Prescriptive Measure Assessment

MA26C02-B-RXASSESS

Prepared by Resource Innovations

Date: 10.02.2026

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Executive Summary

In March of 2026, the Massachusetts Program Administrators (PAs) contracted with Resource Innovations (RI) to review a selection of commercial and industrial (C&I) prescriptive measures to inform annual updates to the Massachusetts (MA) Technical Reference Manual (TRM) 2026 Prospective Version.[1] This TRM update focused on key prescriptive C&I measures associated with 20% of the sector's 2025-2027 net lifetime savings. This selection of prescriptive measures had not been reviewed lately due to prioritization and intentional focus on custom measure evaluation in recent years.

The study centered around three goals:

1. Identifying prescriptive measures in need of evaluation and updates. .
2. Exploring opportunities to cost-effectively update the measure savings values using existing, secondary data sources.
3. Recommending updates to measure savings when sufficient secondary sources were identified to support revisions to the TRM values.

RI identified 43 measures that were not recently evaluated or part of an ongoing study. We ranked these measures based on actual lifetime savings generated in 2025 and found that the top eight measures contributed 86% of the savings from all 43 measures. Based on guidance from the study's subcommittee, made up of the PAs, Energy Efficiency Advisory Council (EEAC) consultants, and other C&I evaluation teams, we selected seven measures for further review.

A summary of all study findings is provided in Section 3. Many of the recommended updates in Section 2 are minor adjustments aligning input assumptions and sources with more current data. The most significant recommended revisions relate to the Motor & VFD measure methodology, as outline in Appendix C. Collectively, these recommended updates help ensure that the MA TRM relies on the most recent and best available savings methodologies and input assumptions going forward.

[1] https://www.masssavedata.com/documents/technical-reference/Technical%20Reference%20Manual%202026%20Prospective%20-%20Final.pdf

1 Introduction

In recent years, Commercial & Industrial (C&I) evaluation resources have focused primarily on custom measure evaluation. Custom measures have historically driven and had the highest impact on total C&I sector savings—a trend that continues in the 2025–2027 three-year implementation cycle PAs anticipate that half the sector's net lifetime savings will come from custom measures. However, the focus on custom measures meant that the PAs have not recently evaluated several key prescriptive C&I measures associated with 20% of the sector's 2025-2027 net lifetime savings.

This report summarizes the recommended measure savings updates resulting from RI's review of prioritized prescriptive C&I measures for the MA TRM 2026 Prospective Version. The PAs and EEAC consultants collaborated with RI and provided input throughout the measure prioritization, review, and savings update process.

1.1 Study Goals

The goals of this study are to improve the reliability of the measure savings associated with prescriptive C&I measures by:

1. Identifying prescriptive measures in need of evaluation and updates.
2. Exploring opportunities to cost-effectively update the measure savings values using existing, secondary data sources
3. Recommending updates to measure savings when sufficient secondary sources were identified to support revisions to the TRM values.

1.2 Measure Prioritization

In coordination with the PAs, EEAC, and other C&I evaluation teams, RI created a list of 43 prescriptive C&I measures in the MA TRM 2026 Prospective Version that are not included in an ongoing study or in a recent evaluation. To identify the most impactful of these 43 measures, the team sorted the list by actual lifetime savings generated in 2025 (the first year of the current three-year plan). The team found that the top eight measures in the list represented 86% of the savings from all 43 measures.

In close collaboration with the PA evaluation, implementation, and engineering teams, as well as the EEAC consultants, the RI team selected seven of the eight measures to focus on in this study. A previous study identified one of the eight measures (COM-R-RFR) already had a strong methodology and supporting sources. Since that measure required no further review, it was excluded from this study.

In Table 1 we summarize the seven measures selected for review. These seven measures were selected because they contributed substantially to the 2025 actual lifetime savings.

Table 1. Measures Selected for Further Review.

Measure Code	Measure(s)	Percent of 2025 Actual C&I Portfolio All Fuel Net Lifetime Savings
COM-MD-MVFD	Prescriptive - Motors & VFD	6.8%
COM-BS-IN	Prescriptive Insulation (Electric, Oil, Propane)	4.2%
COM-BS-AS	Prescriptive Air Sealing (Electric, Oil, Propane)	1.1%
COM-BS-IREU	Insulation - C&I Metered Multi-Family	1.0%
COM-MAD-VFD	Prescriptive - Variable Frequency Drive	0.9%
COM-CA-PCA	Prescriptive - Compressed Air	0.8%
COM-R-PR	Prescriptive - Refrigeration	0.5%

1.3 Secondary Research Approach

Our approach to finding and reviewing secondary research relied on comparing current savings methodologies with other TRMs as well identifying other key sources unique to each measure.

Table 2 summarizes the secondary research and sources our team reviewed during this study.

Table 2. Summary of Secondary Sources Reviewed for Each Measure.

Measure(s)	Measure Code(s)	Sources

All	All	TRMs: IL[2], NY[3], WI[4], IESO[5], MN[6]
Motors & VFDs	COM-MD-MVFD COM-MAD-VFD	ComStock®[7] Lawrence Berkley National Laboratory (LBNL) U.S. Motor System Market Assessment (MSMA)[8] Department of Energy Technical Support Documents
Insulation and Air Sealing	COM-BS-IN COM-BS-IREU COM-BS-AS	DNV (2025). Custom Express Weatherization Tool Evaluation Final Memo; Custom Express Weatherization Tool – Deemed Prescriptive Values; ORNL (2023). Energy Savings and Moisture Transport Calculator[9]; Massachusetts State Building Code
Compressed Air	COM-CA-PCA	DNV (2025). Industry Standard Practice: Compressed Air LBNL (2016). Improving Compressed Air System Performance A Sourcebook for Industry Third Edition
Refrigeration	COM-R-PR	DNV (2022). X1931-5 PSD Commercial Refrigeration Efficiency Update Study ORNL (2015). Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits. Cadmus (2015). Commercial Refrigeration Loadshape Project. DOE (2014). Technical Support Document: Energy Efficiency Program for Consumer and Industrial Equipment Commercial Refrigeration Equipment.

[2] https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010126_v14.0_Vol_2_C_and_I_09192025_FINAL.pdf
[3] https://dps.ny.gov/technical-resource-manual-version-13-filed-december-12-2025-effective-january-1-2026
[4] https://assets.focusonenergy.com/production/inline-files/Focus-on-Energy-2025-TRM.pdf
[5] https://www.ieso.ca/-/media/Files/IESO/Document-Library/conservation/Measures-and-Assumptions/IESO-Prescriptive-Measures-Assumptions-List-Technical-Supplement-June-2025.pdf
[6] https://mn.gov/commerce-stat/trm/releases/5.0.pdf
[7] https://comstock.nlr.gov/
[8] https://motors.lbl.gov/
[9] https://airleakage-calc.ornl.gov/#/

2 Recommendations

RI developed recommendations related to the seven measures reviewed. Summaries of the recommendations are provided below. Detailed TRM language updates, when applicable, are housed in Section 4.

1. **COM-MAD-VFD: Variable Frequency Drive**

   RI recommends updating the measure savings using the existing methodology, but with more current input assumptions. We provide updated savings values in Section 0**Error! Reference source not found.** and summarize the updated savings methodology in Appendix C .

2. **COM-MD-MVFD: Motors & VFDs**

   RI recommends removing motor savings from this measure because the minimum motor efficiency currently required on the Mass Save application[10] is equal to the minimum efficiency allowed by the current federal standard, which has been in effect since December 19, 2010. At this point, existing motors replaced through the program are unlikely to be below the minimum federal standard, which means no energy savings should be expected from motors.

   Without the motor component this measure becomes the COM-MAD-VFD, Variable Frequence Drive (VFD) measure. Consequently, we recommend removing COM-MD-MVFD from the TRM. Most of the current savings for COM-MD-MVFD are associated with the installation of a VFD or integrated VFD, with only a minor portion of the savings coming from the assumed higher efficiency motor; therefore, this change should have a minor impact on overall program savings.

   We considered a couple alternative options for this measure including maintaining current application efficiencies and increasing the application efficiencies to align with NEMA Premium 4 efficiencies. The group decided against both options for the following reasons.

   - **Maintain Current Application Efficiencies:** this option assumed that some incentivized motors would exceed the minimum efficiencies. Estimating savings would require analyzing historic program data to estimate average motor efficiencies

[10] https://www.masssave.com/business/rebates-offers-services/specialty-equipment/-/media/3D0439B561E6402DB31E0DAE25A4FE96.ashx

of incentivized motors. Gathering this data would require significant effort and would not necessarily result in significant savings.

- **Increase Application Efficiencies:** the option could have impacts on project eligibility and volume of applications. The concern was related to NEMA Premium 4 motors being too costly with limited availability, which could decrease program participation. The increase in savings from the NEMA Premium 4 efficiencies would be minor and most likely overshadowed by a decrease in program participation.

3. COM-BS-AS: Prescriptive Air Sealing

RI recommends updating three assumed inputs using the existing methodology:

- Revise the HDD using TMYx data.
- Align the temperature setpoints with the current Wx tool custom assumptions.
- Align the heating equipment efficiency with the Massachusetts Commercial and Industrial Existing Buildings Baseline Study.
- Once the concurrent update to the Custom Weatherization Tool is complete, review the updates, specifically relating to the interaction between mechanical ventilation and infiltration, and confirm they do not impact any of the assumed prescriptive inputs.

4. COM-BS-IN: Prescriptive Insulation

RI recommends no changes currently. Once the concurrent update to the Custom Weatherization Tool is complete, we suggest reviewing the updates and confirming they do not impact any of the assumed prescriptive inputs.

5. COM-BS-IREU: Insulation C&I Metered Multi-Family

RI recommends updating the baseline efficiency language to align with the custom nature of the savings calculation for this measure.

6. COM-CA-PCA: Compressed Air

RI recommends updating a few inputs and documenting several sources across compressed air technologies. The following is a summary of the recommended changes:

- **Air Nozzle:** align efficiency with 2025 ISP.
- **Low Pressure Drop Filter:** add a source for savings assumptions.
- **Zero Loss Condensate Drains**: add a source for savings assumptions and align the deemed inputs.

7. COM-R-PR: Refrigeration

RI recommends aligning inputs across refrigeration technologies and updating assumptions to align with publicly available sources where applicable. The following is a summary of the recommended changes:

- **Evaporator Fan Control:** update power factor and compressor hours.
- **ECM Evaporator Fan motors for Walk-in Coolers:** update power factor, load reduction factor, and evaporator fan run time.
- **Cooler Night Cover:** update savings factors.
- **Case Motor Replacement:** update load reduction factor and refrigeration system efficiency.
- **Door Heater Controls:** annual door heater run hours and update door heater off time.
- **Electronic Defrost Control:** update defrost reduction factor.
- **Novelty Cooler Shutoff:** update weighted average annual duty cycle.
- **Walk-In Cooler Economizer:** add sources and clean up the calculation.

3 Study Findings

3.1 Variable Frequency Drive

After reviewing the current TRM methodology, RI's key findings are:

- TRM values (for kWh/hp) match the supporting documentation.
- Methodology for the deemed kWh/HP is sound.
- Source documents are not transparent enough to compare assumptions with the current industry standards.
- Assumptions were based on old data sets. For example, the current load shapes use Itron's proprietary software eShapes data from 2002

RI presented our findings and proposed a measure calculation refresh to the subcommittee. The refresh would leverage the existing methodology update input assumptions using the current data sources and provide a transparent workbook with all data and formulas used to calculate the savings. The subcommittee approved this approach. RI have included a full description of the VFD savings methodology in Appendix C.

3.2 Motors & VFD

RI's key findings after the Motors & VFD measure current TRM methodology review were the same as the findings uncovered during the Variable Frequency Drive measure review, with a minor difference. The TRM savings (kWh/hp) values are higher than those presented in source documents. We believe the difference accounts for the motor savings as the source document only accounts for the VFD savings.

RI proposed leveraging the Variable Frequency Drive measure refresh to update the VFD portion of this measure's savings and to document the savings associated with the motor's replacement. However, while working on the motor savings update, RI determined that it is unlikely this measure can claim motor savings going forward. The current minimum motor efficiencies on the Mass Save Motor & VFD application[11] are equal to the current federal standard that has been in effect since December 19, 2010.

Reviewing the LBNL MSMA[12] data, we found the age of most fan and pump motors, (that LBNL MSMA was able to collect data for), are less than 20 years old. Based on this information, it is assumed that baseline motors are at the current federal standard. As a

[11] https://www.masssave.com/business/rebates-offers-services/specialty-equipment/-/media/3D0439B561E6402DB31E0DAE25A4FE96.ashx
[12] https://motors.lbl.gov/

result, the baseline motor efficiency is equal to the replacement motor efficiency and generates no savings.

3.3 Prescriptive Air Sealing

The prescriptive air sealing savings values in the TRM are based on the Custom Express Weatherization Savings Calculator (Wx tool). RI's initial key findings after reviewing the prescriptive component of the tool were:

- TRM deemed savings match the Wx tool prescriptive values.
- The prescriptive air sealing methodology uses a heating degree days (HDD) method and does not align with the custom methodology.
- Only heating savings are considered.
- The PAs are currently revising the custom portion of the Wx tool based on a recent DNV evaluation of the Wx tool[13].

Based on the initial findings, RI proposed updating several input assumptions used to calculate heating degree days (HDD) with more current sources and data. RI was unable to find more recent or robust data related to the current savings factor (CFM 50) or the conversion factor (CFM50 to CFM natural infiltration).

The HDD calculation uses TMY3 instead of TMYx. Additionally, the temperature setpoints used to calculated HDD do not align with the recommended values in DNV's recent Custom Express Weatherization Tool Evaluation Final Memo. However; RI found that the hours used to assume occupied versus unoccupied set points align with DNV's *Massachusetts Commercial and Industrial Existing Buildings Baseline Study*.

3.4 Prescriptive Insulation

The prescriptive insulation measure values in the TRM are based on the Wx tool. RI's key findings after reviewing the prescriptive component of the tool were:

- TRM deemed savings match the Wx tool prescriptive values and include cooling savings.
- A previous subcommittee vetted current input assumptions and calculations used to generate prescriptive values in the Wx tool. The prescriptive values align with comparable custom outputs. For example, space cooling setpoints are 75° F for occupied and 80° F for unoccupied.
- The PAs are currently revising the custom portion of the Wx tool based on a recent DNV evaluation of the Wx tool**Error! Bookmark not defined.**.

[13] https://ma-eeac.org/wp-content/uploads/MA2507-B-WEATOOL-Tool-Evaluation-Memo_FINAL_clean.pdf

The assumed heating equipment efficiency did not align with the custom assumptions in the Wx tool and RI, could not find a source supporting the existing values. RI identified DNV's *Massachusetts Commercial and Industrial Existing Buildings Baseline Study* as a source to update the heating equipment efficiency.

3.5 Insulation - C&I Metered Multi-Family

The review findings for the Insulation C&I Metered Multi-Family measure were:

- Savings methodology for the Insulation C&I Metered Multi-Family measure is sound and aligns with the equivalent residential measure.
- The TRM baseline language is inaccurate as it states default R-values for ceiling, floor, and wall. RI confirmed that baseline insulation values are custom inputs based on when the building was constructed.

3.6 Prescriptive Compressed Air

This measure covers five different compressed air technologies including:

- Air Nozzle
- Refrigerated Air Dryers
- High Efficiency Air Compressor
- Low Pressure Drop Filter
- Zero Loss Condensate Drains

RI had two key findings after reviewing the savings methodologies for the five technologies in the prescriptive compressed air measure:

- TRM savings methodologies are sound.
- Some measures have default inputs with no sources.

3.7 Prescriptive Refrigeration

This measure encompasses eight different refrigeration technologies including:

- Evaporator Fan Control
- ECM Evaporator Fan Motors for Walk-In Coolers
- Cooler Night Cover
- Case Motor Replacement
- Door Heater Controls

- Electronic Defrost Control
- Novelty Cooler Shutoff
- Walk In Cooler Economizer

RI had three key findings after reviewing the savings methodologies for the eight technologies in the prescriptive refrigeration measure.

- Savings methodologies are sound across all technologies.
- Many assumed inputs are based on NRM (vendor) assumptions that are not publicly available and require updating.
- Deemed inputs vary across measures.

4 TRM Language Updates

4.1 Overview

Each measure-specific summary in this report includes the following information:

- The descriptive measure name (e.g., "Motor – Motors & VFDs")
- The TRM measure code
- The page number where the measure can be found in the PDF version of the TRM
- TRM language updates, which may include the following:
    - Measure description
    - BCR Measure IDs
    - Algorithms for calculating energy savings.
    - Baseline and high efficiency
    - Source endnotes

The TRM language updates section includes the existing language from the current TRM in black text. We used red text to indicate changes, such as additions and deletions (shown using the strikethrough feature, e.g., ~~deletion~~).

Text formatted like this is a comment and not intended for inclusion in the TRM.

4.2 Variable Frequency Drive

Measure Code	COM-MAD-VFD
Market	Commercial
Program Type	Retrofit
Category	Motors and Drives

Measure Description:
This measure covers the installation of variable speed drives according to the terms and conditions stated on the statewide worksheet. The measure covers multiple end use types and building types. The installation of this measure saves energy since the power required to rotate a pump or fan at lower speeds requires less power than when rotated at full speed.

BCR Measure IDs:

Measure Name	Core Initiative	BCR Measure ID
Prescriptive - Motors & VFD	C&I Small Business Turnkey Retrofit (CI_SBTR)	EC1c031
Prescriptive - Motors & VFD	C&I Existing Building (CI_EXST)	EC1b023

Algorithms for Calculating Primary Energy Impact:
$\Delta kWh = (HP)x(kWh/HP)$
$\Delta kW_{SP} = (HP)x(kW/HP_{SP})$
$\Delta kW_{WP} = (HP)x(kW/HP_{WP})$

Where:
HP = Rated horsepower for the impacted motor.
kWh / HP = Annual electric energy reduction based on building and equipment type. See table below.
kW / HPSP = Summer demand reduction based on building and equipment type. See table below.
kW / HP_{WP} = Winter demand reduction based on building and equipment type. See table below.

Savings factors below already account for motor efficiency and consequently an adjustment is not required in the algorithm.

Savings Factors for C&I VFDs (kWh/HP, kW/HP$_{SP}$, and kW/HP$_{WP}$) [1]

Building Type	Building Exhaust Fan	Cooling Tower Fan	Chilled Water Pump	Boiler Feed Water Pump	Hot Water Circulating Pump	MAF - Make-up Air Fan	Return Fan	Supply Fan	WS Heat Pump Circulating Loop
Annual Energy Savings Factors (kWh/HP)									
University/ College	3641	449	745	2316	2344	3220	1067	1023	3061
Elementary/ High School	3563	365	628	1933	1957	3402	879	840	2561
Multi-Family	3202	889	1374	2340	2400	3082	1374	1319	3713
Hotel/ Motel	3151	809	1239	2195	2239	3368	1334	1290	3433
Health	3375	1705	2427	2349	2406	3002	1577	1487	3670
Warehouse	3310	455	816	2002	2087	3229	1253	1205	2818
Restaurant	3440	993	1566	1977	2047	2628	1425	1363	3542
Retail	3092	633	1049	1949	2000	2392	1206	1146	2998
Grocery	3126	918	1632	1653	1681	2230	1408	1297	3285
Offices	3332	950	1370	1866	1896	3346	1135	1076	3235
Summer Demand Savings Factors (kW/HP$_{SP}$)									
University/ College	0.109	-0.023	0.174	0.457	0.091	0.109	0.287	0.274	0.218
Elementary/ High School	0.377	-0.023	0.174	0.457	0.091	0.109	0.287	0.274	0.218

Building Type	Building Exhaust Fan	Cooling Tower Fan	Chilled Water Pump	Boiler Feed Water Pump	Hot Water Circulating Pump	MAF - Make-up Air Fan	Return Fan	Supply Fan	WS Heat Pump Circulating Loop
Multi-Family	0.109	-0.023	0.174	0.457	0.091	0.109	0.287	0.274	0.218
Hotel/ Motel	0.109	-0.023	0.174	0.457	0.091	0.109	0.287	0.274	0.218
Health	0.109	-0.023	0.174	0.457	0.091	0.109	0.287	0.274	0.218
Warehouse	0.109	-0.023	0.174	0.457	0.091	0.261	0.287	0.274	0.218
Restaurant	0.261	-0.023	0.174	0.457	0.091	0.109	0.287	0.274	0.218
Retail	0.109	-0.023	0.174	0.457	0.091	0.109	0.287	0.274	0.218
Grocery	0.261	-0.023	0.174	0.457	0.091	0.109	0.287	0.274	0.218
Offices	0.109	-0.023	0.174	0.457	0.091	0.109	0.287	0.274	0.218
Winter Demand Savings Factors (kW/HP_{WP})									
University/ College	0.377	-0.006	0.184	0.457	0.21	0.109	0.26	0.252	0.282
Elementary/ High School	0.457	-0.006	0.184	0.457	0.21	0.109	0.26	0.252	0.282
Multi-Family	0.109	-0.006	0.184	0.355	0.21	0.109	0.26	0.252	0.282
Hotel/ Motel	0.109	-0.006	0.184	0.418	0.21	0.109	0.26	0.252	0.282
Health	0.377	-0.006	0.184	0.275	0.21	0.109	0.26	0.252	0.282
Warehouse	0.377	-0.006	0.184	0.178	0.21	0.261	0.26	0.252	0.282

~~Building Type~~	~~Building Exhaust Fan~~	~~Cooling Tower Fan~~	~~Chilled Water Pump~~	~~Boiler Feed Water Pump~~	~~Hot Water Circulating Pump~~	~~MAF - Make-up Air Fan~~	~~Return Fan~~	~~Supply Fan~~	~~WS Heat Pump Circulating Loop~~
~~Restaurant~~	~~0.109~~	~~0.006~~	~~0.184~~	~~0.355~~	~~0.21~~	~~0.109~~	~~0.26~~	~~0.252~~	~~0.282~~
~~Retail~~	~~0.109~~	~~0.006~~	~~0.184~~	~~0.275~~	~~0.21~~	~~0.109~~	~~0.26~~	~~0.252~~	~~0.282~~
~~Grocery~~	~~0.457~~	~~0.006~~	~~0.184~~	~~0.418~~	~~0.21~~	~~0.109~~	~~0.26~~	~~0.252~~	~~0.282~~
~~Offices~~	~~0.457~~	~~0.006~~	~~0.184~~	~~0.418~~	~~0.21~~	~~0.109~~	~~0.26~~	~~0.252~~	~~0.282~~

The following table provides updated savings for all current VFD applications; however, the building types have changed. The new building types align with available building types in ComStock, as described in Appendix B. We have not provided mapping between the old building types and the new building types based on feedback from the Existing Buildings Subcommittee.

Building Type	Building Exhaust Fan	Cooling Tower Fan	Chilled Water Pump	Boiler Feed Water Pump	Hot Water Circulating Pump	MAF - Make-up Air Fan	Return Fan	Supply Fan	WS Heat Pump Circulating Loop
Annual Energy Savings Factors (kWh/HP)									
Full-Service Restaurant	2,156	843	940	1,959	3,945	2,156	3,776	3,776	2,585
Grocery	1,310	1,024	1,140	2,005	2,005	1,310	3,735	3,735	2,689

Building Type	Building Exhaust Fan	Cooling Tower Fan	Chilled Water Pump	Boiler Feed Water Pump	Hot Water Circulating Pump	MAF - Make-up Air Fan	Return Fan	Supply Fan	WS Heat Pump Circulating Loop
Hospital	3,467	1,548	1,724	2,339	3,742	3,467	3,694	3,694	4,249
Large Hotel	3,390	1,309	1,455	2,075	3,996	3,390	3,770	3,770	3,209
Large Office	3,925	1,468	1,636	1,921	3,916	3,925	3,884	3,884	2,726
Medium Office	3,425	1,368	1,526	1,876	4,320	3,425	3,805	3,805	2,543
Outpatient	3,499	1,333	1,489	1,758	4,109	3,499	3,824	3,824	2,627
Primary School	3,261	929	1,039	1,854	3,951	3,261	3,028	3,028	2,095
Quick Service Restaurant	1,535	996	1,110	1,843	1,843	1,535	3,746	3,746	2,383
Retail Stand alone	2,549	745	830	1,646	1,646	2,549	3,351	3,351	2,098
Retail Strip mall	2,660	766	853	1,591	1,591	2,660	3,208	3,208	2,123
Secondary School	2,931	840	939	1,777	4,025	2,931	2,852	2,852	1,983
Small Hotel	2,966	1,963	2,188	1,258	2,007	2,966	3,916	3,916	2,445
Small Office	2,937	818	913	1,578	1,844	2,937	3,867	3,867	1,787

Building Type	Building Exhaust Fan	Cooling Tower Fan	Chilled Water Pump	Boiler Feed Water Pump	Hot Water Circulating Pump	MAF - Make-up Air Fan	Return Fan	Supply Fan	WS Heat Pump Circulating Loop
Warehouse	3,445	759	848	1,220	1,323	3,445	3,921	3,921	1,220
Summer Demand Savings Factors (kW/HP$_{SP}$)									
Full-Service Restaurant	0.009	0.322	0.358	0.014	0.419	0.009	0.215	0.215	0.365
Grocery	-0.020	0.290	0.321	0.455	0.455	-0.020	0.158	0.158	0.314
Hospital	0.295	0.412	0.457	0.498	0.221	0.295	0.316	0.316	0.339
Large Hotel	0.209	0.360	0.398	0.032	0.008	0.209	0.268	0.268	0.350
Large Office	0.366	0.387	0.427	0.040	0.135	0.366	0.367	0.367	0.396
Medium Office	0.248	0.395	0.437	0.029	0.276	0.248	0.328	0.328	0.414
Outpatient	0.219	0.419	0.464	0.041	0.162	0.219	0.308	0.308	0.396
Primary School	0.332	0.413	0.458	0.059	0.219	0.332	0.360	0.360	0.447
Quick Service Restaurant	-0.020	0.314	0.348	0.027	0.027	-0.020	0.179	0.179	0.355
Retail Stand alone	0.072	0.330	0.366	0.003	0.003	0.072	0.248	0.248	0.366

Building Type	Building Exhaust Fan	Cooling Tower Fan	Chilled Water Pump	Boiler Feed Water Pump	Hot Water Circulating Pump	MAF - Make-up Air Fan	Return Fan	Supply Fan	WS Heat Pump Circulating Loop
Retail Strip mall	0.065	0.334	0.370	0.402	0.402	0.065	0.244	0.244	0.380
Secondary School	0.357	0.410	0.455	0.086	0.164	0.357	0.384	0.384	0.440
Small Hotel	0.149	0.313	0.347	0.003	-0.018	0.149	0.244	0.244	0.347
Small Office	0.126	0.366	0.406	0.008	0.496	0.126	0.289	0.289	0.410
Warehouse	0.240	0.339	0.377	0.016	0.017	0.240	0.325	0.325	0.377
Winter Demand Savings Factors (kW/HP$_{WP}$)									
Full-Service Restaurant	-0.02	0.38	0.43	0.43	0.38	-0.02	0.43	0.34	0.34
Grocery	-0.02	0.22	0.25	0.45	0.45	-0.02	0.45	0.34	0.34
Hospital	-0.02	0.02	0.03	0.43	0.38	-0.02	0.43	0.26	0.26
Large Hotel	0.28	0.02	0.02	0.45	0.34	0.28	0.47	0.39	0.39
Large Office	0.14	0.02	0.02	0.46	0.46	0.14	0.48	0.42	0.42
Medium Office	0.14	0.02	0.02	0.46	0.48	0.14	0.47	0.40	0.40
Outpatient	0.08	0.02	0.02	0.43	0.48	0.08	0.44	0.41	0.41

Building Type	Building Exhaust Fan	Cooling Tower Fan	Chilled Water Pump	Boiler Feed Water Pump	Hot Water Circulating Pump	MAF - Make-up Air Fan	Return Fan	Supply Fan	WS Heat Pump Circulating Loop
Primary School	0.08	0.01	0.01	0.45	0.44	0.08	0.45	0.41	0.41
Quick Service Restaurant	0.04	0.38	0.43	0.42	0.42	0.04	0.43	0.32	0.32
Retail Stand alone	0.13	0.16	0.18	0.45	0.45	0.13	0.45	0.40	0.40
Retail Strip mall	0.09	0.38	0.43	0.45	0.45	0.09	0.45	0.40	0.40
Secondary School	0.36	0.02	0.02	0.45	0.47	0.36	0.45	0.43	0.43
Small Hotel	0.27	0.36	0.40	0.44	0.42	0.27	0.44	0.40	0.40
Small Office	0.22	0.04	0.04	0.40	0.45	0.22	0.40	0.43	0.43
Warehouse	0.30	0.02	0.02	0.39	0.41	0.30	0.39	0.43	0.43

Baseline Efficiency:
The baseline efficiency case measure varies with equipment type. All baselines assume either a constant or 2-speed motor with significant load diversity and no existing VFD. Air or water volume/temperature is controlled using three-way or throttling valves, dampers, and/or inlet vanes ~~reheats~~. Additionally, if the local code requires a VFD for the specific application, then only projects that are not considered additions, alterations, or change of occupancy or use (categories requiring a project to meet current code) are eligible.

High Efficiency:
In the high efficiency case, pump flow or fan air volume is directly controlled using downstream information. The pump or fan will automatically adjust its speed based on inputted set points and the downstream feedback it receives. In hydronic systems, removal and/or replacement of existing valves will occur to ensure efficient operation of the new VFD.

Measure Life:
This measure has been determined to be an add on single baseline measure for retrofit scenarios.[2] [3]

Measure Name	Core Initiative	PA	EUL	OYF	RUL	AML
Prescriptive - Motors & VFD	CI_SBTR	All	13	n/a	n/a	13

Other Resource Impacts:
There are no other resource impacts identified for this measure. Interactive HVAC effects were not considered.

Impact Factors for Calculating Adjusted Gross Savings:

Measure Name	Core Initiative	PA	ISR	RR_E	RR_{NE}	RR_{SP}	RR_{WP}	CF_{SP}	CF_{WP}
Prescriptive - Motors & VFD	CI_SBTR	Eversource / Unitil	1.00	0.946	n/a	1.265	1.415	1.00	1.00
Prescriptive - Motors & VFD	CI_SBTR	National Grid / CLC	1.00	1.049	n/a	0.941	1.174	1.00	1.00

In-Service Rates:

All installations have 100% in service rate since all PAs programs include verification of equipment installations.

Realization Rates:
Energy and Demand RRs for Turnkey installations are based on the Impact Evaluation of PY 2017 Small Business Initiative Non-Lighting Measures study.[4]

Coincidence Factors:
Coincidence factors are derived from the C&I Loadshape study.[5]

Impact Factors for Calculating Net Savings:
All PAs use statewide prescriptive net-to-gross results for non-residential end use measures.[6]

Measure Name	Core Initiative	PA	NTG
Prescriptive - Motors & VFD	CI_SBTR	All	0.94

Non-Energy Impacts:
Non-energy benefits come from the 2021 NEI study.[7]

Measure Name	Core Initiative	PA	Annual $ per Unit	One-time $ per Unit	Annual $ per kWh[6]	One-time $ per KWh	Annual $ per Therm	One-time $ per Therm
Prescriptive - Motors & VFD	CI_SBTR	All			$0.003			

Endnotes:
1 : ~~Chan, Tumin (2010). Formulation of a Prescriptive Incentive for the VFD and Motors & VFD impact tables at NSTAR.~~
~~Chan_2010_Formulation_of_a_Prescriptive_Incentive_for_the_VFD_and_Motors_and_VFD_Impact_Tables_at_NSTAR~~ RI (2026). Prescriptive Measure Assessment MA26C02-B-RXASSESS.
2 : Energy & Resource Solutions (2005). Measure Life Study. ERS_2005_Measure_Life_Study
3 : Baseline Categories and preliminary Out Year Factors are described at a high level in DNV GL, ERS (2018). Portfolio Model Companion Sheet. Additional background on the baseline categorization given in DNV GL, ERS (2018). Portfolio Model Methods and Assumptions – Electric and Natural Gas Memo.
2018_DNVGL_ERS_Portfolio_Model_Companion_Sheet
4 : DNV GL. (2019). Impact Evaluation of PY 2017 Small Business Initiative Non-lighting measures. Final Report MA19C03-E-SBIMPCT 03202020
5 : DNV (2024). C&I Impact Shape Study. 2024_DNV_C&I_Impact Shape Study

6 : NMR Group, Inc. (2024). C&I Omnibus Net-to-Gross (NTG) Study 2024_NMR_C&I_Omnibus_Study
7 : NMR Group Inc (2021). O&M and Non-O&M NEI Study. 2021_NMR_CIOM and NonOM NEI Study

4.3 Prescriptive Air Sealing

Measure Code	COM-BS-AS
Market	Commercial
Program Type	Retrofit
Category	Building Shell

Measure Description:
Air sealing to an existing building. The building must be 20,000 square feet or less in size and cannot have heating and cooling loads that are highly driven by ventilation requirements, such as those incurred by food service or laboratory settings.

BCR Measure IDs:

Measure Name	Core Initiative	BCR Measure ID
Air Sealing, Electric	C&I Multifamily (CI_MF)	EC1d001
Air Sealing, Oil	C&I Multifamily (CI_MF)	EC1d002
Air Sealing, Other	C&I Multifamily (CI_MF)	EC1d003
Moderate Income Qualified - Air Sealing, Electric	C&I Multifamily (CI_MF)	EC1d033
Moderate Income Qualified - Air Sealing, Oil	C&I Multifamily (CI_MF)	EC1d034
Moderate Income Qualified - Air Sealing, Other	C&I Multifamily (CI_MF)	EC1d035
Air Sealing, Gas	C&I Multifamily (CI_MF)	GC1d001
Moderate Income Qualified - Air Sealing, Gas	C&I Multifamily (CI_MF)	GC1d024

Algorithms for Calculating Primary Energy Impact:
Savings are derived from a combination of sources, including the ~~Guidehouse Energy Optimization model~~ *Massachusetts Commercial and Industrial Existing Buildings Baseline Study*,[†] TMYx meteorological data, residential air sealing program data, and a Lawrence Berkeley National Laboratory model for estimating natural infiltration rates. Savings are deemed per hour of air sealing work. The savings in the BC models are PA specific.

Deemed Savings (per hour of air sealing work)

Measure Name	Electric Savings - Annual kWh	Oil Savings - MMBtu per year	Propane Savings - MMBtu per year	Gas Savings - MMBtu per year
Prescriptive Air Sealing, Electric	~~175.95~~ 170.74	n/a	n/a	n/a
Prescriptive Air Sealing, Oil	n/a	~~0.78~~ 0.69	n/a	n/a
Prescriptive Air Sealing, Propane	n/a	n/a	~~0.71~~ 0.69	n/a
Prescriptive Air Sealing, Gas	n/a	n/a	n/a	~~0.71~~ 0.70

Savings are only from heating. Cooling would have a minor impact, contributing less than 6 kWh to the electric savings.

Baseline Efficiency:
The baseline efficiency case is the existing building before the air sealing measure is implemented. The baseline building is characterized by an assumed baseline heating system efficiency ~~which is~~ derived from the Massachusetts Commercial and Industrial Existing Buildings Baseline Study.[1] ~~the Guidehouse Energy Optimization model~~, ~~and an a~~Assumed heating degree day (HDD) value of ~~5485~~ 5,324, based on a TMYx meteorological data population-weighted average.[2] Set points used to estimate HDD align with the Custom Express Weatherization Tool Evaluation Final Memo,[3] which recommend an occupied heating setpoint of 70°F and an unoccupied heat setpoint of 60°F. Occupied and unoccupied hours are estimated assuming the building is open 8 am to 5 pm, Monday through Saturday and is closed on all holidays. The total hours are in line with findings from the Massachusetts Commercial and Industrial Existing Buildings Baseline Study.[4]

High Efficiency:
The high efficiency case is the existing building after the air sealing measure is implemented. The high efficiency building is characterized by the previously mentioned heating system efficiencies and heating degree day values, and by an improved cubic feet per minute (CFM) infiltration rate, based on the amount of air sealing work-hours associated with the project. An assumed pressurized infiltration rate of 62.5 CFM50 saved per hour[5] of air sealing is adjusted using an LBNL N-Factor of 14.8, which is for ~~infiltration model that assumes~~ a two story building with normal ~~average~~ wind shielding,[6] ~~in order~~ to calculate a natural infiltration rate savings value.

Measure Life:
The measure life is 15 years.[2 7]

Impact Factors for Calculating Adjusted Gross Savings:

Measure Name	Core Initiative	PA	ISR	RR_E	RR_{NE}	RR_{SP}	RR_{WP}	CF_{SP}	CF_{WP}
Prescriptive Air Sealing	CI_EXST	All	1.00	1.00	1.00	1.00	1.00	0.28	0.07
Prescriptive Air Sealing	CI_SBTR	All	1.00	1.00	1.00	1.00	1.00	PA Specific	PA Specific
Prescriptive Air Sealing	CI_ERII	All	1.00	1.00	1.00	1.00	1.00	0.28	0.07

In-Service Rates:
All installations have 100% in service rate since all PA programs include verification of equipment installations.

Realization Rates:
Realization rates are set to 100% until evaluated.

Coincidence Factors:
Summer and winter coincidence factors are estimated using the demand allocation methodology described in the Demand Impact Model.[3 8] For CI_ERII the coincidence factors are deemed.

Impact Factors for Calculating Net Savings:
All PAs should use statewide results.[4 5 9 10]

Measure Name	Core Initiative	PA	FR	SO_P	SO_{NP}	NTG[4]
Prescriptive Air Sealing	CI_EXST, CI_ERII	All				0.877
Prescriptive Air Sealing	CI_SBTR	All				0.964
Prescriptive Air Sealing, Gas	CI_EXST, CI_ERII	All				1.038
Prescriptive Air Sealing, Gas	CI_SBTR	All				0.844

Non-Energy Impacts:
There are no NEIs associated with these measures.

Endnotes:
1 : ~~Navigant. (2020). EO Model Update. 2019_Navigant_EO_Update~~ DNV (2024). Massachusetts Commercial and Industrial Existing Buildings Baseline Study. https://ma-eeac.org/wp-content/uploads/MA22C05-B-BSLN-Existing-Buildings-Baseline_FINAL_20240506.pdf
~~2 : IECC 2018 International Energy Code~~
2 : DNV (2023). Massachusetts Typical Weather – Research and Dataset Development. https://ma-eeac.org/wp-content/uploads/MA22C04-B-TMY-Final_Report.pdf
3 : DNV (2025). Custom Express Weatherization Tool Evaluation Final Memo. https://ma-eeac.org/wp-content/uploads/MA2507-B-WEATOOL-Tool-Evaluation-Memo_FINAL_clean.pdf
4 : DNV (2024). Massachusetts Commercial and Industrial Existing Buildings Baseline Study. https://ma-eeac.org/wp-content/uploads/MA22C05-B-BSLN-Existing-Buildings-Baseline_FINAL_20240506.pdf
5: CLEAResult (2016). Mass Save® Home Energy Services Program Insulation & Air Sealing Reference Manual Field Guide
6 : (2022). Infiltration Guidance for Buildings at Design Conditions] LBNL N-Factors for Relating ACH50 Values to Natural Average ACH values (from BPI) infiltration-guidance-for-buildings-at-design-conditions.pdf
7 ~~2~~ : GDS Associates, Inc. (2007). Measure Life Report Residential and C&I Lighting and HVAC Measures.
GDS_2007_Measure_Life_Report_Residential_and_CI_Lighting_and_HVAC_Measures
8 ~~3~~: Guidehouse. (2020). MA Residential Baseline Study Phase 4.
2020_Guidehouse_Residential_Baseline_Phase_4
9 ~~4~~: NMR Group, Inc. (2024). C&I Prescriptive and Custom Electric Net-to-Gross Omnibus Study. 2024_NMR_C&I_Omnibus_Study
10 ~~5~~ : NMR Group, Inc. (2024). C&I Gas Omnibus Net-to-Gross Study. 2024_NMR_CI_Gas_Omnibus_Study
~~6 : NMR Group, Inc. (2022). C&I Health and Safety Non-Energy Impacts 2022_DNV_C&I_Heath_&_Safety_NEIs~~

Existing Endnote 6 is not referenced in the body of the text. RI recommends removing it or identifying what component of the measure uses it as a source.

4.4 Insulation - C&I Metered Multi-Family

Measure Code	COM-BS-IREU
Market	Commercial
Program Type	Retrofit
Category	Building Shell

Measure Description:
Insulation upgrades are applied in existing multifamily facilities.

BCR Measure IDs:

Measure Name	Core Initiative	BCR Measure ID
Insulation, Electric	C&I Multifamily (CI_MF)	EC1d004
Insulation, Gas	C&I Multifamily (CI_MF)	EC1d005
Insulation, Oil	C&I Multifamily (CI_MF)	EC1d006
Insulation, Other	C&I Multifamily (CI_MF)	EC1d007
Moderate Income Qualified - Insulation, Electric	C&I Multifamily (CI_MF)	EC1d036
Moderate Income Qualified - Insulation, Oil	C&I Multifamily (CI_MF)	EC1d037
Moderate Income Qualified - Insulation, Other	C&I Multifamily (CI_MF)	EC1d038
Insulation, Gas	C&I Multifamily (CI_MF)	GC1d002
Moderate Income Qualified - Insulation, Gas	C&I Multifamily (CI_MF)	GC1d025

Algorithms for Calculating Primary Energy Impact:

kW Factors for Vendor Measures[1] :

Measure	kW/kWh Factor
Insulation (Electric)	0.00073
Insulation (Gas, Oil, Other FF)	0.00076
Insulation, Central AC in Electrically-Heated Unit	0.00059

$MMBtu = ((1/R_{exist} - 1/R_{new})*HDD * 24 * Area) / (1000000 * \eta_{heat})$
$kWh = MMBtu * 293.1$
$kW = kWh * kW/kWh_{heat}$

Where:
R_{exist} = Existing effective R-value (R-ExistingInsulation + R-Assembly),ft2-°F/Btuh
R_{new} = New total effective R-value (R-ProposedMeasure + R-ExistingInsulation+ R-Assembly), ft2-°F/Btuh
Area = Square footage of insulated area

η_{heat} = Efficiency of the heating system (AFUE or COP), site specific
293.1 = Conversion constant (1MMBtu = 293.1 kWh)
24 = Conversion for hours per day
HDD = Heating Degree Days; dependent on location, see table below
1,000,000 = Conversion from Btu to MMBtu
kW/kWh_{heat} = Average annual kW reduction per kWh reduction: 0.00073 kW/kWh

If Facility has central cooling then also calculate air conditioning savings:
$kWh_{cool} = ((1/R_{exist} - 1/R_{new}) * CDH * DUA * Area) / (1000 Btu/kBtu * \eta cool)$
$kW = kWh * kW/kWh_{cool}$

Where:
R_{exist} = Existing effective R-value (R-ExistingInsulation + R-Assembly),ft2-°F/Btuh
R_{new} = New total effective R-value (R-ProposedMeasure + R-ExistingInsulation+ R-Assembly), ft2-°F/Btuh
DUA = Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 75°F = 0.75[2]
Area = Square footage of insulated area
ηcool = Efficiency of air conditioning equipment (SEER), site specific
CDH = Cooling Degree Hours; dependent on location, see table below
kW/kWh_{cool} = Average annual kW reduction per kWh reduction: 0.00073 kW/kWh

Hours:
Heating hours are characterized by the heating degree days for the facility. The heating degree days and cooling degree hours are looked up based on the nearest weather station to the customer, as selected by the program vendor.

TMYx - City/Station	HDD	CDH
Barnstable Muni Boa	4,241	2,159
Beverly Muni	4,736	3,799
Boston Logan Int'l Arpt	4,156	5,937
Chicopee Falls Westo	5,078	6,642
Lawrence Muni	4,607	5,009
Marthas Vineyard	4,335	2,234
Nantucket Memorial AP	3,900	448
New Bedford Rgnl	4,319	5,082

TMYx - City/Station	HDD	CDH
North Adams	5,420	3,507
Norwood Memorial	4,509	7,230
Otis ANGBb	4,440	2,420
Plymouth Municipal	4,589	4,189
Provincetown (AWOS)	4,103	1,785
Westfield Barnes Muni AP	4,916	4,796
Worchester Regional Arpt	5,082	3,207

These values have been derived from TMYx data downloaded from the Massachusetts Typical Weather - Research and Dataset Development Evaluation.[3] The HDD values were calculated by taking the minimum and maximum temperatures for each day, and calculating a daily average and assume a 60° F balance point. CDH assumes a 75° F cooling set point.

Baseline Efficiency:
The baseline efficiency case is characterized by the total R-value of the existing attic, basement or sidewall (Rexist). This is calculated as the R-value of the existing insulation~~, estimated by the program contractor,~~ plus the R-value of the ceiling, floor, or wall. R-value of existing insulation is typically based on the Massachusetts building code that was current at the time of construction or estimated by the program auditor if the R-value of the insulation found on site is greater than required by code at the time of construction. ~~(for all projects: RCEILING = 3.36; RFLOOR = 6.16; RWALL = 6.65).~~[4]

High Efficiency:
The high efficiency case is characterized by the total R-value of the attic after the installation of additional attic, basement or sidewall insulation. This is calculated as the sum of the existing R-value (Rexist) plus the R-value of the added insulation.

Measure Life:
The measure life is 25 years.[5]

Impact Factors for Calculating Adjusted Gross Savings:

Measure Name	Core Initiative	PA	ISR	RR_E	RR_{NE}	RR_{SP}	RR_{WP}	CF_{SP}	CF_{WP}
Insulation, Electric	CI_MF	All	1.00	0.86	n/a	0.86	0.86	0.00	0.58
Insulation, Gas	CI_MF	All	1.00	n/a	0.86	n/a	n/a	n/a	n/a
Insulation, Oil	CI_MF	All	1.00	n/a	0.86	n/a	n/a	0.54	0.00
Moderate Income Qualified - Insulation, Electric	CI_MF	All	1.00	0.86	n/a	0.86	0.86	0.00	0.58
Moderate Income Qualified - Insulation, Oil	CI_MF	All	1.00	n/a	0.86	n/a	n/a	n/a	n/a
Moderate Income Qualified - Insulation, Other	CI_MF	All	1.00	n/a	0.86	n/a	n/a	0.54	0.00
Insulation, Other	CI_MF	All	1.00	n/a	0.86	n/a	n/a	0.54	0.00
Moderate Income Qualified - Insulation, Gas	CI_MF	All	1.00	n/a	0.86	n/a	n/a	0.54	0.00

In-Service Rates:
All installations have 100% in service rate since all PA programs include verification of equipment installations.

Realization Rates:
Realization rates are based on evaluation results and are applied to the vendor estimated savings.[6]

Coincidence Factors:
Summer and winter coincidence factors are estimated using the demand allocation methodology described in the Demand Impact Model which is developed based on the Residential Baseline Study.[7]

Impact Factors for Calculating Net Savings:
Net to gross factors based on evaluation results.[8]

Measure Name	Core Initiative	PA	FR	SO_P	SO_{NP}	NTG
Insulation	CI_MF	All	0.14	0.0	0.0	0.86
Moderate Income Insulation	CI_MF	All	0.14	0.0	0.0	0.86

Endnotes:

1 : Guidehouse (2020). Residential Baseline Study Phase 4 2020_Guidehouse_Residential_Baseline_Phase_4

2 : The Cadmus Group (2012). Massachusetts 2011 Residential Retrofit Multifamily Program Impact Analysis. CADMUS_2012_Multifamily_Impacts_Analysis_Report

3 : DNV (2023). Massachusetts Typical Weather – Research and Dataset Development Study. 2023_DNV_MA_TMYx-Final_Report

4 : ~~Assumptions from National Grid program vendor.~~ Massachusetts State Building Energy Code Base Code (780 CMR) or opt-in Stretch Code or opt-in Specialized Code as adopted by the local municipality. https://www.mass.gov/massachusetts-state-building-code-780-cmr and https://www.mass.gov/info-details/massachusetts-building-energy-codes

5 : GDS Associates (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. GDS_2007_Measure_Life_Report_Residential_and_CI_Lighting_and_HVAC_Measures

6 : Navigant Consulting (2018). Multi-Family Program Impact and Net-to-Gross Evaluation. 2018_Navigant_Multifamily_Program_Impact_Evaluation

7 : Guidehouse (2023). MA RBUECS Demand Impact Model 2023_Guidehouse_MA_RBUECS_Demand_Impact_Model

8 : Guidehouse (2021). Residential Programs Net-to-Gross Research of RCD and Select Products. 2021_Guidehouse_MA_Res_NTG_Final_Report

4.5 Prescriptive Compressed Air

Measure Code	COM-CA-PCA
Market	Commercial
Program Type	Lost Opportunity, Retrofit
Category	Compressed Air

Measure Description:

Air Nozzle: Covers the installation of engineered air nozzles which provide effective air nozzle action while reducing compressed air system air flow.

Refrigerated Air Dryers: The installation of cycling or variable frequency drive (VFD)-equipped refrigerated compressed air dryers. Refrigerated air dryers remove the moisture from a compressed air system to enhance overall system performance. An efficient refrigerated dryer cycles on and off or uses a variable speed drive as required by the demand for compressed air instead of running continuously. Only properly sized refrigerated air dryers used in a single-compressor system are eligible.

***High Efficiency Air Compressor*:** Covers the installation of oil flooded, rotary screw compressors with Variable Speed Drive or Variable Displacement capacity control with properly sized air receiver. Efficient air compressors use various control schemes to improve compression efficiencies at partial loads

Low Pressure Drop Filter: Filters keep the air stream clean and free of small particles. Air compressors maintain adequate system pressure by compensating for any pressure drops across filters. Low pressure drop filters reduces the energy required to maintain system pressure.

Zero Loss Condensate Drains: Drains remove water from a compressed air system. Zero loss condensate drains remove water from a compressed air system without venting any air, resulting in less air demand and consequently greater efficiency.

BCR Measure IDs:

Measure Name	Core Initiative	BCR Measure ID
Prescriptive - Compressed Air	C&I Existing Buildings (CI_EXST)	EC1b018

Algorithms for Calculating Primary Energy Impact:

Air Nozzle:

ΔkW = Delta_kWh / hr

ΔkWh = (FLOW_base - FLOW_eng) x kW_SCFM x USE x hr

Where:

FLOW_base = open nozzle flow at 100 psi (site specific)

FLOW_eng = engineered nozzle flow at 100 psi (site specific)

hr = annual operating hours

kW_SCFM = ~~0.29~~ 0.17[1] (site specific if available)

USE = 0.05 (site specific if available)

Refrigerated Air Dryer:
ΔkWh = (CFMDRYER) x (Save) x (HRS)
ΔkW = (CFMDRYER) x (Save)

Where:
CFMDRYER = Full flow rated capacity of the refrigerated air dryer in cubic feet per minute (CFM). Obtain from equipment's Compressed Air Gas Institute Datasheet.
Save = Refrigerated air dryer kW reduction per dryer full flow rated CFM: 0.00554.[1] [2]
Hours = Annual operating hours of the refrigerated air dryer.

High Efficiency Air Compressor:
ΔkWh = (HPCOMPRESSOR) x (Save) x (Hours)
ΔkW = (HPCOMPRESSOR) x (Save)

Where:
$HP_{COMPRESSOR}$ = Nominal rated horsepower of high efficiency air compressor.
Save = Air compressor kW reduction per HP: 0.168 for Replace on Failure and 0.125 for New Construction.[2] [3]
Hours = Annual operating hours of the air compressor.

Low Pressure Drop Filter:
ΔkWh = [(HPcomp) x (0.7457) / eff] x [((Existing P) - (Adjusted P)) / (2x100)] x (Hours)
ΔkW = [(HPcomp) x (0.7457) / eff] x [((Existing P) - (Adjusted P)) / (2x100)]

Where:
ΔkWh = Energy savings
ΔkW = Demand savings
HPCOMP = Average compressor load. Site specific.
0.7457 = Conversion from HP to kW
eff = Full Load NEMA Premium Motor Efficiency - see below
2 x 100 = % Savings calculated with the assumption that for every 2 psi increase in discharge pressure, energy consumption will increase by approximately 1%[4]
Hours = Annual operating hours of the lower pressure drop filter. Site specific.

NEMA Premium Motor Full Load Efficiency:

HP	Efficiency
15	92.4%
20	93.0%
25	93.6%
30	93.6%
40	94.1%
50	94.5%
60	95.0%
75	95.4%

Savings algorithm source: PA calculation tool, "Prescriptive_CAIR_ZLD_LPDF_Tool.xlsx" (2016)

Zero Loss Condensate Drain:
ΔkWh = (Quantity) x (CFMpipe) x (CFMsave) x (Save) x (Hours)
ΔkW = (Quantity) x (CFMpipe) x (CFMsave) x (Save)

Where:
ΔkWh = Energy savings
ΔkW = Demand savings
CFMpipe = CFM capacity of piping. Site specific.
CFMsaved = Average CFM saved per CFM of piping capacity: 0.049[5]
Save = Average savings per CFM: ~~0.210~~ 0.24386 kW/CFM[3,5]
Hours = Annual operating hours of the zero-loss condensate drain

Baseline Efficiency:

Air Nozzle	The baseline is a standard nozzle on a compressed air system.
Refrigerated Air Dryer	The baseline efficiency case is a non-cycling refrigerated air dryer.
High Efficiency Air Compressor	The baseline efficiency case is a typical load/unload compressor.
Low Pressure Drop Filter	The baseline efficiency case is a standard coalescing filter with initial drop of between 1 and 2 pounds per sq inch (psi) with an end of life drop of 10 psi.

Zero Loss Condensate Drain	The baseline efficiency case is installation of a standard condensate drain on a compressor system.

High Efficiency:

Air Nozzle	The high efficient case is the same air compressor with an engineered nozzle. Rated 15 - 100 HP.
Refrigerated Air Dryer	The high efficiency case is a cycling refrigerated dryer or a refrigerated dryer equipped with a VFD. Rated 15 - 100 HP.
High Efficiency Air Compressor	The high efficient case is an oil-flooded, rotary screw compressor with Variable Speed Drive or Variable Displacement capacity control with a properly sized air receiver. Air receivers are designed to provide a supply buffer to meet short-term demand spikes which can exceed the compressor capacity. Installing a larger receiver tank to meet occasional peak demands can allow for the use of a smaller compressor. Rated 15 - 100 HP. This measure is not applicable to units larger than 75 HP if the total operating HP of the compressed air system is greater than 200 HP.
Low Pressure Drop Filter	The high efficiency case is a low pressure drop filter with initial drop not exceeding 1 psi over life and 3 psi at element change. Filters must be deep-bed, "mist eliminator" style and installed on a single operating compressor rated 15 – ~~75~~ 100 HP.
Zero Loss Condensate Drain	The high efficiency case is installation of a zero loss condensate drain on a single operating compressor rated ≤ ~~75~~ 100 HP.

*Due to a change in compressor size limits for the 'Compressed Air – Prescriptive Compressed Air' measure for program year 2026, Table 1-1 of MA24C09-E-ISPCAIR: Industry Standard Practice: Compressed Air no longer correctly maps this measure's BCR Measure ID (EC1b018) to the applicable ISP baselines. In 2026, PAs expanded the scope of the prescriptive compressed air measure from 15HP – 75HP to 15HP – 100HP. When the prescriptive compressed air measure is applied to air compressors between 75 HP and 100 HP, the applicable ISP baseline values are equivalent to the Custom Compressed Air measure (BCR Measure EC1b002) ISP baseline values, as identified in Table 1-1. For air compressors at or below 75 HP, the ISP baseline values listed in Table 1-1 are still applicable.

Measure Life:

This measure has been determined to be an add on single baseline measure for retrofit installations.[~~4~~ 6]

Impact Factors for Calculating Adjusted Gross Savings:

Measure Name	Core Initiative	PA	ISR	RR_E	RR_{NE}	RR_{SP}	RR_{WP}	CF_{SP}	CF_{WP}
Prescriptive - Compressed Air	CI_EXST	CLC	1.00	1.25	1.00	0.95	0.80	0.70	0.64
Prescriptive - Compressed Air	CI_EXST	Eversource	1.00	1.25	1.00	0.95	0.80	0.70	0.64
Prescriptive - Compressed Air	CI_EXST	National Grid	1.00	1.00	1.00	1.00	1.00	0.70	0.64
Prescriptive - Compressed Air	CI_EXST	Unitil	1.00	1.00	1.00	1.00	1.00	0.70	0.64

In-Service Rates:

All installations have 100% in service rate since PA programs include verification of equipment installations.

Realization Rates:

For CLC and Eversource realization rates are based on the Business & Construction Solutions (BS/BC) programs measurement & verification - 2006 Final Report.~~4~~ 6

For National Grid and Unitil realization rates are based on an impact evaluation of 2004 compressed air prescriptive rebates.~~5~~ 7

Coincidence Factors:

Coincident factors are derived from the C&I Loadshape study.~~6~~ 8

Impact Factors for Calculating Net Savings:

All PAs use statewide prescriptive net-to-gross values based on study results.~~7~~ 9

Measure Name	Core Initiative	PA	FR	SO_P	SO_{NP}	NTG
Prescriptive - Compressed Air	CI_EXST	All				0.877

Non-Energy Impacts:

NEI's are based on the O&M and Non-O&M NEI Study~~8~~ 10

Endnotes:

1 : LBNL (2016). Improving Compressed Air System Performance A Sourcebook for Industry Third Edition Third edition. Page 46. https://www.compressedairchallenge.org/data/sites/1/media/library/sourcebook/Improving_Compressed_Air-Sourcebook.pdf

~~1~~ **2** : DNV GL (2015). Impact Evaluation of Prescriptive Chiller and Compressed Air Installations. DNVGL_2015_Impact_Eval_Prescriptive_Chiller_CAIR_FINAL
~~2~~ **3 :** DNV (2025) MA24C09-E-ISPCAIR: Industry Standard Practice: Compressed Air. Page 33. ~~DNVGL_2015_Impact_Eval_Prescriptive_Chiller_CAIR_FINAL~~ Update this link to the ISP Compressed Air report (MA-RI-Compressed-Air-ISP-Memo-11.1.2025_Clean.pdf).
4 : LBNL (2016). Improving Compressed Air System Performance A Sourcebook for Industry Third Edition Third edition. Page 21. https://www.compressedairchallenge.org/data/sites/1/media/library/sourcebook/Improving_Compressed_Air-Sourcebook.pdf
~~5~~ **3** ~~: Savings algorithm source: PA calculation tool, "Prescriptive_CAIR_ZLD_LPDF_Tool.xlsx" (2016)~~ DNV-GL (2015). Impact Evaluation of Prescriptive Chiller and Compressed Air Installations. Page. 45. https://www.ma-eeac.org/wp-content/uploads/MA30-Prescriptive-Chiller-and-CAIR-Report_FINAL_151026.pdf[14]
~~4~~ **6** : RLW Analytics (2008). Business & Construction Solutions (BS/BC) Programs Measurement & Verification - 2006 Final Report. RLW_2008_Business_and_Construction_Solutions_Programs_Measurement_and_Verification_2006_Final_Report
~~5~~ **7** : DMI (2006). Impact Evaluation of 2004 Compressed Air Prescriptive Rebates. Results analyzed in RLW Analytics (2006). Sample Design and Impact Evaluation Analysis for Prescriptive Compressed Air Measures in Energy Initiative and Design 2000 Programs. DMI_2006_Impact_Evaluation_of_2004_Compressed_Air_Prescriptive_Rebates
~~6~~ **8** : DNV (2024). C&I Impact Shape Study 2024_DNV_C&I_Impact Shape Study
~~7~~ **9** : NMR (2024). C&I Prescriptive and Custom Electric Net-to-Gross Omnibus Study Final Report 2024_NMR_C&I_Omnibus_Study
~~8~~ **10** : NMR Group, Inc. (2021) O&M and Non-O&M NEI Study. 2021_NMR_CIOM and NonOM NEI Study

[14] The prescriptive tool does not provide a source for this value. We found an impact evaluation with the CFMsaved value as well as the formula for calculating savings and it had the value of 0.24386 kW/CFM listed instead of 0.210 kW/CFM.

4.6 Prescriptive Refrigeration

Measure Code	COM-R-PR
Market	Commercial
Program Type	Lost Opportunity, Retrofit
Category	Refrigeration

Measure Description:

Evaporator Fan Control- Installation of controls to modulate or turn off the evaporator fans based on temperature control when the refrigerant flow to the evaporator is off. Energy savings include fan energy savings from reduced fan operating hours, refrigeration energy savings from reduced waste heat, and compressor energy savings resulting from the ~~electronic~~ direct digital control (DDC) temperature control. ~~Electronic controls~~ DDC temperature control allow less fluctuation in temperature, thereby creating savings.

ECM Evaporator Fan Motors for Walk In Coolers- Installation of various sizes of electronically commutated motors (ECMs) in walk-in coolers and freezers to replace existing evaporator fan motors.

Cooler Night Cover- Installation of retractable aluminum woven fabric covers for open-type refrigerated display cases, where the covers are deployed during the facility unoccupied hours in order to reduce refrigeration energy consumption.

Case Motor Replacement- Installation of electronically commutated motors (ECMs) in multi-deck and freestanding coolers and freezers, typically on the retail floor of convenience stores, liquor stores, and grocery stores.

Door Heater Controls- Installation of controls to reduce the run time of door and frame heaters for freezers and walk-in or reach-in coolers. The reduced heating results in a reduced cooling load.

Electronic Defrost Control- A control mechanism to skip defrost cycles when defrost is unnecessary.

Novelty Cooler Shutoff- Installation of controls to shut off a facility's novelty coolers for non-perishable goods based on pre-programmed store hours. Energy savings occur as coolers cycle off during facility unoccupied hours.

~~The assumptions and algorithms for the measures above are specific to NRM products.~~

Walk In Cooler Economizer- Installation of louvers and fans controlled to supply outside air when ambient conditions are cool enough.

BCR Measure IDs:

Measure Name	Core Initiative	BCR Measure ID
Prescriptive - Refrigeration	C&I Small Business Turnkey Retrofit (CI_SBTR)	EC1c027

Algorithms for Calculating Primary Energy Impact[1]:

Updates to deemed savings, algorithms, baseline efficiency, and/or high-efficiency edits are suggestions from the C&I Comprehensive TRM Review[2] and MA26C02-B-RXASSESS study[3]

Evaporator Fan Control

$\Delta kWh = \Delta kWh_{Fan} + \Delta kWh_{Heat} + \Delta kWh_{Control}$

$\Delta kWh_{Fan} = kW_{Fan} * 8760 * \%OFF$

$\Delta kWh_{Heat} = \Delta kWh_{Fan} * 0.28 * Eff_{RS}$

$\Delta kWh_{Control} = [kW_{CP} * Hours_{CP} + kW_{Fan} * 8760 * (1-\%OFF)] * 5\%$

$\Delta kW = \Delta kWh/8760$

Where :

ΔkWh_{Fan}= Energy savings due to evaporator being shut off

ΔkWh_{Heat}= Energy savings due to reduced heat from the evaporator fans

$\Delta kWh_{Control}$ = Energy savings due to the ~~electronic~~ direct digital controls (DDC) on compressor and evaporator

kW_{Fan} = Power demand of evaporator fan calculated from equipment nameplate data and estimated 0.61~~0.55~~ power factor/ adjustment[4] : Amps x Voltage x PF x √Phase

%OFF = Percent of annual hours that the evaporator is turned off: 46%[5]

0.28 = Conversion of kW to tons: 3,413 Btuh/kW divided by 12,000 Btuh/ton.

Eff_{RS} = Efficiency of typical refrigeration system: 1.05 kW/ton for coolers, 1.87 kW/ton[6] for freezers

kW_{CP} = Total power demand of compressor motor and condenser fan calculated from equipment nameplate data and estimated 0.85 power factor [7] : Amps x Voltage x PF x √Phase

$Hours_{CP}$ = Equivalent annual full load hours of compressor operation: ~~4,072~~ 3,154 hours [8]

5% = Reduced run-time of compressor and evaporator due to electronic temperature controls [9]

ΔkW = Average demand savings

8,760 = Hours per Year

ECM Evaporator Fan Motors for Walk-In Coolers

$\Delta kWh = \Delta kWh_{Fan} + \Delta kWh_{Heat}$

$\Delta kWh_{Fan} = kW_{Fan} * LRF * Hours_{Fan}$

$\Delta kWh_{Heat} = \Delta kWh_{Fan} * 0.28 * Eff_{RS}$
$\Delta kW = \Delta kWh / 8760$

Where:
ΔkWhFan = Energy savings due to increased efficiency of evaporator fan motor
ΔkWhHeat = Energy savings due to reduced heat from the evaporator fans
kWFan = Power demand of evaporator fan calculated from equipment nameplate data and estimated 0.61~~0.55~~ power factor/adjustment~~[7]~~[10] : Amps x Voltage x PF x √Phase
LRF = Load reduction factor for motor replacement ~~(65%)[8]~~: 70% Shaded-Pole (SP) motor, 56% Permanent Split Capacitor (PSC) motor[11]
$Hours_{Fan}$ = ~~Annual fan operating hours.~~ Effective run time for evaporator fan motors: 8,760 for uncontrolled motors; 4,730 hours (8,760 x (1-46%)) for controlled motors[12]
0.28 = Conversion factor between kW and tons: 3,413 Btuh/kW divided by 12,000 Btuh/ton
Eff_{RS} = Efficiency of typical refrigeration system: 1.05 kW/ton for coolers, 1.87 kW/ton[13] for freezers
ΔkW = Average demand savings
8,760 = Hours per year

Cooler Night Cover
ΔkWh = (Width) x (Save) x (Hours)
ΔkW = (Width) x (Save)

Where:
ΔkWh = Energy Savings
ΔkW = Connected load reduction
Width = Width of the opening that the night covers protect (ft)
Save = Savings factor based on the temperature of the case (kW/ft). See table below~~[10]~~[14]
Hours = Annual hours that the night covers are in use

Savings Factors:

Cooler Case Type ~~Temperature~~	Savings Factor
~~Low Temperature (-35 F to -5 F)~~	~~0.03 kW/ft~~
~~Medium Temperature (0 F to 30 F)~~	~~0.02 kW/ft~~
~~High Temperature (35 F to 55 F)~~	~~0.01 kW/ft~~
Vertical Open, Remote Condensing, Medium Temp (38° F)	0.05 kW/ft
Vertical Open, Remote Condensing, Low Temp (0° F)	0.10 kW/ft
Vertical Open, Self Contained, Medium Temp (38° F)	0.08 kW/ft

Semivertical Open, Remote Condensing, Medium Temp (38° F)	0.04 kW/ft
Semivertical Open, Self Contained, Medium Temp (38° F)	0.07 kW/ft

Case Motor Replacement

$\Delta kWh = \Delta kWh_{Motor} + \Delta kWh_{Heat}$

$\Delta kWh_{Motor} = kW_{Motor} \times LRF \times Hours$

$\Delta kWh_{Heat} = \Delta kWh_{Motor} \times 0.28 \times Eff_{rs}$

$\Delta kW = \Delta kWh/8760$

Where:

ΔkWh_{Motor} = Energy savings due to increased efficiency of case motor

ΔkWh_{Heat} = Energy savings due to reduced heat from evaporator fans

kW_{motor} = Metered load of case motor

LRF = ~~Load reduction factor: 53% when shaded pole motors are replaced, 29% when PSC motors are replaced.~~ 70% Shaded-Pole (SP) motor, 56% Permanent Split Capacitor (PSC) motor[~~11~~ 15]

Hours = Average runtime of case motors (8,500 hours)[~~12~~ 16]

0.28 = Conversion of kW to tons: 3,413 Btuh/kW divided by 12,000 Btuh/ton.

~~Eff_{rs} = Efficiency of typical refrigeration system (1.6 kW/ton)[13]~~

Eff_{RS} = Efficiency of typical refrigeration system: 1.05 kW/ton for coolers, 1.87 kW/ton[17] for freezers

ΔkW = Average demand savings

8,760 = Hours per year

Door Heater Controls

$\Delta kWh = kW_{DH} * \%OFF * $ ~~8760~~ 7,945

$\Delta kW = kW_{DH} * \%OFF$

Where:

kW_{DH} = Total demand of the door heater, calculated as Volts * Amps / 1000

~~8760~~ 7,945 = Door heater annual run hours before controls (8,760 * 90.7%)[18]

%OFF Door heater Off time: 48% ~~46% for freezer door heaters or 74% for cooler door heaters)[14 19]~~

Electronic Defrost Control

$\Delta kWh_{Defrost} = kW_{Defrost} \times Hours \times DRF$

$\Delta kWh_{Heat} = \Delta kWh_{Defrost} \times 0.28 \times Eff_{RS}$

$\Delta kWh = \Delta kWh_{Defrost} + \Delta kWh_{Heat}$

$\Delta kW = \Delta kWh/8760$

Where:

$\Delta kWh_{Defrost}$ = Energy savings resulting from an increase in operating efficiency due to the addition of electronic defrost controls.
ΔkWh_{Heat} = Energy savings due to reduced heat from reduced number of defrosts.
$kW_{Defrost}$ = Load of electric defrost.
Hours = Number of hours defrost occurs over a year without the defrost controls.
DRF = Defrost reduction factor- percent reduction in defrosts required per year (30%~~35%~~)~~15~~ 20
0.28 = Conversion of kW to tons: 3,413 Btuh/kW divided by 12,000 Btuh/ton.
EffRS = Efficiency of typical refrigeration system = 1.05 kW/ton for coolers, 1.87 kW/ton~~16~~ 21 for freezers
ΔkW = Average demand savings
8,760 = Hours per year

Novelty Cooler Shutoff

$\Delta kWh = kW_{NC} * DC_{AVG} * Hours_{OFF}$
$\Delta kW = 0$

Where:
ΔkW = 0 since savings are assumed to occur during evening hours and are therefore not coincident with either summer or winter peak periods.
kW_{NC} = Power demand of novelty cooler calculated from equipment nameplate data and estimated 0.85 power factor~~17~~ 22
$Hours_{OFF}$ = Potential hours off every night per year, estimated as one less than the number of hours the store is closed per day
DC_{AVG} = Weighted average annual duty cycle: ~~48.75~~ 45%~~18~~ 23

Freezer/Cooler LEDs

~~Updates to deemed savings, algorithms, baseline efficiency, and/or high-efficiency edits are suggestions from the C&I Comprehensive TRM Review.~~[1]
$\Delta kWh = \Delta kWh_{LED} + \Delta kWh_{HeatFreezer}$
$\Delta kWh = \Delta kWh_{LED} + \Delta kWh_{HeatRefrigerator}$
$\Delta kWh_{HeatFreezer} = \Delta kWh_{LED} \times 0.28 \times Eff_{Freezer}$
$\Delta kWh_{HeatRefrigerator} = \Delta kWh_{LED} \times 0.28 \times Eff_{Refrigerator}$
ΔkWh_{LED} = Summation of i=1 to n ($Count_i * kW_i * Hours_i)_{BASE}$ - Summation of i=1 to m ($Count_j * kW_j * Hours_j)_{LED}$
$\Delta kW = \Delta kWh / Hours_j$

Where:
ΔkWh_{LED} = Reduction in lighting energy
ΔkWh_{Heat} = Reduction in refrigeration energy due to reduced heat loss from the lighting fixtures
N = Total number of lighting fixture types in the pre-retrofit case

M = Total number of lighting fixture types in the post-retrofit case
$Count_i$ = Quantity of type i fixtures in the pre-retrofit case
kW_i = Power demand of pre-retrofit lighting fixture type i (kW/fixture)
$Hours_i$ = Pre-retrofit annual operating hours of fixture type i
$Count_j$ = Quantity of type j fixtures in the pre-retrofit case
kW_j = Power demand of lighting fixture type j (kW/fixture)
$Hours_j$ = Post-retrofit annual operating hours of fixture type j
0.28 = Unit conversion between kW and tons calculated as 3,413 Btuh/kW divided by 12,000 Btuh/ton

$Eff_{Freezer}$ = Efficiency of typical freezer system: 1.87 kW/ton~~2~~ [24]
EffRefrigerator = Efficiency of typical refrigeration system: 1.05 kW/ton~~3~~ [25]

Walk In Cooler Economizer

$\Delta kWh = Hours_{Econ} * (kW_{Comp} * DutyCycle_{Winter} - kW_{Econ} - kW_{Humid})$
$kW_{Econ} = CFM_{Econ} * DutyCycle_{EconFan} * 0.0017$ kW/cfm
$kW_{Humid} = (2.43*10^{-5}) * Volume_{Cooler} + 0.0689$
$kW_{load} = 0.85 * (Amp_{Comp} * Volt_{comp} * \sqrt{phase_{Comp}} + (1-\%OFF) * Amp_{Fan} * Volt_{Fan} * \sqrt{phase_{Fan}}) / 1000$
$\Delta kW_{Summer} = kWload * CF_{Summer}$
$\Delta kW_{Winter} = (kW_{Comp} * DutyCycle_{Winter} - kW_{Econ} - kW_{Humid}) * CF_{Winter}$

Where:
Comp = Compressor motor
Fan = Fan motor
Econ = Economizer
$Hours_{Econ}$ = Hours the economizer runs in the winter: 1,339 (Bin analysis using TMYx Chicopee data assume economizer operates when the outdoor air temperature is below 32° F)
kW_{Comp}= vendor provided
$DutyCycle_{Winter}$ = 52% [26]
$CFM_{Econ} = 0.0595 * Volume_{Cooler} + 45.72$
$DutyCycle_{EconFan}$ = 75% [27]
$Volume_{Cooler}$ = Length * Width * Height
$Height_{default}$ = 8 ft
0.85 = Power Factor [28]
$Amp_{Comp\ or\ Fan} = f(Volume_{Cooler})$ see table below.
$Volt_{Comp\ or\ Fan}$= vendor provided
$Phase_{Comp\ or\ Fan}$= vendor provided
%OFF = Percent of annual hours that the evaporator is turned off: 46%~~; MA TRM measure 3.94~~ [29]
1,000 = conversion from W to kW
CF_{Summer} = 0%
CF_{Winter} = ~~7.39~~73.9%

~~ΔkWh = Hours_econ * (kW_compressor*DutyCycle_winter - kW_econ - kW_humid)~~

~~comp -> compressor motor~~
~~fan -> fan motor~~
~~kW_load = 0.85 * (Amp_comp*Volt_comp*sqrt(phase_comp) + (1-%OFF)*Amp_fan*Volt_fan*sqrt(phase_fan)) / 1000~~
~~Summer ΔkW = 0~~
~~Winter ΔkW = (kW_compressor*DutyCycle_winter - kW_econ - kW_humidifier)*0.74~~
~~Where:~~
~~Summer Coincidence = 0~~
~~Winter Coincidence = 7.39~~
~~Hours_econ = 1,339~~
~~kW_compressor= vendor provided~~
~~DutyCycle_winter = 52%~~
~~kW_econ = cfm_econ * DutyCycle_econFan * 0.0017 kW/cfm~~
~~%OFF = 46%, MA TRM measure 3.94~~
~~DutyCycle_econFan = 75%~~
~~cfm_econ = 0.0595 * Volume_cooler + 45.72~~
~~Volume_cooler = Length * Width * Height~~
~~kW_humid = (2.43*10^-5) * Volume_cooler + .0689~~
~~Amp_XX = f(Volume_cooler)~~
~~phase_comp= vendor provided~~
~~Volt_comp= vendor provided~~
~~Height_default = 8 ft~~

$Volume_{cooler}$ (ft^3)	Amp_{fan}	Amp_{comp}
≥(30x8x8)	3.2	12
≥(8x8x8) and ≤(30x8x8)	3	9.5

$Volume_{cooler}$ (ft^3)	Amp_{fan}	Amp_{comp}
<(8x8x8)	1.7	8.1

Baseline Efficiency:

Evaporator Fan Control- The baseline efficiency case assumes evaporator fans that run 8,760 annual hours with no temperature control.

ECM Evaporator Fan Motors for Walk In Coolers- The baseline efficiency case is an existing evaporator fan motor.

Cooler Night Cover- The baseline efficiency case is the annual operation of open-display cooler cases.

Case Motor Replacement- The baseline efficiency case is the existing case motor.

Door Heater Controls- The baseline efficiency case is a cooler or freezer door heater that operates 7,945 hours per year without any controls.

Electronic Defrost Control- The baseline efficiency case is an evaporator fan electric defrost system that uses a time clock mechanism to initiate defrost.

Novelty Cooler Shutoff- The baseline efficiency case is the novelty coolers operating 8,760 hours per year.

Freezer/Cooler LEDs- The baseline efficiency case is the existing lighting fixtures in the cooler or freezer cases.

Walk In Cooler Economizer- The baseline efficiency case is mechanical refrigeration 8,760 hours/year.

~~**Measure Name**~~	~~**Baseline Efficiency**~~
~~Evaporator Fan Control~~	~~The baseline efficiency case assumes evaporator fans that run 8,760 annual hours with no temperature control.~~
~~ECM Evaporator Fan Motors for Walk-In Coolers~~	~~The baseline efficiency case is an existing evaporator fan motor.~~
~~Cooler Night Cover~~	~~The baseline efficiency case is the annual operation of open-display cooler cases.~~
~~Case Motor Replacement~~	~~The baseline efficiency case is the existing case motor.~~
~~Door Heater Controls~~	~~The baseline efficiency case is a cooler or freezer door heater that operates 8,760 hours per year without any controls.~~

~~Measure Name~~	~~Baseline Efficiency~~
~~Electronic Defrost Control~~	~~The baseline efficiency case is an evaporator fan electric defrost system that uses a time clock mechanism to initiate defrost.~~
~~Novelty Cooler Shutoff~~	~~The baseline efficiency case is the novelty coolers operating 8,760 hours per year.~~
~~Freezer/Cooler LEDs~~	~~The baseline efficiency case is the existing lighting fixtures in the cooler or freezer cases.~~
~~Walk In Cooler Economizer~~	~~The baseline efficiency case is mechanical refrigeration 8,760 hours/year.~~

High Efficiency:

Evaporator Fan Control- The high efficiency case is the use of an energy management system to control evaporator fan and compressor operation based on temperature.

ECM Evaporator Fan Motors for Walk In Coolers- The high efficiency case is the replacement of existing evaporator fan motors with ECMs.

Cooler Night Cover- The high efficiency case is the use of night covers to protect the exposed area of display cooler cases during unoccupied hours.

Case Motor Replacement- The high efficiency case is the replacement of the existing case motor with an ECM.

Door Heater Controls- The high efficiency case is a cooler or freezer door heater connected to a heater control system, which controls the door heaters by measuring the ambient humidity and temperature of the store, calculating the dew point, and using pulse width modulation (PWM) to control the anti-sweat heater based on specific algorithms for freezer and cooler doors. Door temperature is typically maintained about 5°F above the store air dew point temperature.[30]

Electronic Defrost Control- The high efficiency case is an evaporator fan defrost system with electric defrost controls.

Novelty Cooler Shutoff- The high efficiency case is the novelty coolers operating fewer than 8,760 hours per year since they are controlled to cycle each night based on pre-programmed facility unoccupied hours.

Freezer/Cooler LEDs - The high efficiency case is the installation of LED lighting fixtures on the cooler or freezer cases, replacing the existing lighting fixtures.

Walk In Cooler Economizer- The high efficiency case is installation of louvers and fans controlled to supply outside air when ambient conditions are cool enough.

~~Measure Name~~	~~High Efficiency~~
~~Evaporator Fan Control~~	~~The high efficiency case is the use of an energy management system to control evaporator fan and compressor operation based on temperature.~~
~~ECM Evaporator Fan Motors for Walk In Coolers~~	~~The high efficiency case is the replacement of existing evaporator fan motors with ECMs.~~
~~Cooler Night Cover~~	~~The high efficiency case is the use of night covers to protect the exposed area of display cooler cases during unoccupied hours.~~
~~Case Motor Replacement~~	~~The high efficiency case is the replacement of the existing case motor with an ECM.~~
~~Door Heater Controls~~	~~The high efficiency case is a cooler or freezer door heater connected to a heater control system, which controls the door heaters by measuring the ambient humidity and temperature of the store, calculating the dew point, and using pulse width modulation (PWM) to control the anti-sweat heater based on specific algorithms for freezer and cooler doors. Door temperature is typically maintained about 5°F above the store air dew point temperature.~~[19]
~~Electronic Defrost Control~~	~~The high efficiency case is an evaporator fan defrost system with electric defrost controls.~~
~~Novelty Cooler Shutoff~~	~~The high efficiency case is the novelty coolers operating fewer than 8,760 hours per year since they are controlled to cycle each night based on pre-programmed facility unoccupied hours.~~
~~Freezer/Cooler LEDs~~	~~The high efficiency case is the installation of LED lighting fixtures on the cooler or freezer cases, replacing the existing lighting fixtures.~~
~~Walk In Cooler Economizer~~	~~The high efficiency case is installation of louvers and fans controlled to supply outside air when ambient conditions are cool enough.~~

Measure Life:
This measure has been determined to be an add on single baseline measure for retrofit installations.~~20 21~~ 31 32

Measure Name	PA	EUL	OYF	RUL	AML

Evaporator Fan Control	All	10	1	n/a	10
ECM Evaporator Fan Motors for Walk In Coolers	All	9	1	n/a	9
Cooler Night Cover	All	5	1	n/a	5
Case Motor Replacement	All	15	1	n/a	15
Door Heater Controls	All	10	1	n/a	10
Electronic Defrost Control	All	10	1	n/a	10
Novelty Cooler Shutoff	All	10	1	n/a	10
Freezer/Cooler LEDs	All	10	n/a	n/a	10
Walk In Cooler Economizer	All	10	n/a	n/a	10

Other Resource Impacts:
There are no other resource impacts identified for this measure.

Impact Factors for Calculating Adjusted Gross Savings:

Measure Name	Core Initiative	PA	ISR	RR_E	RR_{NE}	RR_{SP}	RR_{WP}	CF_{SP}	CF_{WP}
Prescriptive - Refrigeration	CI_SBTR	CLC, NGRID	1.00	1.05	1.00	0.94	1.17	0.68	0.72
Prescriptive - Refrigeration	CI_SBTR	Eversource, Unitil	1.00	0.95	1.00	1.27	1.42	0.68	0.72

In-Service Rates:
All installations have 100% in service rate since PA programs include verification of equipment installations.

Realization Rates:
Realization rates based on small business non-lighting impact evaluation of PY2017 projects[~~22~~ 33].

Coincidence Factors:
Coincident factors are derived from the C&I Loadshape study[~~23~~ 34].

Impact Factors for Calculating Net Savings:
All PAs use statewide prescriptive net-to-gross values based on study results.[~~24~~ 35]

Measure Name	Core Initiative	PA	FR	SO_P	SO_{NP}	NTG
Prescriptive - Refrigeration	CI_SBTR	All				0.964

Non-Energy Impacts:

NEIs are based on the 2021 O&M and Non-O&M NEI Study.~~25~~ 36 Values corrected for sign error per the 2025 NEI Gap Study Memo.~~26~~ 37

Measure Name	Core Initiative	PA	Annual $ per Unit	One-time $ per Unit	Annual $ per kWh	One-time $ per kWh	Annual $ per Therm	One-time $ per Therm
Prescriptive - Compressed Air	CI_EXST	All	$0.00	$0.00	$0.001	$0.00	$0.00	$0.00

Endnotes:

1 : Where applicable, the assumptions and algorithms used in this section are specific to NRM products.

2 : Cadeo (2022). Non-Residential Technical Reference Manual Review. https://ma-eeac.org/wp-content/uploads/MA22C01-B_TRM-Review_FINAL_31OCT2022.pdf

3 : RI (2026). Prescriptive Measure Assessment. MA26C02-B-RXASSESS

~~**1** : Conservative value based on 15 years of NRM field observations and experience.~~

~~**2** : The value is an estimate by NRM based on hundreds of downloads of hours of use data. These values are also supported by Select Energy Services, Inc. (2004). Cooler Control Measure Impact Spreadsheet User's Manual. Prepared for NSTAR~~
~~Select_Energy_2004_Cooler_Control_Measure_Impact_Spreadsheet_Users_Manual~~

4 : ORNL (2015). Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits. Table 1.
https://betterbuildingssolutioncenter.energy.gov/sites/default/files/Pub58600.pdf

5 : Select Energy Services, Inc. (2004). Analysis of Cooler Control Energy Conservation Measures. Prepared for NSTAR. Table 5-2: Percent reduction of evaporator fan duty cycle 46%.
Select_Energy_2004_Analysis_of_Cooler_Control_Energy_Conservation_Measures

~~**3** **6** : DNV. May 12, 2022. "X1931-5 PSD Commercial Refrigeration Efficiency Update Study." Connecticut Energy Efficiency Board and Evaluation Administrators.~~

~~**4** : This value is an estimate by NRM based on hundreds of downloads of hours of use data from the electronic controller.~~

7 : Select Energy Services, Inc. (2004). Analysis of Cooler Control Energy Conservation Measures. Prepared for NSTAR. Table 3-4.
Select_Energy_2004_Analysis_of_Cooler_Control_Energy_Conservation_Measures

~~**5** : Conservative value based on 15 years of NRM field observations and experience.~~

8 : Select Energy Services, Inc. (2004). Analysis of Cooler Control Energy Conservation Measures. Prepared for NSTAR. Table 5-2: Compressor annual average duty cycle 36%.
Select_Energy_2004_Analysis_of_Cooler_Control_Energy_Conservation_Measures.

~~**6** **9** : Conservative estimate supported by less conservative values given by several utility-sponsored 3rd Party studies including: Select Energy Services, Inc. (2004). Analysis of Cooler Control Energy Conservation Measures. Prepared for NSTAR.~~
Select_Energy_2004_Analysis_of_Cooler_Control_Energy_Conservation_Measures

~~**7** : Conservative value based on 15 years of NRM field observations and experience.~~
10 : ORNL (2015). Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected Benefits. Table 1.
https://betterbuildingssolutioncenter.energy.gov/sites/default/files/Pub58600.pdf
~~**8** : Load factor is an estimate by NRM based on several pre- and post-meter readings of installations; the value is supported by RLW Analytics (2007). Small Business Services Custom Measure Impact Evaluation. Prepared for National Grid.~~
~~RLW_2007_Small_Business_Services_Custom_Measure_Impact_Evaluation~~
11 : DOE (2014). Technical Support Document: Energy Efficiency Program for Consumer and Industrial Equipment Commercial Refrigeration Equipment. Table 5.6.5 Details for Evaporator Fan Motor Design Option. https://downloads.regulations.gov/EERE-2010-BT-STD-0003-0102/content.pdf
12 : Select Energy Services, Inc. (2004). Analysis of Cooler Control Energy Conservation Measures. Prepared for NSTAR. Table 5-2: Percent reduction of evaporator fan duty cycle 46%. Assumed duty cycle of 54%. Select_Energy_2004_Analysis_of_Cooler_Control_Energy_Conservation_Measures
~~**9** **13**~~: DNV. May 12, 2022. "X1931-5 PSD Commercial Refrigeration Efficiency Update Study." Connecticut Energy Efficiency Board and Evaluation Administrators.
~~**10** **14**: CL&P Program Savings Documentation for 2011 Program Year (2010). Factors based on Southern California Edison (1997). Effects of the Low Emissive Shields on Performance and Power Use of a Refrigerated Display Case.~~
~~SoCalEdison_1997_Effects_of_the_Low_Emissive_Shields_on_Performance_and_Power_Use_of_a_Refrigerated_Display_Case~~
DOE (2014). Technical Support Document: Energy Efficiency Program for Consumer and Industrial Equipment Commercial Refrigeration Equipment. Table 5A.2.2, Table 5A.2.1, Figure 5.7.1, Figure 5.7.2, Figure 5.7.3, Figure 5.7.4, and Figure 5.7.5.
https://downloads.regulations.gov/EERE-2010-BT-STD-0003-0102/content.pdf
~~**11** **15** : Load factor is an estimate by NRM based on several pre- and post-meter readings of installations~~
DOE (2014). Technical Support Document: Energy Efficiency Program for Consumer and Industrial Equipment Commercial Refrigeration Equipment. Table 5.6.5 Details for Evaporator Fan Motor Design Option. https://downloads.regulations.gov/EERE-2010-BT-STD-0003-0102/content.pdf
~~**12** **16** : Conservative value based on 15 years of NRM field observations and experience.~~
The Cadmus Group, Inc. (2015), Commercial Refrigeration Loadshape Project Final Report. Table 4.
https://neep.org/sites/default/files/resources/NEEP%20CRL_Report_FINAL_clean.pdf
~~**13** **17** : Assumed average refrigeration efficiency for typical installations. Conservative value based on 15 years of NRM field observations and experience. Value supported by Select Energy (2004). Cooler Control Measure Impact Spreadsheet Users' Manual. Prepared for NSTAR. Select_Energy_2004_Cooler_Control_Measure_Impact_Spreadsheet_Users_Manual~~
DNV. May 12, 2022. "X1931-5 PSD Commercial Refrigeration Efficiency Update Study." Connecticut Energy Efficiency Board and Evaluation Administrators.

18 : The Cadmus Group, Inc. (2015). Commercial Refrigeration Loadshape Project Final Report. Table 5: Uncontrolled run time (8,760 hrs. * 90.7% = 7,945 hrs.)
https://neep.org/sites/default/files/resources/NEEP%20CRL_Report_FINAL_clean.pdf
~~**14 19** : The value is an estimate by NRM based on hundreds of downloads of hours of use data from Door Heater controllers. These values are also supported by Select Energy Services, Inc. (2004). Cooler Control Measure Impact Spreadsheet User's Manual. Prepared for NSTAR.~~
~~Select_Energy_2004_Cooler_Control_Measure_Impact_Spreadsheet_Users_Manual~~
The Cadmus Group, Inc. (2015). Commercial Refrigeration Loadshape Project Final Report. Table 5: Uncontrolled run time (90.7%) minus micro pulse control run time (42.8%).
https://neep.org/sites/default/files/resources/NEEP%20CRL_Report_FINAL_clean.pdf
~~**15 20** : Supported by 3rd party evaluation: Independent Testing was performed by Intertek Testing Service on a Walk-in Freezer that was retrofitted with Smart Electric Defrost capability.~~
NREL (2013). Advanced Energy Retrofit Guide Grocery Stores. Section F.2.9.
https://www.osti.gov/biblio/1045045
~~**16 21**~~: DNV. May 12, 2022. "X1931-5 PSD Commercial Refrigeration Efficiency Update Study." Connecticut Energy Efficiency Board and Evaluation Administrators.
~~**17 22**: Conservative value based on 15 years of NRM field observations and experience.~~
Select Energy Services, Inc. (2004). Analysis of Cooler Control Energy Conservation Measures. Prepared for NSTAR. Table 3-11.
Select_Energy_2004_Analysis_of_Cooler_Control_Energy_Conservation_Measures
~~**18 23**: The estimated duty cycles for Novelty Coolers are supported by Select Energy Services, Inc. (2004). Cooler Control Measure Impact Spreadsheet Users' Manual. Prepared for NSTAR. The study gives a less conservative value than used by NRM.~~
~~Select_Energy_2004_Cooler_Control_Measure_Impact_Spreadsheet_Users_Manual~~
Select Energy Services, Inc. (2004). Analysis of Cooler Control Energy Conservation Measures. Prepared for NSTAR. Table 5-5: Compressor average nighttime duty cycle.
Select_Energy_2004_Analysis_of_Cooler_Control_Energy_Conservation_Measures
24 : DNV. May 12, 2022. "X1931-5 PSD Commercial Refrigeration Efficiency Update Study." Connecticut Energy Efficiency Board and Evaluation Administrators.
25: DNV. May 12, 2022. "X1931-5 PSD Commercial Refrigeration Efficiency Update Study." Connecticut Energy Efficiency Board and Evaluation Administrators.
~~**19** : California eTRM. (2020). https://www.caetrm.com/measure/SWFS016/01/~~

We recommend removing Endnote 19 because the referenced source is a CA eTRM measure for a Refrigerated Chef Base, which is no longer included in the Prescriptive Refrigeration measure.

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26 : Select Energy Services, Inc. (2004). Analysis of Cooler Control Energy Conservation Measures. Prepared for NSTAR. Table 5-1: Compressor duty cycle during winter without economizer cycle. Select_Energy_2004_Analysis_of_Cooler_Control_Energy_Conservation_Measures
27 : This value is an estimate by NRM
28 : Select Energy Services, Inc. (2004). Analysis of Cooler Control Energy Conservation Measures. Prepared for NSTAR. Table 3-4.
Select_Energy_2004_Analysis_of_Cooler_Control_Energy_Conservation_Measures
29 : Select Energy Services, Inc. (2004). Analysis of Cooler Control Energy Conservation Measures. Prepared for NSTAR. Table 5-2: Percent reduction of evaporator fan duty cycle 46%.
Select_Energy_2004_Analysis_of_Cooler_Control_Energy_Conservation_Measures
~~**19**~~ **30** : Select Energy Services, Inc. (2004). Analysis of Cooler Control Energy Conservation Measures. Prepared for NSTAR.
Select_Energy_2004_Analysis_of_Cooler_Control_Energy_Conservation_Measures
~~**20**~~ **31** : Baseline Categories and preliminary Out Year Factors are described at a high level in DNV GL, ERS (2018). Portfolio Model Companion Sheet. Additional background on the baseline categorization given in DNV GL, ERS (2018). Portfolio Model Methods and Assumptions – Electric and Natural Gas Memo.
2018_DNVGL_ERS_Portfolio_Model_Companion_Sheet
~~**21**~~ **32** : Energy & Resource Solutions (2005). Measure Life Study.
ERS_2005_Measure_Life_Study
~~**22**~~ **33**: DNV GL. (2019). Impact Evaluation of PY 2017 Small Business Initiative Non-lighting measures. Final Report MA19C03-E-SBIMPCT 03202020
~~**23**~~ **34** : DNV(2024). C&I Impact Shape Study. 2024_DNV_C&I_Impact Shape Study
~~**24**~~ **35** : NMR(2024). C&I Electric Omnibus NTG Study. 2024_NMR_C&I_Omnibus_Study
~~**25**~~ **36** : NMR(2021). C&I O&M and Non-O&M NEI Study. 2021_NMR_CIOM and NonOM NEI Study
~~**26**~~ **37** : NMR Group, Inc. (2025). NEI Gap Identification and Updates. NMR_2025_NEI_Gap_Identification_MA25X03

Appendix A Subcommittee Members

RI relied on the members of the subcommittee listed in Table 3 throughout the study to provide real-time input on ongoing activities and to discuss interim results, which lead to the recommendations throughout this report.

Table 3. Study Subcommittee Members

Name	Representing	Role
Elias Guadeloupe (PA Study Lead)	National Grid	Evaluation Subcommittee
Nate Baker	Eversource	Evaluation Subcommittee
Matt Siska	Unitil, Liberty, & Berkshire	Evaluation Subcommittee
Sharon Jones	Eversource	Evaluation Subcommittee
Pete Jacobs	EEAC Consultant	Evaluation Subcommittee
Jennifer Chiodo	EEAC Consultant	Evaluation Subcommittee
Geoff Cooper	DNV	Evaluation Subcommittee
Zack Lippert	National Grid	Implementation Stakeholder (Small Business)
Greg Krantz	National Grid	Implementation Stakeholder (Instant Savings)
Jerry Song	National Grid	Implementation Stakeholder (Instant Savings)
Stephanie Terach	Eversource	Implementation Stakeholder (Small Business)
Brad Hunter	Unitil	Implementation Stakeholder (Instant Savings)
Dan Schell	CLC	C&I Eval Lead
Lindsay Henderson	CLC	Implementation Stakeholder
Lisa Zagura	Eversource	Implementation Support
Autum Synder	Liberty	Evaluation Subcommittee

Appendix B ComStock® Data

The following fuel, end use, and building type definitions are taken directly from the *ComStock Reference Document: 2025 Release 3*.[15] RI leveraged ComStock data to develop load profiles used for calculating savings related to the Variable Frequency Drive and Motors & VFD measures. Appendix C outlines the full methodology for the new VFD savings.

Building Type Definitions

Comstock uses DOE prototype[16] buildings to model energy end use by fuel type for commercial building stock across the United States. ComStock developers leveraged multiple data sources (CoStar[17], CBECS[18], and Homeland Infrastructure Foundation-Level Data (HIFLD)[19]) to align DOE prototype models with actual building stock. The following definitions represent the ComStock developers understanding of what each building type does and does not represent. For a more detailed explanation please see the *ComStock Reference Document: 2025 Release 3.*[15]

- **Full Service Restaurant:** Both sit-down restaurants and bars are included in this category, as both typically require significant cooking and sanitation equipment for their operation.
- **Grocery Store:** Grocery stores, also commonly referred to as supermarkets, are buildings whose primary purpose is the sale of food and dry goods rather than general merchandise. This category includes facilities that feature extensive refrigerated and frozen storage, fresh produce, and prepared foods, typically supported by substantial lighting, heating, ventilation, and refrigeration equipment loads. Convenience stores, small specialty food shops, and general merchandise retailers that include grocery sections are not represented by this category.
- **Hospital:** Wherever possible, are disambiguated from outpatient clinics through the existence of around the-clock medical facilities. This is not possible in many states, in which case the differentiation is based on available CoStar data.

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[15] https://natlabrockies.github.io/ComStock.github.io/assets/files/comstock_reference_documentation_2025_3.pdf

[16] https://www.energycodes.gov/prototype-building-models

[17] CoStar Property - Commercial Property Research and Information. http://www.costar.com/products/costarproperty-professional

[18] https://www.eia.gov/consumption/commercial/

[19] https://www.dhs.gov/gmo/hifld

- **Large Hotel:** Large hotels are differentiated from small hotels on the basis of conference or casino spaces. Hotels that have major facilities for conferences, events, or gambling are classified as large hotels.
- **Offices:** Offices are divided up into three subsets: small, medium, and large. Each type of office is based on the thresholds used by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Appendix G (ASHRAE), which include both size and number of stories. In the case of large offices, there are additional probability distributions that determine what percent (if any) of the office is a data center.
- **Outpatient:** Outpatient facilities, as represented in ComStock, include non-hospital medical centers, rehabilitation centers, and medical offices.
- **Primary School:** The primary school type is used to represent all schools that do not include secondary or post secondary education, i.e., grades 9 and beyond. Schools that provide education for pre-secondary to post secondary students (e.g., grades 5–12) are classified as secondary schools. This grouping means that any daycare facilities classified as schools by HIFLD are included as primary schools, unless the facilities also support secondary students.
- **Quick Service Restaurant:** Quick service restaurants consist entirely of fast food restaurants.
- **Retail:** This category predominantly features large national retailers, excluding grocery stores. This includes big box stores, garden centers, department stores, and any other freestanding retailers that do not include a significant grocery section.
- **Secondary School:** Secondary schools incorporate all schools that offer instruction to pupils in grades 9–12. No post-secondary institutions (e.g., community colleges and universities) are represented by ComStock unless they fall into another building type defined herein.
- **Small Hotel:** Small hotels encompass all hotels that do not have significant spaces for conferences, meetings, or gambling.
- **Strip Mall:** Strip malls encompass all multi-tenant retail buildings, as well as single-tenant buildings that are not classified as large retailers, such as post offices, showrooms, etc. These buildings have additional probability distributions that determine how much of the building floor area (if any) is a restaurant. This is critically important, as restaurants have a far higher EUI and as a result can cause strip malls to have far higher energy uses than would otherwise be expected in a stand alone retail building.
- **Warehouse:** Warehouses are perhaps the most differentiated building type in the commercial building stock. They are represented in ComStock as a conjunction of office spaces and high-bay spaces. This building type is used to model distribution centers, light manufacturing, and some showroom and truck terminal spaces, as well as airplane hangars, service depots, and self-storage centers. The spaces encompass a large number of functions; however, it is difficult to differentiate these spaces when examining national databases of building stock characteristics. This makes further disambiguation of these buildings impossible without additional data sources

Fuel and End-Use Outputs

ComStock provides modeled 8,760 energy consumption data for all building types. The output breaks out energy consumption by fuel type and end use. The following provides fuel type and end use definitions.

Fuel Definitions

- **Electricity:** This represents the electricity that is delivered to the building through the power grid and consumed on-site. How this electricity is generated depends on the generation mix found on the power grid in the region serving the building. This does not include electricity that is generated through a backup generator.
- **Natural Gas:** This represents the natural gas that is delivered to the building through the natural gas pipeline system and consumed on-site.
- **Propane:** This represents the propane that is delivered to the building in tanks and consumed on-site.
- **Fuel Oil:** This represents the liquid fuel oil that is delivered to the building, stored in tanks, and consumed on-site.
- **District Heating:** This represents the hot water or steam that is delivered to the building through a district heating piping system and consumed on-site. The quantity of energy consumed represents only the energy extracted from the district heating system by the building; it does not represent the consumption of electricity or natural gas at the district heating plant required to provide heat to the building. In order to capture the energy consumption of the district heating plant, assumptions about distribution heat losses, pumping power, and district heating plant equipment efficiency and controls may be made.
- **District Cooling:** This represents the chilled water that is delivered to the building through a district cooling piping system and consumed on-site. The quantity of energy consumed represents only the energy extracted from the district cooling system by the building; it does not represent the consumption of electricity or natural gas at the district cooling plant required to provide chilled water to the building. In order to capture the energy consumption of the district cooling plant, assumptions about distribution heat gains, pumping power, and district cooling plant equipment efficiency and controls may be made.

End Use Definitions

ComStock outputs energy consumption broken out by fuel and end use. Definitions of each modeled output fuels are below.

- **Cooling:** This includes all energy consumed by primary cooling equipment such as chillers, direct expansion air conditioners (includes condenser fan energy), and direct expansion heat pumps in cooling mode (includes condenser fan energy). This also includes parasitic energy consumption of the equipment, such as pan heaters, defrost energy, and any energy needed to overcome modeled pipe losses.
- **Heating:** This represents all energy consumed by primary heating equipment such as boilers, furnaces, natural gas heating coils, electric resistance strip heating coils, and direct expansion heat pumps in heating mode (includes evaporator fan energy). This also includes parasitic energy consumption of the equipment, such as pilot lights, standby losses, defrost energy, and any energy needed to overcome modeled pipe losses.
- **Fans:** This includes all energy consumed by supply fans, return fans, exhaust fans, and kitchen hoods in the building. It excludes the condenser fan energy from direct expansion coils, which is captured in cooling and heating, as described above.
- **Pumps:** This includes all energy consumed by pumps for the purpose of moving hot water for heating and service water heating, chilled water for cooling, and condenser water for heat rejection.
- **Heat Recovery:** This includes the energy used to turn heat or enthalpy wheels, plus the increased fan energy associated with the increased pressure rise caused by the heat recovery wheels.
- **Heat Rejection:** This includes the energy used to run cooling towers and fluid coolers to reject heat from the condenser water loop to the air. As previously noted, condenser fans on direct expansion cooling and heating coils are included in heating and cooling.
- **Humidification:** This includes all energy used to purposely increase humidity in the building. Most buildings are assumed not to use humidification.
- **Water Systems:** This includes all energy consumed by the primary service hot water supply equipment, such as boilers and water heaters. This also includes parasitic energy consumption of the equipment, such as pilot lights, standby losses, and any energy needed to overcome modeled pipe losses.
- **Refrigeration:** This includes all energy used by large refrigeration cases and walk-ins such as those commonly found in grocery stores and large commercial kitchens. Plug-in refrigerators, such as those commonly found in the checkout areas of retail stores, are included in interior equipment.
- **Interior Lighting:** This includes all energy used to light the interior of the building, including general lighting, task lighting, accent lighting, and exit lighting.
- **Exterior Lighting:** This includes all energy used to light the exterior of the building and the surrounding area, including parking lot lighting, entryway illumination, and wall washing.
- **Interior Equipment:** This includes all energy used in the building that was not included in one of the other categories. This covers miscellaneous electric loads such as computers and monitors, large equipment such as elevators, and special-purpose

equipment such as data center and IT-closet servers. This is a large and coarse bin, largely because the variety of energy-consuming devices found in buildings is large and little comprehensive data are available.

Appendix C Motor & VFD Methodology

The recommended variable frequency drive (VFD) savings methodology aligns with the current methodology but aligns with currently available sources. Section 0**Error! Reference source not found.** summarizes the deemed savings (kWh or kW) per horsepower by building type and VFD installation type, which result from the revised savings calculations. We used a three-step process to generate new deemed savings as outlined below.

Step 1. Load Profile Development

ComStock Data

RI leveraged ComStock data to develop new load profiles for each VFD installation type by building type. **Error! Reference source not found.**Table 4 summarizes all building types, end uses, and fuel types available in ComStock. We have included definitions of building type, end use and fuel type definitions in Appendix B.

Table 4. ComStock Building Types, End Uses, and Fuel Types.

Building Types	End Uses	Fuel Types
Full-service restaurant	Heating	Electricity
Grocery	Cooling	Natural Gas
Hospital	Water System or Service Hot Water (SHW)	Fuel Oil
Large Hotel	Interior Lighting	Propane
Large Office	Exterior Lighting	District Heating
Medium Office	Interior Equipment	District Cooling
Outpatient	Fans	
Primary School	Pumps	
Quick Serve Restaurant	Heat Recovery	
Retail Standalone	Heat Rejection	
Retail Strip Mall	Refrigeration	
Secondary School		
Small Hotel		
Small Office		
Warehouse		

Building Stock Vintage

ComStock leveraged two sources, CoStar[20] and Homeland Infrastructure Foundation-Level Data (HIFLD),[21] to map building vintage to the existing commercial market. Building vintage informed building model energy consumption by aligning building systems and construction characteristics with the code that was current in Massachusetts for each period. Table 5 summarizes the ComStock vintage bins, modeled building coded broken out by percent of commercial floor area each modeled building code represents. For a more detailed explanation please see the *ComStock Reference Document: 2025 Release 3.*[22]

Table 5. ComStock Vintage Bins Mapped to Modeled Building Code and Percent of Massachusetts Commercial Floor Area.

ComStock Vintage Bin	Modeled Building Code	Percent of Commercial Floor Area
Before 1946	DOE Ref Pre-1980	31%
1946 to 1959		9%
1960 to 1969		17%
1970 to 1979		12%
1980 to 1989	DOE Ref 1980-2004	10%
1990 to 1999		3%
2000 to 2012	90.1-2004	1%
	90.1-2007	<1%
	90.1-2010	16%
2013 to 2018	90.1-2013	2%

VFD Installation Type Mapping

The TRM currently has nine installation types, which RI maintained in the new methodology. In collaboration with the study's subcommittee, RI mapped ComStock end use and fuel types to existing VFD installation types in the TRM. Table 6 summarizes the mapping and

[20] CoStar Property - Commercial Property Research and Information. http://www.costar.com/products/costarproperty-professional

[21] https://www.dhs.gov/gmo/hifld

[22] https://natlabrockies.github.io/ComStock.github.io/assets/files/comstock_reference_documentation_2025_3.pdf

reasoning for mapping. RI's methodology for combining end use profiles to generate load profiles is described in detail below. Exhaust fans

Table 6. ComStock End Use Profiles Mapped to VFD Installation Type

VFD Installation Type	Mapped ComStock End Use Profile(s)	Reasoning
Building Exhaust Fan	Fans	Used fans end use to estimate the building exhaust fan load profile. Fans end use includes supply fans, return fans, exhaust fans, and kitchen hoods in a building. Building exhaust fans help maintain building pressure and, when applicable, remove contaminants from the air such as smoke from a commercial kitchen exhaust system.
Cooling Tower Fan	Heat Rejection or Cooling	Used heat rejection end use where available; otherwise, cooling end use to estimate the cooling tower fan load profile. Heat rejection directly covers the energy used for cooling towers and fluid coolers; however, some building types do not have this end use. In those cases, we default to using the cooling end use as a proxy for the cooling tower fan load profile.
Chilled Water Pump	Heat Rejection or Cooling	Used heat rejection end use where available; otherwise, cooling end use to estimate the cooling tower fan load profile. While the pumps end use does include energy for moving chilled water, it also includes energy use to move heating and SHW hot water, as well as condenser water for heat rejection. Because we cannot separate out chilled water pump energy from the pumps end use, we use heat rejection, when available, as a proxy for developing the chilled water pump load profile. Heat rejection end uses covers energy used to run cooling towers and fluid coolers to reject heat. Our assumption is that cooling tower/fluid coolers are typically operating when chilled water pumps are operating. In cases where heat rejection is not an available end use, we use the cooling end use as a proxy for the chilled water pump

VFD Installation Type	Mapped ComStock End Use Profile(s)	Reasoning
		load profile. Cooling end use covers primary cooling equipment energy consumption including chillers, direct expansion air conditioners, and direct expansion heat pumps.
Boiler Feed Water Pump	Heating	Used heating end use to estimate the boiler feed water pump load profile. Boiler feed water pump operation follows boiler/heating demand and heating end use includes all energy consumed by primary heating equipment.
Hot Water Circulation Pump	Heating + Pumps	Used a combination of heating and pump end uses to estimate the boiler feed water pump load profile. Pumps end use includes moving hot water for ehating and service hot water as well as chilled water for cooling, and condenser water for heat rejection. We incorporated heating end use to better align with heating components of the pumps end use.
MAF (Make-up Air Fan)	Fans	Used fans end use to estimate the MAF load profile. Fans end use includes supply fans, return fans, exhaust fans, and kitchen hoods in a building. We assume MAF will follow kitchen exhaust fan operation.
Water-Source Heat Pump Loop Pump	Heating + Cooling	Used a combination of heating and cooling end uses to estimate the water-source heat pump loop pump load profile. We assume the loop pump operation follows heating and cooling demand.
Return Fan	Cooling + Heating + Fans	Used a combination of heating, cooling, and fans end uses to estimate the return fans load profile. Fans end use includes supply fans, return fans, exhaust fans, and kitchen hoods in a building. We incorporate heating and cooling end uses because return fans generally operate in conjunction with cooling or heating demand.
Supply Fan	Cooling + Heating + Fans	Used a combination of heating, cooling, and fans end uses to estimate the supply fans load profile.

VFD Installation Type	Mapped ComStock End Use Profile(s)	Reasoning
		Fans end use includes supply fans, return fans, exhaust fans, and kitchen hoods in a building. We incorporate heating and cooling end uses because return fans

Bin Annual Hours of Operation

RI calculated percent of maximum load for each hour of the year using the hourly kWh and the annual peak kWh. It is important to note that while a VFD installation type may map to more than one ComStock end use profile, RI did not always simply add the end use values together to generate load profiles as outlined in Table 7**Error! Reference source not found.**. We have provided descriptions for each combination method below.

Single Use: RI normalized a single end use.

Sum individual end uses and then normalize them: RI added the mapped end uses actual consumption together by hour. Then RI normalized each hour by dividing the hourly summed usage by the total peak annual usage to get an hourly percent of peak load. In this case the largest end use dominates the load profile.

Normalize individual end uses then sum and normalize: RI normalized each end use by dividing each hourly value by the peak annual usage to get an hourly percent of peak load for each end use. Then RI took the sum of the normalized end use values and normalized them again by dividing each hourly value by the new peak annual percent of peak load.

Table 7. Summary of Methods Used to Combine ComStock End Use Profiles to Align with VFD Installation Types.

VFD Installation Type	ComStock End Use Profile(s) Combination Method	Combination Method Description
Building Exhaust Fan	Fans (electricity)	Single End use: Use fans end use.
Cooling Tower Fan	Heat Rejection[23] (electricity) **OR** Cooling (electricity)	Single End use: Use heat rejection when available; otherwise use cooling.
Chilled Water Pump	Heat Rejection (electricity) **OR** Cooling (electricity)	Single end use: Use heat rejection when available; otherwise use cooling.
Boiler Feed Water Pump	Heating (all fuels)	Sum individual end uses and then normalizes.
Hot Water Circulation Pump[24]	Heating (all fuels)	Sum individual end uses and then normalizes.
MAF (Make-up Air Fan)	Fans (electricity)	Single End use: Use fans end use.
Water-Source Heat Pump Loop Pump	Cooling (all fuels) + Heating (all fuels)	Sum individual end uses and then normalizes.
Return Fan	Cooling (all fuels) + Heating (all fuels) + Fans (electricity)	Normalize individual end uses then sum and normalize.
Supply Fan	Cooling (all fuels) + Heating (all fuels) + Fans (electricity)	Normalize individual end uses then sum and normalize.

Once we had hourly percent of peak load values for each VFD installation type, we summed the hours into bins as illustrated in Table 8. Each bin represents a 10% increment of maximum load and is based on peak load or combined peak load of the mapped end use(s). We assumed all hours with less than 10% peak load to be hours when the equipment is off. We summed all hours with a peak load equal to 10% in the 10% bin. We summed the remaining hours into bins based on the ceiling of the bin. For example, the 90% bin includes all hours at greater than 80% peak load and less than or equal to 90% peak load. A complete set of binned hours by application and building type are included in the supporting documents in Appendix D.

[23] Heat rejection rule: When the Heat Rejection - Electricity end use is non-zero (Hospital, Large Hotel, Large Office, Medium Office, Outpatient, Primary School, Secondary School) and falls back to Cooling - Electricity for the other 8 building types. The two equipment types are therefore identical.
[24] RI assumed hot water circulation pump was related to

Table 8. Hours of Operation Binned by Percent of Annual Peak Load for Four VFD Installation Types for Medium Office Building.

Percent of Annual Peak	Supply Fan	Return Fan	Chilled Water Pump	Hot Water Circulation Pump
0%	0	0	5,634	116
10%	0	0	0	0
20%	1,374	1,374	1,026	2,015
30%	2,257	2,257	843	3,275
40%	2,419	2,419	457	2,316
50%	1,517	1,517	369	624
60%	701	701	289	196
70%	301	301	105	114
80%	112	112	20	36
90%	36	36	11	46
100%	43	43	6	22

It might be surprising to see that the supply fan and return fan load profiles indicate the fans run 8,760. This appears high as we would assume that HVAC fans would be scheduled to turn off during unoccupied hours in a medium office. While that would be the most efficient way to operate the supply and return fans, it is not necessary how buildings operate in the field. ComStock fan operation was informed by a BAS data from 5,700 AHUs. The data showed that 27% of AHU fans were scheduled to run during unoccupied times, 53% of AHU fans were scheduled to cycle with ventilation to maintain thermostat setpoints, and the remaining 23% AHU fans cycled without ventilation to maintain thermostat setpoints.[25] The *Massachusetts Commercial and Industrial Existing Buildings Baseline Study*[26] anlayzed HVAC control capabilities. It found that only 25% of customers, by weighted square footage, have a BMS or smart/Wi-Fi thermostat, 22% have programmable thermostats, and 52% have

[25] https://natlabrockies.github.io/ComStock.github.io/assets/files/comstock_reference_documentation_2025_3.pdf

[26] https://ma-eeac.org/wp-content/uploads/MA-Baseline-Framework-Updated_Final_clean.pdf

manual or handheld manual thermostats. While we do not have insight into how the thermostats are used or programed, it is reasonable to assume that many of them are not set up to control fans efficiently.

Bin Peak Demand Hours of Operation

We used a similar method to bin summer and winter peak load hours by the percent of annual peak load. We assumed summer peak hours were between 1 and 5 p.m. on weekdays in June, July, and August. We assumed winter peak hours were between 5 and 7 p.m. on weekdays in December and January. Our assumptions are based on the MA TRM 2026 Prospective Version. We provide a summary of summer peak and winter peak binned hours for a selection of VFD installation types for a medium office Table 9 and Table 10.

Table 9. Summer Peak Hours of Operation Binned by Percent of Annual Peak Load for Four VFD Installation Types for Medium Office Building.

Percent of Annual Peak	Supply Fan	Return Fan	Chilled Water Pump	Hot Water Circ Pump
0%	0	0	4	0
10%	0	0	0	0
20%	0	0	8	0
30%	0	0	16	0
40%	19	19	48	1
50%	52	52	82	2
60%	75	75	75	21
70%	57	57	21	108
80%	37	37	5	90
90%	16	16	3	33
100%	8	8	2	9

Table 10. Winter peak hours of operation binned by percent of annual peak load for four VFD installation types for medium office building.

Percent of Annual Peak	Supply Fan	Return Fan	Chilled Water Pump	Hot Water Circulation Pump
0%	0	0	81	0
10%	0	0	0	0
20%	0	0	2	7
30%	3	3	1	38
40%	29	29	0	24
50%	37	37	0	8
60%	9	9	0	3
70%	2	2	0	3
80%	4	4	2	2
90%	2	2	1	1
100%	2	2	1	2

Step 2. Establish Fan and Pump Curves

After binning annual operating hours by percent of peak load, we needed to calculate the part load flow rate for each bin. The part load flow rate varies based on type of fan and pump as well as the existing control strategy. The high efficiency control strategy for both is a VFD. RI leveraged the *Variable Frequency Drive Evaluation Protocol*[27] that the National Renewable Energy Laboratory (NREL) developed as part of the Uniform Methods Project[28] to generate part load curves for fan and pump baseline, along with high efficiency. We used the default curve method outlined in Section 4.2 of the protocol.

Baseline Part Load Flow Rates

The protocol's Table 1. Fan Default Curve Correlation Coefficients included three types of fans and three types of baseline fan control strategies. RI eliminated all but three

[27] https://www.nlr.gov/docs/fy17osti/68574.pdf
[28] https://www.energy.gov/cmei/buildings/uniform-methods-project-determining-energy-efficiency-savings-specific-measures

combinations (forward curved fan with discharged dampers, backwards curved fan with discharge dampers, and backwards curved with inlet vanes) for the baseline based on aligning fan type and control strategy with current application eligibility requirements. We also added a no control option that assumes the fan has no part load and is either on or off. RI calculated a weighted average assuming 70% no control, and 10% each for forward curve fan with discharge dampers, backwards curved fan with discharge dampers, and backwards curved with inlet vanes. Based on our review of the LBNL U.S. Motor System Market Assessment (MSMA)[29], fan motors for these installation types typically have no control. To be conservative, we opted not to assume 100% of baseline motors had no control.

The protocol's Table 2. Pump Default Curve Correlation Coefficients only included a single pump type (centrifugal) and one baseline strategy (throttle valve). We also added a no control option which assumes the pump has no part load and is either on or off. We calculated a weighted average assuming 80% no control and 20% with throttling valves. Like fan motors, based on RI's review of LBNL's MSMA, pump motors for these installation types typically have no control. To be conservative, RI opted not to assume 100% of baseline motors had no control.

VFD Part Load Flow Rates

We also used Table 1 and Table 2 from the Protocol to generate VFD part load flow rates, which remained the same regardless of fan or pump type.

Step 3. Calculate Savings

The following describes RI's process for calculating savings. A complete set of calculations are included in the supporting documents included in Appendix D.

Annual kWh Savings

RI calculated the kWh per HP savings factors for each application and building type using Equation 1, Equation 2, and Equation 3.

Equation 1. Baseline kWh per HP

$$Base\frac{kWh}{HP} = \frac{0.746 * LF}{\eta_{motor}} * \sum_{0\%}^{100\%} Hours * PLR_{Base}$$

[29] https://motors.lbl.gov/

Equation 2. VFD kWh per HP

$$VFD\ \frac{kWh}{HP} = \frac{0.746 * LF}{\eta_{motor} * \eta_{VFD}} * \sum_{0\%}^{100\%} Hours * PLR_{Eff}$$

Equation 3. Savings Factor kWh per HP

$$Savings\ Factor\ \frac{kWh}{HP} = Base\ \frac{kWh}{HP} - VFD\ \frac{kWh}{HP}$$

Where:

0.746 = Conversion from HP to kW
LF = Load Factor: 0.75
η_{motor} = Motor Efficiency: 87.8% for fans, and 90.4% for pumps
η_{VFD} = VFD Efficiency: 97%[30]
Hours = Hours the motor operates at each bin (0% to 100% in 10% increments): An example of these binned hours are shown in Table 8[31]
PLR_{Base} = Part Load Ratio Baseline: See Table 11
PLR_{VFD} = Part Load Ratio VFD: See Table 11

Table 11. Part Load Ratios for Fan and Pump Baseline and VFD applications

Motor	PLR	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Fan	**Baseline**	0.81	0.82	0.84	0.85	0.87	0.89	0.92	0.94	0.97	1.00
	VFD	0.15	0.11	0.11	0.13	0.20	0.29	0.42	0.58	0.77	1.00
Pump	**Baseline**	0.92	0.93	0.95	0.96	0.96	0.97	0.98	0.99	0.99	1.00
	VFD	0.15	0.11	0.11	0.13	0.20	0.29	0.42	0.58	0.77	1.00

Load Factor

RI estimated load factor using LBNL MSMA data. Figure 58 in the *U.S. Industrial and Commercial Motor System Market Assessment Report Volume 1: Characteristics of the Installed Base*[32] shows that the average commercial motor load factor is around 0.65 for

[30] https://motors.lbl.gov/download/report/3
[31] A complete set of annual operating hours for each application and building type are included in the documents in Appendix D.
[32] https://motors.lbl.gov/download/report/1

motors 50 hp or less. It is important to note that rather than using spot checks to determine load factors, the MSMA team estimated load factors based on information gathered onsite and from the staff. When a motor load factor could not be determined the default was set at 0.75 based on the assumption that the motor was right sized.

RI also reviewed the online motor systems inventory[33] in hopes of leveraging the data to identify a load factor more applicable to the variable frequency drive measure applications. Unfortunately, the granularity in the data was not sufficient to confidently estimate an average load factor by application or equipment type and RI decided to use the 0.75 default.

Motor Efficiency

Motor efficiency assumptions are averages weighted by motor hp, pole configuration, and enclosure type. RI used the DOE Electric Motors Technical Support Document (TSD) to estimate the market distribution of motors by pole configuration and enclosure type the LBNL MSMA data to estimate motor hp distribution. We summarized the weighting values in Table 12 and Table 13 that were used to calculate the weighted average motor efficiency for fan motors and pump motors used in Equation 1and Equation 2. Motor efficiency is the same value for both Equation 1 and Equation 2 because this measure requires the VFD be installed on an existing fan or pump motor or in other words the existing motor is assumed to remain in place.

Table 12. Percent of 2022 Motor Shipments by Pole Configuration and Enclosure Type.

Pole Configuration	% of 2022 Shipments by Pole Configuration	Enclosure Type	% of 2022 Shipments by Enclosure Type
2-pole	23%	**Open**	38%
4-pole	67%	**Enclosed**	62%
6-pole	8%		

[33] https://motors.lbl.gov/login

Table 13. Total Connected HP by Motor Bins for Pump and Fan Applications.

Motor Size Bins (HP)	Total Connected Pump HP	% of Connected Pump HP	Total Connected Fan HP	% of Connected Fan HP
1-5	1,668,132	85%	1,668,132	85.4%
6-20	5,791,202	91%	5,791,202	90.8%
21-50	4,090,969	93%	4,090,969	93.2%
51-100	3,175,250	95%	3,175,250	94.7%
101-200	4,862,030	96%	4,862,030	95.5%

Peak kW Savings

RI used the same equations and inputs to estimate the peak kW savings factor as used previously with one minor change. Bin hours are only based on hours that occurred during peak periods rather than the total annual hours. Summer peak hours were weekdays in June, July, and August from 1 pm to 5 pm for a total of 264 hours. Winter peak hours were weekdays in December and January from 5 pm to 7 pm for a total of 88 hours. Bin hours were used to weight the peak kW per HP savings factors by VFd installation type and building type.

Equation 4. Baseline kWh per HP

$$Base\,\frac{kW}{HP} = \frac{\frac{0.746 * LF}{\eta_{motor}} * \sum_{0\%}^{100\%} Hours_{Peak} * PLR_{Base}}{Hours_{Peak}}$$

Equation 5. VFD kWh per HP

$$VFD\,\frac{kW}{HP} = \frac{\frac{0.746 * LF}{\eta_{motor} * \eta_{VFD}} * \sum_{0\%}^{100\%} Hours_{Peak} * PLR_{Eff}}{Hours_{Peak}}$$

Equation 6. Savings Factor kWh per HP

$$Peak\ Savings\ Factor\ \frac{kW}{HP} = Base\,\frac{kW}{HP} - VFD\,\frac{kW}{HP}$$

Where:
0.746 = Conversion from HP to kW
LF = Load Factor: 0.75

η_{motor} = Motor Efficiency: 87.8% for fans, and 90.4% for pumps
η_{VFD} = VFD Efficiency: 97%[34]
$Hours_{Peak}$ = Hours the motor operates at each bin (0% to 100% in 10% increments) during summer or winter peak times.[35]
PLR_{Base} = Part Load Ratio Baseline: See Table 11
PLR_{VFD} = Part Load Ratio VFD: See Table 11

[34] https://motors.lbl.gov/download/report/3
[35] A complete set of annual operating hours for each application and building type are included in the documents in Appendix D.

Appendix D VFD Energy Savings Supporting Documents

The following documents summarize the inputs and calculations used to generate the deemed savings factors in the Variable Frequency Drive measure.

All_End_Uses_by_Fuel_and_Building_Type.x

Step1_Hourly_Profiles_to_Equipment_Bins.

Step2_Equipment_Bins_to_Savings_Factors

Appendix E Air Sealing Energy Savings Calculations

The following document contains the updated inputs and calculations used to generate the deemed savings factors in the Air Sealing Measure.

Air Sealing Calculation.xlsx