessary.
Plans Examiner	• Identify relevant requirements. • Confirm data on documents is compliant. • Confirm plans/specifications match data on documents. • Provide correction comments if necessary.	• Quickly and easily determine requirements based on scope. • Quickly and easily determine if data in documents meets requirements. • Quickly and easily determine if plans/specs match documents. • Quickly and easily provide correction comments that would resolve issue.	• Would need to verify new calculations are compliant. • Would need to verify existing conditions baseline. • Would need to verify calculations match plans	• Compliance document could auto-verify data is compliant with standards. • Record compliance on documents in a way easily compared to plans.

Table 137: Roles of Market Actors in the Proposed Compliance Process – Submeasure C

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
OEM	Provide equipment submittals to customer	Provide sufficient information in equipment submittals to allow for compliance calculations to be completed	Additional documentation would need to be provided to customer currently not provided (rated capacity and power and Title 24, Part 6 defined rating conditions)	Standardized Title 24, Part 6 ratings that are consistent across all applications
Engineering Design Firms/ Design Build Contractors	• Identify relevant requirements • Perform required calculations for relevant equipment confirm compliance. • Complete compliance document for permit application. • Review submittals during construction.	• Quickly and easily determine requirements based on scope. • Demonstrate compliance with calculations required for other design tasks. • Clearly communicate system requirements to constructors. • Quickly complete compliance documents. • Easily identify noncompliant substitutions.	• Would need to perform additional calculations for relevant equipment with proposed requirements. • Would need to document compliance with new requirement, not currently being documented.	• Revise compliance document to automate compliance calculations. • Additional documentation would need to be requested from evaporator manufacturer currently not provided (rated capacity and power and Title 24, Part 6 defined rating conditions)

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Plans Examiner	• Identify relevant requirements. • Confirm data on documents is compliant. • Confirm plans/specifications match data on documents. • Provide correction comments if necessary.	• Quickly and easily determine requirements based on scope. • Quickly and easily determine if data in documents meets requirements. • Quickly and easily determine if plans/specs match documents. • Quickly and easily provide correction comments that would resolve issue.	• Would need to verify new calculations are compliant. • Would need to verify calculations match plans	• Compliance document could auto-verify data is compliant with standards. • Record compliance on documents in a way easily compared to plans.

Table 138: Roles of Market Actors in the Proposed Compliance Process – Submeasure D

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Engineering Design Firms/ Design Build Contractors	• Identify relevant requirements • Ensure proper hardware is specified for relevant doors • Complete compliance document for permit application. • Review submittals during construction.	• Quickly and easily determine requirements based on scope. • Clearly communicate hardware requirements to constructors. • Quickly complete compliance documents. • Easily identify noncompliant substitutions. • Minimize coordination during construction.	Would need to document compliance with new requirement, not currently being documented.	• Revise compliance document to automate compliance calculations. • Proposed documentation methodology uses materials already produced as part of the design/construction process. No additional documentation necessary.
Plans Examiner	• Identify relevant requirements. • Confirm data on documents is compliant. • Confirm plans/specifications match data on documents. • Provide correction comments if necessary.	• Quickly and easily determine requirements based on scope. • Quickly and easily determine if data in documents meets requirements. • Quickly and easily determine if plans/specs match documents. • Quickly and easily provide correction comments that would resolve issue.	Would need to verify plans match required door hardware specifications	• Compliance document could auto-verify data is compliant with standards. • Existing conditions documented via as-builts or photos or field technician. Do not require additional field visit by Authority Having Jurisdiction. • Record compliance on documents in a way easily compared to plans.

Table 139: Roles of Market Actors in the Proposed Compliance Process – Submeasure E

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Work Flow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Field Technician	• Identify relevant acceptance test procedures. • Perform relevant acceptance test procedures	• Ensure systems installed meet acceptance testing criteria • Coordinate with design build contractor/owner as necessary to report any corrective actions required	Would require additional training for field technicians as proposed test are entirely new	• Compliance document could auto-verify data is compliant with standards for some testing • Ensure test procedures are clearly written and easy to follow

Appendix G: Summary of Stakeholder Engagement

Collaborating with stakeholders that might be impacted by proposed changes is a critical aspect of the Statewide CASE Team's efforts. The Statewide CASE Team aims to work with interested parties to identify and address issues associated with the proposed code changes so that the proposals presented to the Energy Commission in this Final CASE Report are generally supported. Public stakeholders provide valuable feedback on draft analyses and help identify and address challenges to adoption including: cost effectiveness; market barriers; technical barriers; compliance and enforcement challenges; or potential impacts on human health or the environment. Some stakeholders also provide data that the Statewide CASE Team uses to support analyses.

This appendix summarizes the stakeholder engagement that the Statewide CASE Team conducted when developing and refining the recommendations presented in this report.

Utility-Sponsored Stakeholder Meetings

Utility-sponsored stakeholder meetings provide an opportunity to learn about the Statewide CASE Team's role in the advocacy effort and to hear about specific code change proposals that the Statewide CASE Team is pursuing for the 2022 code cycle. The goal of stakeholder meetings is to solicit input on proposals from stakeholders early enough to ensure the proposals and the supporting analyses are vetted and have as few outstanding issues as possible. To provide transparency in what the Statewide CASE Team is considering for code change proposals, during these meetings the Statewide CASE Team asks for feedback on:

- Proposed code changes
- Draft code language
- Draft assumptions and results for analyses
- Data to support assumptions
- Compliance and enforcement, and
- Technical and market feasibility

The Statewide CASE Team hosted two stakeholder meetings for Refrigeration System Opportunities measures via webinar. Please see below for dates and links to event pages on Title24Stakeholders.com. Materials from each meeting. Such as slide presentations, proposal summaries with code language, and meeting notes, are included in the bibliography section of this report.

Meeting Name	Meeting Date	Event Page from Title24stakeholders.com
First Round of Nonresidential Covered Processes Utility-Sponsored Stakeholder Meeting	Thursday November 7, 2019	https://title24stakeholders.com/event/nonresidential-covered-processes-utility-sponsored-stakeholder-meeting/
Second Round of Nonresidential Covered Processes Utility-Sponsored Stakeholder Meeting	Thursday April 2, 2020	https://title24stakeholders.com/event/covered-processes-part-1-refrigeration-system-opportunities-utility-sponsored-stakeholder-meeting/

The first round of utility-sponsored stakeholder meetings occurred from September to November 2019 and were important for providing transparency and an early forum for stakeholders to offer feedback on measures being pursued by the Statewide CASE Team. The objectives of the first round of stakeholder meetings were to solicit input on the scope of the 2022 code cycle proposals; request data and feedback on the specific approaches, assumptions, and methodologies for the energy impacts and cost-effectiveness analyses; and understand potential technical and market barriers. The Statewide CASE Team also presented initial draft code language for stakeholders to review.

The second round of utility-sponsored stakeholder meetings occurred from January to April 2020 and provided updated details on proposed code changes. The second round of meetings introduced early results of energy, cost-effectiveness, and incremental cost analyses, and solicited feedback on refined draft code language.

Utility-sponsored stakeholder meetings were open to the public. For each stakeholder meeting, two promotional emails were distributed from info@title24stakeholders.com One email was sent to the entire Title 24 Stakeholders listserv, totaling over 1,900 individuals, and a second email was sent to a targeted list of individuals on the listserv depending on their subscription preferences. The Title 24 Stakeholders' website listserv is an opt-in service and includes individuals from a wide variety of industries and trades, including manufacturers, advocacy groups, local government, and building and energy professionals. Each meeting was posted on the Title 24 Stakeholders' LinkedIn page[31] (and cross-promoted on the Energy Commission LinkedIn page) two weeks before each meeting to reach out to individuals and larger organizations and channels outside of the listserv. The Statewide CASE Team conducted extensive personal outreach to

[31] Each meeting was posted on the Title 24 Stakeholders' LinkedIn page (and cross-promoted on the Energy Commission LinkedIn page) two weeks before each meeting to reach out to individuals and larger organizations and channels outside of the listserv.

stakeholders identified in initial work plans who had not yet opted in to the listserv. Exported webinar meeting data captured attendance numbers and individual comments, and recorded outcomes of live attendee polls to evaluate stakeholder participation and support.

Statewide CASE Team Communications

The Statewide CASE Team held personal communications over email and phone with numerous stakeholders when developing this report. A summary table of the key stakeholders and their contributions are shown in the table below.

Table 140: Key Stakeholders Summary

Submeasure	Organization	Input
Submeasure A	Industry Organization A	Market information, and assistance with distribution of CO2 questionnaire
Submeasure A	Rack Manufacturer A	Input on CO2 standard practice and impact of proposed code language
Submeasure A	Gas Cooler Manufacturer A	Input on common gas cooler sizing practices, gas cooler pricing, gas cooler performance data
Submeasure A	Rack Manufacturer B	Input on CO2 standard practice
Submeasure A	Gas Cooler Manufacturer B	Input on common gas cooler sizing practices, gas cooler pricing, gas cooler performance
Submeasure A	Engineering Firm A	Input on common gas cooler sizing practices
Submeasure A	Rack Manufacturer C	Input on CO2 standard practice
Submeasure A	CO2 Equipment Manufacturer A	Input on CO2 standard practice
Submeasure A	CO2 Equipment Manufacturer B	Input on CO2 compressor performance, system controls
Submeasure B	Package Manufacturer A	Input on market barriers and typical air-cooled condenser sizing practices
Submeasure B	Package Manufacturer B	Input on market barriers and typical air-cooled condenser sizing practices
Submeasure B	Package Manufacturer C	Input on market barriers and typical air-cooled condenser sizing practices
Submeasure B	Package Manufacturer D	Input on market barriers and typical air-cooled condenser sizing practices
Submeasure C	Evaporator Manufacturer A	Input on compliance issues and performance data related to evaporators
Submeasure C	Evaporator Manufacturer B	Input on performance data, pros/cons of various certification methodologies, incremental cost data
Submeasure C	Evaporator Manufacturer C	Input on performance data and importance of ratings standards
Submeasure C	Evaporator Manufacturer D	Input on performance data, and standard selection practices for evaporators
Submeasure D	Engineering Firm B	Input on common practices

Other stakeholders were also engaged such as major food retailers and refrigeration design/build contractors, although overall input was limited.

Summary of Submitted Comments

Formal comments were submitted to the Statewide CASE Team following the second stakeholder meeting and the release of the Draft CASE Report. The comments and how the information was incorporated into the Final CASE Report are summarized in the table below.

Table 141: Summary of Submitted Comments

Submeasure	Organization	Input	Final CASE Report Action
Submeasure A	Industry Organization A	Request to utilize parallel compression or ejectors as an alternative to air cooled gas cooler restriction	A preliminary analysis was performed for a marginally cost-effective climate zone to compare energy savings of a parallel compressor system configuration with air cooled gas cooler restriction.
Submeasure A	Industry Organization A	Request to include a specified pressure for gas cooler sizing/specific efficiency	No action taken. It was clarified that pressure is specified along with temperature for the gas cooler specific efficiency.
Submeasure B	Industry Organization A	Clarify the definition of condenser vs. condensing unit in the code language	A proposed condensing unit definition was appended to the proposed code language. Resources can also be found in the compliance manual.
Submeasure C	Industry Organization A	Request to utilize dew point ratings for glide refrigerants to align with DOE rating conditions	Dew point rating conditions were adopted for glide refrigerants for evaporator specific efficiency
Submeasure C	Industry Organization A	Request to include CO_2 evaporators into evaporator specific efficiency requirements	Unable to include CO_2 evaporators due to lack of budget and time in the code cycle, but is noted for future code cycles
Submeasure C	Industry Organization A	Recommendation to use the DOE AWEF rating standard instead of proposed specific efficiency	No action taken. Minimum specific efficiency level was developed using annual load profiles and assumptions common to refrigerated warehouses. Methodology is more straightforward than AHRI1250 and is based on single steady state test similar to AHRI 420.

Submeasure C	Industry Organization A	Clarify how evaporator specific efficiency does not interfere with federal standards for walk in coolers and freezers	Clarified that the existing introductory paragraph of Title 24, Part 6 Section 120.6(a) defers to the federal walk in standards (via Title 20) for spaces less than 3,000 square feet
Submeasure E	Industry Organization A	Clarify responsible party for commercial refrigeration acceptance testing	It was clarified that the field test technician can conduct the test and that if they are a licensed professional (contractor, engineer, architect) they can sign as the responsible party otherwise if their employer is a licensed professional they can sign as the responsible party

Transcritical CO_2 Refrigeration System Standard Practice Survey

In order to establish a base line from which to measure energy savings for the proposed transcritical CO_2 refrigeration system measures, a survey was developed and sent to multiple CO_2 rack manufacturers that represent a majority of the CO_2 market. Questions were developed to understand current best practices for system design and controls. Responses were received from four rack manufacturers in November and December of 2019. A summary of the questions and anonymized responses are shown in the table below.

Table 142: CO_2 Questionnaire Responses

	Manufacturer A	Manufacturer B	Manufacturer C	Manufacturer D
Typical Gas Cooler Sizing (air cooled, TD between DBT and leaving gas temperature)	2-5°F	3.6°F	10°F and below	5°F
Gas Cooler Variable speed fan control	100% of installations, controlled in unison	95%+ , controlled in unison	75%, controlled in unison	90%, controlled in unison
Subcritical FHP Control (WBT/DBT following)	100% of installations	95% of installations	100% of installations	100% of installations
Transcritical FHP Control (optimized algorithm to set gas cooler pressure, fan speed varies for constant TD control between ambient and gas cooler outlet)	100% of installations	95% of installations	0% of installations	100% of installations
Transcritical FHP Control (optimized algorithm to set gas cooler pressure, fan speed always operates at 100%)	0% of installations	5% of installations	100% of installations	0% of installations
Min SCT	57°F	51°F – 59°F	Varies	50°F
Parallel Compression	0% of installations	15-25% of installations	<10% of installations	15%
Gas Ejectors	0%	2-5% of installations	<1% of installations	50%
Adiabatic vs. Air Cooled	40% air cooled, 60% adiabatic	88% air cooled, 18% adiabatic	50% air cooled, 50% adiabatic	10% air cooled, 90% adiabatic
Use of Variable Speed Compressors	100% of installations	95% of installations	75-80% installations	100% of installations

Appendix H: Simulation Assumptions for Building Prototypes

The following tables summarize the assumptions utilized in the DOE2.2R simulation software for each relevant prototype building model.

Table 143: Large Refrigerated Warehouse Prototype (Transcritical CO_2)

System Information				
Refrigerant	R-744 (CO_2)			
System Type	Transcritical system. Two suction groups – LT (Booster) and HT (High Stage). No intercooler			
Design DBT, WBT	Climate Zone	Representative City	Design DBT 0.1%	Design WBT 0.1%
	CZ1	Arcata	75	61
	CZ2	Santa Rosa	99	71
	CZ3	Oakland	91	67
	CZ4	San Jose-Reid	94	70
	CZ5	Santa Maria	90	67
	CZ6	Torrance	93	71
	CZ7	San Diego-Lindbergh	88	72
	CZ8	Fullerton	100	73
	CZ9	Burbank-Glendale	101	72
	CZ10	Riverside	106	75
	CZ11	Red Bluff	107	73
	CZ12	Sacramento	104	74
	CZ13	Fresno	104	75
	CZ14	Palmdale	107	71
	CZ15	Palm Spring-Intl	117	79
	CZ16	Blue Canyon	88	64
Subcooling	The liquid/gas coming from the condenser/gas cooler is expanded in the intermediate pressure vessel (also called flash tank). Thereby the liquid in the vessel is at the saturated temperature, corresponding to the intermediate pressure. The liquid, which is at a lower temperature than the saturated condensing temperature or the gas cooler outlet temperature, is supplied to all loads. The vessel setpoint is 568 psig (40F)			

<table>
<tr><th>Load Information</th><th></th></tr>
<tr><td>Temperature Setpoints</td><td>Freezer: -10°F
Cooler: 35°F
Dock: 40°F</td></tr>
<tr><td>Load Profiles</td><td>Internal loads are product load, lights, infiltration, people, forklifts/pallet lifts, equipment</td></tr>
<tr><td>People Loads</td><td>Calculated using the following formula from the ASHRAE Refrigeration Handbook:
$(1295-11.5*T_{space})*1.25$
12 people in Freezer, 16 in Cooler and 4 in Dock.
Subject to hourly schedule</td></tr>
<tr><td>Forklifts</td><td><table>
<tr><th>Space</th><th>Number of Forklifts</th><th>Number of Pallet Lifts</th></tr>
<tr><td>Freezer</td><td>6</td><td>6</td></tr>
<tr><td>Cooler</td><td>8</td><td>8</td></tr>
<tr><td>Dock</td><td>2</td><td>2</td></tr>
</table>
Estimated 20 MBH/forklift, 10 MBH/pallet-lift
Subject to hourly schedule</td></tr>
<tr><td>Infiltration and Interzonal Air Exchange</td><td>Dock: (20) 10’ x 10’ dock doors. Assumed 200 CFM infiltration per dock door, subject to infiltration schedule
Cooler: (2) 10’ x 10’ doors from Cooler to Dock
Freezer: (2) 10’ x 10’ doors from Freezer to Dock
Each forklift and pallet lift is assumed to make a trip from the Dock into the Freezer or Cooler every six minutes. 5 seconds per opening. Doors are not assumed to have strip or air curtains. Subject to hourly production schedule
Cooler: (2) 7’ x 3’ exterior doors for personnel movement
Freezer: (2) 7’ x 3’ exterior doors for personnel movement
Freezer and Dock: (2) 7’ x 3’ interior doors for personnel movement
Cooler and Dock: (2) 7’ x 3’ interior doors for personnel movement
Freezer and Cooler: (2) 7’ x 3’ interior doors for personnel movement
Each interior door meant for man movement is estimated to be opened 2 times per operating hour with 5 seconds of passage time per opening. Also, each door is estimated to be stand-open for 15 seconds per hour as it is not immediately shut after the use.
The calculated air changes per hour for Cooler and Freezer due to the exterior door opening is estimated to be 0.005, based on an estimated 50 CFM per door.</td></tr>
</table>

	The interior door leakage in the closed position is estimated to be 2% of the maximum through the door in the open position. Each interior door is estimated to have 4 seconds of passage time per opening, as the cam hinge / spring type door closer quickly shuts the door to closed position. Also, the door stand-open is estimated to be 0 seconds per hour as the cam hinge / spring type door closer quickly shuts the door to closed position. The interior door leakage in the closed position is estimated to be 1.6% of the maximum through the door in the open position, as the magnetic gasket or snap door closer closes it tightly. Similarly, the calculated air changes per hour for Cooler and Freezer due to the exterior door opening is estimated to be 0.004.
Product Loads	Freezer: 41.7 MBH (Assumed 400,000 lb/day product load, from -5°F to -10°F, with specific heat of 0.50) Cooler: 226.0 MBH (Assumed 400,000 lb/day product load, from 45°F to 40°F, with specific heat of 0.65, plus 750 tons of respiring product. Heat of respiration: 5,500 Btuh/ton of product per 24 hours) Dock: 0 Btuh *Load is 100% sensible, 0% latent. Subject to production schedule*
General Facility Information and Envelope	
Azimuth	0°
Building Size	Freezer: 40,000 S.F. (200’ x 200’) Cooler: 40,000 S.F. (200’ x 200’) Dock: 12,000 S.F. (400’ x 30’) Total area: 92,000 S.F. Ceiling heights: 30’
Roof Construction	<u>Freezer</u> Construction: Built-up roof, R-40 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual) <u>Cooler</u> Construction: Built-up roof, R-28 urethane insulation

	Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual) <u>Dock</u> Construction: Built-up roof, R-28 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual)
Wall Construction	<u>Freezer</u> R-36 urethane insulation <u>Cooler</u> R-28 urethane insulation <u>Dock</u> R-28 urethane insulation
Floor Construction	<u>Freezer</u> 8” Concrete slab, R-35 insulation <u>Cooler</u> 8” Concrete slab (no insulation, assumed concrete U-factor: 0.20) <u>Dock</u> 8” Concrete slab (no insulation, assumed concrete U-factor: 0.20)
Hours of Operation	9 AM to 1 AM, 7 Days/Week (lights, infiltration, people, forklift/pallet lifts)
Lighting	
Lighting Power Density	0.45 Watts/S.F. for Freezer and Cooler: as per Title 24 2019 for Commercial/Industrial Storage (Warehouse) 0.6 Watts/S.F. for Dock: as per Title 24 2019 for Commercial/Industrial Storage (Shipping & Handling)

<table>
<tr><td>Lighting ON Hours</td><td>Same as operating hours</td></tr>
<tr><td>Evaporator Coil Information</td><td></td></tr>
<tr><td>Air Unit Fan Operation</td><td><u>All zones</u>
Fans run 100% of the time. Variable speed control, 70% minimum speed, 2 hours/day at 100% speed</td></tr>
<tr><td>Defrost Assumptions</td><td>Cooler: (2) 30-minute hot-gas defrosts/day
Dock: (2) 30-minute off-cycle defrosts/day
Freezer: (2) 30-minute hot-gas defrosts/day</td></tr>
<tr><td>Air Unit Quantity</td><td>Cooler: 6
Dock: 6
Freezer: 6</td></tr>
<tr><td>Air Unit Capacity (per unit)</td><td>
<table>
<tr><th>Climate Zone</th><th>Total for Cooler (MBH) at 10°F</th><th>Total for Freezer (MBH) at 10°F</th><th>Total for Dock (MBH) at 10°F</th></tr>
<tr><td>CZ1</td><td>970</td><td>1,315</td><td>475</td></tr>
<tr><td>CZ2</td><td>1,030</td><td>1,360</td><td>670</td></tr>
<tr><td>CZ3</td><td>1,010</td><td>1,345</td><td>590</td></tr>
<tr><td>CZ4</td><td>1,020</td><td>1,355</td><td>650</td></tr>
<tr><td>CZ5</td><td>1,010</td><td>1,345</td><td>585</td></tr>
<tr><td>CZ6</td><td>1,015</td><td>1,350</td><td>665</td></tr>
<tr><td>CZ7</td><td>1,005</td><td>1,340</td><td>685</td></tr>
<tr><td>CZ8</td><td>1,035</td><td>1,365</td><td>710</td></tr>
<tr><td>CZ9</td><td>1,035</td><td>1,365</td><td>690</td></tr>
<tr><td>CZ10</td><td>1,050</td><td>1,375</td><td>755</td></tr>
<tr><td>CZ11</td><td>1,055</td><td>1,380</td><td>710</td></tr>
<tr><td>CZ12</td><td>1,045</td><td>1,370</td><td>735</td></tr>
<tr><td>CZ13</td><td>1,045</td><td>1,370</td><td>755</td></tr>
<tr><td>CZ14</td><td>1,055</td><td>1,380</td><td>670</td></tr>
<tr><td>CZ15</td><td>1,080</td><td>1,400</td><td>845</td></tr>
<tr><td>CZ16</td><td>1,005</td><td>1,340</td><td>530</td></tr>
</table>
</td></tr>
<tr><td>Design TD</td><td>10°F for all air units</td></tr>
<tr><td>Design SET:</td><td>Cooler: 25°F
Dock: 30°F
Freezer: -20°F</td></tr>
<tr><td>Air Flow Rate (per unit)</td><td>
<table>
<tr><th>Climate Zone</th><th>Total for Cooler (CFM)</th><th>Total for Freezer (CFM)</th><th>Total for Dock (CFM)</th></tr>
<tr><td>CZ1</td><td>180,000</td><td>240,000</td><td>90,000</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td></td><td>
<table>
<tr><td>CZ2</td><td>180,000</td><td>240,000</td><td>120,000</td></tr>
<tr><td>CZ3</td><td>180,000</td><td>240,000</td><td>108,000</td></tr>
<tr><td>CZ4</td><td>180,000</td><td>240,000</td><td>120,000</td></tr>
<tr><td>CZ5</td><td>180,000</td><td>240,000</td><td>108,000</td></tr>
<tr><td>CZ6</td><td>180,000</td><td>240,000</td><td>120,000</td></tr>
<tr><td>CZ7</td><td>180,000</td><td>240,000</td><td>132,000</td></tr>
<tr><td>CZ8</td><td>192,000</td><td>240,000</td><td>132,000</td></tr>
<tr><td>CZ9</td><td>192,000</td><td>240,000</td><td>132,000</td></tr>
<tr><td>CZ10</td><td>192,000</td><td>240,000</td><td>144,000</td></tr>
<tr><td>CZ11</td><td>192,000</td><td>252,000</td><td>132,000</td></tr>
<tr><td>CZ12</td><td>192,000</td><td>252,000</td><td>132,000</td></tr>
<tr><td>CZ13</td><td>192,000</td><td>252,000</td><td>144,000</td></tr>
<tr><td>CZ14</td><td>192,000</td><td>252,000</td><td>120,000</td></tr>
<tr><td>CZ15</td><td>204,000</td><td>264,000</td><td>156,000</td></tr>
<tr><td>CZ16</td><td>180,000</td><td>240,000</td><td>96,000</td></tr>
</table>
</td></tr>
<tr><td>Fan Power</td><td>
<table>
<tr><th>Climate Zone</th><th>Total for Cooler (kW)</th><th>Total for Freezer (kW)</th><th>Total for Dock (kW)</th></tr>
<tr><td>CZ1</td><td>27.36</td><td>36.96</td><td>13.41</td></tr>
<tr><td>CZ2</td><td>28.98</td><td>38.40</td><td>18.84</td></tr>
<tr><td>CZ3</td><td>28.44</td><td>37.92</td><td>16.63</td></tr>
<tr><td>CZ4</td><td>28.80</td><td>38.16</td><td>18.36</td></tr>
<tr><td>CZ5</td><td>28.44</td><td>37.92</td><td>16.52</td></tr>
<tr><td>CZ6</td><td>28.62</td><td>38.16</td><td>18.72</td></tr>
<tr><td>CZ7</td><td>28.26</td><td>37.68</td><td>19.27</td></tr>
<tr><td>CZ8</td><td>29.18</td><td>38.40</td><td>20.06</td></tr>
<tr><td>CZ9</td><td>29.18</td><td>38.40</td><td>19.40</td></tr>
<tr><td>CZ10</td><td>29.57</td><td>38.64</td><td>21.31</td></tr>
<tr><td>CZ11</td><td>29.76</td><td>38.81</td><td>20.06</td></tr>
<tr><td>CZ12</td><td>29.38</td><td>38.56</td><td>20.72</td></tr>
<tr><td>CZ13</td><td>29.38</td><td>38.56</td><td>21.31</td></tr>
<tr><td>CZ14</td><td>29.76</td><td>38.81</td><td>18.84</td></tr>
<tr><td>CZ15</td><td>30.40</td><td>39.34</td><td>23.87</td></tr>
<tr><td>CZ16</td><td>28.26</td><td>37.68</td><td>14.98</td></tr>
</table>
Based on specific efficiency of 34.0 Btuh/W at 10°F TD between SET and space temperature
</td></tr>
<tr><td>Gas Cooler Information</td><td></td></tr>
<tr><td>Gas cooler type</td><td>Air cooled
EEM: Air Cooled Gas Cooler Restriction</td></tr>
</table>

<table>
<tr><td></td><td>Adiabatic gas cooler. The gas cooler operates in wet mode above 60F dry bulb temperature. The evaporative efficiency (ability to bring the temperature close to the WBT) of the gas cooler is estimated to be 0.8.</td></tr>
<tr><td>Design TD and SCT</td><td>
<table>
<tr><th>Climate Zone</th><th>Design DBT 0.1%</th><th>Design Approach</th><th>Design Gas Cooler Outlet Temperature</th><th>Optimized Pressure (psia)</th></tr>
<tr><td>CZ1</td><td>75</td><td>8</td><td>83</td><td>1,088</td></tr>
<tr><td>CZ2</td><td>99</td><td>8</td><td>109</td><td>1,419</td></tr>
<tr><td>CZ3</td><td>91</td><td>8</td><td>99</td><td>1,270</td></tr>
<tr><td>CZ4</td><td>94</td><td>8</td><td>103</td><td>1,326</td></tr>
<tr><td>CZ5</td><td>90</td><td>8</td><td>98</td><td>1,251</td></tr>
<tr><td>CZ6</td><td>93</td><td>8</td><td>101</td><td>1,307</td></tr>
<tr><td>CZ7</td><td>88</td><td>8</td><td>96</td><td>1,214</td></tr>
<tr><td>CZ8</td><td>100</td><td>8</td><td>108</td><td>1,437</td></tr>
<tr><td>CZ9</td><td>101</td><td>8</td><td>109</td><td>1,456</td></tr>
<tr><td>CZ10</td><td>106</td><td>8</td><td>114</td><td>1,549</td></tr>
<tr><td>CZ11</td><td>107</td><td>8</td><td>115</td><td>1,568</td></tr>
<tr><td>CZ12</td><td>104</td><td>8</td><td>112</td><td>1,512</td></tr>
<tr><td>CZ13</td><td>104</td><td>8</td><td>112</td><td>1,512</td></tr>
<tr><td>CZ14</td><td>107</td><td>8</td><td>115</td><td>1,568</td></tr>
<tr><td>CZ15</td><td>117</td><td>8</td><td>125</td><td>1,754</td></tr>
<tr><td>CZ16</td><td>88</td><td>8</td><td>96</td><td>1,214</td></tr>
</table>
EEM: Minimum Air-Cooled Gas Cooler Sizing
Design approach of 7°F, 6°F, 5°F, and 4°F are used in EEM simulation runs.
EEM: Air Cooled Gas Cooler Restriction
Adiabatic gas cooler with a design TD of 15°F in dry mode.
</td></tr>
<tr><td>Capacity</td><td>
<table>
<tr><th>Climate Zone</th><th>Gas Cooler Capacity (MBH) at 8°F Approach and Respective Optimized Pressure</th><th>Gas Cooler Capacity (MBH) at 10°F Approach and Respective Optimized Pressure</th></tr>
<tr><td>CZ1</td><td>4,704</td><td>7,245</td></tr>
<tr><td>CZ2</td><td>6,991</td><td>7,550</td></tr>
<tr><td>CZ3</td><td>6,240</td><td>7,738</td></tr>
<tr><td>CZ4</td><td>6,766</td><td>7,916</td></tr>
<tr><td>CZ5</td><td>6,414</td><td>8,146</td></tr>
<tr><td>CZ6</td><td>6,732</td><td>8,012</td></tr>
<tr><td>CZ7</td><td>6,460</td><td>8,592</td></tr>
<tr><td>CZ8</td><td>7,252</td><td>7,687</td></tr>
</table>
</td></tr>
</table>

CZ9	7,275	7,638
CZ10	7,667	7,590
CZ11	7,706	7,629
CZ12	7,550	7,626
CZ13	7,587	7,663
CZ14	7,631	7,555
CZ15	8,641	7,690
CZ16	6,208	8,256

The gas cooler is sized at a temperature difference of 8°F between the ambient dry bulb temperature and gas cooler leaving gas temperature.

EEM: Air Cooled Gas Cooler Restriction

Adiabatic gas cooler capacity value for each climate zone is the same as that of the air cooled gas cooler, but the adiabatic gas cooler is sized at an approach of 15°F between the ambient drybulb temperature and gas cooler leaving gas temperature.

EEM: Minimum Air-Cooled Gas Cooler Sizing

The gas cooler capacity value is the same as the Base Case, but the gas cooler is sized at an approach of 7°F, 6°F, 5°F, and 4°F between the ambient drybulb temperature and gas cooler leaving gas temperature.

Multipliers were used for calculating the gas cooler capacity at various approach temperatures and for calculating the gas cooler capacity when the gas cooler operates as a condenser in the subcritical mode.

Fan power based on 160 Btuh/W specific efficiency at 10°F Approach and 1,400 psia discharge pressure

Climate Zone	Fan Power (kW)
CZ1	45.3
CZ2	47.2
CZ3	48.4
CZ4	49.5
CZ5	50.9
CZ6	50.1
CZ7	53.7
CZ8	48.0
CZ9	47.7
CZ10	47.4
CZ11	47.7
CZ12	47.7
CZ13	47.9
CZ14	47.2
CZ15	48.1

CZ16	51.6

EEM: Air Cooled Gas Cooler Restriction

Adiabatic gas cooler fan power is calculated based on a specific efficiency value of 90 Btuh/W at 10°F approach and 1,100 psia discharge pressure.

Climate Zone	Gas Cooler Capacity (MBH) at 10°F Approach and 1,100 psia Discharge Pressure	Fan Power (kW)
CZ1	3,857	42.9
CZ2	5,733	63.7
CZ3	5,117	56.9
CZ4	5,548	61.6
CZ5	5,260	58.4
CZ6	5,521	61.3
CZ7	5,297	58.9
CZ8	5,946	66.1
CZ9	5,892	65.5
CZ10	6,287	69.9
CZ11	6,242	69.4
CZ12	6,116	68.0
CZ13	6,221	69.1
CZ14	6,105	67.8
CZ15	6,999	77.8
CZ16	5,090	56.6

EEM: Minimum Air-Cooled Gas Cooler Sizing

Gas cooler sized at Design approach of 7°F, 6°F, 5°F and 4°F.

Climate Zone	Fan Power (kW) 7F	Fan Power (kW) 6F	Fan Power (kW) 5F	Fan Power (kW) 4F
CZ1	50.4	55.6	60.9	66.2
CZ2	50.0	52.9	56.6	60.3
CZ3	51.5	54.6	59.3	64.0
CZ4	52.6	55.8	60.3	64.7
CZ5	54.3	57.7	62.5	67.3
CZ6	53.4	56.8	61.2	65.6
CZ7	57.7	61.8	67.0	72.3
CZ8	51.0	53.9	57.8	61.6
CZ9	50.5	53.2	57.1	60.9
CZ10	50.1	52.7	56.5	60.4
CZ11	50.3	53.0	56.8	60.7

<table>
<tr><td></td><td><table>
<tr><td>CZ12</td><td>50.5</td><td>53.3</td><td>57.3</td><td>61.3</td></tr>
<tr><td>CZ13</td><td>50.7</td><td>53.6</td><td>57.6</td><td>61.6</td></tr>
<tr><td>CZ14</td><td>49.8</td><td>52.5</td><td>56.3</td><td>60.1</td></tr>
<tr><td>CZ15</td><td>50.5</td><td>52.9</td><td>56.7</td><td>60.5</td></tr>
<tr><td>CZ16</td><td>55.5</td><td>59.4</td><td>64.4</td><td>69.4</td></tr>
</table></td></tr>
<tr><td>Number of gas coolers and fans</td><td>(8) gas coolers, (10) fans per gas cooler</td></tr>
<tr><td>Gas cooler fan control</td><td><u>Subcritical operation</u>
60°F drybulb-reset SCT control
1°F throttling range
59°F fixed backflood setpoint
Variable-speed fan control. All fans operate in unison and modulate the speed.
<u>Transcritical operation</u>
Optimal pressure control. The optimal pressure in Pascals is calculated suing the following formula:
$2.3083 \times 10^5 \times DBT + 1.19 \times 10^6$ when the DBT is equal to or above 27°C (80°F). Otherwise the optimal pressure is 7.5×10^6 Pascals.
Gas cooler fans run at 100% fan speed in the transcritical mode.
The (optimized) pressure in the transcritical mode is controlled based on the outdoor drybulb temperature. The system is made to operate in the transcritical mode when the drybulb temperature is above 80°F, and in the subcritical mode when the drybulb temperature is above 70°.
EEM: Supercritical Optimized Head Pressure Control w/ Modulating Fan Speeds
Gas cooler / condenser fans modulate fan speed in order to maintain a 6°F temperature difference between the gas cooler outlet temperature and the outdoor drybulb temperature in the transcritical mode.</td></tr>
<tr><td>Compressor Information</td><td></td></tr>
<tr><td>Compressor description</td><td><u>LT System:</u> Serves freezer area. (8) reciprocating compressors with cycling control
<u>HT System:</u> Serves cooler and dock areas. (8) reciprocating compressors with cycling control</td></tr>
<tr><td>Suction Group Design</td><td>LT: -23°F
HT: 22°F</td></tr>
</table>

SST	
Suction Group Design SCT or Design Discharge Pressure.	The SCT for the low stage is equal to the SST for the high stage The design discharge pressure for the high stage is equal to the optimal discharge pressure and gas cooler leaving refrigerant temperature, calculated from the design DBT for each climate zone, as follows:

Climate Zone	Design DBT 0.1%	Gas Cooler Leaving Temperature (°F)	Design / Optimal Discharge Pressure (psia)
CZ1	75	83	1,088
CZ2	99	107	1,419
CZ3	91	99	1,270
CZ4	94	102	1,326
CZ5	90	98	1,251
CZ6	93	101	1,307
CZ7	88	96	1,214
CZ8	100	108	1,437
CZ9	101	109	1,456
CZ10	106	114	1,549
CZ11	107	115	1,568
CZ12	104	112	1,512
CZ13	104	112	1,512
CZ14	107	115	1,568
CZ15	117	125	1,754
CZ16	88	96	1,214

EEM: Air Cooled Gas Cooler Restriction: the highest temperature entering the adiabatic condenser after pre-cooling and the corresponding optimal discharge pressure (psia) for each climate zone are:

Climate Zone	Highest Temperature after Pre-cooler	Design / Optimal Discharge Pressure (psia)
CZ1	67	1,088
CZ2	79	1,088
CZ3	72	1,088
CZ4	76	1,088
CZ5	71	1,088
CZ6	75	1,088
CZ7	74	1,088
CZ8	78	1,088

	CZ9	83	1,121
	CZ10	81	1,084
	CZ11	83	1,121
	CZ12	83	1,121
	CZ13	82	1,103
	CZ14	85	1,158
	CZ15	88	1,214
	CZ16	69	1,088

Compressor capacity, power, nominal motor HP, and motor efficiency at design conditions

Number of compressors in LT (booster) and HT (high stage) suction groups: 8 in each

Climate Zone	LT		HT	
	Mass Flow of Each Compressor	**Power of Each Compressor**	**Mass Flow of Each Compressor**	**Power of Each Compressor**
CZ1	1,691	10.3	6,538	46.28
CZ2	1,751	10.7	11,182	107.53
CZ3	1,731	10.5	10,135	86.08
CZ4	1,739	10.6	11,427	101.97
CZ5	1,729	10.5	11,133	92.84
CZ6	1,736	10.6	11,454	100.4
CZ7	1,723	10.5	11,365	91.54
CZ8	1,754	10.7	11,792	115.10
CZ9	1,756	10.7	11,761	116.32
CZ10	1,768	10.8	12,024	127.33
CZ11	1,772	10.8	12,016	128.86
CZ12	1,751	10.7	11,978	122.7
CZ13	1,763	10.7	12,037	124.25
CZ14	1,772	10.8	11,900	127.61
CZ15	1,797	10.9	12,718	154.13
CZ16	1,723	10.5	10,922	87.97

HT compressor performances in subcritical mode are as follows. The mass flow rates are different for subcritical operation than transcritical operation because the design mass flow rates are calculated based on the enthalpy difference between the leavings gas cooler / condenser temperature (that goes to the loads) and the saturated suction temperature (that comes from the loads). The subcritical mass flow rates are calculated for simulation purpose; the relation between the transcritical and subcritical mass flow rates for an actual compressor may be different.

<table>
<tr><td></td><td>
<table>
<tr><th>Climate Zone</th><th>SST</th><th>SCT</th><th>Mass Flow of Each Compressor</th><th>Power of Each Compressor</th></tr>
<tr><td>CZ1</td><td>22</td><td>85</td><td>7,451</td><td>49.62</td></tr>
<tr><td>CZ2</td><td>22</td><td>85</td><td>8,779</td><td>58.46</td></tr>
<tr><td>CZ3</td><td>22</td><td>85</td><td>8,422</td><td>56.09</td></tr>
<tr><td>CZ4</td><td>22</td><td>85</td><td>8,621</td><td>57.41</td></tr>
<tr><td>CZ5</td><td>22</td><td>85</td><td>8,399</td><td>55.93</td></tr>
<tr><td>CZ6</td><td>22</td><td>85</td><td>8,641</td><td>57.55</td></tr>
<tr><td>CZ7</td><td>22</td><td>85</td><td>8,575</td><td>57.10</td></tr>
<tr><td>CZ8</td><td>22</td><td>85</td><td>8,897</td><td>59.24</td></tr>
<tr><td>CZ9</td><td>22</td><td>85</td><td>8,873</td><td>59.09</td></tr>
<tr><td>CZ10</td><td>22</td><td>85</td><td>9,072</td><td>60.41</td></tr>
<tr><td>CZ11</td><td>22</td><td>85</td><td>9,065</td><td>60.37</td></tr>
<tr><td>CZ12</td><td>22</td><td>85</td><td>9,037</td><td>60.18</td></tr>
<tr><td>CZ13</td><td>22</td><td>85</td><td>9,081</td><td>60.47</td></tr>
<tr><td>CZ14</td><td>22</td><td>85</td><td>8,978</td><td>59.79</td></tr>
<tr><td>CZ15</td><td>22</td><td>85</td><td>9,595</td><td>63.90</td></tr>
<tr><td>CZ16</td><td>22</td><td>85</td><td>8,240</td><td>54.87</td></tr>
</table>
The compressor mass flow (along with associated power) in each climate zone were scaled to match the design cooling load. This was done to ensure accurate comparison of the performance characteristics of the compressors in each design. This eliminates unintended and unrepresentative advantages that can arise from sizing differences in the actual equipment in each climate zone.
</td></tr>
<tr><td>Suction Group SST Control Strategy</td><td>LT System: -23°F fixed SST setpoint, 1°F throttling range
HT System: 22°F fixed SST setpoint, 1°F throttling range</td></tr>
<tr><td>Compressor capacity control</td><td>One digital compressor with variable capacity in each suction group. Other compressors cycle.</td></tr>
<tr><td>Suction Group Throttling Range</td><td>1°F</td></tr>
<tr><td>Useful superheat for compressor ratings</td><td>0°F</td></tr>
</table>

Liquid subcooling for compressor ratings	0°F

Table 144: Large Supermarket Prototype (Transcritical CO_2)

<table>
<tr><th>System Information</th><th></th></tr>
<tr><td>Refrigerant</td><td>R-744 (CO_2)</td></tr>
<tr><td>System Type</td><td>Transcritical system. Two suction groups – LT (Booster) and HT (High Stage).
No intercooler</td></tr>
<tr><td>Design DBT, WBT</td><td>
<table>
<tr><th>Climate Zone</th><th>Representative City</th><th>Design DBT 0.1%</th><th>Design WBT 0.1%</th></tr>
<tr><td>CZ1</td><td>Arcata</td><td>75</td><td>61</td></tr>
<tr><td>CZ2</td><td>Santa Rosa</td><td>99</td><td>71</td></tr>
<tr><td>CZ3</td><td>Oakland</td><td>91</td><td>67</td></tr>
<tr><td>CZ4</td><td>San Jose-Reid</td><td>94</td><td>70</td></tr>
<tr><td>CZ5</td><td>Santa Maria</td><td>90</td><td>67</td></tr>
<tr><td>CZ6</td><td>Torrance</td><td>93</td><td>71</td></tr>
<tr><td>CZ7</td><td>San Diego-Lindbergh</td><td>88</td><td>72</td></tr>
<tr><td>CZ8</td><td>Fullerton</td><td>100</td><td>73</td></tr>
<tr><td>CZ9</td><td>Burbank-Glendale</td><td>101</td><td>72</td></tr>
<tr><td>CZ10</td><td>Riverside</td><td>106</td><td>75</td></tr>
<tr><td>CZ11</td><td>Red Bluff</td><td>107</td><td>73</td></tr>
<tr><td>CZ12</td><td>Sacramento</td><td>104</td><td>74</td></tr>
<tr><td>CZ13</td><td>Fresno</td><td>104</td><td>75</td></tr>
<tr><td>CZ14</td><td>Palmdale</td><td>107</td><td>71</td></tr>
<tr><td>CZ15</td><td>Palm Spring-Intl</td><td>117</td><td>79</td></tr>
<tr><td>CZ16</td><td>Blue Canyon</td><td>88</td><td>64</td></tr>
</table>
</td></tr>
<tr><td>Subcooling</td><td>The liquid/gas coming from the condenser/gas cooler is expanded in the intermediate pressure vessel (also called flash tank). Thereby the liquid in the vessel is at the saturated temperature, corresponding to the intermediate pressure. The liquid, which is at a lower temperature than the saturated condensing temperature or the gas cooler outlet temperature, is supplied to all loads.
The vessel setpoint is 568 psig (40F)</td></tr>
</table>

Load Information	
Walk-ins	HS Suction Group: (1) Deli Cooler, 640 ft^3 (8' x 8' x 10') Evaporator Temp: +26°F Discharge Temp: +36°F Coil Capacity @ 10°F TD: 7,552 Btuh Coil Air Flow: 1,400 cfm No. of coils = 1 Defrost Type: Off Cycle Walk-in Box Load: 5,900 Btuh (1) Wine Cooler, (11 x 11 x 10) ft3 Evaporator Temp: +26°F Discharge Temp: +36°F Coil Capacity @ 10°F TD: 11,904 Btuh Coil Air Flow: 1,200 cfm No. of coils = 1 Defrost Type: Off Cycle Walk-in Box Load: 9,260 Btuh (1) Produce Cooler, (20 x 20 x 10) ft3 Evaporator Temp: +26°F Discharge Temp: +36°F Coil Capacity @ 10°F TD: 14,976 Btuh Coil Air Flow: 2,800 cfm No. of coils = 2 Defrost Type: Off Cycle Walk-in Box Load: 21,800 Btuh (2) Meat Prep, (780) ft^2 x12ft Evaporator Temp: +36°F Discharge Temp: +50°F Coil Capacity @ 10°F TD: 10,800 Btuh Coil Air Flow: 1,800 cfm No. of coils = 4 Defrost Type: Off Cycle Walk-in Box Load: 78,400 Btuh (1) Bakery Retarder, (10 x 7 x 10) ft^3 Evaporator Temp: +26°F Discharge Temp: +36°F Coil Capacity @ 10°F TD: 8,064 Btuh Coil Air Flow: 1,400 cfm

	No. of coils = 1 Defrost Type: Off Cycle Walk-in Box Load: 6,250 Btuh (1) Dairy Cooler, (41 x 16 x 10) ft^3 Evaporator Temp: +26°F Discharge Temp: +36°F Coil Capacity @ 10°F TD: 22,752 Btuh Coil Air Flow: 3,900 cfm No. of coils = 2 Defrost Type: Off Cycle Walk-in Box Load: 35,550 Btuh (1) Meat Cooler, (15 x 36 x 10) ft^3 Evaporator Temp: +26°F Discharge Temp: +36°F Coil Capacity @ 10°F TD: 19,296 Btuh Coil Air Flow: 3,250 cfm No. of coils = 2 Defrost Type: Off Cycle Walk-in Box Load: 30,150 Btuh (1) Meat Holding, (13 x 7 x 10) ft^3 Evaporator Temp: +26°F Discharge Temp: +36°F Coil Capacity @ 10°F TD: 9,600 Btuh Coil Air Flow: 1,300 cfm No. of coils = 1 Defrost Type: Off Cycle Walk-in Box Load: 7,550 Btuh (1) Floral Cooler, (10 x 7 x 10) ft^3 Evaporator Temp: +32°F Discharge Temp: +38°F Coil Capacity @ 10°F TD: 7,200 Btuh Coil Air Flow: 1,200 cfm No. of coils = 2 Defrost Type: Off Cycle Walk-in Box Load: 5,800 Btuh LT Suction Group: (1) Bakery Freezer, (18 x 18 x 10) ft^3 Evaporator Temp: -15°F Discharge Temp: -5°F

	Coil Capacity @ 10°F TD: 12,992 Btuh Coil Air Flow: 2,600 cfm No. of coils = 2 Defrost Type: Hot Gas Walk-in Box Load: 20,300 Btuh (1) Deli Freezer, (12 x 8 x 10) ft^3 Evaporator Temp: -15°F Discharge Temp: -5°F Coil Capacity @ 10°F TD: 8,256 Btuh Coil Air Flow: 1,950 cfm No. of coils = 1 Defrost Type: Hot Gas Walk-in Box Load: 8,600 Btuh (1) Grocery Freezer, (36 x 15 x 10) ft^3 Evaporator Temp: -15°F Discharge Temp: -5°F Coil Capacity @ 10°F TD: 19,360 Btuh Coil Air Flow: 3,900 cfm No. of coils = 2 Defrost Type: Hot Gas Walk-in Box Load: 30,250 Btuh *Capacity de-rated by 20% in the simulation to account for actual operation.*
Walk-in Fan Control	Continuous operation with no VFD FAN-CONTROL = SPEED MIN-FLOW-RATIO = 1
Walk-in Defrosts	Quantity of Defrosts per Day: 2 Defrost Duration: 30 minutes Time initiated, per frequency mentioned above OFF-CYCLE for HS, HOT GAS for LT

Display Cases	All cases comply with the Federal Case Standard, as per the manufacturer data sheets. MT Suction Group: (1) Sushi Bar Case Length: 3 ft Evaporator Temp: +20°F Discharge Temp: +28°F Fan Power: 11 Watts/ft No. Fans: 1 fan/12 ft Canopy Light W/ft: 11 Shelf Light Watts: 0 No. Canopy Lights: 1row No. Shelves w/ Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 60 mins. (1) Sushi Case Length: 8 ft Evaporator Temp: +20°F Discharge Temp: +24°F Fan Power: 8.7 Watts/ft No. Fans: 1 fan/12 ft Canopy Light W/ft: 2.6 Shelf Light Watts: 0 No. Canopy Lights: 1row No. Shelves w/ Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 40 mins. (1) Sandwich Prep Case Length: 10 ft Evaporator Temp: +20°F Discharge Temp: +30°F Fan Power: 4 Watts/ft No. Fans: 1 fan/12 ft Canopy Light W/ft: 2.6 Shelf Light W/ft: 3.6 No. Canopy Lights: 1row No. Shelves w/ Lights: 2rows Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 60 mins.

	(1) Pizza Case Length: 8 ft Evaporator Temp: +20°F Discharge Temp: +30°F Fan Power: 3.5 Watts/ft No. Fans: 1 fan/12 ft Canopy Light W/ft: 15.3 Shelf Light Watts: 0 No. Canopy Lights: 2rows No. Shelves w/ Lights: Defrost Type: Off Cycle Defrost Freq x Duration: 3 x 40 mins. (1) Service Deli Case Length: 20 ft Evaporator Temp: +20°F Discharge Temp: +25°F Fan Power: 6 W/ft No. Fans: 9 fans/12 ft Canopy Light W/ft: 14.2 Shelf Light W/ft: 5 No. Canopy Lights: 2rows No. Shelves: 2 No. Shelf Lights: 1row Defrost Type: Off Cycle Defrost Freq x Duration: 2 x 90 mins. (1) Cheese back bar Case Length: 12 ft Evaporator Temp: +20°F Discharge Temp: +30°F Fan Power: 3.5 W/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 2.6 No. Canopy Lights: 1row No. Shelves w/ Lights: 0 Shelf Light Watts: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 20 mins.

	(1) SS Cheese Case Length: 26 ft Evaporator Temp: +20°F Discharge Temp: +27°F Fan Power: 4 Watt/ft No. Fans: 3 fans/12 ft Canopy Light Watts: 2.6 Shelf Light Watts: 0 No. Canopy Lights: 1row No. Shelves w/ Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 30 mins. (1) Cheese Table Case Length: 12 ft Evaporator Temp: +20°F Discharge Temp: +27°F Fan Power: 6.7 Watt/ft No. Fans: 10 fans/12 ft Canopy Light Watts: 2.9 Shelf Light Watts: 9.6 No. Canopy Lights: 1row No. Shelves w/ Lights: 3 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 30 mins. (1) SS Deli Case Length: 32 ft Evaporator Temp: +26°F Discharge Temp: +30°F Fan Power: 4.5 Watt/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 5.3 Shelf Light W/ft: 10 No. Canopy Lights: 1row No. Shelves: 4 No. Shelf Lights: 1row Defrost Type: Off Cycle Defrost Freq x Duration: 3 x 30 mins.

	(1) Beverage Case Length: 56 ft Evaporator Temp: +26°F Discharge Temp: +30°F Fan Power: 4.5 Watt/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 5.3 Shelf Light Watts: 0 No. Canopy Lights: 1row No. Shelves w/ Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 3 x 30 mins. (1) Grab N Go Case Length: 16 ft Evaporator Temp: +21°F Discharge Temp: +29°F Fan Power: 3.5 Watt/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 15.2 Shelf Light Watts: 0 No. Canopy Lights: 2rows No. Shelves w/ Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 40 mins. (1) Meat 1 Case Length: 20 ft Evaporator Temp: +26°F Discharge Temp: +30°F Fan Power: 9 Watt/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 4.8 No. Canopy Lights: 2rows Shelf Light W/ft: 7.5 No. Shelf Lights: 3rows No. of Shelves: 3 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 30 mins. (1) Meat 2 Case Length: 20 ft

	Evaporator Temp: +26°F Discharge Temp: +30°F Fan Power: 9 Watt/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 4.8 No. Canopy Lights: 2rows Shelf Light W/ft: 7.5 No. Shelf Lights: 3rows No. of Shelves: 3 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 30 mins. (1) Lunch Meat 1 Case Length: 24 ft Evaporator Temp: +26°F Discharge Temp: +30°F Fan Power: 4.5 Watt/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 5.3 No. Canopy Lights: 1row Shelf Light W/ft: 7.5 No. Shelf Lights: 3rows No. of Shelves: 3 Defrost Type: Off Cycle Defrost Freq x Duration: 3 x 30 mins. (1) Lunch Meat 2 Case Length: 28 ft Evaporator Temp: +26°F Discharge Temp: +30°F Fan Power: 4.5 Watt/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 5.3 No. Canopy Lights: 1row Shelf Light W/ft: 7.5 No. Shelf Lights: 3rows No. of Shelves: 3 Defrost Type: Off Cycle Defrost Freq x Duration: 3 x 30 mins. (1) Bakery Service Case Length: 16 ft Evaporator Temp: +20°F

	Discharge Temp: +25°F Fan Power: 21.7 Watt/ft No. Fans: 1 fans/12 ft Canopy Light W/ft: 13.2 Shelf Light Watts: 6.6 No. Canopy Lights: 2rows No. Shelves w/ Lights: 1 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 60 mins. (1) Service/Cookie+Refg Stand Case Length: 10 ft Evaporator Temp: +30°F Discharge Temp: +35°F Fan Power: 3.67 Watt/ft No. Fans: 1 fans/12 ft Canopy light W/ft: 14.4 Shelf Light Watts: 0 No. Canopy Lights: 2rows No. Shelves w/ Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 60 mins. (1) Bakery Case Lngth: 10 ft Evaporator Temp: +20°F Discharge Temp: +27°F Fan Power: 6.7 Watt/ft No. Fans: 10 fans/12 ft Canopy Light W/ft: 3.8 Shelf Light W/ft: 1 No. Canopy Lights: 1row No. Shelves w/ Lights: 1 Defrost Type: Off Cycle Defrost Freq x Duration: 6 x 20 mins. (1) Egg Case Length: 12 ft Evaporator Temp: +28°F Discharge Temp: +32°F Fan Power: 4.5 Watt/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 5.3

	Shelf Light Watts: 0 No. Canopy Lights: 1row No. Shelves w/ Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 3 x 30 mins. (1) Dairy Case Length: 70 ft Evaporator Temp: +26°F Discharge Temp: +30°F Fan Power: 4.5 Watt/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 5.3 Shelf Light Watts: None No. Canopy Lights: 1row No. Shelves w/ Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 3 x 30 mins. (1) Pizza Case Length: 6 ft Evaporator Temp: +26°F Discharge Temp: +30°F Fan Power: 4.5 Watt/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 5.3 Shelf Light Watts: 0 No. Canopy Lights: 1row No. Shelves w/ Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 3 x 30 mins. (1) Fish Case Length: 8 ft Evaporator Temp: +18°F Discharge Temp: +25°F Fan Power: 3.5 Watt/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 7.6 Shelf Light Watts: 0 No. Canopy Lights: 2rows No. Shelves w/ Lights: 0 Defrost Type: Off Cycle

	Defrost Freq x Duration: 4 x 40 mins. (1) Service Fish Case Length: 12 ft Evaporator Temp: +20°F Discharge Temp: +28°F Fan Power: 16.7 Watt/ft No. Fans: 9 fans/12 ft Canopy Light Watts: 5.7 Shelf Light Watts: 0 No. Canopy Lights: 1row No. Shelves w/ Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 3 x 46 mins. (1) Service Meat Case Length: 12 ft Evaporator Temp: +22°F Discharge Temp: +27°F Fan Power: 7.5 W/ft No. Fans: 6 fans/12 ft Canopy Light W/ft: 2.2 No. Canopy Lights: 2rows Shelf Light W/ft: 0 No. Shelf Lights: 0 No. of Shelves: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 1 x 90 mins. (1) Produce 1 Case Length: 28 ft Evaporator Temp: +24°F Discharge Temp: +33°F Fan Power: 3.5 W/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 3.5 No. Canopy Lights: 2rows Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 3 x 30 mins. (1) Produce 2

	Case Length: 32 ft Evaporator Temp: +24°F Discharge Temp: +33°F Fan Power: 3.5 W/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 3.5 No. Canopy Lights: 2rows Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 3 x 30 mins. (1) Produce Promo Case Length: 16 ft Evaporator Temp: +26°F Discharge Temp: +31°F Fan Power: 3.5 W/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 4.8 No. Canopy Lights: 1row Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 2 x 30 mins. (1) Produce End Case Length: 6 ft Evaporator Temp: +24°F Discharge Temp: +32°F Fan Power: 9 W/ft No. Fans: 6 fans/12 ft Canopy Light W/ft: 4.8 No. Canopy Lights: 1row Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 35 mins. (1) Produce 3 Case Length: 20 ft Evaporator Temp: +24°F Discharge Temp: +32°F Fan Power: 9 W/ft

	No. Fans: 6 fans/12 ft Canopy Light W/ft: 4.8 No. Canopy Lights: 1row Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 35 mins. (1) Produce 4 Case Length: 24 ft Evaporator Temp: +24°F Discharge Temp: +32°F Fan Power: 9 W/ft No. Fans: 6 fans/12 ft Canopy Light W/ft: 4.8 No. Canopy Lights: 1row Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 35 mins. (1) Produce 5 Case Length: 20 ft Evaporator Temp: +28°F Discharge Temp: +31°F Fan Power: 9 W/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 4.8 No. Canopy Lights: 1row Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 30 mins. (1) Juice Case Length: 6 ft Evaporator Temp: +24°F Discharge Temp: +32°F Fan Power: 9 W/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 4.8 No. Canopy Lights: 1row Shelf Light W/ft: 0

	No. Shelf Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 35 mins. (1) Natural Foods Case Length: 8 ft Evaporator Temp: +26°F Discharge Temp: +30°F Fan Power: 4.5 W/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 4.8 No. Canopy Lights: 1row Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 3 x 30 mins. (1) Produce Promo 2 Case Length: 12 ft Evaporator Temp: +21°F Discharge Temp: +29°F Fan Power: 3.5 W/ft No. Fans: 3 fans/12 ft Canopy Light W/ft: 7.6 No. Canopy Lights: 2rows Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Off Cycle Defrost Freq x Duration: 4 x 40 mins. LT Suction Group: (1) Reach in icecream Case Length: 62 drs Evaporator Temp: -17°F Discharge Temp: -12°F Fan Power: 18 Watt/dr No. Fans: 5 fans/5 drs Std Vertical Light W/dr:18.5 Anti-sweat Heater W/dr:54 Defrost Type: Hot Gas Defrost Freq x Duration: 1 x 20 mins. (1) Reach in Frozen Food

	Case Length: 62 drs Evaporator Temp: -9°F Discharge Temp: -5°F Fan Power: 18 Watt/dr No. Fans: 5 fans/5 drs Std Vertical Light W/dr:18.5 Anti-sweat Heater W/dr:54 Defrost Type: Hot Gas Defrost Freq x Duration: 1 x 20 mins. (1) Dual Temp 1 Case Length: Half 12ft Case + one 7ft end Evaporator Temp: -20°F Discharge Temp: -12°F Fan Power: 5.14 Watt/dr No. Fans: 4 /12 ft for the case and 1 fan for the end Canopy Light W/ft: 0 No. Canopy Lights: 0 Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Hot Gas Defrost Freq x Duration: 1 x 20 mins. (1) Dual Temp 2 Case Length: Half 12ft Case + one 7ft end Evaporator Temp: -20°F Discharge Temp: -12°F Fan Power: 5.14 Watt/dr No. Fans: 4 /12 ft for the case and 1 fan for the end Canopy Light W/ft: 0 No. Canopy Lights: 0 Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Hot Gas Defrost Freq x Duration: 1 x 20 mins. (1) Dual Temp 3

	Case Length: Half 16ft Case + one 7ft end Evaporator Temp: -20°F Discharge Temp: -12°F Fan Power: 5.14 Watt/dr No. Fans: 4 /12 ft for the case and 1 fan for the end Canopy Light W/ft: 0 No. Canopy Lights: 0 Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Hot Gas Defrost Freq x Duration: 1 x 20 mins. (1) Dual Temp 4 Case Length: Half 16ft Case + one 7ft end Evaporator Temp: -20°F Discharge Temp: -12°F Fan Power: 5.14 Watt/dr No. Fans: 4 /12 ft for the case and 1 fan for the end Canopy Light W/ft: 0 No. Canopy Lights: 0 Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Hot Gas Defrost Freq x Duration: 1 x 20 mins. (1) Dual Temp 5 Case Length: Half 12ft Case + one 7ft end Evaporator Temp: -20°F Discharge Temp: -12°F Fan Power: 5.14 Watt/dr No. Fans: 4 /12 ft for the case and 1 fan for the end Canopy Light W/ft: 0 No. Canopy Lights: 0 Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Hot Gas

	Defrost Freq x Duration: 1 x 20 mins. (1) Dual Temp 6 Case Length: Half 12ft Case + one 7ft end Evaporator Temp: -20°F Discharge Temp: -12°F Fan Power: 5.14 Watt/dr No. Fans: 4 /12 ft for the case and 1 fan for the end Canopy Light W/ft: 0 No. Canopy Lights: 0 Shelf Light W/ft: 0 No. Shelf Lights: 0 Defrost Type: Hot Gas Defrost Freq x Duration: 1 x 20 mins. (1) Reach in Natural Foods Case Length: 6 drs Evaporator Temp: -9°F Discharge Temp: -5°F Fan Power: 18 Watt/dr No. Fans: 5 fans/5 drs Std Vertical Light W/dr:18.5 Anti-sweat Heater W/dr:54 Defrost Type: Hot Gas Defrost Freq x Duration: 1 x 20 mins.
General Facility Information and Envelope	

Azimuth	0°
Building Size	60,000 ft^2 (gross area), 28 ft height for the main sales area.
Roof, Wall, Floor Construction	U-factor based on Title 24 – Table 143-A Prescriptive Envelope Criteria for Roofs For Sacramento (CZ12), U-factor = 0.039
Hours of Operation	24 hours a day
People Density	200 ft^2/person for the main sales area, 100 ft^2/person for the employee areas. People heat gain: 600 Btu/hr/person
HVAC	
Packaged rooftop units (RTU)	Packaged Rooftop Units with EER per Title 24 standards
Main Air Handling Unit	(1) Main Air Handler Unit for Main Sales area with supply fan motor efficiency per Title 24
Fan Operation	Always On
Temperature Control	Two fixed setpoints
Main Sales HVAC Cooling Setpoint	74°F
Main Sales HVAC Heating Setpoint	70°F
Ventilation Control	Fixed Volume
Lighting	
Lighting Power Density	Walk-ins: 0.45 Watts/S.F – estimated. The applicable standard for the walk-ins is the Federal Walk-in Standard. Title 24 2019 mandates this value for commercial/industrial storage. Retail spaces: 1.05 Watts/S.F – as per Title 24 2019 for retail spaces. Office spaces: 0.7 Watts/S.F – as per Title 24 2019 for offices. Breakroom spaces: 0.65 Watts/S.F – as per Title 24 2019 for breakrooms.
Lighting ON Hours	24 hours a day Walk-ins lights are estimated to be off for 20% time as they have occupancy sensors.
Gas Cooler Information	

<table>
<tr><td>Condenser type</td><td>Air cooled
EEM: Air Cooled Gas Cooler Restriction
Adiabatic gas cooler. The condenser operates in wet mode above 60°F dry bulb temperature. The evaporative efficiency (ability to bring the temperature close to the WBT) of the condenser is estimated to be 0.8.</td></tr>
<tr><td>Design TD and SCT</td><td>

Climate Zone	Design DBT 0.1%	Design TD	Design Gas Cooler Outlet Temperature	Optimized Pressure (psia)
CZ1	75	8	83	1,088
CZ2	99	8	109	1,419
CZ3	91	8	99	1,270
CZ4	94	8	103	1,326
CZ5	90	8	98	1,251
CZ6	93	8	101	1,307
CZ7	88	8	96	1,214
CZ8	100	8	108	1,437
CZ9	101	8	109	1,456
CZ10	106	8	114	1,549
CZ11	107	8	115	1,568
CZ12	104	8	112	1,512
CZ13	104	8	112	1,512
CZ14	107	8	115	1,568
CZ15	117	8	125	1,754
CZ16	88	8	96	1,214

EEM: Minimum Air Cooled Gas Cooler Sizing
Design TD of 7°F and 6°F are used in EEM simulation runs.
EEM: Air Cooled Gas Cooler Restriction
Adiabatic gas cooler with a design approach of 15°F in dry mode.</td></tr>
<tr><td>Capacity</td><td>

Climate Zone	Gas Cooler Capacity (MBH) at 8°F Approach and Respective Optimized Pressure	Gas Cooler Capacity (MBH) at 10°F Approach and Respective Optimized Pressure
CZ1	1,922	2,960
CZ2	2,466	2,663
CZ3	2,300	2,852
CZ4	2,360	2,761
CZ5	2,280	2,896
CZ6	2,339	2,783

</td></tr>
</table>

	CZ7	2,246	2,987
	CZ8	2,492	2,642
	CZ9	2,513	2,639
	CZ10	2,630	2,604
	CZ11	2,654	2,627
	CZ12	2,583	2,609
	CZ13	2,583	2,609
	CZ14	2,654	2,627
	CZ15	2,923	2,601
	CZ16	2,246	2,987

The gas cooler is sized at a temperature difference of 8°F between the ambient dry bulb temperature and gas cooler leaving gas temperature.

EEM: Air Cooled Gas Cooler Restriction

Adiabatic gas cooler capacity value for each climate zone is the same as that of the air-cooled gas cooler, but the adiabatic gas cooler is sized at a temperature difference of 15°F between the ambient dry bulb temperature and gas cooler leaving gas temperature.

EEM: Minimum Air Cooled Gas Cooler Sizing

The gas cooler capacity value is the same as the Base Case, but the gas cooler is sized at a temperature difference of 7°F, 6°F, 5°F, and 4°F between the ambient dry bulb temperature and gas cooler leaving gas temperature.

Multipliers were used for calculating the gas cooler capacity at various approach temperatures and for calculating the condenser capacity when the gas cooler operates as a condenser in the subcritical mode.

Fan power based on 160 Btuh/W specific efficiency at 10°F Approach and 1,400 psia discharge pressure

Climate Zone	Fan Power (kW)
CZ1	18.5
CZ2	16.7
CZ3	17.8
CZ4	17.3
CZ5	18.1
CZ6	17.4
CZ7	18.7
CZ8	16.5
CZ9	16.5
CZ10	16.3
CZ11	16.4
CZ12	16.3
CZ13	16.3

CZ14	16.4
CZ15	16.3
CZ16	18.7

EEM: Air Cooled Gas Cooler Restriction

Adiabatic gas cooler fan power is calculated based on a specific efficiency value of 90 Btuh/W at 10°F approach and 1,100 psia discharge pressure.

Climate Zone	Gas Cooler Capacity (MBH) at 10°F Approach and 1,100 psia Discharge Pressure	Fan Power (kW)
CZ1	1,576	17.5
CZ2	2,022	22.5
CZ3	1,886	21.0
CZ4	1,935	21.5
CZ5	1,870	20.8
CZ6	1,918	21.3
CZ7	1,841	20.5
CZ8	2,044	22.7
CZ9	2,036	22.6
CZ10	2,157	24.0
CZ11	2,150	23.9
CZ12	2,093	23.3
CZ13	2,118	23.5
CZ14	2,113	23.6
CZ15	2,367	26.3
CZ16	1,841	20.5

EEM: Minimum Air Cooled Gas Cooler Sizing

Gas cooler sized at Design approach of 7°F, 6°F, 5°F and 4°F.

Climate Zone	Fan Power (kW) 7F	Fan Power (kW) 6F	Fan Power (kW) 5F	Fan Power (kW) 4F
CZ1	20.6	22.7	24.9	27.0
CZ2	17.7	18.7	20.0	21.3
CZ3	19.0	20.1	21.9	23.6
CZ4	18.4	19.5	21.0	22.6
CZ5	19.3	20.5	22.2	23.9
CZ6	18.6	19.7	21.3	22.8
CZ7	20.1	21.5	23.3	25.1

CZ8	17.5	18.5	19.9	21.1
CZ9	17.4	18.4	19.7	21.0
CZ10	17.2	18.1	19.4	20.7
CZ11	17.3	18.3	19.6	20.9
CZ12	17.3	18.3	19.6	21.0
CZ13	17.3	18.3	19.6	21.0
CZ14	17.3	18.3	19.6	20.9
CZ15	17.1	17.9	19.2	20.5
CZ16	20.1	21.5	23.3	25.1

Number of fans	10 fans per gas cooler, 8 gas coolers in all
Condenser fan control	<u>Subcritical operation</u> 60°F drybulb-reset SCT control 1°F throttling range 59°F fixed backflood setpoint Variable-speed fan control. All fans operate in unison and modulate the speed. <u>Supercritical operation</u> Optimal pressure control. The optimal pressure in Pascals is calculated suing the following formula: $2.3083 \times 10^5 \times DBT + 1.19 \times 10^6$ when the DBT is equal to or above 27°C (80°F). Otherwise the optimal pressure is 7.5×10^6 Pascals. Gas cooler fans run at 100% fan speed in the transcritical mode. The pressure in the transcritical mode is controlled based on the outdoor drybulb temperature. The system is made to operate in the transcritical mode when the drybulb temperature is above 80°F, and in the subcritical mode when the drybulb temperature is above 70°. **EEM: Supercritical Optimized Head Pressure Control with Modulating Fan Speeds** Gas cooler / condenser fans modulate fan speed in order to maintain a 4°F temperature difference between the gas cooler outlet temperature and the outdoor drybulb temperature.
Compressor Information	
Compressor description	<u>LT System:</u> Serves freezer area. (4) reciprocating compressors with cycling control <u>HT System:</u> Serves cooler and dock areas. (8) reciprocating compressors with cycling control

<table>
<tr><td>Suction Group Design SST</td><td>LT: -22°F
HT: 16°F</td></tr>
<tr><td>Suction Group Design SCT or Design Discharge Pressure.</td><td>The SCT for the low stage is equal to the SST for the high stage
The design discharge pressure for the high stage is equal to the optimal discharge pressure and gas cooler leaving refrigerant temperature, calculated from the design DBT for each climate zone, as follows:
<table>
<tr><th>Climate Zone</th><th>Design DBT 0.1%</th><th>Gas Cooler Leaving Temperature (°F)</th><th>Design / Optimal Discharge Pressure (psia)</th></tr>
<tr><td>CZ1</td><td>75</td><td>83</td><td>1,088</td></tr>
<tr><td>CZ2</td><td>99</td><td>107</td><td>1,419</td></tr>
<tr><td>CZ3</td><td>91</td><td>99</td><td>1,270</td></tr>
<tr><td>CZ4</td><td>94</td><td>102</td><td>1,326</td></tr>
<tr><td>CZ5</td><td>90</td><td>98</td><td>1,251</td></tr>
<tr><td>CZ6</td><td>93</td><td>101</td><td>1,307</td></tr>
<tr><td>CZ7</td><td>88</td><td>96</td><td>1,214</td></tr>
<tr><td>CZ8</td><td>100</td><td>108</td><td>1,437</td></tr>
<tr><td>CZ9</td><td>101</td><td>109</td><td>1,456</td></tr>
<tr><td>CZ10</td><td>106</td><td>114</td><td>1,549</td></tr>
<tr><td>CZ11</td><td>107</td><td>115</td><td>1,568</td></tr>
<tr><td>CZ12</td><td>104</td><td>112</td><td>1,512</td></tr>
<tr><td>CZ13</td><td>104</td><td>112</td><td>1,512</td></tr>
<tr><td>CZ14</td><td>107</td><td>115</td><td>1,568</td></tr>
<tr><td>CZ15</td><td>117</td><td>125</td><td>1,754</td></tr>
<tr><td>CZ16</td><td>88</td><td>96</td><td>1,214</td></tr>
</table>
EEM 1: the highest temperature entering the adiabatic condenser after pre-cooling and the corresponding optimal discharge pressure (psia) for each climate zone are:
<table>
<tr><th>Climate Zone</th><th>Highest Temperature after Pre-cooler</th><th>Design / Optimal Discharge Pressure (psia)</th></tr>
<tr><td>CZ1</td><td>67</td><td>1,088</td></tr>
<tr><td>CZ2</td><td>79</td><td>1,088</td></tr>
<tr><td>CZ3</td><td>72</td><td>1,088</td></tr>
<tr><td>CZ4</td><td>76</td><td>1,088</td></tr>
<tr><td>CZ5</td><td>71</td><td>1,088</td></tr>
<tr><td>CZ6</td><td>75</td><td>1,088</td></tr>
</table></td></tr>
</table>

CZ7	74	1,088
CZ8	78	1,088
CZ9	83	1,121
CZ10	81	1,084
CZ11	83	1,121
CZ12	83	1,121
CZ13	82	1,103
CZ14	85	1,158
CZ15	88	1,214
CZ16	69	1,088

Compressor capacity, power, nominal motor HP, and motor efficiency at design conditions

Number of compressors: (4) LT (booster) and (8) in HT (high stage) suction group

Climate Zone	LT		HT	
	Mass Flow of Each Compressor	**Power of Each Compressor**	**Mass Flow of Each Compressor**	**Power of Each Compressor**
CZ1	595	3.35	2,320	19.75
CZ2	595	3.35	3,321	37.70
CZ3	595	3.35	3,150	31.85
CZ4	595	3.35	3,208	33.98
CZ5	595	3.35	3,136	31.17
CZ6	595	3.35	3,190	33.22
CZ7	595	3.35	3,105	29.94
CZ8	595	3.35	3,348	38.62
CZ9	595	3.35	3,370	39.35
CZ10	595	3.35	3,497	43.48
CZ11	595	3.35	3,521	44.31
CZ12	595	3.35	3,444	41.83
CZ13	595	3.35	3,444	41.83
CZ14	595	3.35	3,521	44.31
CZ15	595	3.35	3,806	53.81
CZ16	595	3.35	3,105	29.94

HT compressor performances in subcritical mode are as follows. The mass flow rates are different for subcritical operation than transcritical operation because the design mass flow rates are calculated based on the enthalpy difference between the leavings gas cooler / condenser temperature (that goes to the loads) and the saturated suction temperature (that comes from the loads). The subcritical mass flow

	rates are calculated for simulation purpose; the relation between the transcritical and subcritical mass flow rates for an actual compressor may be different. <table><tr><th>Climate Zone</th><th>SST</th><th>SCT</th><th>Mass Flow of Each Compressor</th><th>Power of Each Compressor</th></tr><tr><td>CZ1</td><td>16</td><td>85</td><td>2,601</td><td>20.83</td></tr><tr><td>CZ2</td><td>16</td><td>85</td><td>2,701</td><td>21.63</td></tr><tr><td>CZ3</td><td>16</td><td>85</td><td>2,688</td><td>21.53</td></tr><tr><td>CZ4</td><td>16</td><td>85</td><td>2,693</td><td>21.56</td></tr><tr><td>CZ5</td><td>16</td><td>85</td><td>2,687</td><td>21.52</td></tr><tr><td>CZ6</td><td>16</td><td>85</td><td>2,692</td><td>21.55</td></tr><tr><td>CZ7</td><td>16</td><td>85</td><td>2,685</td><td>21.50</td></tr><tr><td>CZ8</td><td>16</td><td>85</td><td>2,703</td><td>21.65</td></tr><tr><td>CZ9</td><td>16</td><td>85</td><td>2,705</td><td>21.66</td></tr><tr><td>CZ10</td><td>16</td><td>85</td><td>2,714</td><td>21.73</td></tr><tr><td>CZ11</td><td>16</td><td>85</td><td>2,715</td><td>21.74</td></tr><tr><td>CZ12</td><td>16</td><td>85</td><td>2,710</td><td>21.70</td></tr><tr><td>CZ13</td><td>16</td><td>85</td><td>2,710</td><td>21.70</td></tr><tr><td>CZ14</td><td>16</td><td>85</td><td>2,715</td><td>21.74</td></tr><tr><td>CZ15</td><td>16</td><td>85</td><td>2,733</td><td>21.88</td></tr><tr><td>CZ16</td><td>16</td><td>85</td><td>2,685</td><td>21.50</td></tr></table> The compressor mass flow (along with associated power) in each climate zone were scaled to match the design cooling load. This was done to ensure accurate comparison of the performance characteristics of the compressors in each design. This eliminates unintended and unrepresentative advantages that can arise from sizing differences in the actual equipment in each climate zone.

Suction Group SST Control Strategy	LT System: -25°F fixed SST setpoint, 1°F throttling range HT System: 14°F fixed SST setpoint, 1°F throttling range
Compressor capacity control	One digital compressor with variable capacity in each suction group. Other compressors cycle.
Suction Group Throttling Range	1°F
Useful superheat for compressor ratings	10°F
Compressor RGT Adjustment (RGT = Return Gas Temperature)	Compressor power and mass flow rates adjusted with respect to the return gas temperatures.
Liquid subcooling for compressor ratings	0°F

Table 145: Large Refrigerated Warehouse Simulation Assumptions (Ammonia)

<table>
<tr><th>System Information</th><th></th></tr>
<tr><td>Refrigerant</td><td>R-717</td></tr>
<tr><td>System Type</td><td>Recirculated system.
Single stage system with two suction groups – LT and HT.</td></tr>
<tr><td>Design DBT, WBT</td><td>
<table>
<tr><th>Climate Zone</th><th>Representative City</th><th>Design DBT 0.1%</th><th>Design WBT 0.1%</th></tr>
<tr><td>CZ1</td><td>Arcata</td><td>75</td><td>61</td></tr>
<tr><td>CZ2</td><td>Santa Rosa</td><td>99</td><td>71</td></tr>
<tr><td>CZ3</td><td>Oakland</td><td>91</td><td>67</td></tr>
<tr><td>CZ4</td><td>San Jose-Reid</td><td>94</td><td>70</td></tr>
<tr><td>CZ5</td><td>Santa Maria</td><td>90</td><td>67</td></tr>
<tr><td>CZ6</td><td>Torrance</td><td>93</td><td>71</td></tr>
<tr><td>CZ7</td><td>San Diego-Lindbergh</td><td>88</td><td>72</td></tr>
<tr><td>CZ8</td><td>Fullerton</td><td>100</td><td>73</td></tr>
<tr><td>CZ9</td><td>Burbank-Glendale</td><td>101</td><td>72</td></tr>
<tr><td>CZ10</td><td>Riverside</td><td>106</td><td>75</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td></td><td>
<table>
<tr><td>CZ11</td><td>Red Bluff</td><td>107</td><td>73</td></tr>
<tr><td>CZ12</td><td>Sacramento</td><td>104</td><td>74</td></tr>
<tr><td>CZ13</td><td>Fresno</td><td>104</td><td>75</td></tr>
<tr><td>CZ14</td><td>Palmdale</td><td>107</td><td>71</td></tr>
<tr><td>CZ15</td><td>Palm Spring-Intl</td><td>117</td><td>79</td></tr>
<tr><td>CZ16</td><td>Blue Canyon</td><td>88</td><td>64</td></tr>
</table>
</td></tr>
<tr><td>Subcooling</td><td>LT liquid line is subcooled by the HT suction group</td></tr>
<tr><td>Load Information</td><td></td></tr>
<tr><td>Temperature Setpoints</td><td>Freezer: -10°F
Cooler: 35°F
Dock: 40°F</td></tr>
<tr><td>Load Profiles</td><td>Internal loads are product load, lights, infiltration, people, forklifts/pallet lifts, equipment</td></tr>
<tr><td>People Loads</td><td>Calculated using the following formula from the ASHRAE Refrigeration Handbook:
$(1295-11.5*T_{space})*1.25$
12 people in Freezer, 16 in Cooler and 4 in Dock.
Subject to hourly schedule</td></tr>
<tr><td>Forklifts</td><td>
<table>
<tr><th>Space</th><th>Number of Forklifts</th><th>Number of Pallet Lifts</th></tr>
<tr><td>Freezer</td><td>6</td><td>6</td></tr>
<tr><td>Cooler</td><td>8</td><td>8</td></tr>
<tr><td>Dock</td><td>2</td><td>2</td></tr>
</table>
Estimated 20 MBH/forklift, 10 MBH/pallet-lift
Subject to hourly schedule
</td></tr>
<tr><td>Infiltration and Interzonal Air Exchange</td><td>Dock: (20) 10’ x 10’ dock doors. Assumed 200 CFM infiltration per dock door, subject to infiltration schedule
Cooler: (2) 10’ x 10’ doors from Cooler to Dock
Freezer: (2) 10’ x 10’ doors from Freezer to Dock
Each forklift and pallet lift is assumed to make a trip from the Dock into the Freezer or Cooler every six minutes. 5 seconds per opening. Doors are not assumed to have strip or air curtains. Subject to hourly production schedule
Cooler: (2) 7’ x 3’ exterior doors for man movement
Freezer: (2) 7’ x 3’ exterior doors for man movement
Freezer and Dock: (2) 7’ x 3’ interior doors for man movement
Cooler and Dock: (2) 7’ x 3’ interior doors for man movement
Freezer and Cooler: (2) 7’ x 3’ interior doors for man movement
Each interior door meant for man movement is estimated to be opened</td></tr>
</table>

	2 times per operating hour with 5 seconds of passage time per opening. Also, each door is estimated to be stand-open for 15 seconds per hour as it is not immediately shut after the use. The calculated air changes per hour for Cooler and Freezer due to the exterior door opening is estimated to be 0.005, based on an estimated 50 CFM per door. The interior door leakage in the closed position is estimated to be 2% of the maximum through the door in the open position. EEM: each interior door is estimated to have 4 seconds of passage time per opening, as the cam hinge / spring type door closer quickly shuts the door to closed position. Also, the door stand-open is estimated to be 0 seconds per hour as the cam hinge / spring type door closer quickly shuts the door to closed position. The interior door leakage in the closed position is estimated to be 1.6% of the maximum through the door in the open position, as the magnetic gasket or snap door closer closes it tightly. Similarly, the calculated air changes per hour for Cooler and Freezer due to the exterior door opening is estimated to be 0.004.
Product Loads	Freezer: 41.7 MBH (Assumed 400,000 lb/day product load, from -5°F to -10°F, with specific heat of 0.50) Cooler: 226.0 MBH (Assumed 400,000 lb/day product load, from 45°F to 40°F, with specific heat of 0.65, plus 750 tons of respiring product. Heat of respiration: 5,500 Btuh/ton of product per 24 hours) Dock: 0 Btuh *Load is 100% sensible, 0% latent. Subject to production schedule*
General Facility Information and Envelope	
Azimuth	0°
Building Size	Freezer: 40,000 S.F. (200’ x 200’) Cooler: 40,000 S.F. (200’ x 200’) Dock: 12,000 S.F. (400’ x 30’) Total area: 92,000 S.F. Ceiling heights: 30’
Roof Construction	<u>Freezer</u> Construction: Built-up roof, R-40 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual) <u>Cooler</u>

	Construction: Built-up roof, R-28 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual) <u>Dock</u> Construction: Built-up roof, R-28 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual)
Wall Construction	<u>Freezer</u> R-36 urethane insulation <u>Cooler</u> R-28 urethane insulation <u>Dock</u> R-28 urethane insulation
Floor Construction	<u>Freezer</u> 8” Concrete slab, R-35 insulation <u>Cooler</u> 8” Concrete slab (no insulation, assumed concrete U-factor: 0.20) <u>Dock</u> 8” Concrete slab (no insulation, assumed concrete U-factor: 0.20)
Hours of Operation	9 AM to 1 AM, 7 Days/Week (lights, infiltration, people, forklift/pallet lifts)
Lighting	
Lighting Power Density	0.45 Watts/S.F. for Freezer and Cooler: as per Title 24 2019 for Commercial/Industrial Storage (Warehouse) 0.6 Watts/S.F. for Dock: as per Title 24 2019 for Commercial/Industrial Storage (Shipping & Handling)
Lighting ON Hours	Same as operating hours
Evaporator Coil Information	
Air Unit Fan Operation	<u>All zones</u> Fans run 100% of the time. Variable speed control, 70% minimum speed, 2 hours/day at 100% speed
Defrost	Cooler: (2) 30-minute hot-gas defrosts/day

<table>
<tr><td>Assumptions</td><td>Dock: (2) 30-minute off-cycle defrosts/day
Freezer: (2) 30-minute hot-gas defrosts/day</td></tr>
<tr><td>Air Unit Quantity</td><td>Cooler: 6
Dock: 6
Freezer: 6</td></tr>
<tr><td>Air Unit Capacity (per unit)</td><td>

Climate Zone	Total for Cooler (MBH) at 10°F	Total for Freezer (MBH) at 10°F	Total for Dock (MBH) at 10°F
CZ1	970	1,315	475
CZ2	1,030	1,360	670
CZ3	1,010	1,345	590
CZ4	1,020	1,355	650
CZ5	1,010	1,345	585
CZ6	1,015	1,350	665
CZ7	1,005	1,340	685
CZ8	1,035	1,365	710
CZ9	1,035	1,365	690
CZ10	1,050	1,375	755
CZ11	1,055	1,380	710
CZ12	1,045	1,370	735
CZ13	1,045	1,370	755
CZ14	1,055	1,380	670
CZ15	1,080	1,400	845
CZ16	1,005	1,340	530

</td></tr>
<tr><td>Design TD</td><td>10°F for all air units</td></tr>
<tr><td>Design SET:</td><td>Cooler: 25°F
Dock: 30°F
Freezer: -20°F</td></tr>
<tr><td>Air Flow Rate (per unit)</td><td>

Climate Zone	Total for Cooler (CFM)	Total for Freezer (CFM)	Total for Dock (CFM)
CZ1	180,000	240,000	90,000
CZ2	180,000	240,000	120,000
CZ3	180,000	240,000	108,000
CZ4	180,000	240,000	120,000
CZ5	180,000	240,000	108,000
CZ6	180,000	240,000	120,000
CZ7	180,000	240,000	132,000
CZ8	192,000	240,000	132,000
CZ9	192,000	240,000	132,000

</td></tr>
</table>

CZ10	192,000	240,000	144,000
CZ11	192,000	252,000	132,000
CZ12	192,000	252,000	132,000
CZ13	192,000	252,000	144,000
CZ14	192,000	252,000	120,000
CZ15	204,000	264,000	156,000
CZ16	180,000	240,000	96,000

Fan Power

Climate Zone	Total for Cooler (kW)	Total for Freezer (kW)	Total for Dock (kW)
CZ1	27.36	36.96	13.41
CZ2	28.98	38.40	18.84
CZ3	28.44	37.92	16.63
CZ4	28.80	38.16	18.36
CZ5	28.44	37.92	16.52
CZ6	28.62	38.16	18.72
CZ7	28.26	37.68	19.27
CZ8	29.18	38.40	20.06
CZ9	29.18	38.40	19.40
CZ10	29.57	38.64	21.31
CZ11	29.76	38.81	20.06
CZ12	29.38	38.56	20.72
CZ13	29.38	38.56	21.31
CZ14	29.76	38.81	18.84
CZ15	30.40	39.34	23.87
CZ16	28.26	37.68	14.98

Based on specific efficiency of 34.0 Btuh/W at 10°F TD between SET and space temperature

EEM

The fan power was calculated for each climate zone at specific efficiency values of 45 and 50 Btuh/W for freezers and coolers, respectively. The fan kW/CFM for different specific efficiency values and climate zones were used in the EEM.

Condenser Information

Condenser type: Evaporative cooled

Design TD and SCT

Climate Zone	Design WBT 0.1%	Design TD as per Title 24 2019	Design SCT (WBT + Design TD)
CZ1	61	20	81

	CZ2	71	20	91
	CZ3	67	20	87
	CZ4	70	20	90
	CZ5	67	20	87
	CZ6	71	20	91
	CZ7	72	20	92
	CZ8	73	20	93
	CZ9	72	20	92
	CZ10	75	20	95
	CZ11	73	20	93
	CZ12	74	20	94
	CZ13	75	20	95
	CZ14	71	20	91
	CZ15	79	18	97
	CZ16	64	20	84

Capacity at 100°F SCT and 70°F WBT	**Climate Zone**	**Capacity (MBH)**
	CZ1	8,612
	CZ2	8,396
	CZ3	8,451
	CZ4	8,338
	CZ5	8,437
	CZ6	8,315
	CZ7	8,250
	CZ8	8,366
	CZ9	8,417
	CZ10	8,395
	CZ11	8,454
	CZ12	8,143
	CZ13	8,302
	CZ14	8,504
	CZ15	9,362
	CZ16	8,758

Pump power and efficiency	5 HP, assumed 89.5% efficient (4.17 kW)	
Fan power based on 350 Btuh/W specific efficiency at 100°F SCT	**Climate Zone**	**Fan Power (kW)**
	CZ1	20.4
	CZ2	19.8
	CZ3	20.0
	CZ4	19.7

<table>
<tr><td rowspan="12">and 70°F WBT</td><td>CZ5</td><td>19.9</td></tr>
<tr><td>CZ6</td><td>19.6</td></tr>
<tr><td>CZ7</td><td>19.4</td></tr>
<tr><td>CZ8</td><td>19.7</td></tr>
<tr><td>CZ9</td><td>19.9</td></tr>
<tr><td>CZ10</td><td>19.8</td></tr>
<tr><td>CZ11</td><td>20.0</td></tr>
<tr><td>CZ12</td><td>19.1</td></tr>
<tr><td>CZ13</td><td>19.6</td></tr>
<tr><td>CZ14</td><td>20.1</td></tr>
<tr><td>CZ15</td><td>22.6</td></tr>
<tr><td>CZ16</td><td>20.9</td></tr>
<tr><td>Condenser fan control</td><td colspan="2">70°F wetbulb-reset SCT control, variable-speed fan
1°F throttling range
69°F fixed backflood setpoint
Wetbulb-reset control TD: 17°F
Simulated wetbulb-ratio: 0.0</td></tr>
<tr><td>Compressor Information</td><td colspan="2"></td></tr>
<tr><td>Compressor description</td><td colspan="2">LT System
Serves freezer area. (2) ammonia screw compressors with slide-valve unloading
<u>HT System</u>
Serves cooler and dock areas. (2) ammonia screw compressors with slide-valve unloading</td></tr>
</table>

<table>
<tr><td>Suction Group Design SST</td><td>LT System: -23°F
HT System: 22°F</td></tr>
<tr><td>Suction Group Design SCT</td><td>As per the design SCT table given above</td></tr>
<tr><td>Compressor capacity, power, nominal motor HP, and motor efficiency at design conditions</td><td>
<table>
<tr><th rowspan="2">Climate Zone</th><th colspan="2">LT</th><th colspan="2">HT</th></tr>
<tr><th>Mass Flow of Each Compressor</th><th>Power of Each Compressor</th><th>Mass Flow of Each Compressor</th><th>Power of Each Compressor</th></tr>
<tr><td>CZ1</td><td>1,731</td><td>114.88</td><td>1,907</td><td>56.69</td></tr>
<tr><td>CZ2</td><td>1,792</td><td>134.54</td><td>2,337</td><td>81.25</td></tr>
<tr><td>CZ3</td><td>1,771</td><td>126.50</td><td>2,164</td><td>70.64</td></tr>
<tr><td>CZ4</td><td>1,780</td><td>131.82</td><td>2,282</td><td>78.16</td></tr>
<tr><td>CZ5</td><td>1,769</td><td>126.35</td><td>2,159</td><td>70.50</td></tr>
<tr><td>CZ6</td><td>1,777</td><td>133.42</td><td>2,312</td><td>80.37</td></tr>
<tr><td>CZ7</td><td>1,764</td><td>133.88</td><td>2,332</td><td>82.47</td></tr>
<tr><td>CZ8</td><td>1,795</td><td>137.70</td><td>2,416</td><td>86.71</td></tr>
<tr><td>CZ9</td><td>1,797</td><td>136.40</td><td>2,382</td><td>84.25</td></tr>
<tr><td>CZ10</td><td>1,810</td><td>142.36</td><td>2,517</td><td>93.15</td></tr>
<tr><td>CZ11</td><td>1,813</td><td>139.10</td><td>2,443</td><td>87.67</td></tr>
<tr><td>CZ12</td><td>1,804</td><td>140.40</td><td>2,471</td><td>89.95</td></tr>
<tr><td>CZ13</td><td>1,804</td><td>141.94</td><td>2,508</td><td>92.80</td></tr>
<tr><td>CZ14</td><td>1,813</td><td>136.16</td><td>2,369</td><td>82.36</td></tr>
<tr><td>CZ15</td><td>1,839</td><td>148.24</td><td>2,710</td><td>103.20</td></tr>
<tr><td>CZ16</td><td>1,764</td><td>121.48</td><td>2,052</td><td>63.91</td></tr>
</table>
LT: 200 HP motor on each compressor, 94.5% efficient
HT: 150 HP motor on each compressor, 93.6% efficient
The compressor mass flow (along with associated power) in each climate zone were scaled to match the design cooling load. This was done to ensure accurate comparison of the performance characteristics of the compressors in each design. This eliminates unintended and unrepresentative advantages that can arise from sizing differences in the actual equipment in each climate zone.
</td></tr>
<tr><td>Suction Group SST Control Strategy</td><td>LT System: -23°F fixed SST setpoint, 1°F throttling range
HT System: 22°F fixed SST setpoint, 1°F throttling range</td></tr>
<tr><td>Compressor capacity control</td><td>Slide valve unloading</td></tr>
<tr><td>Suction Group Throttling Range</td><td>1°F</td></tr>
</table>

Oil cooling type	Thermosyphon
Useful superheat for compressor ratings	0°F
Liquid subcooling for compressor ratings	0°F

Table 146: Small Refrigerated Warehouse Prototype (Halocarbon/Ammonia)

<table>
<tr><th>System Information (Halocarbon)</th><th></th></tr>
<tr><td>Refrigerant</td><td>R-404A</td></tr>
<tr><td>System Type</td><td>Direct expansion (DX) system.
Single stage system with two suction groups – LT and HT.</td></tr>
<tr><td>Design DBT, WBT</td><td>
<table>
<tr><th>Climate Zone</th><th>Representative City</th><th>Design DBT 0.1%</th><th>Design WBT 0.1%</th></tr>
<tr><td>CZ1</td><td>Arcata</td><td>75</td><td>61</td></tr>
<tr><td>CZ2</td><td>Santa Rosa</td><td>99</td><td>71</td></tr>
<tr><td>CZ3</td><td>Oakland</td><td>91</td><td>67</td></tr>
<tr><td>CZ4</td><td>San Jose-Reid</td><td>94</td><td>70</td></tr>
<tr><td>CZ5</td><td>Santa Maria</td><td>90</td><td>67</td></tr>
<tr><td>CZ6</td><td>Torrance</td><td>93</td><td>71</td></tr>
<tr><td>CZ7</td><td>San Diego-Lindbergh</td><td>88</td><td>72</td></tr>
<tr><td>CZ8</td><td>Fullerton</td><td>100</td><td>73</td></tr>
<tr><td>CZ9</td><td>Burbank-Glendale</td><td>101</td><td>72</td></tr>
<tr><td>CZ10</td><td>Riverside</td><td>106</td><td>75</td></tr>
<tr><td>CZ11</td><td>Red Bluff</td><td>107</td><td>73</td></tr>
<tr><td>CZ12</td><td>Sacramento</td><td>104</td><td>74</td></tr>
<tr><td>CZ13</td><td>Fresno</td><td>104</td><td>75</td></tr>
<tr><td>CZ14</td><td>Palmdale</td><td>107</td><td>71</td></tr>
<tr><td>CZ15</td><td>Palm Spring-Intl</td><td>117</td><td>79</td></tr>
<tr><td>CZ16</td><td>Blue Canyon</td><td>88</td><td>64</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td>Subcooling</td><td>LT liquid line is subcooled by the HT suction group</td></tr>
<tr><td>Load Information</td><td></td></tr>
<tr><td>Temperature Setpoints</td><td>Freezer: -10°F
Cooler: 35°F
Dock: 40°F</td></tr>
<tr><td>Load Profiles</td><td>Internal loads are product load, lights, infiltration, people, forklifts/pallet lifts, equipment</td></tr>
<tr><td>People Loads</td><td>Calculated using the following formula from the ASHRAE Refrigeration Handbook:
$(1295-11.5*T_{space})*1.25$
6 people in Freezer, 6 in Cooler and 2 in Dock.
Subject to hourly schedule</td></tr>
<tr><td>Forklifts</td><td><table>
<tr><th>Space</th><th>Number of Forklifts</th><th>Number of Pallet Lifts</th></tr>
<tr><td>Freezer</td><td>2</td><td>2</td></tr>
<tr><td>Cooler</td><td>3</td><td>3</td></tr>
<tr><td>Dock</td><td>1</td><td>1</td></tr>
</table>Estimated 20 MBH/forklift, 10 MBH/pallet-lift
Subject to hourly schedule</td></tr>
<tr><td>Infiltration and Interzonal Air Exchange</td><td>Dock: (6) 10’ x 10’ dock doors. Assumed 200 CFM infiltration per dock door, subject to infiltration schedule
Cooler: (1) 10’ x 10’ doors from Cooler to Dock
Freezer: (1) 10’ x 10’ doors from Freezer to Dock
Each forklift and pallet lift is assumed to make a trip from the Dock into the Freezer or Cooler every six minutes. 5 seconds per opening. Doors are not assumed to have strip or air curtains. Subject to hourly production schedule</td></tr>
<tr><td>Product Loads</td><td>Freezer: 10.4 MBH (Assumed 100,000 lb/day product load, from -5°F to -10°F, with specific heat of 0.50)
Cooler: 70.1 MBH (Assumed 100,000 lb/day product load, from 45°F to 40°F, with specific heat of 0.65, plus 750 tons of respiring product. Heat of respiration: 5,500 Btuh/ton of product per 24 hours)
Dock: 0 Btuh
Load is 100% sensible, 0% latent. Subject to production schedule</td></tr>
<tr><td>General Facility Information and Envelope</td><td></td></tr>
<tr><td>Azimuth</td><td>0°</td></tr>
<tr><td>Building Size</td><td>Freezer: 10,000 S.F. (100’ x 100’)</td></tr>
</table>

	Cooler: 10,000 S.F. (100’ x 100’) Dock: 6,000 S.F. (200’ x 30’) Total area: 26,000 S.F. Ceiling heights: 30’
Roof Construction	<u>Freezer</u> Construction: Built-up roof, R-40 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual) <u>Cooler</u> Construction: Built-up roof, R-28 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual) <u>Dock</u> Construction: Built-up roof, R-28 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual)
Wall Construction	<u>Freezer</u> R-36 urethane insulation <u>Cooler</u> R-28 urethane insulation <u>Dock</u> R-28 urethane insulation
Floor Construction	<u>Freezer</u> 8” Concrete slab, R-35 insulation <u>Cooler</u> 8” Concrete slab (no insulation, assumed concrete U-factor: 0.20) <u>Dock</u> 8” Concrete slab (no insulation, assumed concrete U-factor: 0.20)
Hours of Operation	9 AM to 1 AM, 7 Days/Week (lights, infiltration, people, forklift/pallet lifts)
Lighting	
Lighting Power Density	0.45 Watts/S.F. for Freezer and Cooler: as per Title 24 2019 for Commercial/Industrial Storage (Warehouse)

	0.6 Watts/S.F. for Dock: as per Title 24 2019 for Commercial/Industrial Storage (Shipping & Handling)
Lighting ON Hours	Same as operating hours
Evaporator Coil Information	
Air Unit Fan Operation	<u>All zones</u> Fans run 100% of the time. Variable speed control, 70% minimum speed, 2 hours/day at 100% speed
Defrost Assumptions	Cooler: (2) 30-minute hot-gas defrosts/day Dock: (2) 30-minute off-cycle defrosts/day Freezer: (2) 30-minute hot-gas defrosts/day
Air Unit Quantity	Cooler: 4 Dock: 4 Freezer: 4
Air Unit Capacity (per unit)	(see table below)

Air Unit Capacity (per unit):

Climate Zone	Total for Cooler (MBH) at 10°F	Total for Freezer (MBH) at 10°F	Total for Dock (MBH) at 10°F
CZ1	330	420	190
CZ2	340	430	250
CZ3	335	425	220
CZ4	335	425	240
CZ5	335	425	220
CZ6	335	425	245
CZ7	330	425	250
CZ8	340	430	260
CZ9	340	430	255
CZ10	345	435	275
CZ11	345	435	265
CZ12	345	430	270
CZ13	345	430	275
CZ14	345	435	250
CZ15	355	440	305
CZ16	330	425	205

<table>
<tr><td>Design TD</td><td>10°F for all air units</td></tr>
<tr><td>Design SET:</td><td>Cooler: 25°F
Dock: 30°F
Freezer: -20°F</td></tr>
<tr><td>Air Flow Rate (per unit)</td><td>
<table>
<tr><th>Climate Zone</th><th>Total for Cooler (CFM)</th><th>Total for Freezer (CFM)</th><th>Total for Dock (CFM)</th></tr>
<tr><td>CZ1</td><td>64,000</td><td>80,000</td><td>36,000</td></tr>
<tr><td>CZ2</td><td>64,000</td><td>80,000</td><td>48,000</td></tr>
<tr><td>CZ3</td><td>64,000</td><td>80,000</td><td>40,000</td></tr>
<tr><td>CZ4</td><td>64,000</td><td>80,000</td><td>48,000</td></tr>
<tr><td>CZ5</td><td>64,000</td><td>80,000</td><td>40,000</td></tr>
<tr><td>CZ6</td><td>64,000</td><td>80,000</td><td>48,000</td></tr>
<tr><td>CZ7</td><td>64,000</td><td>80,000</td><td>48,000</td></tr>
<tr><td>CZ8</td><td>64,000</td><td>80,000</td><td>48,000</td></tr>
<tr><td>CZ9</td><td>64,000</td><td>80,000</td><td>48,000</td></tr>
<tr><td>CZ10</td><td>64,000</td><td>80,000</td><td>52,000</td></tr>
<tr><td>CZ11</td><td>64,000</td><td>80,000</td><td>48,000</td></tr>
<tr><td>CZ12</td><td>64,000</td><td>80,000</td><td>48,000</td></tr>
<tr><td>CZ13</td><td>64,000</td><td>80,000</td><td>52,000</td></tr>
<tr><td>CZ14</td><td>64,000</td><td>80,000</td><td>48,000</td></tr>
<tr><td>CZ15</td><td>64,000</td><td>80,000</td><td>56,000</td></tr>
<tr><td>CZ16</td><td>64,000</td><td>80,000</td><td>40,000</td></tr>
</table>
</td></tr>
<tr><td>Fan Power</td><td>
<table>
<tr><th>Climate Zone</th><th>Total for Cooler (kW)</th><th>Total for Freezer (kW)</th><th>Total for Dock (kW)</th></tr>
<tr><td>CZ1</td><td>9.28</td><td>11.84</td><td>5.36</td></tr>
<tr><td>CZ2</td><td>9.60</td><td>12.16</td><td>7.06</td></tr>
<tr><td>CZ3</td><td>9.47</td><td>12.00</td><td>6.20</td></tr>
<tr><td>CZ4</td><td>9.47</td><td>12.00</td><td>6.77</td></tr>
<tr><td>CZ5</td><td>9.47</td><td>12.00</td><td>6.20</td></tr>
<tr><td>CZ6</td><td>9.47</td><td>12.00</td><td>6.91</td></tr>
<tr><td>CZ7</td><td>9.28</td><td>12.00</td><td>7.06</td></tr>
<tr><td>CZ8</td><td>9.60</td><td>12.16</td><td>7.34</td></tr>
<tr><td>CZ9</td><td>9.60</td><td>12.16</td><td>7.20</td></tr>
<tr><td>CZ10</td><td>9.73</td><td>12.24</td><td>7.75</td></tr>
<tr><td>CZ11</td><td>9.73</td><td>12.24</td><td>7.49</td></tr>
<tr><td>CZ12</td><td>9.73</td><td>12.16</td><td>7.63</td></tr>
<tr><td>CZ13</td><td>9.73</td><td>12.16</td><td>7.75</td></tr>
<tr><td>CZ14</td><td>9.73</td><td>12.24</td><td>7.06</td></tr>
<tr><td>CZ15</td><td>9.98</td><td>12.40</td><td>8.62</td></tr>
</table>
</td></tr>
</table>

	<table><tr><td>CZ16</td><td>9.28</td><td>12.00</td><td>5.76</td></tr></table>*Based on specific efficiency of 34.0 Btuh/W at 10°F TD between SET and space temperature* **EEM** The fan power was calculated for each climate zone at specific efficiency values of 35 and 40 Btuh/W for freezers and coolers, respectively. The fan kW/CFM for different specific efficiency values and climate zones were used in the EEM.
Condenser Information	
Condenser type	Air cooled
Design TD and SCT	<table><tr><th>Climate Zone</th><th>Design DBT 0.1%</th><th>HT Design TD as per Title 24 2019</th><th>HT Design SCT (DBT + Design TD)</th><th>LT Design TD as per Title 24 2019</th><th>LT Design SCT (DBT + Design TD)</th></tr><tr><td>CZ1</td><td>75</td><td>15</td><td>90</td><td>10</td><td>85</td></tr><tr><td>CZ2</td><td>99</td><td>15</td><td>114</td><td>10</td><td>109</td></tr><tr><td>CZ3</td><td>91</td><td>15</td><td>106</td><td>10</td><td>101</td></tr><tr><td>CZ4</td><td>94</td><td>15</td><td>109</td><td>10</td><td>104</td></tr><tr><td>CZ5</td><td>90</td><td>15</td><td>105</td><td>10</td><td>100</td></tr><tr><td>CZ6</td><td>93</td><td>15</td><td>108</td><td>10</td><td>103</td></tr><tr><td>CZ7</td><td>88</td><td>15</td><td>103</td><td>10</td><td>98</td></tr><tr><td>CZ8</td><td>100</td><td>15</td><td>115</td><td>10</td><td>110</td></tr><tr><td>CZ9</td><td>101</td><td>15</td><td>116</td><td>10</td><td>111</td></tr><tr><td>CZ10</td><td>106</td><td>15</td><td>121</td><td>10</td><td>116</td></tr><tr><td>CZ11</td><td>107</td><td>15</td><td>122</td><td>10</td><td>117</td></tr><tr><td>CZ12</td><td>104</td><td>15</td><td>119</td><td>10</td><td>114</td></tr><tr><td>CZ13</td><td>104</td><td>15</td><td>119</td><td>10</td><td>114</td></tr><tr><td>CZ14</td><td>107</td><td>15</td><td>122</td><td>10</td><td>117</td></tr><tr><td>CZ15</td><td>117</td><td>15</td><td>132</td><td>10</td><td>127</td></tr><tr><td>CZ16</td><td>88</td><td>15</td><td>103</td><td>10</td><td>98</td></tr></table>
Capacity at 10°F TD	<table><tr><th>Climate Zone</th><th>HT Condenser Capacity (MBH)</th><th>LT Condenser Capacity (MBH)</th></tr><tr><td>CZ1</td><td>535</td><td>616</td></tr><tr><td>CZ2</td><td>745</td><td>669</td></tr><tr><td>CZ3</td><td>657</td><td>649</td></tr><tr><td>CZ4</td><td>696</td><td>656</td></tr><tr><td>CZ5</td><td>648</td><td>647</td></tr></table>

	<table><tr><td>CZ6</td><td>693</td><td>654</td></tr><tr><td>CZ7</td><td>661</td><td>642</td></tr><tr><td>CZ8</td><td>765</td><td>672</td></tr><tr><td>CZ9</td><td>768</td><td>673</td></tr><tr><td>CZ10</td><td>837</td><td>686</td></tr><tr><td>CZ11</td><td>834</td><td>688</td></tr><tr><td>CZ12</td><td>810</td><td>680</td></tr><tr><td>CZ13</td><td>816</td><td>680</td></tr><tr><td>CZ14</td><td>821</td><td>688</td></tr><tr><td>CZ15</td><td>996</td><td>714</td></tr><tr><td>CZ16</td><td>619</td><td>642</td></tr></table>
Number of fans	HT: 10 LT: 12
Fan power based on 65 Btuh/W specific efficiency at 10°F TD	<table><tr><th>Climate Zone</th><th>HT Condenser Total Fan Power (kW)</th><th>LT Condenser Total Fan Power (kW)</th></tr><tr><td>CZ1</td><td>8.2</td><td>9.5</td></tr><tr><td>CZ2</td><td>11.5</td><td>10.3</td></tr><tr><td>CZ3</td><td>10.1</td><td>10</td></tr><tr><td>CZ4</td><td>10.7</td><td>10.1</td></tr><tr><td>CZ5</td><td>10.0</td><td>10.0</td></tr><tr><td>CZ6</td><td>10.7</td><td>10.1</td></tr><tr><td>CZ7</td><td>10.2</td><td>9.9</td></tr><tr><td>CZ8</td><td>11.8</td><td>10.3</td></tr><tr><td>CZ9</td><td>11.8</td><td>10.4</td></tr><tr><td>CZ10</td><td>12.9</td><td>10.6</td></tr><tr><td>CZ11</td><td>12.8</td><td>10.6</td></tr><tr><td>CZ12</td><td>12.5</td><td>10.5</td></tr><tr><td>CZ13</td><td>12.6</td><td>10.5</td></tr><tr><td>CZ14</td><td>12.6</td><td>10.6</td></tr><tr><td>CZ15</td><td>15.3</td><td>11</td></tr><tr><td>CZ16</td><td>9.5</td><td>9.9</td></tr></table>
Condenser fan control	70°F dry bulb-reset SCT control, variable-speed fan 1°F throttling range 69°F fixed backflood setpoint Dry bulb-reset control TD: 12°F for LT, 14°F for HT
Compressor Information	
Compressor description	<u>LT System</u> Serves freezer area. (8) reciprocating compressors with cycling control

<table>
<tr><td></td><td><u>HT System</u>
Serves cooler and dock areas. (6) reciprocating compressors with cycling control</td></tr>
<tr><td>Suction Group Design SST</td><td>LT System: -23°F
HT System: 22°F</td></tr>
<tr><td>Suction Group Design SCT</td><td>As per the design SCT table given above</td></tr>
<tr><td>Compressor mass flow and power</td><td>
<table>
<tr><th rowspan="2">Climate Zone</th><th colspan="2">LT</th><th colspan="2">HT</th></tr>
<tr><th>Mass Flow of Each Compressor</th><th>Power of Each Compressor</th><th>Mass Flow of Each Compressor</th><th>Power of Each Compressor</th></tr>
<tr><td>CZ1</td><td>901</td><td>7.2</td><td>1,768</td><td>7.72</td></tr>
<tr><td>CZ2</td><td>920</td><td>8.8</td><td>2,513</td><td>13.93</td></tr>
<tr><td>CZ3</td><td>910</td><td>8.3</td><td>2,184</td><td>11.27</td></tr>
<tr><td>CZ4</td><td>913</td><td>8.5</td><td>2,334</td><td>12.36</td></tr>
<tr><td>CZ5</td><td>908</td><td>8.2</td><td>2,158</td><td>10.99</td></tr>
<tr><td>CZ6</td><td>912</td><td>8.4</td><td>2,328</td><td>12.22</td></tr>
<tr><td>CZ7</td><td>906</td><td>8.1</td><td>2,218</td><td>11.10</td></tr>
<tr><td>CZ8</td><td>921</td><td>8.9</td><td>2,596</td><td>14.51</td></tr>
<tr><td>CZ9</td><td>922</td><td>9.0</td><td>3,280</td><td>18.48</td></tr>
<tr><td>CZ10</td><td>929</td><td>9.3</td><td>3,657</td><td>21.41</td></tr>
<tr><td>CZ11</td><td>931</td><td>9.4</td><td>3,664</td><td>21.61</td></tr>
<tr><td>CZ12</td><td>925</td><td>9.1</td><td>3,507</td><td>20.22</td></tr>
<tr><td>CZ13</td><td>925</td><td>9.1</td><td>3,534</td><td>20.37</td></tr>
<tr><td>CZ14</td><td>931</td><td>9.4</td><td>3,608</td><td>21.28</td></tr>
<tr><td>CZ15</td><td>943</td><td>10.1</td><td>4,631</td><td>29.21</td></tr>
<tr><td>CZ16</td><td>906</td><td>8.1</td><td>2,505</td><td>12.53</td></tr>
</table>
Compressor mass flows (along with associated power) in each climate zone were scaled to match the design cooling load. This was done to ensure accurate comparison of the performance characteristics of the compressors in each design. This eliminates unintended and unrepresentative advantages that can arise from sizing differences in the actual equipment in each climate zone.</td></tr>
</table>

<table>
<tr><td>Suction Group SST Control Strategy</td><td>LT System: -23°F fixed SST setpoint
HT System: 22°F fixed SST setpoint</td></tr>
<tr><td>Compressor capacity control</td><td>Cycling</td></tr>
<tr><td>Suction Group Throttling Range</td><td>1°F</td></tr>
<tr><td>Return Gas Temperature for compressor ratings</td><td>LT: 10°F, i.e., 33°F superheat
HT: 45°F, i.e., 23°F superheat</td></tr>
<tr><td>Liquid subcooling for compressor ratings</td><td>0°F</td></tr>
<tr><td>System Information (Ammonia)</td><td></td></tr>
<tr><td>Refrigerant</td><td>R-717</td></tr>
<tr><td>System Type</td><td>Direct expansion (DX) ammonia system
Single stage system with two suction groups – LT and HT.</td></tr>
<tr><td>Design DBT, WBT</td><td>
<table>
<tr><th>Climate Zone</th><th>Representative City</th><th>Design DBT 0.1%</th><th>Design WBT 0.1%</th></tr>
<tr><td>CZ1</td><td>Arcata</td><td>75</td><td>61</td></tr>
<tr><td>CZ2</td><td>Santa Rosa</td><td>99</td><td>71</td></tr>
<tr><td>CZ3</td><td>Oakland</td><td>91</td><td>67</td></tr>
<tr><td>CZ4</td><td>San Jose-Reid</td><td>94</td><td>70</td></tr>
<tr><td>CZ5</td><td>Santa Maria</td><td>90</td><td>67</td></tr>
<tr><td>CZ6</td><td>Torrance</td><td>93</td><td>71</td></tr>
<tr><td>CZ7</td><td>San Diego-Lindbergh</td><td>88</td><td>72</td></tr>
<tr><td>CZ8</td><td>Fullerton</td><td>100</td><td>73</td></tr>
<tr><td>CZ9</td><td>Burbank-Glendale</td><td>101</td><td>72</td></tr>
<tr><td>CZ10</td><td>Riverside</td><td>106</td><td>75</td></tr>
<tr><td>CZ11</td><td>Red Bluff</td><td>107</td><td>73</td></tr>
<tr><td>CZ12</td><td>Sacramento</td><td>104</td><td>74</td></tr>
<tr><td>CZ13</td><td>Fresno</td><td>104</td><td>75</td></tr>
<tr><td>CZ14</td><td>Palmdale</td><td>107</td><td>71</td></tr>
<tr><td>CZ15</td><td>Palm Spring-Intl</td><td>117</td><td>79</td></tr>
<tr><td>CZ16</td><td>Blue Canyon</td><td>88</td><td>64</td></tr>
</table>
</td></tr>
<tr><td>Subcooling</td><td>LT liquid line is subcooled by the HT suction group</td></tr>
<tr><td>Load Information</td><td></td></tr>
</table>

<table>
<tr><td>Temperature Setpoints</td><td>Freezer: -10°F
Cooler: 35°F
Dock: 40°F</td></tr>
<tr><td>Load Profiles</td><td>Internal loads are product load, lights, infiltration, people, forklifts/pallet lifts, equipment</td></tr>
<tr><td>People Loads</td><td>Calculated using the following formula from the ASHRAE Refrigeration Handbook:
$(1295-11.5*T_{space})*1.25$
6 people in Freezer, 6 in Cooler and 2 in Dock.
Subject to hourly schedule</td></tr>
<tr><td>Forklifts</td><td><table>
<tr><th>Space</th><th>Number of Forklifts</th><th>Number of Pallet Lifts</th></tr>
<tr><td>Freezer</td><td>2</td><td>2</td></tr>
<tr><td>Cooler</td><td>3</td><td>3</td></tr>
<tr><td>Dock</td><td>1</td><td>1</td></tr>
</table>Estimated 20 MBH/forklift, 10 MBH/pallet-lift
Subject to hourly schedule</td></tr>
<tr><td>Infiltration and Interzonal Air Exchange</td><td>Dock: (6) 10’ x 10’ dock doors. Assumed 200 CFM infiltration per dock door, subject to infiltration schedule
Cooler: (1) 10’ x 10’ doors from Cooler to Dock
Freezer: (1) 10’ x 10’ doors from Freezer to Dock
Each forklift and pallet lift is assumed to make a trip from the Dock into the Freezer or Cooler every six minutes. 5 seconds per opening. Doors are not assumed to have strip or air curtains. Subject to hourly production schedule</td></tr>
<tr><td>Product Loads</td><td>Freezer: 10.4 MBH (Assumed 100,000 lb/day product load, from -5°F to -10°F, with specific heat of 0.50)
Cooler: 70.1 MBH (Assumed 100,000 lb/day product load, from 45°F to 40°F, with specific heat of 0.65, plus 750 tons of respiring product. Heat of respiration: 5,500 Btuh/ton of product per 24 hours)
Dock: 0 Btuh
Load is 100% sensible, 0% latent. Subject to production schedule</td></tr>
</table>

General Facility Information and Envelope	
Azimuth	0°
Building Size	Freezer: 10,000 S.F. (100’ x 100’) Cooler: 10,000 S.F. (100’ x 100’) Dock: 6,000 S.F. (200’ x 30’) Total area: 26,000 S.F. Ceiling heights: 30’
Roof Construction	<u>Freezer</u> Construction: Built-up roof, R-40 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual) <u>Cooler</u> Construction: Built-up roof, R-28 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual) <u>Dock</u> Construction: Built-up roof, R-28 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual)
Wall Construction	<u>Freezer</u> R-36 urethane insulation <u>Cooler</u> R-28 urethane insulation <u>Dock</u> R-28 urethane insulation
Floor Construction	<u>Freezer</u> 8” Concrete slab, R-35 insulation <u>Cooler</u> 8” Concrete slab (no insulation, assumed concrete U-factor: 0.20) <u>Dock</u> 8” Concrete slab (no insulation, assumed concrete U-factor: 0.20)
Hours of Operation	9 AM to 1 AM, 7 Days/Week (lights, infiltration, people, forklift/pallet lifts)
Lighting	
Lighting Power Density	0.45 Watts/S.F. for Freezer and Cooler: as per Title 24 2019 for Commercial/Industrial Storage (Warehouse)

<table>
<tr><td></td><td>0.6 Watts/S.F. for Dock: as per Title 24 2019 for Commercial/Industrial Storage (Shipping & Handling)</td></tr>
<tr><td>Lighting ON Hours</td><td>Same as operating hours</td></tr>
<tr><td>Evaporator Coil Information</td><td></td></tr>
<tr><td>Air Unit Fan Operation</td><td><u>All zones</u>
Fans run 100% of the time. Variable speed control, 70% minimum speed, 2 hours/day at 100% speed</td></tr>
<tr><td>Defrost Assumptions</td><td>Cooler: (2) 30-minute hot-gas defrosts/day
Dock: (2) 30-minute off-cycle defrosts/day
Freezer: (2) 30-minute hot-gas defrosts/day</td></tr>
<tr><td>Air Unit Quantity</td><td>Cooler: 4
Dock: 4
Freezer: 4</td></tr>
<tr><td>Air Unit Capacity (per unit)</td><td>
<table>
<tr><th>Climate Zone</th><th>Total for Cooler (MBH) at 10°F</th><th>Total for Freezer (MBH) at 10°F</th><th>Total for Dock (MBH) at 10°F</th></tr>
<tr><td>CZ1</td><td>355</td><td>465</td><td>200</td></tr>
<tr><td>CZ2</td><td>380</td><td>480</td><td>275</td></tr>
<tr><td>CZ3</td><td>370</td><td>475</td><td>245</td></tr>
<tr><td>CZ4</td><td>375</td><td>475</td><td>265</td></tr>
<tr><td>CZ5</td><td>370</td><td>470</td><td>245</td></tr>
<tr><td>CZ6</td><td>370</td><td>475</td><td>270</td></tr>
<tr><td>CZ7</td><td>370</td><td>470</td><td>275</td></tr>
<tr><td>CZ8</td><td>380</td><td>480</td><td>290</td></tr>
<tr><td>CZ9</td><td>380</td><td>480</td><td>285</td></tr>
<tr><td>CZ10</td><td>385</td><td>485</td><td>305</td></tr>
<tr><td>CZ11</td><td>385</td><td>485</td><td>290</td></tr>
<tr><td>CZ12</td><td>380</td><td>480</td><td>300</td></tr>
<tr><td>CZ13</td><td>380</td><td>480</td><td>305</td></tr>
<tr><td>CZ14</td><td>385</td><td>485</td><td>275</td></tr>
<tr><td>CZ15</td><td>395</td><td>490</td><td>340</td></tr>
<tr><td>CZ16</td><td>370</td><td>470</td><td>225</td></tr>
</table>
</td></tr>
<tr><td>Design TD</td><td>10°F for all air units</td></tr>
<tr><td>Design SET:</td><td>Cooler: 25°F
Dock: 30°F
Freezer: -20°F</td></tr>
<tr><td>Air Flow Rate (per unit)</td><td>
<table>
<tr><th>Climate Zone</th><th>Total for Cooler (CFM)</th><th>Total for Freezer (CFM)</th><th>Total for Dock (CFM)</th></tr>
</table>
</td></tr>
</table>

CZ1	64,000	88,000	40,000
CZ2	72,000	88,000	48,000
CZ3	72,000	96,000	48,000
CZ4	72,000	88,000	48,000
CZ5	72,000	88,000	48,000
CZ6	72,000	88,000	48,000
CZ7	72,000	88,000	48,000
CZ8	72,000	88,000	56,000
CZ9	72,000	88,000	56,000
CZ10	72,000	88,000	56,000
CZ11	72,000	88,000	56,000
CZ12	72,000	88,000	56,000
CZ13	72,000	96,000	56,000
CZ14	72,000	88,000	48,000
CZ15	72,000	88,000	64,000
CZ16	72,000	88,000	40,000

Fan Power

Climate Zone	**Total for Cooler (kW)**	**Total for Freezer (kW)**	**Total for Dock (kW)**
CZ1	17.02	22.26	9.60
CZ2	18.22	22.97	13.20
CZ3	17.71	22.75	11.76
CZ4	18.00	22.79	12.72
CZ5	17.71	22.53	11.76
CZ6	17.71	22.79	12.96
CZ7	17.71	22.53	13.20
CZ8	18.22	22.97	13.89
CZ9	18.22	22.97	13.66
CZ10	18.43	23.23	14.62
CZ11	18.43	23.23	13.89
CZ12	18.22	22.97	14.39
CZ13	18.22	23.04	14.62
CZ14	18.43	23.23	13.20
CZ15	18.94	23.50	16.32
CZ16	17.71	22.53	10.80

Based on specific efficiency of 20 Btuh/W at 10°F TD between SET and space temperature

EEM

The fan power was calculated for each climate zone at specific efficiency values of 25 and 35 Btuh/W, respectively. The fan kW/CFM for different specific efficiency values and climate zones were used in

<table>
<tr><td></td><td>the EEM.</td></tr>
<tr><td>Condenser Information</td><td></td></tr>
<tr><td>Condenser type</td><td>Air cooled</td></tr>
<tr><td>Design TD and SCT</td><td>
<table>
<tr><th>Climate Zone</th><th>Design DBT 0.1%</th><th>HT Design TD as per Title 24 2019</th><th>HT Design SCT (DBT + Design TD)</th><th>LT Design TD as per Title 24 2019</th><th>LT Design SCT (DBT + Design TD)</th></tr>
<tr><td>CZ1</td><td>75</td><td>15</td><td>90</td><td>10</td><td>85</td></tr>
<tr><td>CZ2</td><td>99</td><td>15</td><td>114</td><td>10</td><td>109</td></tr>
<tr><td>CZ3</td><td>91</td><td>15</td><td>106</td><td>10</td><td>101</td></tr>
<tr><td>CZ4</td><td>94</td><td>15</td><td>109</td><td>10</td><td>104</td></tr>
<tr><td>CZ5</td><td>90</td><td>15</td><td>105</td><td>10</td><td>100</td></tr>
<tr><td>CZ6</td><td>93</td><td>15</td><td>108</td><td>10</td><td>103</td></tr>
<tr><td>CZ7</td><td>88</td><td>15</td><td>103</td><td>10</td><td>98</td></tr>
<tr><td>CZ8</td><td>100</td><td>15</td><td>115</td><td>10</td><td>110</td></tr>
<tr><td>CZ9</td><td>101</td><td>15</td><td>116</td><td>10</td><td>111</td></tr>
<tr><td>CZ10</td><td>106</td><td>15</td><td>121</td><td>10</td><td>116</td></tr>
<tr><td>CZ11</td><td>107</td><td>15</td><td>122</td><td>10</td><td>117</td></tr>
<tr><td>CZ12</td><td>104</td><td>15</td><td>119</td><td>10</td><td>114</td></tr>
<tr><td>CZ13</td><td>104</td><td>15</td><td>119</td><td>10</td><td>114</td></tr>
<tr><td>CZ14</td><td>107</td><td>15</td><td>122</td><td>10</td><td>117</td></tr>
<tr><td>CZ15</td><td>117</td><td>15</td><td>132</td><td>10</td><td>127</td></tr>
<tr><td>CZ16</td><td>88</td><td>15</td><td>103</td><td>10</td><td>98</td></tr>
</table>
</td></tr>
<tr><td>Capacity at 10°F TD</td><td>
<table>
<tr><th>Climate Zone</th><th>HT Condenser Capacity (MBH)</th><th>LT Condenser Capacity (MBH)</th></tr>
<tr><td>CZ1</td><td>498</td><td>680</td></tr>
<tr><td>CZ2</td><td>651</td><td>782</td></tr>
<tr><td>CZ3</td><td>590</td><td>743</td></tr>
<tr><td>CZ4</td><td>639</td><td>760</td></tr>
<tr><td>CZ5</td><td>586</td><td>738</td></tr>
<tr><td>CZ6</td><td>621</td><td>752</td></tr>
<tr><td>CZ7</td><td>607</td><td>729</td></tr>
<tr><td>CZ8</td><td>668</td><td>788</td></tr>
<tr><td>CZ9</td><td>667</td><td>792</td></tr>
<tr><td>CZ10</td><td>712</td><td>820</td></tr>
<tr><td>CZ11</td><td>703</td><td>825</td></tr>
<tr><td>CZ12</td><td>694</td><td>807</td></tr>
</table>
</td></tr>
</table>

	CZ13 | 700 | 807 CZ14 | 690 | 825 CZ15 | 797 | 873 CZ16 | 562 | 729
Number of fans	HT: 10 LT: 12
Fan power based on 75 Btuh/W specific efficiency at 10°F TD	(see table below)
Condenser fan control	70°F dry bulb-reset SCT control, variable-speed fan 1°F throttling range 69°F fixed backflood setpoint Dry bulb-reset control TD: 12°F for LT, 14°F for HT
Compressor Information	
Compressor description	<u>LT System</u> Serves freezer area. (4) screw compressors with slide valve control <u>HT System</u> Serves cooler and dock areas. (4) screw compressors with slide valve control

Continuation rows (preceding climate zone table):

CZ13	700	807
CZ14	690	825
CZ15	797	873
CZ16	562	729

Fan power based on 75 Btuh/W specific efficiency at 10°F TD:

Climate Zone	HT Condenser Total Fan Power (kW)	LT Condenser Total Fan Power (kW)
CZ1	6.6	9.1
CZ2	8.7	10.4
CZ3	7.9	9.9
CZ4	8.5	10.1
CZ5	7.8	9.8
CZ6	8.3	10.0
CZ7	8.1	9.7
CZ8	8.9	10.5
CZ9	8.9	10.6
CZ10	9.5	10.9
CZ11	9.4	11.0
CZ12	9.3	10.8
CZ13	9.3	10.8
CZ14	9.2	11.0
CZ15	10.6	11.7
CZ16	7.5	9.7

<table>
<tr><td>Suction Group Design SST</td><td>LT System: -23°F
HT System: 22°F</td></tr>
<tr><td>Suction Group Design SCT</td><td>As per the design SCT table given above</td></tr>
<tr><td>Compressor mass flow and power</td><td>
<table>
<tr><th rowspan="2">Climate Zone</th><th colspan="2">LT</th><th colspan="2">HT</th></tr>
<tr><th>Mass Flow of Each Compressor</th><th>Power of Each Compressor</th><th>Mass Flow of Each Compressor</th><th>Power of Each Compressor</th></tr>
<tr><td>CZ1</td><td>228</td><td>16.0</td><td>313</td><td>11.08</td></tr>
<tr><td>CZ2</td><td>236</td><td>22.3</td><td>402</td><td>18.95</td></tr>
<tr><td>CZ3</td><td>233</td><td>19.9</td><td>368</td><td>15.68</td></tr>
<tr><td>CZ4</td><td>234</td><td>20.8</td><td>397</td><td>17.59</td></tr>
<tr><td>CZ5</td><td>232</td><td>19.6</td><td>366</td><td>15.41</td></tr>
<tr><td>CZ6</td><td>233</td><td>20.5</td><td>386</td><td>16.93</td></tr>
<tr><td>CZ7</td><td>232</td><td>19.1</td><td>379</td><td>15.63</td></tr>
<tr><td>CZ8</td><td>236</td><td>22.8</td><td>412</td><td>19.63</td></tr>
<tr><td>CZ9</td><td>236</td><td>23.0</td><td>411</td><td>19.77</td></tr>
<tr><td>CZ10</td><td>238</td><td>24.8</td><td>435</td><td>22.35</td></tr>
<tr><td>CZ11</td><td>238</td><td>25.1</td><td>430</td><td>22.27</td></tr>
<tr><td>CZ12</td><td>237</td><td>24.0</td><td>426</td><td>21.30</td></tr>
<tr><td>CZ13</td><td>237</td><td>24.0</td><td>430</td><td>21.48</td></tr>
<tr><td>CZ14</td><td>238</td><td>25.1</td><td>422</td><td>21.86</td></tr>
<tr><td>CZ15</td><td>241</td><td>28.1</td><td>483</td><td>27.4</td></tr>
<tr><td>CZ16</td><td>232</td><td>19.1</td><td>351</td><td>14.48</td></tr>
</table>
Compressor mass flows (along with associated power) in each climate zone were scaled to match the design cooling load. This was done to ensure accurate comparison of the performance characteristics of the compressors in each design. This eliminates unintended and unrepresentative advantages that can arise from sizing differences in the actual equipment in each climate zone.
</td></tr>
</table>

Suction Group SST Control Strategy	LT System: -23°F fixed SST setpoint HT System: 22°F fixed SST setpoint
Compressor capacity control	Slide valve
Suction Group Throttling Range	1°F
Return Gas Temperature for compressor ratings	LT: 10°F, i.e., 33°F superheat HT: 45°F, i.e., 23°F superheat
Liquid subcooling for compressor ratings	0°F

Table 147: Large Refrigerated Warehouse Prototype Simulation Assumptions (Submeasure D)

System Information	
Refrigerant	R-717
System Type	Single stage system with two suction groups – LT and HT.
Design DBT, WBT	(see nested table below)

Climate Zone	Representative City	Design DBT 0.1%	Design WBT 0.1%
CZ1	Arcata	75	61
CZ2	Santa Rosa	99	71
CZ3	Oakland	91	67
CZ4	San Jose-Reid	94	70
CZ5	Santa Maria	90	67
CZ6	Torrance	93	71
CZ7	San Diego-Lindbergh	88	72
CZ8	Fullerton	100	73
CZ9	Burbank-Glendale	101	72
CZ10	Riverside	106	75
CZ11	Red Bluff	107	73
CZ12	Sacramento	104	74
CZ13	Fresno	104	75
CZ14	Palmdale	107	71
CZ15	Palm Spring-Intl	117	79
CZ16	Blue Canyon	88	64

<table>
<tr><td>Subcooling</td><td>LT liquid line is subcooled by the HT suction group</td></tr>
<tr><td>Load Information</td><td></td></tr>
<tr><td>Temperature Setpoints</td><td>Freezer: -10°F
Cooler: 35°F
Dock: 40°F</td></tr>
<tr><td>Load Profiles</td><td>Internal loads are product load, lights, infiltration, people, forklifts/pallet lifts, equipment</td></tr>
<tr><td>People Loads</td><td>Calculated using the following formula from the ASHRAE Refrigeration Handbook:
$(1295-11.5*T_{space})*1.25$
12 people in Freezer, 16 in Cooler and 4 in Dock.
Subject to hourly schedule</td></tr>
<tr><td>Forklifts</td><td><table>
<tr><th>Space</th><th>Number of Forklifts</th><th>Number of Pallet Lifts</th></tr>
<tr><td>Freezer</td><td>6</td><td>6</td></tr>
<tr><td>Cooler</td><td>8</td><td>8</td></tr>
<tr><td>Dock</td><td>2</td><td>2</td></tr>
</table>
Estimated 20 MBH/forklift, 10 MBH/pallet-lift
Subject to hourly schedule</td></tr>
<tr><td>Infiltration and Interzonal Air Exchange</td><td>Dock: (20) 10’ x 10’ dock doors. Assumed 200 CFM infiltration per dock door, subject to infiltration schedule
Cooler: (2) 10’ x 10’ doors from Cooler to Dock
Freezer: (2) 10’ x 10’ doors from Freezer to Dock
Each forklift and pallet lift is assumed to make a trip from the Dock into the Freezer or Cooler every six minutes. 5 seconds per opening. Doors are not assumed to have strip or air curtains. Subject to hourly production schedule
Cooler: (2) 7’ x 3’ exterior doors for personnel movement
Freezer: (2) 7’ x 3’ exterior doors for personnel movement
Freezer and Dock: (2) 7’ x 3’ interior doors for personnel movement
Cooler and Dock: (2) 7’ x 3’ interior doors for personnel movement (these doors were not considered to have door closers in the EEM as door closers are mandated between coolers and non-refrigerated spaces).
Freezer and Cooler: (2) 7’ x 3’ interior doors for personnel movement
Each interior door meant for man movement is estimated to be opened 2 times per operating hour with 5 seconds of passage time per opening. Also, each door is estimated to be stand-open for 60 seconds per hour as it is not immediately shut after the use.
The calculated air changes per hour for Cooler and Freezer due to the exterior door opening is estimated to be 0.005, based on an estimated</td></tr>
</table>

	50 CFM per door. The interior door leakage in the closed position is estimated to be 5% of the maximum through the door in the open position. EEM: each interior door is estimated to have 4 seconds of passage time per opening, as the cam hinge / spring type door closer quickly shuts the door to closed position. Also, the door stand-open is estimated to be 0 seconds per hour as the cam hinge / spring type door closer quickly shuts the door to closed position. The interior door leakage in the closed position is estimated to be 0% of the maximum through the door in the open position, as the magnetic gasket or snap door closer closes it tightly. Similarly, the calculated air changes per hour for Cooler and Freezer due to the exterior door opening is estimated to be 0.004.
Product Loads	Freezer: 41.7 MBH (Assumed 400,000 lb/day product load, from -5°F to -10°F, with specific heat of 0.50) Cooler: 226.0 MBH (Assumed 400,000 lb/day product load, from 45°F to 40°F, with specific heat of 0.65, plus 750 tons of respiring product. Heat of respiration: 5,500 Btuh/ton of product per 24 hours) Dock: 0 Btuh *Load is 100% sensible, 0% latent. Subject to production schedule*
General Facility Information and Envelope	
Azimuth	0°
Building Size	Freezer: 40,000 S.F. (200' x 200') Cooler: 40,000 S.F. (200' x 200') Dock: 12,000 S.F. (400' x 30') Total area: 92,000 S.F. Ceiling heights: 30'
Roof Construction	<u>Freezer</u> Construction: Built-up roof, R-40 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual) <u>Cooler</u> Construction: Built-up roof, R-28 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual) <u>Dock</u>

	Construction: Built-up roof, R-28 urethane insulation Inside Film Resistance: 0.90 Hr-ft^2-°F/Btu Absorptance: 0.25 (Thermal emittance of 0.75 per 2008 Title 24 compliance manual)
Wall Construction	Freezer R-36 urethane insulation Cooler R-28 urethane insulation Dock R-28 urethane insulation
Floor Construction	Freezer 8” Concrete slab, R-35 insulation Cooler 8” Concrete slab (no insulation, assumed concrete U-factor: 0.20) Dock 8” Concrete slab (no insulation, assumed concrete U-factor: 0.20)
Hours of Operation	9 AM to 1 AM, 7 Days/Week (lights, infiltration, people, forklift/pallet lifts)
Lighting	
Lighting Power Density	0.45 Watts/S.F. for Freezer and Cooler: as per Title 24 2019 for Commercial/Industrial Storage (Warehouse) 0.6 Watts/S.F. for Dock: as per Title 24 2019 for Commercial/Industrial Storage (Shipping & Handling)
Lighting ON Hours	Same as operating hours
Evaporator Coil Information	
Air Unit Fan Operation	All zones Fans run 100% of the time. Variable speed control, 70% minimum speed, 2 hours/day at 100% speed
Defrost Assumptions	Cooler: (2) 30-minute hot-gas defrosts/day Dock: (2) 30-minute off-cycle defrosts/day Freezer: (2) 30-minute hot-gas defrosts/day
Air Unit Quantity	Cooler: 6 Dock: 6 Freezer: 6
Air Unit Capacity	**Climate** | **Total for Cooler** | **Total for** | **Total for**

<table>
<tr><td>(per unit)</td><td>
<table>
<tr><th>Zone</th><th>(MBH) at 10°F</th><th>Freezer (MBH) at 10°F</th><th>Dock (MBH) at 10°F</th></tr>
<tr><td>CZ1</td><td>970</td><td>1,315</td><td>475</td></tr>
<tr><td>CZ2</td><td>1,030</td><td>1,360</td><td>670</td></tr>
<tr><td>CZ3</td><td>1,010</td><td>1,345</td><td>590</td></tr>
<tr><td>CZ4</td><td>1,020</td><td>1,355</td><td>650</td></tr>
<tr><td>CZ5</td><td>1,010</td><td>1,345</td><td>585</td></tr>
<tr><td>CZ6</td><td>1,015</td><td>1,350</td><td>665</td></tr>
<tr><td>CZ7</td><td>1,005</td><td>1,340</td><td>685</td></tr>
<tr><td>CZ8</td><td>1,035</td><td>1,365</td><td>710</td></tr>
<tr><td>CZ9</td><td>1,035</td><td>1,365</td><td>690</td></tr>
<tr><td>CZ10</td><td>1,050</td><td>1,375</td><td>755</td></tr>
<tr><td>CZ11</td><td>1,055</td><td>1,380</td><td>710</td></tr>
<tr><td>CZ12</td><td>1,045</td><td>1,370</td><td>735</td></tr>
<tr><td>CZ13</td><td>1,045</td><td>1,370</td><td>755</td></tr>
<tr><td>CZ14</td><td>1,055</td><td>1,380</td><td>670</td></tr>
<tr><td>CZ15</td><td>1,080</td><td>1,400</td><td>845</td></tr>
<tr><td>CZ16</td><td>1,005</td><td>1,340</td><td>530</td></tr>
</table>
</td></tr>
<tr><td>Design TD</td><td>10°F for all air units</td></tr>
<tr><td>Design SET:</td><td>Cooler: 25°F
Dock: 30°F
Freezer: -20°F</td></tr>
<tr><td>Air Flow Rate (per unit)</td><td>
<table>
<tr><th>Climate Zone</th><th>Total for Cooler (CFM)</th><th>Total for Freezer (CFM)</th><th>Total for Dock (CFM)</th></tr>
<tr><td>CZ1</td><td>180,000</td><td>240,000</td><td>90,000</td></tr>
<tr><td>CZ2</td><td>180,000</td><td>240,000</td><td>120,000</td></tr>
<tr><td>CZ3</td><td>180,000</td><td>240,000</td><td>108,000</td></tr>
<tr><td>CZ4</td><td>180,000</td><td>240,000</td><td>120,000</td></tr>
<tr><td>CZ5</td><td>180,000</td><td>240,000</td><td>108,000</td></tr>
<tr><td>CZ6</td><td>180,000</td><td>240,000</td><td>120,000</td></tr>
<tr><td>CZ7</td><td>180,000</td><td>240,000</td><td>132,000</td></tr>
<tr><td>CZ8</td><td>192,000</td><td>240,000</td><td>132,000</td></tr>
<tr><td>CZ9</td><td>192,000</td><td>240,000</td><td>132,000</td></tr>
<tr><td>CZ10</td><td>192,000</td><td>240,000</td><td>144,000</td></tr>
<tr><td>CZ11</td><td>192,000</td><td>252,000</td><td>132,000</td></tr>
<tr><td>CZ12</td><td>192,000</td><td>252,000</td><td>132,000</td></tr>
<tr><td>CZ13</td><td>192,000</td><td>252,000</td><td>144,000</td></tr>
<tr><td>CZ14</td><td>192,000</td><td>252,000</td><td>120,000</td></tr>
<tr><td>CZ15</td><td>204,000</td><td>264,000</td><td>156,000</td></tr>
</table>
</td></tr>
</table>

	CZ16	180,000	240,000	96,000

Fan Power

Climate Zone	Total for Cooler (kW)	Total for Freezer (kW)	Total for Dock (kW)
CZ1	27.36	36.96	13.41
CZ2	28.98	38.40	18.84
CZ3	28.44	37.92	16.63
CZ4	28.80	38.16	18.36
CZ5	28.44	37.92	16.52
CZ6	28.62	38.16	18.72
CZ7	28.26	37.68	19.27
CZ8	29.18	38.40	20.06
CZ9	29.18	38.40	19.40
CZ10	29.57	38.64	21.31
CZ11	29.76	38.81	20.06
CZ12	29.38	38.56	20.72
CZ13	29.38	38.56	21.31
CZ14	29.76	38.81	18.84
CZ15	30.40	39.34	23.87
CZ16	28.26	37.68	14.98

Based on specific efficiency of 34.0 Btuh/W at 10°F TD between SET and space temperature

EEM

The fan power was calculated for each climate zone at specific efficiency values of 40, 45, 50, 55, 60, 65 and 70 Btuh/W. The fan kW/CFM for different specific efficiency values and climate zones were used in the EEM.

Condenser Information

Condenser type: Evaporative cooled

Design TD and SCT

Climate Zone	Design WBT 0.1%	Design TD as per Title 24 2019	Design SCT (WBT + Design TD)
CZ1	61	20	81
CZ2	71	20	91
CZ3	67	20	87
CZ4	70	20	90
CZ5	67	20	87
CZ6	71	20	91
CZ7	72	20	92
CZ8	73	20	93

	CZ9	72	20	92
	CZ10	75	20	95
	CZ11	73	20	93
	CZ12	74	20	94
	CZ13	75	20	95
	CZ14	71	20	91
	CZ15	79	18	97
	CZ16	64	20	84
Capacity at 100°F SCT and 70°F WBT	**Climate Zone**	**Capacity (MBH)**		
	CZ1	8,426		
	CZ2	8,171		
	CZ3	8,241		
	CZ4	8,119		
	CZ5	8,227		
	CZ6	8,092		
	CZ7	8,025		
	CZ8	8,134		
	CZ9	8,188		
	CZ10	8,155		
	CZ11	8,220		
	CZ12	8,143		
	CZ13	8,065		
	CZ14	8,276		
	CZ15	9,089		
	CZ16	8,554		
Pump power and efficiency	5 HP, assumed 89.5% efficient (4.17 kW)			
Fan power based on 350 Btuh/W specific efficiency at 100°F SCT and 70°F WBT	**Climate Zone**	**Fan Power (kW)**		
	CZ1	19.9		
	CZ2	19.2		
	CZ3	19.4		
	CZ4	19.0		
	CZ5	19.3		
	CZ6	19.0		
	CZ7	18.8		
	CZ8	19.1		
	CZ9	19.2		
	CZ10	19.1		
	CZ11	19.3		

<table>
<tr><td></td><td><table>
<tr><td>CZ12</td><td>19.1</td></tr>
<tr><td>CZ13</td><td>18.9</td></tr>
<tr><td>CZ14</td><td>19.5</td></tr>
<tr><td>CZ15</td><td>21.8</td></tr>
<tr><td>CZ16</td><td>20.3</td></tr>
</table></td></tr>
<tr><td>Condenser fan control</td><td>70°F wetbulb-reset SCT control, variable-speed fan
1°F throttling range
69°F fixed backflood setpoint
Wetbulb-reset control TD: 17°F
Simulated wetbulb-ratio: 0.0</td></tr>
<tr><td>Compressor Information</td><td></td></tr>
<tr><td>Compressor description</td><td><u>LT System</u>
Serves freezer area. (2) ammonia screw compressors with slide-valve unloading
<u>HT System</u>
Serves cooler and dock areas. (2) ammonia screw compressors with slide-valve unloading</td></tr>
</table>

<table>
<tr><td>Suction Group Design SST</td><td>LT System: -23°F
HT System: 22°F</td></tr>
<tr><td>Suction Group Design SCT</td><td>As per the design SCT table given above</td></tr>
<tr><td>Compressor capacity, power, nominal motor HP, and motor efficiency at design conditions</td><td>
<table>
<tr><th rowspan="2">Climate Zone</th><th colspan="2">LT</th><th colspan="2">HT</th></tr>
<tr><th>Mass Flow of Each Compressor</th><th>Power of Each Compressor</th><th>Mass Flow of Each Compressor</th><th>Power of Each Compressor</th></tr>
<tr><td>CZ1</td><td>1,731</td><td>114.88</td><td>1,819</td><td>54.08</td></tr>
<tr><td>CZ2</td><td>1,792</td><td>134.54</td><td>2,213</td><td>76.94</td></tr>
<tr><td>CZ3</td><td>1,771</td><td>126.50</td><td>2,055</td><td>67.07</td></tr>
<tr><td>CZ4</td><td>1,780</td><td>131.82</td><td>2,162</td><td>74.06</td></tr>
<tr><td>CZ5</td><td>1,769</td><td>126.35</td><td>2,050</td><td>66.93</td></tr>
<tr><td>CZ6</td><td>1,777</td><td>133.42</td><td>2,189</td><td>76.10</td></tr>
<tr><td>CZ7</td><td>1,764</td><td>133.88</td><td>2,207</td><td>78.03</td></tr>
<tr><td>CZ8</td><td>1,795</td><td>137.70</td><td>2,285</td><td>82.01</td></tr>
<tr><td>CZ9</td><td>1,797</td><td>136.40</td><td>2,255</td><td>79.73</td></tr>
<tr><td>CZ10</td><td>1,810</td><td>142.36</td><td>2,378</td><td>88.01</td></tr>
<tr><td>CZ11</td><td>1,813</td><td>139.10</td><td>2,311</td><td>82.92</td></tr>
<tr><td>CZ12</td><td>1,804</td><td>140.40</td><td>2,336</td><td>85.03</td></tr>
<tr><td>CZ13</td><td>1,804</td><td>141.94</td><td>2,370</td><td>87.69</td></tr>
<tr><td>CZ14</td><td>1,813</td><td>136.16</td><td>2,243</td><td>78.00</td></tr>
<tr><td>CZ15</td><td>1,839</td><td>148.24</td><td>2,561</td><td>97.52</td></tr>
<tr><td>CZ16</td><td>1,764</td><td>121.48</td><td>1,953</td><td>60.82</td></tr>
</table>
LT: 200 HP motor on each compressor, 94.5% efficient
HT: 150 HP motor on each compressor, 93.6% efficient
The compressor mass flow (along with associated power) in each climate zone were scaled to match the design cooling load. This was done to ensure accurate comparison of the performance characteristics of the compressors in each design. This eliminates unintended and unrepresentative advantages that can arise from sizing differences in the actual equipment in each climate zone.
</td></tr>
<tr><td>Suction Group SST Control Strategy</td><td>LT System: -23°F fixed SST setpoint, 1°F throttling range
HT System: 22°F fixed SST setpoint, 1°F throttling range</td></tr>
<tr><td>Compressor capacity control</td><td>Slide valve unloading</td></tr>
<tr><td>Suction Group Throttling Range</td><td>1°F</td></tr>
<tr><td>Oil cooling type</td><td>Thermosyphon</td></tr>
</table>

Useful superheat for compressor ratings	0°F
Liquid subcooling for compressor ratings	0°F