

In addition to the interior building types specified in IECC 2015, the following LPDs have been established for agricultural greenhouses. Greenhouse types are defined as follows:

- High intensity sole-source greenhouse: All plant lighting is provided by ceiling-mounted high intensity artificial electric lighting.
- Supplemented greenhouse: Most plant lighting is provided by natural sunlight with supplemented artificial electric lighting used to extend daylight hours during winter seasons with short periods of sunlight or on inclement weather days when sunlight levels are suboptimal.
- Vertical farming: Plants are sacked along vertical shelving from floor to ceiling to increase grow area.

Table 5. Lamps & Fixtures—New Construction LPDs for Agricultural Greenhouses²⁰

Facility type ²¹	LPD (W/ft ²)
Agricultural: high intensity sole-source greenhouse	52.16
Agricultural: supplemented greenhouse	10.92
Agricultural: vertical farming ²²	—

The total exterior lighting power allowance for all exterior building applications is the sum of the base site allowance plus the individual allowances for areas that are to be illuminated and are permitted in Table 6.

The reported square footage should represent the illuminated area. Each unique outdoor area should report a unique illuminated area specific to that application and should not be combined under a single space type. For example, a new construction convenience store project should have separate areas for fuel canopy, parking and drives, building facades, and any other applicable space types. Fuel canopies should reflect the area under the canopy rather than the entire exterior lot area. Building facades should reflect the total wall area where wall-mounted fixtures are installed rather than the floor area for any space type surrounding the illuminated wall.

Table 6. Lamps & Fixtures—New Construction LPDs for Exterior Space Types²³

²⁰ “Energy Savings Potential of SSL in Agricultural Applications,” US Department of Energy. June 2020. Table E-1. <https://www.energy.gov/sites/prod/files/2020/07/f76/ssl-agriculture-jun2020.pdf>.

²¹ Weighted average of LPDs specified for LED, HPS/MH, and Fluorescent lighting type categories based on 2019 technology mix from Table E-1.

²² Vertical farming was excluded due to 100% LED adoption in the 2019 technology mix from Table E-1.

²³ IECC 2015 Table C405.5.1(2) and ANSI/ASHRAE/IESNA Standard 90.1-2013 Table 9.4.2-2. Differences between the two standards are noted.

Space type	LPD (W/ft ²)			
	Exterior Climate Zone 1	Climate Exterior Zone 2	Exterior Climate Zone 3	Exterior Climate Zone 4
Base site allowance	500 W	600 W	750 W	1,300 W
Uncovered parking: Parking areas and drives	0.04	0.06	0.10	0.13
Building grounds: Walkways \geq 10 ft. wide, plaza areas, and special feature areas	0.14	0.14	0.16	0.20
Building grounds: Stairways	0.75	1.00	1.00	1.00
Building grounds: Pedestrian tunnels	0.15	0.15	0.20	0.30
Building grounds: Landscaping (ASHRAE 90.1-2013 only) ²⁴	0.04	0.05	0.05	0.05
Building entrances and exits: Entry canopies	0.25	0.25	0.40	0.40
Building entrances, exits, and loading docks: Loading docks (ASHRAE 90.1-2013 specific) ²⁵	0.50	0.50	0.50	0.50
Sales canopies: Free-standing and attached	0.60	0.60	0.80	1.00
Outdoor sales: Open areas	0.25	0.25	0.50	0.70
Building facades ²⁶	–	0.075	0.113	0.150
Entrances and gatehouse inspection stations	0.75	0.75	0.75	0.75
Loading areas for emergency vehicles	0.50	0.50	0.50	0.50

The following default metal halide baseline wattage assumptions have been approved for exterior athletic fields and courts, which are not included in the above LPD table. These baseline wattages were derived based on a review of reported lumen range for available LED products and their reported equivalent metal halide (MH) wattage.

Table 7. Lamps & Fixtures—New Construction Baseline Wattages for Athletic Field/Court LEDs

Equivalent MH wattage	Number of lamps	LED rated lumen range
175	1	< 7,500

²⁴ In June 2016, the Texas Comptroller issued a state certification letter adopting ASHRAE 90.1-2013 as the energy code for state buildings while the Commercial building code remains IECC 2015. State-funded buildings are required to submit SECO compliance certificates as part of the NC/Renovation process. More details can be found at the Comptroller website:

<https://comptroller.texas.gov/programs/seco/code/state-funded.php>. This space type is missing from the IECC 2015 LPD table, but the TRM authorizes the use of these LPDs for non-state-funded buildings.

²⁵ Ibid.

²⁶ ASHRAE 90.1-2013 reflects a higher baseline. The TRM specifies the higher, more conservative, baseline to allow the same LPD to apply to all buildings, regardless of whether they are state-funded.

Equivalent MH wattage	Number of lamps	LED rated lumen range
250	1	7,500-12,499
400	1	12,500-19,999
400	2	20,000-39,999
1,000	1	40,000-59,999
1,500	1	60,000-74,999
1,000	2	75,000-99,999
1,000	3	100,000-124,999
1,000	4	125,000-149,999
1,000	5	150,000-199,999
1,000	6 plus 1 additional lamp for every 50,000 lumens above 200,000 (rounded down)	> 200,000

Operating Hours (Hours) and Coincidence Factors (CFs)

Operating hours and peak demand coincidence factors are assigned by building type, as shown in Table 9 through Table 11. The building types used in this table are based on Commercial Buildings Energy Consumption Survey (CBECS)²⁷ building types but have been modified for Texas. Refer to Volume 1, Section 4 for a description of the Texas peak demand methodology. Winter peak coincidence factors are only specified for outdoor fixtures, including for the “Parking Garage” building type.

The operating hours and coincidence factors specified in this section have been calculated at the facility level and should be applied to the entire facility. Outdoor fixtures that are not associated with the typical building lighting schedule may be claimed separately. These can include parking lot, walkway, wall pack, or another lighting, while building-mounted lighting with an operating schedule that more closely approximates the interior lighting schedule typically should not be claimed separately.

²⁷ DOE-EIA Commercial Building Energy Consumption Survey.
<https://www.eia.gov/consumption/commercial/>.

Table 8. Lamps & Fixtures—Building Type Descriptions and Examples

Building type	Principal building activity	Definition	Detailed business type examples ²⁸
Agriculture	Dairy buildings	Buildings used to house dairy livestock and collect milk from dairy cows.	1) Dairy buildings
	Grow house	Buildings used to grow herbs, fruits, or vegetables under artificial lighting. Sole-source greenhouses rely on 100% artificial lighting, whereas supplemented greenhouses use both natural sunlight and artificial lighting.	1) 24-hour grow house 2) Non-24-hour sole-source greenhouse 3) Non-24-hour supplemented greenhouse
Data center	Data center	Buildings used to house computer systems and associated components.	1) Data center
Education	College/university	Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses. Buildings on education campuses for which the main use is not classroom are included in the category relating to their use. For example, administration buildings are part of "Office," dormitories are "Lodging," and libraries are "Public Assembly."	1) College or university 2) Career or vocational training 3) Adult education
	Primary school		1) Elementary or middle school (<u>grade 8 or lower</u>) 2) Preschool or daycare
	Secondary school ²⁹		1) High school (<u>grade 9 or greater</u>) 2) Religious education
Food sales	Convenience	Buildings used for retail or wholesale of food.	1) 1) Gas station with a convenience store 2) Convenience store

²⁸ Principal Building Activities are based on sub-categories from 2003 CBECS questionnaire.

²⁹ Individual middle and junior high schools may have a campus size and building activities that better align with secondary schools, refer to Measure 2.2.2 for guidance on aligning subcategories.

Building type	Principal building activity	Definition	Detailed business type examples²⁸
	Supermarket		1) Grocery store or food market
Food service	Full-service restaurant	Buildings used for the preparation and sale of food and beverages for consumption.	1) Restaurant or cafeteria
	Quick-service restaurant		1) Fast food
Healthcare	Hospital	Buildings used as diagnostic and treatment facilities for inpatient care.	1) Hospital 2) Inpatient rehabilitation
	Outpatient healthcare	Buildings used as diagnostic and treatment facilities for outpatient care. Medical offices are included here if they use any type of diagnostic medical equipment (if they do not, they are categorized as an office building).	1) Medical office 2) Clinic or outpatient health care 3) Veterinarian
Multifamily	Common area	Buildings containing multifamily dwelling units, having multiple stories, and equipped with elevators.	1) Common area
Lodging	Large hotel	Buildings used to offer multiple accommodations for short-term or long-term residents.	1) Motel or inn
	Nursing home		2) Hotel
	Small hotel/motel		3) Dormitory, fraternity, or sorority 4) Retirement home, nursing home, assisted living, or other residential care 5) Convent or monastery

Building type	Principal building activity	Definition	Detailed business type examples²⁸
Manufacturing	1 Shift (<70 hr/week)	Buildings used for manufacturing/industrial applications.	1) Apparel 2) Beverage, food, and tobacco products 3) Chemicals 4) Computer and electronic products 5) Appliances and components 6) Fabricated metal products 7) Furniture 8) Leather and allied products 9) Machinery 10) Nonmetallic mineral products 11) Paper 12) Petroleum and coal products 13) Plastics and rubber products 14) Primary metals 15) Printing and related support 16) Textile mills 17) Transportation equipment 18) Wood products
	2 Shift (70-120 hr/week)		
	3 Shift (>120 hr/week)		
Mercantile	Stand-alone retail	Buildings used for the sale and display of goods other than food.	1) Retail store 2) Beer, wine, or liquor store 3) Rental center 4) Dealership or showroom for vehicles or boats 5) Studio or gallery
	Strip mall/enclosed mall	Shopping malls comprised of multiple connected establishments.	1) Strip shopping center 2) Enclosed malls

Building type	Principal building activity	Definition	Detailed business type examples²⁸
Office	Large office	Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building).	1) Administrative or professional office 2) Government office 3) Mixed-use office 4) Bank or other financial institution 5) Medical office 6) Sales office 7) Contractor's office (e.g., construction, plumbing, HVAC) 8) Non-profit or social services 9) Research and development 10) City hall or city center 11) Religious office 12) Call center
	Medium office		
	Small office		
Parking	Parking garage	Buildings used for parking applications.	No sub-categories collected.

Building type	Principal building activity	Definition	Detailed business type examples²⁸
Public assembly	Public assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	1) Social or meeting (e.g., community center, lodge, meeting hall, convention center, senior center) 2) Recreation (e.g., gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports) 3) Entertainment or culture (e.g., museum, theater, cinema, sports arena, casino, night club) 4) Library 5) Funeral home 6) Student activities center 7) Armory 8) Exhibition hall 9) Broadcasting studio 10) Transportation terminal
Public order and safety	Jail and prison	Government establishments engaged in justice, public order, and safety.	1) Correctional institutions 2) Prison administration and operation
	Other		1) Police protection 2) Legal counsel and prosecution 3) Fire protection 4) Public order and safety, not elsewhere classified
Religious worship	Religious worship	Buildings in which people gather for religious activities (such as chapels, churches, mosques, synagogues, and temples).	No sub-categories collected.

Building type	Principal building activity	Definition	Detailed business type examples²⁸
Service	Service	Buildings in which some type of service is provided, other than food service or retail sales of goods.	<ol style="list-style-type: none"> 1) Vehicle service or vehicle repair shop 2) Vehicle storage/maintenance 3) Repair shop 4) Dry cleaner or laundromat 5) Post office or postal center 6) Car wash 7) Gas station with no convenience store 8) Photo processing shop 9) Beauty parlor or barber shop 10) Tanning salon 11) Copy center or printing shop 12) Kennel
Warehouse	Warehouse	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).	<ol style="list-style-type: none"> 1) Refrigerated warehouse 2) Non-refrigerated warehouse 3) Distribution or shipping center
Other	Other	For building types not explicitly listed.	Values used for other are the most conservative values from the explicitly listed building types.

Table 9. Lamps & Fixtures—Operating Hours by Building Type

Building type	Operating hours
Agriculture: Long-day lighting ³⁰	6,209
Agriculture: Non-24-hour sole-source greenhouse ³¹	5,479
Agriculture: Non-24-hour supplemented greenhouse ³²	2,000
Data center	4,008
Education: K-12 with summer session, college, university, vocational, and day care	3,577
Education: K-12 with partial summer session ³³	3,177
Education: K-12 without summer session	2,777
Food Sales: Non-24-hour supermarket or convenience store	4,706
Food Sales: 24-hour supermarket or convenience store	6,900
Food service: Full-service restaurant	4,368
Food service: Quick-service restaurant	6,188
Food service: 24-hour restaurant	7,311
Healthcare: Inpatient	5,730
Healthcare: Outpatient	3,386
Lodging: Hotel/motel/dorm—common area	6,630
Lodging: Hotel/motel/dorm—room	3,055
Lodging: Nursing home	4,271
Manufacturing: 1 Shift (<70 hr/week)	2,786
Manufacturing: 2 Shift (70-120 hr/week)	5,188
Manufacturing: 3 Shift (>120 hr/week)	6,414
Mercantile: Non-24-hour stand-alone retail	3,668
Mercantile: Enclosed mall	4,813
Mercantile: Strip mall	3,965
Mercantile: 24-hour retail	6,900
Multifamily: Common area	4,772
Office	3,737

³⁰ Daily operating hours are 17 hours/day based on assumptions from the Minnesota and Wisconsin TRMs and market research indicating average 16–18 hours of daily operation. Annual operating hours are derived by multiplying 17 hours/day by 365.25 days/year.

³¹ Daily operating hours are 15 hours/day based on market research indicating 14-16 hours of daily operation. Annual operating hours are derived by multiplying 15 hours/day by 365.25 days/year.

³² “Energy Savings Potential of SSL in Agricultural Applications,” US Department of Energy. June 2020. Table E-1. <https://www.energy.gov/sites/prod/files/2020/07/f76/ssl-agriculture-jun2020.pdf>.

³³ Assuming a partial summer session in June with no summer session in July.

Building type	Operating hours
Outdoor: Athletic field and court ³⁴	767
Outdoor: Billboard ³⁵	3,470
Outdoor: Dusk-to-dawn ³⁶	4,161
Outdoor: Less than dusk-to-dawn ³⁷	1,998
Parking garage	7,884
Public assembly	2,638
Public order and safety: Jail and prison	7,264
Public order and safety: Other	3,472
Religious worship	1,824
Service: Excluding food	3,406
Warehouse: Non-refrigerated	3,501
Warehouse: Refrigerated	3,798
Other	2,638

Table 10. Lamps & Fixtures—Summer Peak Coincidence Factors by Building Type³⁸

Building type	Summer peak CF				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Agriculture: Long-day lighting	1.00	1.00	1.00	1.00	1.00
Agriculture: Non-24-hour sole-source greenhouse	1.00	1.00	1.00	1.00	1.00

³⁴ “2015 US Lighting Market Characterization,” US Department of Energy. November 2017. Value derived by multiplying average daily operating hours from Table 2-30 by 365.25 hours/year.

³⁵ Ibid.

³⁶ This space type refers to fixtures controlled either by photocells or by timers operating on a dusk-to-dawn schedule. Calculated based on average dark hours for Amarillo (northernmost) and Corpus Christi (southernmost) climate zones from sunrise to sunset excluding ½ of civil twilight period. <https://www.timeanddate.com/sun/>. Note: pending update to US Naval Observatory annual data once website maintenance has completed. https://aa.usno.navy.mil/data/RS_OneYear.

³⁷ This space type refers to fixtures controlled by timers operating on a less than dusk-to-dawn schedule.

³⁸ Building operating schedules are adapted from COMNET Appendix C – Schedules (Rev. 3). <https://comnet.org/appendix-c-schedules>. Updated 7/25/2016.

Building type	Summer peak CF				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Agriculture: Non-24-hour supplemented greenhouse ³⁹	–	–	–	–	–
Data center	0.85	0.85	0.85	0.85	0.85
Education: K-12 with summer session, college, university, vocational, and day care	0.90	0.90	0.90	0.90	0.90
Education: K-12 with partial summer session ⁴⁰	0.42	0.39	0.90	0.90	0.57
Education: K-12 without summer session	0.39	0.39	0.90	0.87	0.40
Food sales: Non-24-hour supermarket or convenience store	0.90	0.90	0.90	0.90	0.90
Food sales: 24-hour supermarket or convenience store	0.90	0.90	0.90	0.90	0.90
Food service: Full-service restaurant	0.90	0.90	0.90	0.90	0.90
Food service: Quick-service restaurant	0.90	0.90	0.90	0.90	0.90
Food service: 24-hour restaurant	0.90	0.90	0.90	0.90	0.90
Healthcare: Inpatient	0.80	0.83	0.81	0.80	0.90
Healthcare: Outpatient	0.70	0.75	0.72	0.71	0.90
Lodging: Hotel/motel/dorm, common area	0.90	0.90	0.90	0.90	0.90
Lodging: Hotel/motel/dorm, room	0.30	0.30	0.30	0.30	0.30
Lodging: Nursing home	0.70	0.75	0.72	0.71	0.90

³⁹ Assuming no peak coincidence because these fixtures are often operated exclusively during off-peak hours (ranging from 10 PM to 6 AM). This time range is not coincident with either the Texas summer or winter peak periods.

⁴⁰ Assuming a partial summer session in June with no summer session in July.

Building type	Summer peak CF				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Mercantile: Non-24-hour retail	0.90	0.90	0.90	0.90	0.90
Mercantile: Enclosed mall	0.90	0.90	0.90	0.90	0.90
Mercantile: Strip mall	0.90	0.90	0.90	0.90	0.90
Mercantile/food sales: 24-hour retail	0.90	0.90	0.90	0.90	0.90
Manufacturing: 1 Shift (<70 hr/week)	0.83	0.84	0.83	0.85	0.85
Manufacturing: 2 Shift (70-120 hr/week)	0.85	0.85	0.85	0.85	0.85
Manufacturing: 3 Shift (>120 hr/week)	0.85	0.85	0.85	0.85	0.85
Multifamily: Common area	0.90	0.90	0.90	0.90	0.90
Office	0.87	0.88	0.86	0.90	0.90
Outdoor: Athletic field and court	–	–	–	–	–
Outdoor: Billboard	–	–	–	–	–
Outdoor: Dusk-to-dawn	–	–	–	–	–
Outdoor: Less than dusk-to-dawn	–	–	–	–	–
Parking garage	1.00	1.00	1.00	1.00	1.00
Public assembly	0.65	0.65	0.65	0.65	0.65
Public order and safety: Jail and prison	0.90	0.90	0.90	0.90	0.90
Public order and safety: Other	0.70	0.75	0.72	0.71	0.90
Religious worship	0.65	0.65	0.65	0.65	0.65
Service: Excluding food	0.90	0.90	0.90	0.90	0.90
Warehouse: Non-refrigerated	0.79	0.81	0.79	0.80	0.85
Warehouse: Refrigerated	0.79	0.81	0.79	0.80	0.85
Other	0.65	0.65	0.65	0.65	0.65

Table 11. Lamps & Fixtures—Winter Peak Coincidence Factors by Building Type⁴¹

Space type	Winter peak CF				
	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Outdoor: Athletic field and court	0.26	0.27	0.24	0.29	0.38
Outdoor: Billboards	0.59	0.62	0.53	0.65	0.87
Outdoor: Dusk-to-dawn ⁴²	0.67	0.71	0.61	0.75	1.00
Outdoor: Less than dusk-to-dawn ⁴³	0.67	0.71	0.61	0.75	1.00
Parking garage	1.00	1.00	1.00	1.00	1.00

Building Type Selection

This section provides additional guidance on Recommendation #1b in the 2013 Statewide Annual Portfolio Evaluation Report.⁴⁴

The deemed lighting hours of use (HOU) and peak summer coincidence factors (CF) for utilities to use in calculating savings associated with lighting are broken down by building type and use. If the building type changes in combination with the retrofit, the selected building type should be consistent with the space condition after improvement. These values are provided in Table 9 through Table 11. For ~~most~~**the majority of the** building types listed in this table, the HOU and CFs were created based on weighted averages of lighting usage across all activity areas of the building.⁴⁵ Therefore, the deemed HOU and CFs are representative of an entire building type, across all activity areas that are in a “typical” building for this type.

The following flow chart, Figure 2, has been provided to assist utilities in understanding how they can use the deemed methods to calculate lighting savings based on HOU and CF provided in the TRM. Additionally, it provides guidance on how to treat lodging facilities and outdoor lighting projects as well as unique building types.

⁴¹ Operating schedules are based on sunrise/sunset times for each climate-zone reference city, adjusted for compliance with IESNA-DG-13-96 and IESNA-DG-13-98 recommendations.

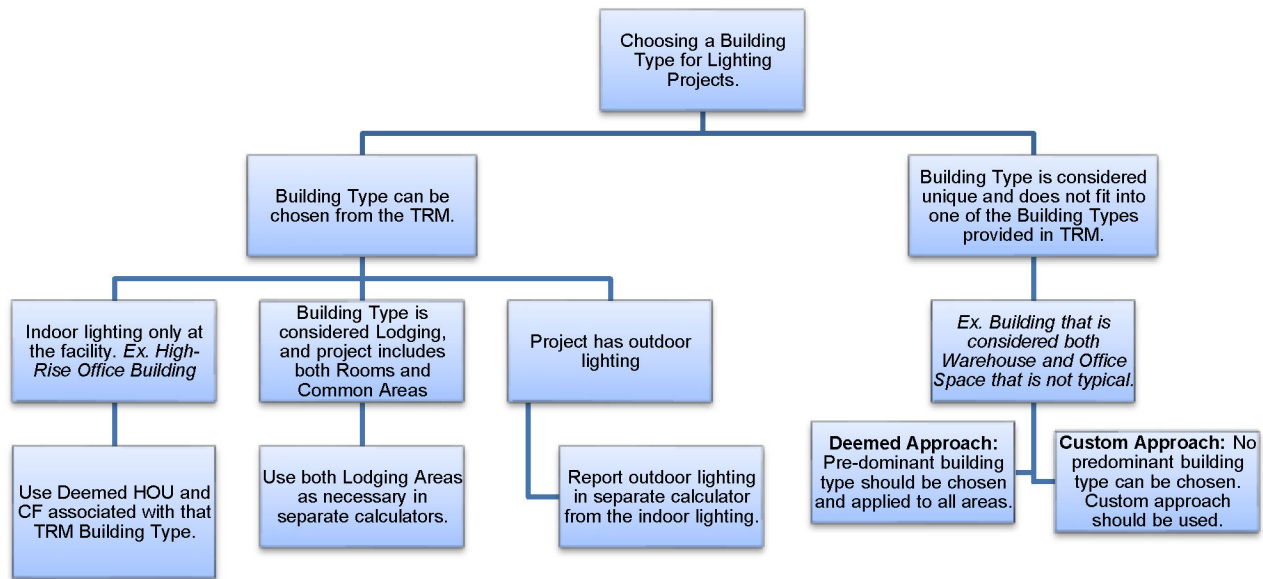
⁴² This space type refers to fixtures controlled either by photocells or by timers operating on a dusk-to-dawn schedule.

⁴³ This space type refers to fixtures controlled by timers operating on a less than dusk-to-dawn schedule.

⁴⁴ *Annual Statewide Portfolio Report for Program Year 2013 – Volume I*. Prepared for the Public Utility Commission of Texas. October 6, 2014.

⁴⁵ More information on how these values were created can be found in PUCT Docket #39146.

Figure 2. Lamps & Fixtures—Building Type Decision-Making



Lodging sites. Lodging facilities (Hotel/Motel/Dormitories) have been identified in the TRM by *Common* and *Rooms*, both with different HOU and CF. As two different values have been provided for these areas, it is acceptable for the utilities to use either or both building types for a single project.

Exterior lighting. Projects involving outdoor lighting should be claimed in a separate calculator or separate inventory within the same calculator. The exception to this is walkway lighting that is more consistent with building operation. In this application, the utilities should use the primary building type as their HOU and CFs have been rolled up into the overall building type calculations (e.g., walkway lighting between two buildings that operates during business hours).

Combination building types. In most cases, all buildings (except greenhouses and parking structures) should be classified based on the building type that represents the majority of the use the predominant square footage to inform the selection of a single building type. Greenhouses and parking garages should be treated separately from other indoor spaces intended for human occupancy.

In other situations where multiple TRM building types seem plausible, or a predominant TRM building type is unclear, the utilities have two choices:

- **Deemed approach.** The deemed approach is a simplified method where utilities should choose a TRM building type based on the “best fit” for the facility. For interior spaces, this is determined by the largest interior area for the potential building types. Although, if that is not best fit, the utilities will use their best judgment to make this decision and provide sufficient, defensible documentation for their decision.

The *manufacturing* building type is specified with 1-, 2-, and 3-shift options:

- Shift 1: Typical operation of 9.5-11.5 hours per day and 4-6 days per week (<70 hours per week)

- Shift 2: Typical operation of 18-20 hours per day and 5-6 days per week (70–120 hours per week)
- Shift 3: Typical operation of 24 hours per day and 5-6 days per week (>120 hours per week)

The following building type combinations are pre-authorized exceptions to this rule. For these combinations, individual fixtures can be reported as either specified building type based on location. All other interior space combinations should reference a single deemed building type unless authorized by the evaluator.

- Office: Warehouse (refrigerated or non-refrigerated)
- Office: Manufacturing (any shift number)
- Manufacturing (buildings with different shift designations by area)
- Inpatient healthcare: Outpatient healthcare
- Lodging, common areas: Lodging, rooms

The *other* building type can be used for business types that are not explicitly listed. The hours and CF values used for other are the most conservative from the explicitly listed building types (with the exception of the CF values specified for “Education: K-12 without Summer Session” and “Lodging: Hotel/Motel/Dorm, Common Areas”, which are associated with very specific operating schedules that experience low coincidence with the summer peak period). When the Other building type is used, a description of the actual building type, the primary business activity, the business hours, and the lighting schedule must be collected for the project site and stored in the utility tracking data system.

“Outdoor Dusk-to-Dawn” applies to outdoor fixtures controlled by a photocell or timer with dusk-to-dawn operation throughout the entire year. Outdoor fixtures controlled by timers with less than dusk-to-dawn operation (excluding athletic fields and courts) may be claimed separately using the “Outdoor Less than Dusk-to-Dawn” building type or using a custom timer schedule.

Exterior spaces may reference multiple outdoor building types differentiated based on typical operating schedules (Outdoor Dusk-to-Dawn, Less than Dusk-to-Dawn, Athletic, or Billboard).

- **Custom approach.** In more unique situations, utilities should consider projects “custom” where (1) the deemed building types in the TRM may not represent the project’s facility type, (2) the facility may represent multiple TRM building types without a clear predominant building type, or (3) the use of a predominant building type may be too conservative in the estimate of savings. The deemed methods only apply to specific scenarios and cannot be developed for all unique situations. Utilities should provide sufficient, defensible documentation for their HOU and CF values used in their savings calculations that the EM&V team can review.

Interactive HVAC Interactive Effects Factors (HVAC Energy, Demand)

Basic lighting savings are adjusted to account for the lighting system interaction with HVAC systems in conditioned or refrigerated spaces. A reduced lighting load reduces the internal heat

gain to the building, which reduces the air conditioning/cooling load while increasing the heating load. Currently, the TRM only considers additional cooling savings, and the heating penalty or increase in usage is ignored.

As Table 12 shows, four conditioned space types are used for the Texas programs: single air-conditioned space type, two options for commercial refrigeration, and refrigerated warehouses: medium and low temperature. Utility procedures state that if the actual application falls between these values, the higher temperature value should be used. The final space type is unconditioned (or more explicitly uncooled as the focus is on cooling). In the lighting calculators, these values are typically assigned at the line-item level based on the conditioning type for the space in which the fixtures are located.

Table 12. Lamps & Fixtures—Deemed Energy and Demand Interactive HVAC Factors⁴⁶

Space conditioning type	Energy-interactive HVAC factor IEF_E	Demand interactive HVAC factor IEF_D
Refrigerated air	1.05	1.10
Evaporative cooling ⁴⁷	1.02	1.04
Medium-temperature refrigeration (33 to 41°F)	1.25	1.25
Low-temperature refrigeration (-10 to 32°F)	1.30	1.30
None (unconditioned/uncooled)	1.00	1.00

Upstream/Midstream Lighting

This section provides guidance on calculating and allocating savings at the sector-level for upstream/midstream lighting programs.

An increased number of utilities are offering or planning to offer upstream and/or midstream lighting programs in Texas. It is important that savings are calculated and reported consistently across utilities and in agreement with industry-standard practice and the Energy Efficiency Rule 16 TAC § 25.181.

Upstream/Midstream Program Assumptions

For upstream/midstream program delivery, use the following AOH and CF assumptions specified by lamp type. Assumed AOH and CF values have been weighted based on building type survey data from 2012⁸ CBECS⁴⁸ and 2014⁸ MECS⁴⁹ as well as lamp density and lamp

⁴⁶ PUCT Docket 39146. Table 7 (page 17) and Table 12 (page 24).

⁴⁷ These factors are only applicable for projects in climate zones 1 and 5. They are derived by taking a ratio of total HVAC energy use for spaces with evaporative and refrigerated cooling then applying that ratio against the IEF factors specified for refrigerated air.

⁴⁸ 2012⁸ Commercial Building Energy Consumption Survey (CBECS). <https://www.eia.gov/consumption/commercial/>. 2018 version not available until mid-2020.

⁴⁹ 2014⁸ Manufacturing Energy Consumption Survey (MECS). <https://www.eia.gov/consumption/manufacturing/>.

type distribution survey data from the DOE [2015-2020 US Lighting Market Characterization \(LMC\)](#)⁵⁰.

All general service, decorative, and reflector lamps with an equivalent wattage of 100 W or lower distributed through upstream or midstream programs should calculate savings using a combination of residential and non-residential savings methodologies with 95 percent of savings allocated to the residential sector and the remaining 5 percent of savings allocated to the commercial sector.⁵¹ While only summer demand savings are specified for the commercial sector, winter demand savings are allowed for the portion of savings allocated to the residential sector.

Table 13. Lamps & Fixtures—Upstream/Midstream Input Assumptions by Lamp Type⁵²

Lamp type	AOH	Coincidence factors ⁵³					ISR
		Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso	
GSL/reflector General service lamp	3,745 3,748	0.72 0.69	0.72 0.69	0.77 0.73	0.77 0.73	0.74 0.74	0.98
Directional/reflector	3,774	0.78	0.79	0.78	0.79	0.82	1.00
LED tube	3,542 3,522	0.75 0.74	0.75	0.83 0.84	0.83 0.84	0.76	1.00
High-bay fixture	3,987 3,796	0.84 0.78	0.85 0.79	0.84 0.83	0.85 0.84	0.85 0.80	1.00
Garage ⁵⁴	7,884	1.00	1.00	1.00	1.00	1.00	1.00
Outdoor ⁵⁵	4,161	0.67	0.71	0.61	0.75	1.00	1.00

Baseline wattage for GSLs is 45 lumens per watt. For non-GSLs, the ~~Additionally,~~ baseline wattage for ENERGY STAR-qualified products is assumed to be equal to the equivalent wattage from the ENERGY STAR certification. Baseline wattage assumptions for DLC- and third-party-qualified products should be determined based on product technical specifications and/or delivered light output (lumens) and detailed in the program qualified product listing.

Deemed Energy and Demand Savings Tables

This section is not applicable as these calculations are entirely dependent on site-specific parameters related to lighting system operation.

⁵⁰ ~~2015~~20 US Lighting Market Characterization, Department of Energy. ~~November-April 2017~~2017. https://www.energy.gov/sites/default/files/2024-08/ssl-lmc2020_apr24.pdfhttps://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

⁵¹ Weighting assumptions based on statewide evaluator review of LED purchasing behavior for similar program designs.

⁵² 201~~28~~ CBECs and 201~~48~~ MECS. <https://www.eia.gov/consumption/commercial/data/2018/>. <https://www.eia.gov/consumption/manufacturing/data/2018/>.

⁵³ Outdoor coincidence factors are specified for winter peak. All other values reference summer peak.

⁵⁴ This category should only be used for products marketed for use in parking garage applications.

⁵⁵ This category should only be used for products marketed for use in outdoor applications.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The estimated useful life (EUL) values are defined for the following lamp/fixture types.⁵⁶ A separate new construction EUL has been established due to account for the whole-building baseline.

- Halogen lamps: 1.5 years
- High-intensity discharge lamps: 15 years
- Integrated-ballast CCFL lamps: 4.5 years
- Integrated-ballast CFL lamps: 2.5 years
- Integral LED lamps: 9 years⁵⁷
- LED fixtures: 15 years
- LED corn cob lamps: 15 years
- LED tubes: 15 years
- Solar LEDs⁵⁸: 10 years
- Modular CFL and CCFL fixtures: 15 years
- T8 and T5 linear fluorescents: 15 years
- New construction interior fixtures/controls⁵⁹: 14 years
- New construction exterior fixtures⁶⁰: 15 years

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Climate zone or county
- Decision/action type: retrofit or new construction

⁵⁶ PUCT Docket 36779.

⁵⁷ PUCT Docket 38023.

⁵⁸ The typical solar battery life is approximately 5–15 years. A typical product warranty for a solar LED fixture is 10 years. This deemed EUL aligns with the average product life expectancy and typical warranty period.

⁵⁹ Based on review of new construction EULs claimed by Oncor and CenterPoint during the PY 2019 and 2020 weighted by energy savings.

⁶⁰ Ibid.

- Building or space type
- Optional: building or space funding source (state or private)
- **For new construction only:**
 - LPD factor
 - Interior and/or exterior lighting schedules and plans
 - Interior and/or exterior space areas and distances
 - If applicable, verify whether SECO compliance certification forms were filed⁶¹
- Conditioned space type: cooling equipment type, refrigerated space temperature range, heating fuel type, percent heated/cooled for new construction only (specified per control)
- Baseline fixture configuration
- Baseline lamp wattage
- Baseline ballast type
- Baseline lighting controls
- Baseline counts of operating fixtures
- Baseline counts of inoperable fixtures
- Post-retrofit manufacturer and model number⁶²
- Post-retrofit fixture configuration
- Post-retrofit lamp wattage⁶³
- Post-retrofit lamp specifications sheets: Post retrofit lamp product qualification information from DLC, ENERGY STAR®, or independent lab testing
- Post-retrofit ballast type
- Post-retrofit lighting controls
- Post-retrofit counts of operating fixtures
- **For field-adjustable light output (FALO) fixtures only:** isolate these fixtures by setting type and location within reported project inventories and track field adjustment settings; photos of the field-adjusted setpoints for a sample of fixtures

⁶¹ State-funded buildings are required to submit SECO compliance forms as part of the NC/renovation process. Buildings that submit SECO compliance forms are considered state-funded and must meet the provisions of ASHRAE 90.1-2013 rather than IECC 2015. Previous tables in this section present the alternative compliance values where they are encountered in the codes.

⁶² See Eligibility Criteria section for additional information and exceptions related to reporting post-retrofit model number.

⁶³ See Eligibility Criteria section for additional information and exceptions related to reporting post-retrofit fixture wattage.

- ~~For field-adjustable light output~~ **FALO fixtures only:** post-retrofit lumen readings for inspection sample
- Equipment operating hours
- Lighting measure group (from Measure Life groupings)
- **For retrofit only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; as-built design drawings; lighting specifications package that provides detailed make and model information on installed lighting; OR an evaluator pre-approved inspection approach
- **For upstream/midstream only:** Qualified product list mapping efficient lighting products to baseline wattage assumptions

Lighting Measure Groups to be Used for Measure Summary Reports

The lighting measure groups, as defined in the Measure Life and Lifetime Savings list above, must be used for reporting summarized savings of lighting measures. Higher-level groupings of lighting technologies, such as “Non-LED” lighting, will not provide enough resolution for evaluation and cost-effectiveness analysis.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Describes EUL
- PUCT Docket 39146—Describes deemed values for energy and demand savings
- PUCT Docket 38023—Describes LED installation and efficiency standards for nonresidential LED products

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 14. Lamps & Fixtures—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. <i>Measure Life section</i> : Added additional energy efficiency measures for consistency with the EUMMOT maintained list. <i>Calculator and Tools section</i> : Eliminated description of calculator output comparisons. <i>Tracking Data Requirements section</i> : Added lighting category requirements for measure summary reports.
v3.0	04/10/2015	TRM v3.0 update. Revised to eliminate T12 lamps as a valid baseline. <i>Measure Description section</i> : General clean-up of technology descriptions. <i>Program Tracking Data section</i> : Minor changes and clarifications.
v3.1	11/05/2015	TRM v3.1 update. Revised to eliminate T12 lamps as a valid baseline and eliminate the Oncor winter peak demand value to use the statewide average in all service territories. <i>Eligibility Criteria</i> : Adding sources for LED lamp and fixture eligibility.
v3.1	03/23/2016	TRM v3.1 March revision. Updated <i>Linear Fluorescent T12 Special Conditions</i> baseline table to include HO and VHO lamps. Updated criteria for miscellaneous length (e.g., 2-ft, 3-ft) T8s. Added footnote to explain how to account for non-rebated fixture lighting controls in savings calculations. Clarified some tracking data requirements.
v4.0	10/10/2016	TRM v4.0 update. Added LPD values and tracking data requirements for exterior space type climate zones used in Codes and Standards.
v5.0	10/2017	TRM v5.0 update. Added two new building types (i.e., Data Centers, 24-Hr Restaurants), and updated the Manufacturing building type to separate 1, 2 and 3 shift operations. Updated sources and references. Completed code updates where applicable (IECC 2015 and ASHRAE 90.1-2013). Note that Texas adopted IECC 2015 for commercial, industrial, and residential buildings taller than three stories and ASHRAE 90.1-2013 for state-funded buildings.
v6.0	10/2018	TRM v6.0 update. Updated eligibility criteria to broaden the qualification paths for LED fixtures. Added rounding opt-in for LED wattages. Clarifications added for building type definitions, including the addition of an “Other” category for buildings that do not fit into the list of pre-defined building types. Updated peak coincident factors for the PDPF methodology outlined in Volume 1.
v7.0	10/2019	TRM v7.0 update. Merged relevant Volume 5 Implementation Guidance into the measure. Changed non-qualified lighting thresholds and accounting procedures for new construction projects. Added guidance for EISA baselines. Added Base Site Allowance for exterior new construction projects. Added equivalent metal halide guidance for exterior athletic fields and courts. Added new building types (Agriculture, Outdoor: Billboards, Education K-12 with partial summer session, Facility-Wide 24-Hour Lighting). Revised Outdoor: Athletic Field and Court factors. Added Midstream lighting guidance, assumptions, and calculations. Program tracking requirements updated.

TRM version	Date	Description of change
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Updated EUL for new construction projects to apply to whole project. Updated dusk-to-dawn operating hours. Minor formula corrections. Updated DLC references to refer to v3.0 or later rather than explicit versions. Removed 10% nonqualified fixture threshold. Established lumens/watt assumptions for new construction baselines.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits. Added guidance for certification of incremented length products. Added upstream clarification. Combined greater and less than 100 W GSLs and reflectors for upstream/midstream. Adjusted upstream/midstream residential vs. commercial split and ISRs. Updated upstream/midstream outdoor hours of use. Added guidance for LED model number, performance characteristics certification, and dates of certification. Changed LSF references to fixture wattage table.
v10.0	10/2022	TRM v10.0 update. Corrected DLC version requirements omitted from final TRM v8.0. Added guidance for field adjustable lights. Addressed savings path for solar fixtures. Added guidance for new construction exterior lighting zone selection. Added guidance for building type selection. Clarified midstream outdoor coincident factor is winter peak.
v11.0	10/2023	TRM v11.0 update. Added guidance for delisted lighting products and for new construction exterior lighting zone selection. Aligned building type names across all commercial measures.
<u>v12.0</u>	<u>10/2024</u>	<u>TRM v12.0 update. Clarified exterior new construction code zone selection guidance, adjusted new construction savings algorithm, updated "Multiple" control type, adjusted non-operational fixture footnote, in-service rate incorporated into retrofit savings algorithm, clarified building type section guidance, and updated midstream building type weighting assumptions.</u>

2.1.2 Lighting Controls Measure Overview

TRM Measure ID: NR-LT-LC

Market Sector: Commercial

Measure Category: Lighting

Applicable Building Types: All commercial, multifamily common areas

Fuels Affected: Electricity (interactive HVAC effects: electric/gas space heating)

Decision/Action Types: Retrofit, new construction

Program Delivery Type: Prescriptive, custom, direct install

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure promotes the installation of lighting controls in both new construction and retrofit applications. For retrofit applications, lighting controls are typically installed where there is no control other than a manual switch (wall or circuit panel). For new construction lighting systems, controls would be added where they are not already required by existing energy or building codes. Promoted technologies include occupancy sensors and daylight dimming controls. Energy and peak demand savings are calculated for these technologies with an controls energy adjustment factor (ECAF) for kWh and a power adjustment factor (PAF) for kW.

Eligibility Criteria

Measures installed through utility programs must be one of the occupancy sensor, daylighting, and tuning controls that are described in Table 15. Savings may be claimed for control types that exceed the minimum code-required controls, mainly occupancy sensors for interior spaces.

New construction (NC) buildings designed after November 1, 2016 must be equipped with lighting controls unless specifically designated in the below exceptions. Most interior building spaces must have occupancy sensor controls or time-switch controls. Daylight responsive controls must be present in daylight zones. Exterior lighting must be installed with daylight sensors. Therefore, NC lighting controls savings can only be claimed in instances where the installed controls exceed energy code. Refer to IECC 2015, Section C405 for more information.

Field adjustable light output: If a product is available with field-adjustable light output (or wattage setpoints) that can be adjusted by an installation contractor to utilize some or all LED nodes on the fixture, this will be noted in the Product Capabilities section of the DLC certification. DLC will typically specify the maximum input wattage. These fixtures should be reported based on the following scenarios:

- ~~If the fixture is installed at a reduced setpoint, it should be reported at the maximum input wattage in combination with the Institutional Tuning control code to claim energy savings associated with a central control lighting output based on tuning sensors. This control type is similar because it is not easily adjustable over time.~~
- ~~If the fixture is installed with additional controls (e.g., occupancy sensor, daylighting), then it should be reported the same as above, unless the control system meets the requirements of networked lighting control (NLC).~~
- ~~If the fixture is installed without adjustment, it should be reported at the maximum input wattage with no control code.~~
- ~~If the fixture is installed with no additional controls and the DLC certificate specifies a lower wattage setpoint, then it should be reported as the lower input wattage with no control code.~~
- ~~For all cases, project documentation should include a screenshot of the DLC certificate and an example photo of the field-adjustable setpoint.~~

NLC: An NLC system uses software control based on the outputs of the sensor equipment. The system requires commissioning to ensure proper operation. A plan detailing the inspection and recalibration frequency that identifies the actions necessary through the end of the EUL period is required to ensure continued operation in accordance with design conditions.

Baseline Condition

The retrofit baseline condition assumes no existing or code required automatic lighting controls are installed on the existing lighting fixtures (i.e., they are only manually switched).

For control types that exceed the minimum required control types (usually occupancy sensors or time switch controls), savings can be claimed with the minimum required controls as the baseline efficiency. In these cases, the applicable baseline ~~control energy and power~~ adjustment factors (~~EC~~AF, ~~PA~~F) are specified for occupancy sensors in Table 16.

For new construction projects, the baseline should be occupancy sensors in most cases unless a specific exception is allowed by code.⁶⁴

High-Efficiency Condition

The energy-efficient condition is properly installed (not bypassed or overridden) and calibrated lighting controls that control overhead lighting in a facility based on occupancy, daylighting, or tuning sensors.

⁶⁴ Per IECC 2015, C405.2 lighting controls are mandatory.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The equations for lighting controls are similar to those used for lighting lamps and fixtures, with the addition of the control adjustment factor (CAF) multipliers, as shown below. Additionally, the pre/post kW difference is replaced by a single kW value (the total fixture wattage controlled by the device).

$$Energy\ Savings\ [kWh] = kW_{controlled} \times ECAF \times Hours \times HVAC_{energy}$$

Equation 5

$$Summer\ Peak\ Demand\ Savings\ [kW] = kW_{controlled} \times PCAF \times CF_s \times HVAC_{demand}$$

Equation 6

Where:

- $kW_{controlled}$ = Total kW of controlled fixtures (Fixture wattage from Standard wattage table multiplied by quantity of fixtures)
- Hours = Hours by building type from Table 9
- ~~$ECAF$ = Lighting Controls Energy Adjustment Factor (see Table 16)~~
- ~~PAF = Lighting control Power Adjustment Factor (see Table 16)~~
- CF_s = Summer peak coincidence factor by building type (see Table 10)
- $HVAC_{energy}$ = Energy Interactive HVAC factor by building type (see Table 12)
- $HVAC_{demand}$ = Demand Interactive HVAC factor by building type (see Table 12)

See Section 2.1.1 of this volume for a full explanation of the non-control variables and their corresponding values. The lighting controls ~~$ECAF$ s and PAF s~~ for different building types are presented in Table 16. The ~~$ECAF$ s and PAF~~ represent the reduction in energy and demand usage. For example, a factor of 0.24 would equate to 24 percent energy and demand savings. The same values from the referenced LBNL study are used for both energy ~~EAF~~ and demand ~~PAF~~ factors due to the lack of published data for coincidence factors.

Table 15. Lighting Controls—Control Definitions

Control type	Description
None	No control
Occupancy	Adjusting light levels according to the presence of occupants <ul style="list-style-type: none"> • Wall- or ceiling-mounted occupancy sensors • Wall- or ceiling-mounted occupancy sensors • Integrated fixture occupancy sensors • Time clocks • Energy management systems

Control type	Description
Daylighting (indoor)	Adjusting light levels automatically in response to the presence of natural light <ul style="list-style-type: none"> • Photosensors
Outdoor	Outdoor on/off photosensor/time clock controls; no savings attributed because already required by code
Personal tuning	Adjusting individual light levels by occupants according to their personal preference; applies to private offices, workstation-specific lighting in open-plan offices, and classrooms <ul style="list-style-type: none"> • Dimmers • Wireless ON/OFF switches • Personal computer-based controls • Pre-set scene selection
Institutional tuning	Adjustment of light levels through commissioning or provision of switches or controls for areas or groups of occupants <ul style="list-style-type: none"> • Dimmable ballasts • ON/OFF or dimmer switches for non-personal tuning • Field adjustable light output
Networked lighting control	Lighting systems with a combination of sensors, networked interfaces, software, and controllers that affect lighting changes in luminaires, retrofit kits, or lamps. NLC systems can be installed with or without luminaire level lighting control (LLLC), referring to the capability to have a networked occupancy sensor and ambient light sensor installed for each luminaire or kit.

Table 16. Lighting Controls—Energy and Power Adjustment Factors⁶⁵

Control type	Control codes	CAF	
		Retrofit	NC ⁶⁶
None	None	–	–
Occupancy	OS	0.24	0.00
Continuous daylighting (indoor)	DL	0.28	0.04
Outdoor ⁶⁷	Outdoor	–	–

⁶⁵ Williams, Alison, Atkinson, Barbara, Barbesi, Karina, and Rubinstein, Francis, “A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings”. Lawrence Berkeley National Laboratory. September 2011. Table 6, p. 14. Weighted average by number of “reviewed” and “non-reviewed” papers. <https://eta.lbl.gov/publications/meta-analysis-energy-savings-lighting#:~:text=Based%20on%20the%20meta%20analysis,and%2038%25%20for%20multiple%20approaches>.

⁶⁶ NC CAFs are derived by deducting the OS CAF from the equivalent retrofit CAF value.

⁶⁷ No control savings are allowed for outdoor controls because they are already required by code. ASHRAE 90.1-1989, Section 6.4.2.8 specifies that exterior lighting not intended for 24-hour continuous use shall be automatically switched by timer, photocell, or a combination of timer and photocell. This is consistent with current specifications in ASHRAE 90.1-2010, Section 9.4.1.3, which specifies that lighting for all exterior applications shall have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours.

Control type	Control codes	CAF	
		Retrofit	NC ⁶⁶
Personal tuning	PT	0.31	0.07
Institutional tuning	IT	0.36	0.12
Networked lighting control	NLC ⁶⁸	0.49	0.25

Deemed Energy and Demand Savings Tables

Not applicable.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

Lighting controls savings for interior new construction projects should be claimed at the project level (combined fixture and controls savings) using the estimated useful life (EUL) matching the lighting equipment.⁶⁹

For retrofit applications, the EUL for lighting controls is provided by the 2007 GDS Associates Report.⁷⁰

- Retrofit sensors and controls: 10 years
- New construction interior fixtures/controls⁷¹: 14 years

⁶⁸ “Energy Savings from Networked Lighting Control (NLC) Systems with and without LLLC,” Prepared by DesignLights Consortium for Northwest Energy Efficiency Alliance (NEEA). September 24, 2020. <https://www.designlights.org/resources/reports/report-energy-savings-from-networked-lighting-control-nlc-systems-with-and-without-lllc/>. Savings range from 0.35 without LLLC to 0.63 with LLLC, with an overall average of 0.49. Average is selected because report concludes that additional study is needed to verify the impact of LLLC.

⁶⁹ Based on review of new construction EULs claimed by Oncor and CenterPoint during the PY 2019 and 2020 weighted by energy savings.

⁷⁰ GDS Associates. Measure Life Report—Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for the New England State Program Working Group (SPWG). June 2007. This report only specifies an EUL for Occupancy Sensors and Photocells, so it is assumed that the same EUL was applied to time clocks. <http://library.cee1.org/content/measure-life-report-residential-and-commercial-industrial-lighting-and-hvac-measures>.

⁷¹ Based on review of new construction EULs claimed by Oncor and CenterPoint during the PY 2019 and 2020 weighted by energy savings.

Program Tracking Data and Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- Climate zone or county
- Decision/action type: retrofit or new construction
- Building type
- Conditioned space type: cooling equipment type, refrigerated space temperature range (specified per control)
- Location of controlled lighting: interior or exterior (specified per control)
- Baseline and installed lighting control type code⁷²
- Lighting control mount type: wall, ceiling, integrated fixture, etc.
- Lighting control equipment specification sheets
- For NLC systems:
 - Lighting control network specification sheets,
 - Lighting control commissioning report,
 - Lighting control network inspection and recalibration plan, or
 - other evaluator pre-approved documentation
- Controlled fixture lamp type
- Controlled fixture wattage
- **For retrofit only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; as-built design drawings; lighting specifications package that provides detailed make and model information on installed lighting; OR an evaluator pre-approved inspection approach

⁷² For a control type that combines multiple features (e.g., occupancy + daylighting) but does not qualify as an NLC system, specify the installed control type that corresponds to the highest control savings.

References and Efficiency Standards

Petitions and Rulings

- “A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings.” Williams, Alison, Atkinson, Barbara, Barbesi, Karina, and Rubinstein, Francis, Lawrence Berkeley National Laboratory (LBNL). September 2011. Table 6, p. 14. Weighted average by the number of “reviewed” and “non-reviewed” papers.
- PUCT Docket 40668—Describes deemed values to be used in energy and demand savings calculations.
- PUCT Docket 36779—Describes EUL.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 17. Lighting Controls—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. No revision.
v2.1	01/30/2015	TRM v2.1 update. Corrections to Equation 5 and Equation 6 to accurately reflect the energy and power adjustment factors and to reflect savings based on connected load rather than a delta load. Consolidation of algorithms for retrofit and new construction projects.
v3.0	04/10/2015	TRM v3.0 update. Update EAF and PAF factors with values from a more current and comprehensive controls study. Update equations to use a “controlled lighting watts” approach for both retrofit and new construction. Updated Program Tracking parameters for consistency with other Lighting measures and added interior/exterior location.
v4.0	10/10/2016	TRM v4.0 update. No revision.
v5.0	10/2017	TRM v5.0 update. Completed source and code updates where applicable (IECC 2015 and ASHRAE 90.1-2013). Note that Texas adopted IECC 2015 for commercial, industrial, and residential buildings taller than three stories and ASHRAE 90.1-2013 for state-funded buildings.
v6.0	10/2018	TRM v6.0 update. Revised multiple/combined control types EAF and PAF.
v7.0	10/2019	TRM v7.0 update. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Added eligibility criteria for new construction applications.

TRM version	Date	Description of change
v10.0	10/2022	TRM v10.0 update. Added guidance for field adjustable lights. Clarified baseline controls for new construction projects.
v11.0	10/2023	TRM v11.0 update. Clarified new construction controls eligibility. Updated control types. Consolidated EAF and PAF into CAF and added column for new construction CAF. Added documentation requirements for NLC systems.
<u>v12.0</u>	<u>10/2024</u>	<u>TRM v12.0 update. Consolidated "EAF" and "PAF" coefficient label to "CAF".</u>

2.1.3 Exterior Photocell and Time Clock Repair Measure Overview

TRM Measure ID: NR-LT-PR

Market Sector: Commercial

Measure Category: Lighting

Applicable Building Types: All commercial

Fuels Affected: Electricity

Decision/Action Types: Retrofit

Program Delivery Type: Prescriptive, custom, direct install

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure is for the repair of a photocell or time clock on an existing exterior light fixture. A photocell is designed to switch exterior light fixtures off during daylight hours. If broken, these fixtures may remain on as much as 8,760 hours per year.

Eligibility Criteria

This measure is only applicable to exterior retrofit applications where an existing photocell or time clock is not functioning as designed. New construction applications are not eligible.

The fixture must be manually controlled except for the photocell/time clock and may not be installed in combination with any supplemental controls.

Baseline Condition

The baseline condition is an exterior light fixture controlled by a photocell or time clock that is not functioning, allowing the fixture to operate continuously.

High-Efficiency Condition

The high-efficiency condition is a light fixture installed in combination with a functioning (repaired or new) photocell or time clock control.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

This section describes the deemed savings methodology for both energy and demand savings for all lighting projects. Savings are calculated using separate methods for retrofit and new construction projects.

$$\text{Energy Savings [kWh]} = kW_{\text{fixture}} \times (8,760 - \text{AOH})$$

Equation 7

$$\text{Peak Demand Savings [kW]} = kW_{\text{fixture}} \times (1 - CF_{S/W})$$

Equation 8

Where:

kW_{fixture} = Total kW of controlled fixture (approved baseline fixture code wattage from deemed savings tool divided by 1,000 and multiplied by fixture/lamp quantity)⁷³

AOH = Hours by outdoor application (see Table 18)

$CF_{S/W}$ = Seasonal peak coincidence factor by outdoor application and climate zone (see Table 19)

Table 18. Exterior Photocell Repair—Annual Operating Hours by Outdoor Application

Building type	AOH
Outdoor: Athletic field and court ⁷⁴	767
Outdoor: Billboard ⁷⁵	3,470
Outdoor: Dusk-to-dawn ⁷⁶	4,161
Outdoor: Less than dusk-to-dawn ⁷⁷	1,998

⁷³ Look up approved fixture wattage from the Standard Fixture Wattage Table. <http://texasefficiency.com/index.php/regulatory-filings/lighting>.

⁷⁴ "2015 US Lighting Market Characterization," US Department of Energy. November 2017. Value derived by multiplying average daily operating hours from Table 2-30 by 365.25 hours per year.

⁷⁵ Ibid.

⁷⁶ This space type refers to fixtures controlled either by photocells or by timers operating on a dusk-to-dawn schedule. Calculated based on average dark hours for Amarillo (northernmost) and Corpus Christi (southernmost) climate zones from sunrise to sunset excluding one-half of civil twilight period. <https://www.timeanddate.com/sun/>. Note: pending update to US Naval Observatory annual data once website maintenance has completed. https://aa.usno.navy.mil/data/RS_OneYear.

⁷⁷ This space type refers to fixtures controlled by timers operating on a less than dusk-to-dawn schedule.

Table 19. Exterior Photocell Repair—Winter Peak Coincidence Factors by Outdoor Application^{78,79}

Building type	Summer peak CF	Winter peak CF				
	All climate zones	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone 5: El Paso
Outdoor: Athletic field and court ⁸⁰	–	0.26	0.27	0.24	0.29	0.38
Outdoor: Billboard ⁸¹	–	0.59	0.62	0.53	0.65	0.87
Outdoor: Dusk-to-dawn ⁸²	–	0.67	0.71	0.61	0.75	1.00
Outdoor: Less than dusk-to-dawn ⁸³	–	0.67	0.71	0.61	0.75	1.00

Deemed Energy and Demand Savings Tables

This section is not applicable as these calculations are entirely dependent on site-specific parameters related to lighting system operation.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

The estimated useful life (EUL) is 1 year for photocell repair based on the estimated remaining life of an exterior lamp operating 8,760 hours per year.⁸⁴ This value is further capped at 1 year based on the expectation that the photocell would be repaired in absence of utility program intervention beyond this point.

⁷⁸ Operating schedules are based on sunrise/sunset times for each climate-zone reference city, adjusted for compliance with IESNA-DG-13-96 and IESNA-DG-13-98 recommendations.

⁷⁹ Summer coincidence factor is set to zero for all exterior lighting applications.

⁸⁰ “2015 US Lighting Market Characterization,” US Department of Energy. November 2017. Value derived by multiplying average daily operating hours from Table 2-30 by 365.25 hours per year.

⁸¹ Ibid.

⁸² This space type refers to fixtures controlled either by photocells or by timers operating on a dusk-to-dawn schedule. Calculated based on average dark hours for Amarillo (northernmost) and Corpus Christi (southernmost) climate zones from sunrise to sunset excluding one-half of civil twilight period. <https://www.timeanddate.com/sun/>. Note: pending update to US Naval Observatory annual data once website maintenance has completed. https://aa.usno.navy.mil/data/RS_OneYear.

⁸³ This space type refers to fixtures controlled by timers operating on a less than dusk-to-dawn schedule.

⁸⁴ Metal halide rated life expected between 6,000–15,000 hours. 10,500–hour midpoint divided by 8,760 hours yields 1.2 years.

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Climate zone or county
- Outdoor application
- Controlled fixture quantity
- Controlled fixture/lamp type
- Controlled fixture/lamp wattage
- Existing control type (photocell, time clock)
- Control intervention (repair, replacement)
- New control manufacturer and model number (replacement only)
- Photo of controlled light fixture nameplate, model number, or wattage stamp
- Photo demonstrating that fixture is operating during daytime hours
- Copy of project invoice detailing affected fixture quantity and control intervention
 - New photocell/time clock model number (replacement only)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 20. Exterior Photocell Repair—Revision History

TRM version	Date	Description of change
v10.0	10/2022	TRM v10.0 origin.
v11.0	10/2023	TRM v11.0 update. No revision.
<u>v12.0</u>	<u>10/2024</u>	<u>TRM v12.0 update. No revision.</u>

2.1.4 LED Traffic Signals Measure Overview

TRM Measure ID: NR-LT-TS

Market Sector: Commercial

Measure Category: Lighting

Applicable Building Types: Outdoor

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive, custom, direct install

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure is for the installation of light emitting diode (LED) traffic signals (typically available in red, yellow, green, and pedestrian formats) at traffic lights serving any intersection, in retrofit applications.

Eligibility Criteria

New construction applications are not eligible for this measure, as incandescent traffic signals are not compliant with the current federal standard⁸⁵, effective January 1, 2006.

Baseline Condition

For all retrofit applications, the baseline is a fixture with incandescent lamps.

High-Efficiency Condition

Due to the increased federal standard for traffic signals, the ENERGY STAR® Traffic Signal specification was suspended effective May 1, 2007. ENERGY STAR chose to suspend the specification rather than revise it due to minimal additional savings that would result from a revised specification. Because the ENERGY STAR specification no longer exists, the efficiency standard is an equivalent LED fixture for the same application. The equivalent LED fixture must be compliant with the current federal standard except for yellow “ball” or “arrow” fixtures where there is no federal standard.

⁸⁵ Current federal standards for traffic and pedestrian signals can be found at the DOE website at: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=12.

Table 21. LED Traffic Signals—Federal Standard Maximum Wattages⁸⁶ and Nominal Wattages⁸⁷

Module type	Maximum wattage	Nominal wattage
12" red ball	17	11
8" red ball	13	8
12" red arrow	12	9
12" green ball	15	15
8" green ball	12	12
12" green arrow	11	11
Combination walking man/hand	16	13
Walking man	12	9
Orange hand	16	13

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

This section describes the deemed savings methodology for both energy and demand savings for all LED traffic signal projects.

$$\text{Energy Savings [kWh]} = (kW_{pre} - kW_{installed}) \times \text{Hours}$$

Equation 9

$$\text{Summer Peak Demand Savings [kW]} = (kW_{pre} - kW_{installed}) \times CF_s$$

Equation 10

Where:

kW_{pre} = Total kW of existing measure (fixture wattage multiplied by quantity)

$kW_{installed}$ = Total kW of retrofit measure (fixture wattage multiplied by quantity)

Hours = Annual operating hours from Table 22

CF_s = Summer peak coincidence factor from Table 22

⁸⁶ Maximum wattage is the wattage at which power consumed by the module after being operated for 60 minutes while mounted in a temperature testing chamber so that the lensed portion of the module is outside the chamber, all portions of the module behind the lens are within the chamber at a temperature of 74°C, and the air temperature in front of the lens is maintained at a minimum of 49°C.

⁸⁷ Nominal wattage is defined as power consumed by the module when it is operated within a chamber at a temperature of 25°C after the signal has been operated for 60 minutes.

Table 22. LED Traffic Signals—Savings Calculation Input Assumptions⁸⁸

Fixture type	Incandescent wattage	LED wattage	AOH	CF _s ⁸⁹
8" red ball	86	8	4,746	0.54
8" green ball		10	3,751	0.43
8" yellow ball		13	263	0.03
12" red ball	149	11	4,746	0.54
12" green ball		12	3,751	0.43
12" yellow ball		10	263	0.03
8" red arrow	69	8	6,570	0.75
8" green arrow		8	1,825	0.21
8" yellow arrow		10	263	0.03
12" red arrow	128	7.5	7,771	0.89
12" green arrow		10	726	0.08
12" yellow arrow		10	263	0.03
Large (16"x18") pedestrian signal		9	8,642	0.99
Small (12"x12") pedestrian signal	107	9	8,642	0.99

Deemed Energy and Demand Savings Tables

Table 23. LED Traffic Signals—Energy and Peak Demand Savings per Fixture

Fixture type	kWh savings	kW savings
8" red ball	370	0.042
8" green ball	285	0.033
8" yellow ball	19	0.002
12" red ball	655	0.075
12" green ball	514	0.059
12" yellow ball	37	0.004
8" red arrow	401	0.046
8" green arrow	111	0.013
8" yellow arrow	31	0.004
12" red arrow	936	0.107
12" green arrow	86	0.010
12" yellow arrow	31	0.004
Large (16"x18") pedestrian signal	1,210	0.138
Small (12"x12") pedestrian signal	847	0.097

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Measure Life and Lifetime Savings

According to the Northwest Power and Conservation Council Regional Technical Forum, the EUL is 5 to 6 years depending on the installed fixture type, as shown in the following table.

Table 24. LED Traffic Signals—EULs by Fixture Type⁹⁰

Fixture type	EUL (years)
8" and 12" red, green, and yellow ball	6
8" and 12" red, green, and yellow arrow	
Large (16"x18") pedestrian signal	5
Small (12"x12") pedestrian signal	

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data should be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Decision/Action Type: retrofit or NC (NC not eligible)
- Fixture type
- Quantity of installed fixtures
- Proof of purchase: invoice showing model number; a photo of the model number on product packaging and installed fixture; OR an evaluator pre-approved inspection approach

References and Efficiency Standards

Petitions and Rulings

Not applicable.

⁸⁸ Northwest Power and Conservation Council: Regional Technical Forum. Commercial LED Traffic Signals measure workbook. Version 2.2 updated 6/29/2016. <https://rtf.nw council.org/deactivated-measures/>.

⁸⁹ Traffic signals operate consistently during each hour of the year. Therefore, CFs are calculated by dividing the assumed AOH value by 8,760 hours/year.

⁹⁰ Northwest Power and Conservation Council: Regional Technical Forum. Commercial LED Traffic Signals measure workbook. Version 2.2 updated 6/29/2016. <http://rtf.nw council.org/measures/measure.asp?id=114&decisionid=37>.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 25. LED Traffic Signals—Revision History

TRM version	Date	Description of change
v7.0	10/2019	TRM v7.0 origin.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. No revision.
v10.0	10/2022	TRM v10.0 update. General reference checks and text edits.
v11.0	10/2023	TRM v11.0 update. No revision.
<u>v12.0</u>	<u>10/2024</u>	<u>TRM v12.0 update. No revision.</u>

2.2 NONRESIDENTIAL: HVAC

2.2.1 Air Conditioner and Heat Pump Tune-Ups Measure Overview

TRM Measure ID: NR-HV-TU

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: ~~See Table 34 through Table 40~~ All commercial

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Engineering algorithms and estimates

Measure Description

This measure applies to direct expansion central air conditioners (AC) and heat pumps (HP) of any configuration where all applicable actions from the checklist below are completed. An AC tune-up involves checking, cleaning, adjusting, and resetting the equipment to factory conditions to restore operating efficiencies, closer to as-new performance. This measure applies to all commercial applications.

For this measure, the service technician must complete the following tasks according to industry best practices. To properly assess and adjust the refrigerant charge level, the unit must be operating under significant (normal) cooling load conditions. Therefore, this measure may only be performed for energy savings reporting purposes when the outdoor ambient dry bulb temperature is above 75°F and the indoor return air dry bulb temperature is above 70°F.

HVAC Air Conditioner Inspection and Tune-up Checklist.⁹¹

- Check thermostat settings
- Tighten all electrical connections, measure motor voltage and current
- Lubricate all moving parts, including motor and fan bearings
- Inspect and clean condensate drain

⁹¹ Based on ENERGY STAR® HVAC Maintenance Checklist.

~~www.energystar.gov/index.cfm?c=heat_cool.pr_maintenance~~<https://www.energystar.gov/saveathome/heating-cooling/maintenance-checklist>.

- Inspect controls of the system to ensure proper and safe operation; check startup/shutdown cycle of the equipment to assure the system starts, operates, and shuts off properly
- Clean evaporator and condenser coils
- Check refrigerant level and adjust to manufacturer specifications
- Clean indoor blower fan components and adjust to provide proper system airflow
- Inspect and clean (or change) air filters; replacement preferred best practice
- Measure airflow via static pressure across the cooling coil and adjust to manufacturers specifications
- ~~Check refrigerant level and adjust to manufacturer specifications~~
- Check capacitor functionality and capacitance; compare to OEM specifications

Eligibility Criteria

HVAC systems must be manufactured before January 1, 2023, to be eligible for this measure.⁹² All commercial customers are eligible for this measure if they have direct expansion refrigerated air conditioning that has not been serviced through a utility program in the last 5 years.

This measure also applies to packaged terminal air conditioners and heat pumps (PTAC/PTHP), but chillers are ineligible.

Baseline Condition

The baseline is a system with all or some of the following issues:

- Dirty condenser coil
- Dirty evaporator coil
- Dirty blower wheel
- Dirty filter
- Improper airflow
- Incorrect refrigerant charge

⁹² The current federal standard became effective on January 1, 2023, with full manufacturing compliance of the new SEER2 testing procedure being enforced as of April 24, 2023. This measure will be updated in the future to address the new efficiency ratings. <https://www.regulations.gov/document/EERE-2021-BT-TP-0030-0027>.

The baseline system efficiency should be calculated using the following formulas:

$$EER_{pre} = (1 - EL) \times EER_{post}$$

Equation 11

$$HSPF_{pre} = (1 - EL) \times HSPF_{post}$$

Equation 12

Where:

- EER_{pre} = Efficiency of the cooling equipment before tune-up [Btuh/W]
- EL = Efficiency loss due to dirty coils, blower, filter, improper airflow, and/or incorrect refrigerant charge = 0.05
- EER_{post} = Deemed cooling efficiency of the equipment after tune-up [Btuh/W] (see Table 26)
- $HSPF_{pre}$ = Heating efficiency of the air source heat pump before tune-up [Btuh/W]
- $HSPF_{post}$ = Deemed heating efficiency of air source heat pumps after tune-up [Btuh/W] (see Table 26)

Table 26. AC/HP Tune-Ups—Default EER and HSPF per Size Category⁹³

Size category (Btuh/hr)	AC only default EER	Heat pump default EER	Default HSPF
< 65,000	11.2	11.2	7.7
≥ 65,000 and < 135,000	10.1	9.9	10.9
≥ 135,000 and < 240,000	9.5	9.1	10.6
≥ 240,000 and < 760,000	9.3	8.8	10.6
≥ 760,000	9.0	8.8	10.6

High-Efficiency Condition

After the tune-up, the equipment must be clean with airflows and refrigerant charges adjusted as appropriate and set forth above. Additionally, refrigerant charge adjustments must be within ± 3 degrees of target sub-cooling for units with thermal expansion valves (TXV) and ± 5 degrees of target super heat for units with fixed orifices or capillary tubes.

The efficiency standard, or efficiency after the tune-up, is deemed to be the manufacturer specified energy efficiency ratio (EER) of the existing central air conditioner or heat pump, which has been determined using the following logic and standards. The useful life of an AC unit is 19 years. The useful life of a heat pump is 16 years. Therefore, it is conservatively thought that the

⁹³ Code specified EER and HSPF value from ASHRAE 90.1-2010 (efficiency value effective January 23, 2006 for units < 65,000 Btu/hr and prior to January 1, 2010 for units ≥ 65,000 Btu/hr). HSPF = COP x 3.412.

majority of existing, functioning units were installed under the federal standard in place between January 23, 2006 and January 1, 2015 for units less than 65,000 Btuh, which set a baseline of 13 SEER and 7.7 HSPF⁹⁴, and prior to January 1, 2010 for units greater than 65,000 Btuh. A 13 SEER is equivalent to approximately 11.2 EER⁹⁵ using the conversion developed by Lawrence Berkeley Lab and US DOE: $EER = -0.02 \times SEER^2 + 1.12 \times SEER$. A 3.2 and 3.1 COP is equivalent to approximately 10.9 and 10.6 HSPF, respectively, using the conversion of $HSPF = 3.412 \times COP$.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Savings are based on an assumed efficiency loss factor of five percent due to dirty coils, dirty filters, improper airflow, and/or incorrect refrigerant charge.⁹⁶

Heating energy savings are only applicable to heat pumps.

$$Total\ Energy\ Savings\ [kWh] = kWh_C + kWh_H$$

Equation 13

$$Cooling\ Energy\ Savings\ [kWh_C] = Cap_C \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}} \right) \times EFLH_C \times \frac{1\ kW}{1,000\ W}$$

Equation 14

$$Heating\ Energy\ Savings\ [kWh_H] = Cap_H \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}} \right) \times EFLH_H \times \frac{1\ kW}{1,000\ W}$$

Equation 15

Where:

Cap_C = Rated cooling/heating capacity of the equipment based on model number [Btuh] (1 ton = 12,000 Btuh)

$EFLH_{C/H}$ = Cooling/heating equivalent full-load hours for appropriate climate zone [hours]; see Table 36 through Table 40 in Section 2.2.2

Demand Savings Algorithms

Summer and winter demand savings are determined by applying a coincidence factor for each season. Winter peak demand savings are only applicable to heat pumps.

⁹⁴ Code specified HSPF from federal standard effective January 23, 2006, through January 1, 2015.

⁹⁵ Code specified 13 SEER from federal standard effective January 23, 2006, through January 1, 2015, converted to EER using $EER = -0.02 \times SEER^2 + 1.12 \times SEER$. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. <http://www.nrel.gov/docs/fy11osti/49246.pdf>.

⁹⁶ Energy Center of Wisconsin, May 2008; "Central Air-Conditioning in Wisconsin, A Compilation of Recent Field Research."

$$\text{Summer Peak Demand Savings [kW]} = \text{Cap}_C \times \left(\frac{1}{\text{EER}_{pre}} - \frac{1}{\text{EER}_{post}} \right) \times \text{CF}_S \times \frac{1 \text{ kW}}{1,000 \text{ W}}$$

Equation 16

$$\text{Winter Peak Demand Savings [kW]} = \text{Cap}_H \times \left(\frac{1}{\text{HSPF}_{pre}} - \frac{1}{\text{HSPF}_{post}} \right) \times \text{CF}_W \times \frac{1 \text{ kW}}{1,000 \text{ W}}$$

Equation 17

Where:

$\text{CF}_{S/W}$ = Summer/winter seasonal peak coincidence factor; see Table 36 through Table 40 in Section 2.2.2

Deemed Energy Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Deemed Summer Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Deemed Winter Demand Savings Tables

There are no lookup tables available for this measure. See engineering algorithms in the previous section for calculating energy and demand savings.

Claimed Peak Demand Savings

Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Additional Calculators and Tools

Not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for a tune-up is 5 years.⁹⁷

⁹⁷ GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group; Page 1-3, Table 1.

Program Tracking Data and Evaluation Requirements

Primary inputs and contextual data that should be specified and tracked by the program database to inform the evaluation and apply the savings properly are:

- The most recent tune-up service date or confirmation that system has not been serviced within the previous five years
- Climate zone or county
- Equipment type (split AC, split HP, packaged AC, packaged HP, PTAC, PTHP)
- Manufacturer and model number
- Cooling capacity of the serviced unit (tons)
- Heating capacity of the serviced unit, if applicable (tons)
- Before and after tune-up pictures of components illustrating condition change due to cleanings (Note: pictures that include well-placed familiar objects like hand tools often provide a sense of scale and a reference for color/shading comparisons. Pictures of equipment nameplates are useful).
- Recommended:
 - Serial number
 - Refrigerant type
 - Amount of refrigerant added or removed
 - Target superheat or subcooling
 - Post-tune-up superheat or subcooling
 - ~~Amount of refrigerant added or removed~~
 - Static pressures before and after a tune-up
 - Return and supply dry bulb and wet bulb temperatures
 - ~~Before and after tune-up pictures of components illustrating condition change due to cleanings (Note: pictures that include well-placed familiar objects like hand tools often provide a sense of scale and a reference for color/shading comparisons. Pictures of equipment nameplates are useful).~~

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Efficiency Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 27. AC/HP Tune-Ups—Revision History

TRM version	Date	Description of change
v4.0	10/10/2016	TRM v4.0 origin.
v5.0	10/2017	TRM v5.0 update. No revision.
v6.0	10/2018	TRM v6.0 update. No revision
v7.0	10/2019	TRM v7.0 update. No revision.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits.
v9.0	10/2021	TRM v9.0 update. Updated EUL reference.
v10.0	10/2022	TRM v10.0 update. No revision.
v11.0	10/2023	TRM v11.0 update. Clarified eligibility criteria.
v12.0	10/2024	TRM v12.0 update. Updated tune-up checklist to match ENERGY STAR HVAC Maintenance Checklist.

2.2.2 Split and Packaged Air Conditioners and Heat Pumps Measure Overview

TRM Measure ID: NR-HV-SP

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: ~~See Table 34 through Table 40~~ All commercial

Fuels Affected: Electricity

Decision/Action Type: Replace-on-burnout, early retirement, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

This section summarizes the deemed savings methodology for the installation of air-cooled split system and single packaged air conditioning (AC) and heat pump (HP) systems. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) based on the age of the replaced equipment and for replace-on-burnout (ROB) and new construction (NC) situations based on efficiency standards. Savings calculations incorporate the use of both full-load and part-load efficiency values. For ER, the actual age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible. Default values are provided for when the actual age of the unit is unknown.

Applicable efficient measure types include:

- Packaged and split direct expansion (DX) ACs
- Packaged and split DX HPs

Eligibility Criteria

For a measure to be eligible to use this deemed savings approach, the following conditions must be met:

- The existing and proposed cooling equipment is electric.
- The building falls into one of the categories listed in Table 36 through Table 40. Building type descriptions and examples are provided in Table 34 and Table 35.

- For ER projects: ER projects involve the replacement of a working system. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. A ROB approach should be used for these scenarios.
- If these conditions are not met, the deemed savings approach cannot be used, and the Simplified M&V Methodology or the Full M&V Methodology must be used.

Manufacturer datasheets for installed equipment or documentation of Air-Conditioning, Heating, and Refrigeration Institute (AHRI) or DOE CCMS certification must be provided.^{98,99}

Baseline Condition

The baseline conditions related to efficiency and system capacity for ER and replace-on-burnout/new construction are as follows:

Early Retirement

Early Retirement (ER) systems involve the replacement of a working system, prior to natural burnout. The ER baseline cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred.

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is the same as ROB/NC scenario. For the ER period, the baseline efficiency should be estimated using the values from Table 28 through Table 32 according to the capacity, system type, and age (based on year manufactured) of the replaced system.¹⁰⁰ When the system age can be determined (e.g., from nameplate, building prints, equipment inventory list), the baseline efficiency levels provided in Table 28 through Table 32 should be used. If individual system components were installed at different times, use the condenser age as a proxy for the entire system. When the system age is unknown, assume a default value equal to the EUL. This corresponds to an age of 15 years.¹⁰¹ A default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

PUCT Docket 40885 provided baseline efficiencies for split and packaged systems replaced via ER.

⁹⁸ Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: <https://www.ahridirectory.org/>.

⁹⁹ Department of Energy Compliance Certification Management System (DOE CCMS): <https://www.regulations.doe.gov/certification-data/>.

¹⁰⁰ The actual age should be determined from the nameplate, building prints, equipment inventory list, etc. and whenever possible the actual source used should be identified in the project documentation.

¹⁰¹ As noted in Docket 40885, page 14-15: Failure probability weights are established by assuming that systems for which age information will be unavailable are likely to be older, setting a minimum age threshold, and using the survival functions for the relevant system type to estimate the likelihood that an operational system is of a given age beyond that threshold. Baseline efficiency for each year of system age is established relative to program year. Baseline efficiency levels can be estimated for the next ten program years, considering increments in efficiency standards that took place in the historical period.

ER baseline efficiency values represent the code-specified efficiency in effect at the time the system was installed. Prior to 2002, code-specified efficiencies from ASHRAE 90.1-1989 were in effect. Code-specified efficiencies increased in 2002, approximating the effective date of ASHRAE 90.1-1999, which went into effect on October 29, 2001. Code-specified efficiencies increased again in 2010 and 2018, coinciding with the IECC 2009 and IECC 2015 code increases. The baseline efficiency levels shown in Table 28 through Table 32 are based on assumptions of the predominant heating types expected in the state. For air conditioners, baseline cooling efficiencies are displayed for a natural gas furnace heating section type. For HPs, baseline cooling efficiencies are displayed for electric resistance supplemental heating section type.

For units < 65,000 btuh (approximately 5.42 tons), EER, SEER, and HSPF values are converted to EER2, SEER2, and HSPF2 for consistency with the current federal standard. Unspecified EER2 are calculated by multiplying average EER/EER2 ratios, referencing EER2 values specified in the current federal standard for 12.2 and 11.7 EER. Unspecified SEER2 values are calculated by multiplying average SEER/SEER2 ratios, referencing SEER2 values specified for 14, 14.5, 15, and 16 SEER. Unspecified HSPF2 values are calculated by multiplying average HSPF/HSPF2 ratios, referencing HSPF2 values specified for 8.0 and 8.8 HSPF.

~~Refer to TRM 9.0 for exempted HPs < 5.4 tons referencing the previous federal standard. Units with a SEER2 rating are expected to comply with the guidelines outlined in this measure.~~

For ~~5-465,000+ ton~~65,000+ tonbtuh units, baseline EER values shown from ASHRAE/IECC assume natural gas heating for the predominant heating section type expected for commercial facilities in Texas. For units installed from 2002 to present, 0.2 EER may be added for “Electric Resistance (or None)” heating types. For units installed before 2002 and 135,000-41.3+ tonsbtuh (approximately 11.3 tons), 0.2 EER may be added for no heating.

Table 28. DX HVAC—ER Baseline Full-Load Efficiency for ACs

Year installed (replaced system)	Split < 3.75 tons (EER2)	Split 3.75 to 5.42 tons (EER2)	Packaged < 5.42 tons (EER2)	All 5.42 to < 11.3 tons (EER)	All 11.3 to < 20 tons (EER)	All 20 to < 63.3 tons (EER)	All ≥ 63.3 tons (EER)
≤ 2005	7.8	7.8	7.5	10.1	9.5	9.3	9.0
2006–2009	10.1	10.1	10.1	10.1	9.5	9.3	9.0
2010–2017	10.1	10.1	10.1	11.0	10.8	9.8	9.5
2018–2022	10.1	10.1	10.9	11.0	10.8	9.8	9.5
≥ 2023	11.7	11.2	10.9	11.0	10.8	9.8	9.5

Table 29. DX HVAC—ER Baseline Part-Load Efficiency for ACs¹⁰²

Year installed (replaced system)	Split < 3.75 tons (SEER2)	Split 3.75 to < 5.42 tons (SEER2)	Packaged < 5.42 tons (SEER2)	All 5.42 to < 11.3 tons (IEER)	All 11.3 to < 20 tons (IEER)	All 20 to < 63.3 tons (IEER)	All ≥ 63.3 tons (IEER)
≤ 2005	9.5	9.5	9.2	10.3	9.7	9.4	9.1
2006–2009	12.4	12.4	12.4	10.3	9.7	9.4	9.1
2010–2017	12.4	12.4	12.4	11.2	11.0	9.9	9.6
2018–2022	12.4	12.4	13.4	12.6	12.2	11.4	11.0
≥ 2023	14.3	13.8	13.4	14.6	14.0	13.0	11.0

Table 30. DX HVAC—ER Baseline Full-Load Cooling Efficiency for HPs

Year installed (replaced system)	Split < 5.42 tons (EER2)	Packaged < 5.42 tons (EER2)	All 5.42 to < 11.3 tons (EER)	All 11.3 to < 20 tons (EER)	All 20 to < 63.3 tons (EER)	All ≥ 63.3 tons (EER)
≤ 2005	7.8	7.5	10.1	9.3	9.0	9.0
2006–2009	10.1	10.1	10.1	9.3	9.0	9.0
2010–2017	10.1	10.1	11.0	10.6	9.5	9.5
2018–2022	10.9	10.9	11.0	10.6	9.5	9.5
≥ 2023	11.7	10.9	11.0	10.6	9.5	9.5

Table 31. DX HVAC—ER Baseline Part-Load Cooling Efficiency for HPs¹⁰³

Year installed (replaced system)	Split < 5.42 tons (SEER2)	Packaged < 5.42 tons (SEER2)	All 5.42 to < 11.3 tons (IEER)	All 11.3 to < 20 tons (IEER)	All 20 to < 63.3 tons (IEER)	All ≥ 63.3 tons (IEER)
≤ 2005	9.5	9.2	10.3	9.5	9.1	9.1
2006–2009	12.4	12.4	10.3	9.5	9.1	9.1
2010–2017	12.4	12.4	11.2	10.7	9.6	9.6
2018–2022	13.4	13.4	12.0	11.6	10.6	10.6
≥ 2023	14.3	13.4	14.1	13.5	12.5	10.6

¹⁰² IEER values were not added to the Standard until 2010, so IEERs for prior years are approximated as EER + 0.2 for systems between 5.4 tons and less than 20 tons and as EER + 0.1 for systems greater than 20 tons based on the relationship of EER to IEER from the current federal standard.

¹⁰³ IEER values were not added to the Standard until 2010, so IEERs for prior years are approximated as EER + 0.2 for systems between 5.4 tons and less than 20 tons and as EER + 0.1 for systems greater than 20 tons based on the relationship of EER to IEER from the current federal standard.

Table 32. DX HVAC—ER Baseline Heating Efficiency for HPs

Year installed (replaced system)	Split < 5.42 tons (HSPF2)	Packaged < 5.42 tons (HSPF2)	All 5.42 to < 11.3 tons (COP)	All 11.3 to < 20 tons (COP)	All ≥ 20 tons (COP)
≤ 2005	5.7	5.6	3.2	3.1	3.1
2006–2009	6.5	6.5	3.2	3.1	3.1
2010–2017	6.5	6.5	3.3	3.2	3.2
2018–2022	6.9	6.7	3.3	3.2	3.2
≥ 2023	7.5	6.7	3.4	3.3	3.2

Replace-on-Burnout (ROB) and New Construction (NC)

Baseline efficiency levels for package and split DX ACs and HPs are provided in Table 33. The baseline part-load efficiency levels reflect the latest minimum efficiency requirements from the current federal standard, effective January 1, 2023, for units with a rated cooling capacity of less than 65,000 Btu/hour (Btuh) (5.42 tons)¹⁰⁴ and for units rated between 65,000-759,999 Btuh.¹⁰⁵ Full-load efficiency levels are estimated for < 65,000 Btuh systems using a comparison of AHRI SEER2 and EER2 efficiency ratings. Part-load efficiency for 760,000+ Btuh systems and full-load efficiency for 65,000+ Btuh systems are specified in the IECC codes. The current statewide energy code is IECC 2015, but local jurisdictions may have adopted more recent codes with higher efficiencies, such as IECC 2021.^{106,107}

An updated federal standard¹⁰⁸, effective September 17, 2024 with a manufacturing compliance date of January 1, 2029, will establish new integrated ventilation, economizing, and cooling (IVEC) and integrated ventilation and heating efficiency (IVHE) minimum efficiency requirements. After the compliance date, IVEC will replace IEER, and IVHE will replace COP.

¹⁰⁴ US Department of Energy (DOE) federal minimum efficiency standard for < 65,000 btuh systems, 10 CFR 430.32. <https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32>.

¹⁰⁵ US DOE federal minimum efficiency standard for 65,000-759,999 btuh systems, 10 CFR 431.97. <https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-F/subject-group-ECFR2640f6ad978e4e6/section-431.97>.

¹⁰⁶ IECC 2015 Table C403.2.3(1) and C403.2.3(2), 2015 International Energy Conservation Code (IECC). <https://codes.iccsafe.org/content/IECC2015>.

¹⁰⁷ Cities Adopted Code List: 2012 or Newer IECC. SPEER. <https://eepartnership.org/wp-content/uploads/2024/05/2024-Cities-Adopted-Code-5.28.24.xlsx>.

¹⁰⁸ US DOE federal minimum efficiency standard for air-cooled commercial package air conditioners and heat pumps. <https://www.regulations.gov/document/EERE-2022-BT-STD-0015-0100>.

For ACs, baseline cooling efficiencies are displayed for a natural gas furnace heating section type. For HPs, baseline cooling efficiencies are displayed for electric resistance supplemental heating section type. For all other heating section types, or for no heating section type, the baseline efficiencies may need to be adjusted as specified by the footnotes in the tables.

Table 33. DX HVAC—NC/ROB Baseline Efficiency Levels¹⁰⁹

System type	Capacity (tons)	Baseline efficiencies	Source ¹¹⁰
Air conditioner	Split < 3.75	11.7 EER2 14.3 SEER2	DOE Standards
	Split ≥ 3.75	11.2 EER2 13.8 SEER2	
	Packaged < 5.42 tons	10.9 EER2 ¹¹¹ 13.4 SEER2	
	All < 5.42 tons rated at ≥ 15.2 SEER2	9.8 EER2 ¹¹²	
	5.42 to < 11.3	11.0 EER 14.6 IEER	DOE Standards IECC 2015
	11.3 to < 20	10.8 EER 14.0 IEER	
	20 to < 63.3	9.8 EER 13.0 IEER	
	≥ 63.3	9.5 EER 11.0 IEER	IECC 2015
Heat pump (cooling) ¹¹³	Split < 5.42	11.7 EER2 14.3 SEER2	DOE Standards
	Packaged < 5.42	10.9 EER2 ¹¹⁴ 13.4 SEER2	

¹⁰⁹ IECC 2015 Table C403.2.3(1) and C403.2.3(2).

¹¹⁰ These baseline efficiency standards noted as “DOE Standards” are cited in the Code of Federal Regulations, 10 CFR 430.32 for < 65,000 Btu/h and 10 CFR 431.97 for 65,000-759,999 Btu/h.

¹¹¹ Unspecified EER2 values are calculated by multiplying average EER/EER2 ratios, referencing EER2 values specified in the current federal standard for 12.2 and 11.7 EER.

¹¹² When installing any system with a part-load efficiency rating of 15.2 SEER2 or higher, the reduced 9.8 EER2 full-load efficiency baseline should be applied in lieu of the applicable value presented earlier in the table except where the specified baseline EER2 value is lower than 9.8 EER2.

¹¹³ ASHRAE 90.1-2010 Table 6.8.1B. These systems larger than 5.4 tons, the minimum efficiency levels provided in this table are based on systems with heating type “No Heating or Electric Resistance Heating”, excluding systems with “All Other Types of Heating”.

¹¹⁴ Unspecified EER2 values are calculated by multiplying average EER/EER2 ratios, referencing values specified in the current federal standard for 12.2 and 11.7 EER.

System type	Capacity (tons)	Baseline efficiencies	Source ¹¹⁰
	All < 5.4 2 tons rated at \geq 15.2 SEER2	9.8 EER2 ¹¹⁵	
	5.4 2 to < 11.3	11.0 EER 14.1 IEER	DOE Standards IECC 2015
	11.3 to < 20	10.6 EER 13.5 IEER	
	20 to < 63.3	9.5 EER 12.5 IEER	
	> 63.3	9.5 EER 10.6 IEER	IECC 2015
Heat pump (heating) ¹¹⁶	Split < 5.4 2	7.5 HSPF2	DOE Standards
	Packaged < 5.4 2	6.7 HSPF2	
	5.4 2 to < 11.3 25	3.4 3 COP	DOE Standards
	11.3 to < 20	3.3 COP	
	\geq 20	3.2 COP	IECC 2015

High-Efficiency Condition

Split and packaged systems must exceed the minimum efficiencies specified in Table 33. Split system efficiencies are driven primarily by the efficiency of the condenser unit. If the paired outdoor and indoor units are not listed on the AHRI certification listing and only provide DOE CCMS testing results, then the capacity and efficiency of the high-efficiency condition shall not exceed the average of the AHRI certification listing pairing for the matching condenser. The DOE CCMS listing provides documentation of the results that are on the AHRI certification listing and can be downloaded and filtered based on listing using a similar condenser and various indoor units.

For reference, both ENERGY STAR^{®117} and the Consortium for Energy Efficiency (CEE)¹¹⁸ offer suggested guidelines for high-efficiency equipment. Additional conditions for replace-on-burnout, ER and new construction are in the sections below.

¹¹⁵ When installing any system with a part-load efficiency rating of 15.2 SEER2 or higher, the reduced 9.8 EER2 full-load efficiency baseline should be applied in lieu of the applicable value presented earlier in the table except where the specified baseline EER2 value is lower than 9.8 EER2.

¹¹⁶ Heat pump retrofits must also exceed the baseline efficiency levels for heating efficiencies.

¹¹⁷ ENERGY STAR Heating & Cooling, https://www.energystar.gov/products/heating_cooling.

¹¹⁸ CEE Program Resources, <http://www.cee1.org/content/cee-program-resources>.

New Construction and Replace-on-Burnout

This scenario includes equipment used for new construction and retrofit/replacements that are not covered by ER, such as units that are replaced after natural failure.

Early Retirement

The high-efficiency retrofits must meet the following criteria:¹¹⁹

- For ER projects only, when downsizing, the pre-installed cooling capacity must be less than is limited to a maximum of 120 percent of the newly installed equipment's cooling capacity must be within at or above 80 percent to 120 percent of the replaced electric cooling capacity when downsizing. There is no cap limit on upsizing because the savings are calculated using the lower pre-capacity.
- For scenarios involving the replacement of a combination of systems by an alternate combination of systems of varying capacities, ER savings can still be claimed if the overall pre- and post-capacities for the total combination of systems are compliant with the guidance in the previous bullet within ± 20 percent. In these cases, a custom calculation should be performed to establish the following weighted savings factors to be applied over the ER portion of the savings calculation: manufacturer year, EUL, RUL, full and part-load baseline efficiency, coincidence factor, and EFLH. These factors should be weighted based on contribution to overall capacity.
- No additional measures are being installed that directly affect the operation of the cooling equipment (e.g., control sequences, cooling towers, and condensers).

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$\text{Summer Peak Demand Savings [kW]} = \left(\frac{\text{Cap}_{C,pre}}{\eta_{baseline,C}} - \frac{\text{Cap}_{C,post}}{\eta_{installed,C}} \right) \times CF_S \times \frac{1 \text{ kW}}{1,000 \text{ W}}$$

Equation 18

$$\text{Winter Peak Demand Savings [kW]} = \left(\frac{\text{Cap}_{H,pre}}{\eta_{baseline,H}} - \frac{\text{Cap}_{H,post}}{\eta_{installed,H}} \right) \times CF_W \times \frac{1 \text{ kW}}{3,412 \text{ Btuh}}$$

Equation 19

$$\text{Total Energy Savings [kWh]} = \text{kWh}_C + \text{kWh}_H$$

Equation 20

$$\text{Cooling Energy Savings [kWh}_C] = \left(\frac{\text{Cap}_{C,pre}}{\eta_{baseline,C}} - \frac{\text{Cap}_{C,post}}{\eta_{installed,C}} \right) \times EFLH_C \times \frac{1 \text{ kW}}{1,000 \text{ W}}$$

Equation 21

¹¹⁹ From PUCT Docket #41070.

$$\text{Heating Energy Savings [kWh}_H] = \left(\frac{\text{Cap}_{H,pre}}{\eta_{baseline,H}} - \frac{\text{Cap}_{H,post}}{\eta_{installed,H}} \right) \times \text{EFLH}_H \times \frac{1 \text{ kWh}}{3,412 \text{ Btu}}$$

Equation 22

Where:

$\text{Cap}_{C/H,pre}$ = For ER and ROB, rated equipment cooling/heating capacity of the existing equipment at AHRI-standard conditions with a maximum of 20 percent larger than the post-capacity; for NC, rated equipment cooling/heating capacity of the new equipment at AHRI-standard conditions [Btuh]; 1 ton = 12,000 Btuh

$\text{Cap}_{C/H,post}$ = Rated equipment cooling/heating capacity of the newly installed equipment at AHRI-standard conditions with a maximum equal to the baseline pre-capacity [Btuh]; 1 ton = 12,000 Btuh

Note: The capacity in the equations ~~may~~ will not always match the capacity of the units.

$\eta_{baseline,C}$ = Cooling efficiency of existing equipment (ER) or standard equipment (ROB/NC) [Btuh/W]

$\eta_{installed,C}$ = Rated cooling efficiency of the newly installed equipment (Must exceed ROB/NC baseline efficiency standards in Table 33) [Btuh/W]

$\eta_{baseline,H}$ = Heating efficiency of existing equipment (ER) or standard equipment (ROB/NC) [COP]

$\eta_{installed,H}$ = Rated heating efficiency of the newly installed equipment (Must exceed baseline efficiency standards in Table 33) [COP]

Note: Use EER2/EER for summer kilowatt, SEER2/IEER for cooling kilowatt-hour, and COP for heating kilowatt-hour and winter kilowatt savings calculations. The COP expressed for units ≥ 5.4 tons is a full-load COP. Heating efficiencies expressed as HSPF will be approximated as a seasonal COP and should be converted using the following equation:

$$\text{COP} = \frac{\text{HSPF}}{3.412}$$

Equation 23

CF_{SW} = Summer/winter seasonal peak coincidence factor (see Table 36 through Table 40)

$\text{EFLH}_{C/H}$ = Cooling/heating equivalent full-load hours [hours] (see Table 36 through Table 40)

Early Retirement Savings

The first-year savings algorithms in the above equations are used for all HVAC projects, across NC, ROB, and ER projects. However, ER projects require weighted savings calculated over both the ER and ROB periods, accounting for both the EUL and RUL. The ER savings are applied over the remaining useful life (RUL) period, and the ROB savings are applied over the remaining period (EUL-RUL). The final reported savings for ER projects are not actually a “first-year” savings, but an “average annual savings over the lifetime (EUL) of the measure.” These savings calculations are explained in Appendix A.

System Type Conversion

Chiller to AC: Conversions from chiller-based systems to a packaged/split AC system are covered under this measure. See the reference tables in the HVAC Chillers measure for the savings.

AC to HP: Conversions from AC to HP are acceptable in commercial applications. Use CAP_H , $\eta_{\text{baseline,H}}$, CF_W , and $EFLH_H$ values for the new HP as a proxy for the baseline AC heating savings coefficients.

Deemed Energy and Demand Savings Tables

Deemed peak coincidence factor (CF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. A description of the building types that are used for HVAC systems is presented in Table 34 **Error! Not a valid bookmark self-reference.** and Table 35. These building types are derived from the EIA Commercial Building Energy Consumption Survey (CBECS) study.¹²⁰

The CF and EFLH values for packaged and split AC and HP units are presented in Table 36 through Table 40.

A description of the calculation method used to derive these values can be found in Docket No. 40885, Attachment B.

Combination building types. In situations where multiple TRM building types seem plausible or a predominant TRM building type is unclear, the utilities have two choices:

- **Deemed approach.** The deemed approach is a simplified method where utilities should choose a TRM building type based on the “best fit” for the facility. This is determined by the largest interior area for the potential building types. Although, if that is not best fit, the utilities will use their best judgment to make this decision and provide sufficient, defensible documentation for their decision.

¹²⁰ The Commercial Building Energy Consumption Survey (CBECS), implemented by the US Energy Information Administration, includes a principal building activity categorization scheme that separates the Commercial sector into 29 categories and 51 subcategories based on principal building activity (PBA). For its purposes, the CBECS defines commercial buildings as those buildings greater than 1,000 square feet that devote more than half of their floorspace to activity that is neither residential, manufacturing, industrial, nor agricultural. The high-level building types adopted for the TRM are adapted from this CBECS categorization, with some building types left out and one additional building type—Large Multifamily—included. <https://www.eia.gov/consumption/commercial/>.

The following building type combinations are pre-authorized exceptions to this rule. For these combinations, individual fixtures can be reported as either specified building type based on location. All other interior space combinations should reference a single deemed building type unless authorized by the evaluator.

- Office (any size): Warehouse
- Hospital: Outpatient healthcare

The *other* building type can be used for business types that are not explicitly listed. The CF and EFLH values used for *other* are the most conservative from the explicitly listed building types. When the *other* building type is used, a description of the actual building type, the primary business activity, the business hours, and the HVAC schedule must be collected for the project site and stored in the utility tracking data system.

For those combinations of technology, climate zone, and building type with no values, a project with that specific combination should use the *other* building type.

- **Custom approach.** In more unique situations, utilities should consider projects “custom” where (1) the deemed building types in the TRM may not represent the project’s facility type, (2) the facility may represent multiple TRM building types without a clear predominant building type, or (3) the use of a predominant building type may be too conservative in the estimate of savings. The deemed methods only apply to specific scenarios and cannot be developed for all unique situations. Utilities should provide sufficient, defensible documentation for their EFLH and CF values used in their savings calculations that the EM&V team can review.

Table 34. DX HVAC—Building Type Descriptions and Examples

Building type	Principal building activity	Definition	Detailed business type examples ¹²¹
Data center	Data center	Buildings used to house computer systems and associated components.	1) Data center
Education	College/university		1) College or university 2) Career or vocational training 3) Adult education
	Primary school		1) Elementary or middle school (<u>grade 8 or lower</u>) 2) Preschool or daycare

¹²¹ Principal Building Activities are based on sub-categories from [2003-CBECS-questionnaire](https://www.eia.gov/consumption/commercial/building-type-definitions.php)
<https://www.eia.gov/consumption/commercial/building-type-definitions.php>.

Building type	Principal building activity	Definition	Detailed business type examples ¹²¹
	Secondary school ¹²²	Buildings used for academic or technical classroom instruction, such as elementary, middle, or high schools, and classroom buildings on college or university campuses. Buildings on education campuses for which the main use is not classroom are included in the category relating to their use. For example, administration buildings are part of "Office," dormitories are "Lodging," and libraries are "Public Assembly."	<ol style="list-style-type: none"> 1) High school <u>(grade 9 or greater)</u> 2) Religious education
Food sales	Convenience store	Buildings used for retail or wholesale of food.	<ol style="list-style-type: none"> 1) Gas station with a convenience store 2) Convenience store
	Supermarket		<ol style="list-style-type: none"> 1) Grocery store or food market
Food service	Full-service restaurant	Buildings used for the preparation and sale of food and beverages for consumption.	<ol style="list-style-type: none"> 1) Restaurant or cafeteria
	Quick-service restaurant		<ol style="list-style-type: none"> 1) Fast food
Healthcare	Inpatient	Buildings used as diagnostic and treatment facilities for inpatient care.	<ol style="list-style-type: none"> 1) Hospital 2) Inpatient rehabilitation
	Outpatient	Buildings used as diagnostic and treatment facilities for outpatient care. Medical offices are included here if they use any type of diagnostic medical equipment (if they do not, they are categorized as an office building).	<ol style="list-style-type: none"> 1) Medical office 2) Clinic or outpatient health care 3) Veterinarian

¹²² Individual middle and junior high schools may have a campus size and building activities that better align with secondary schools (see Table 35). The use of secondary school assumptions in lieu of primary school assumptions is subject to evaluator pre-approval. Otherwise, Education subcategory should be determined by lowest grade.

Building type	Principal building activity	Definition	Detailed business type examples ¹²¹
Large multifamily	Midrise apartment	Buildings containing multifamily dwelling units, having multiple stories, and equipped with elevators.	No sub-categories collected.
Lodging	Large hotel	Buildings used to offer multiple accommodations for short-term or long-term residents, including skilled nursing and other residential care buildings.	<ol style="list-style-type: none"> 1) Motel or inn 2) Hotel 3) Dormitory, fraternity, or sorority 4) Retirement home, nursing home, assisted living, or other residential care 5) Convent or monastery
	Nursing home		
	Small hotel/motel		
Mercantile	Stand-alone retail	Buildings used for the sale and display of goods other than food.	<ol style="list-style-type: none"> 1) Retail store 2) Beer, wine, or liquor store 3) Rental center 4) Dealership or showroom for vehicles or boats 5) Studio or gallery
	Strip and enclosed mall	Shopping malls comprised of multiple connected establishments.	<ol style="list-style-type: none"> 1) Strip shopping center 2) Enclosed malls
Office	Large office	Buildings used for general office space, professional office, or administrative offices. Medical offices are included here if they do not use any type of diagnostic medical equipment (if they do, they are categorized as an outpatient health care building).	<ol style="list-style-type: none"> 1) Administrative or professional office 2) Government office 3) Mixed-use office 4) Bank or other financial institution 5) Medical office 6) Sales office 7) Contractor's office (e.g., construction, plumbing, HVAC) 8) Non-profit or social services 9) Research and development 10) City hall or city center 11) Religious office 12) Call center
	Medium office		
	Small office		

Building type	Principal building activity	Definition	Detailed business type examples ¹²¹
Public assembly	Public assembly	Buildings in which people gather for social or recreational activities, whether in private or non-private meeting halls.	<ol style="list-style-type: none"> 1) Social or meeting (e.g., community center, lodge, meeting hall, convention center, senior center) 2) Recreation (e.g., gymnasium, health club, bowling alley, ice rink, field house, indoor racquet sports) 3) Entertainment or culture (e.g., museum, theater, cinema, sports arena, casino, night club) 4) Library 5) Funeral home 6) Student activities center 7) Armory 8) Exhibition hall 9) Broadcasting studio 10) Transportation terminal
Religious worship	Religious worship	Buildings in which people gather for religious activities (such as chapels, churches, mosques, synagogues, and temples).	No sub-categories collected.
Service	Service: Excluding food	Buildings in which some type of service is provided, other than food service or retail sales of goods.	<ol style="list-style-type: none"> 1) Vehicle service or vehicle repair shop 2) Vehicle storage/maintenance 3) Repair shop 4) Dry cleaner or laundromat 5) Post office or postal center 6) Car wash 7) Gas station with no convenience store 8) Photo processing shop 9) Beauty parlor or barber shop 10) Tanning salon 11) Copy center or printing shop 12) Kennel
Warehouse	Warehouse	Buildings used to store goods, manufactured products, merchandise, raw materials, or personal belongings (such as self-storage).	<ol style="list-style-type: none"> 1) Refrigerated warehouse 2) Non-refrigerated warehouse 3) Distribution or shipping center
Other	Other	For building types not explicitly listed.	Values used for other are the most conservative values from the explicitly listed building types.

Table 35. DX HVAC—Building Type Floor Area and Number of Floors¹²³

Building type	Principal building activity	Average floor area (ft²)	Average number of floors
Data center	Data center	Not specified	Not specified
Education	College/university	Not specified	Not specified
	Primary school	73,960	1
	Secondary school	210,887	2
Food sales	Convenience store	Not specified	1
	Supermarket	45,000	1
Food service	Full-service restaurant	5,500	1
	Quick-service restaurant	2,500	1
Healthcare	Inpatient	241,351	5
	Outpatient	40,946	3
Large multifamily	Midrise apartment	33,740	4
Lodging	Large hotel	122,120	6
	Nursing home	Not specified	Not specified
	Small hotel/motel	43,200	4
Mercantile	Stand-alone retail	24,962	1
	Strip and enclosed mall	22,500	1
Office	Large office	498,588	12
	Medium office	53,628	3
	Small office	5,500	1
Public assembly	Public assembly	Not specified	Not specified
Religious worship	Religious worship	Not specified	Not specified
Service	Service: Excluding food	Not specified	Not specified
Warehouse	Warehouse	52,045	1

¹²³ Building prototype information from DOE Commercial Reference Buildings, “Not specified” means that a building prototype is not defined for that building type. <http://energy.gov/eere/buildings/Commercial-reference-buildings>.

Table 36. DX HVAC—CF and EFLH Values for Climate Zone 1: Amarillo

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump ¹²⁴			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _H
Data center	Data center	0.89	2,048	0.89	2,048	–	–
Education	College/university	0.69	787	0.69	787	–	–
	Primary school	0.64	740	0.64	740	0.43	701
	Secondary school	0.69	535	0.69	535	0.43	736
Food sales	Convenience store	0.73	884	0.73	884	–	–
	Supermarket	0.29	219	0.29	219	–	–
Food service	Full-service restaurant	0.83	1,020	0.83	1,020	0.43	1,123
	24-hour full-service restaurant	0.81	1,093	0.81	1,093	0.43	1,346
	Quick-service restaurant	0.73	765	0.73	765	0.48	1,029
	24-hour quick-service restaurant	0.74	817	0.74	817	0.48	1,300
Healthcare	Inpatient	0.72	2,185	0.72	2,185	–	–
	Outpatient	0.71	2,036	0.71	2,036	0.27	579
Large multifamily	Midrise apartment	0.68	674	0.68	674	–	–
Lodging	Large hotel	0.58	1,345	0.58	1,345	0.86	1,095
	Nursing home	0.68	685	0.68	685	–	–
	Small hotel/motel	0.57	1,554	0.57	1,554	0.36	475
Mercantile	Stand-alone retail	0.68	623	0.68	623	0.99	907
	24-hour retail	0.80	820	0.80	820	0.43	1,277
	Strip and enclosed mall	0.75	687	0.75	687	0.39	753
Office	Large office	0.90	2,058	0.90	2,058	–	–
	Medium office	0.64	925	0.64	925	0.72	576
	Small office	0.72	711	0.72	711	0.29	340
Public assembly	Public assembly	0.64	995	0.64	995	–	–
Religious worship	Religious worship	0.57	387	0.57	387	–	–
Service	Service: Excluding food	0.83	790	0.83	790	–	–
Warehouse	Warehouse	0.34	173	0.34	173	–	–
Other	Other	0.29	173	0.29	173	0.27	340

¹²⁴ For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the *other* building type for heating energy/demand savings.

Table 37. DX HVAC—CF and EFLH Values for Climate Zone 2: Dallas

Building type	Principal building activity	Package and Split DX					
		Air Conditioner		Heat Pump ¹²⁵			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _H
Data center	Data center	1.08	3,401	1.08	3,401	–	–
Education	College/university	1.02	1,595	1.02	1,595	–	–
	Primary school	0.88	1,208	0.88	1,208	0.66	397
	Secondary school	1.02	1,084	1.02	1,084	0.59	489
Food sales	Convenience store	1.08	1,835	1.08	1,835	–	–
	Supermarket	0.58	615	0.58	615	–	–
Food service	Full-service restaurant	1.09	1,823	1.09	1,823	0.50	688
	24-hour full-service restaurant	1.09	2,061	1.09	2,061	0.49	873
	Quick-service restaurant	1.08	1,588	1.08	1,588	0.61	631
	24-hour quick-service restaurant	1.08	1,765	1.08	1,765	0.60	794
Healthcare	Inpatient	0.92	3,097	0.92	3,097	–	–
	Outpatient	0.80	2,532	0.80	2,532	0.28	310
Large multifamily	Midrise apartment	1.04	1,709	1.04	1,709	–	–
Lodging	Large hotel	0.70	2,079	0.70	2,079	0.82	464
	Nursing home	1.04	1,736	1.04	1,736	–	–
	Small hotel/motel	0.55	2,281	0.55	2,281	0.42	249
Mercantile	Stand-alone retail	0.95	1,157	0.95	1,157	0.55	352
	24-hour retail	1.01	1,539	1.01	1,539	0.57	632
	Strip and enclosed mall	0.91	1,100	0.91	1,100	0.55	376
Office	Large office	1.03	2,379	1.03	2,379	–	–
	Medium office	0.76	1,236	0.76	1,236	0.66	262
	Small office	0.92	1,203	0.92	1,203	0.40	153
Public assembly	Public assembly	0.88	1,624	0.88	1,624	–	–
Religious worship	Religious worship	0.55	567	0.55	567	–	–
Service	Service: Excluding food	1.09	1,412	1.09	1,412	–	–
Warehouse	Warehouse	0.84	597	0.84	597	–	–
Other	Other	0.55	567	0.55	567	0.28	153

¹²⁵ For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the *other* building type for heating energy/demand savings.

Table 38. DX HVAC—CF and EFLH Values for Climate Zone 3: Houston

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump ¹²⁶			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _H
Data center	Data center	1.05	4,022	1.05	4,022	–	–
Education	College/university	0.98	1,843	0.98	1,843	–	–
	Primary school	0.88	1,443	0.88	1,443	0.50	239
	Secondary school	0.98	1,253	0.98	1,253	0.54	293
Food sales	Convenience store	1.03	2,142	1.03	2,142	–	–
	Supermarket	0.60	744	0.60	744	–	–
Food service	Full-service restaurant	1.05	2,135	1.05	2,135	0.44	429
	24-hour full-service restaurant	1.06	2,426	1.06	2,426	0.44	559
	Quick-service restaurant	1.03	1,853	1.03	1,853	0.51	372
	24-hour quick-service restaurant	1.05	2,059	1.05	2,059	0.50	483
Healthcare	Inpatient	0.90	3,490	0.90	3,490	–	–
	Outpatient	0.80	2,844	0.80	2,844	0.29	196
Large multifamily	Midrise apartment	1.00	2,031	1.00	2,031	–	–
Lodging	Large hotel	0.70	2,531	0.70	2,531	0.33	250
	Nursing home	1.00	2,063	1.00	2,063	–	–
	Small hotel/motel	0.65	2,316	0.65	2,316	0.19	147
Mercantile	Stand-alone retail	0.95	1,399	0.95	1,399	0.43	204
	24-hour retail	0.97	1,804	0.97	1,804	0.41	374
	Strip and enclosed mall	0.92	1,330	0.92	1,330	0.42	218
Office	Large office	1.00	2,619	1.00	2,619	–	–
	Medium office	0.75	1,387	0.75	1,387	0.42	149
	Small office	0.88	1,338	0.88	1,338	0.28	69
Public assembly	Public assembly	0.88	1,940	0.88	1,940	–	–
Religious worship	Religious worship	0.65	576	0.65	576	–	–
Service	Service: Excluding food	1.05	1,653	1.05	1,653	–	–
Warehouse	Warehouse	0.84	633	0.84	633	–	–
Other	Other	0.60	576	0.60	576	0.19	69

¹²⁶ For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the *other* building type for heating energy/demand savings.

Table 39. DX HVAC—CF and EFLH Values for Climate Zone 4: Corpus Christi

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump ¹²⁷			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _H
Data center	Data center	0.97	4,499	0.97	4,499	–	–
Education	College/university	0.96	2,211	0.96	2,211	–	–
	Primary school	0.88	1,680	0.88	1,680	0.30	156
	Secondary school	0.96	1,503	0.96	1,503	0.35	196
Food sales	Convenience store	0.94	2,510	0.94	2,510	–	–
	Supermarket	0.54	894	0.54	894	–	–
Food service	Full-service restaurant	0.98	2,530	0.98	2,530	0.35	292
	24-hour full-service restaurant	0.97	2,897	0.97	2,897	0.36	377
	Quick-service restaurant	0.94	2,172	0.94	2,172	0.34	232
	24-hour quick-service restaurant	0.93	2,440	0.93	2,440	0.34	296
Healthcare	Inpatient	0.86	3,819	0.86	3,819	–	–
	Outpatient	0.78	3,092	0.78	3,092	0.08	122
Large multifamily	Midrise apartment	0.92	2,236	0.92	2,236	–	–
Lodging	Large hotel	0.65	2,981	0.65	2,981	0.21	131
	Nursing home	0.92	2,271	0.92	2,271	–	–
	Small hotel/motel	0.58	2,530	0.58	2,530	0.10	82
Mercantile	Stand-alone retail	0.84	1,582	0.84	1,582	0.22	131
	24-hour retail	0.86	2,118	0.86	2,118	0.25	255
	Strip and enclosed mall	0.82	1,510	0.82	1,510	0.21	141
Office	Large office	0.91	2,778	0.91	2,778	–	–
	Medium office	0.66	1,523	0.66	1,523	0.24	83
	Small office	0.80	1,504	0.80	1,504	0.14	39
Public assembly	Public assembly	0.88	2,259	0.88	2,259	–	–
Religious worship	Religious worship	0.58	629	0.58	629	–	–
Service	Service: Excluding food	0.98	1,959	0.98	1,959	–	–
Warehouse	Warehouse	0.73	665	0.73	665	–	–
Other	Other	0.54	629	0.54	629	0.08	39

¹²⁷ For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the *other* building type for heating energy/demand savings.

Table 40. DX HVAC—CF and EFLH Values for Climate Zone 5: El Paso

Building type	Principal building activity	Package and split DX					
		Air conditioner		Heat pump ¹²⁸			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _H
Data center	Data center	0.88	2,547	0.88	2,547	–	–
Education	College/university	0.87	1,092	0.87	1,092	–	–
	Primary school	0.91	996	0.91	996	0.37	408
	Secondary school	0.87	742	0.87	742	0.43	431
Food sales	Convenience store	0.76	1,251	0.76	1,251	–	–
	Supermarket	0.38	347	0.38	347	–	–
Food service	Full-service restaurant	0.76	1,276	0.76	1,276	0.28	613
	24-hour full-service restaurant	0.74	1,413	0.74	1,413	0.27	809
	Quick-service restaurant	0.76	1,082	0.76	1,082	0.26	522
	24-hour quick-service restaurant	0.77	1,171	0.77	1,171	0.26	697
Healthcare	Inpatient	0.81	2,555	0.81	2,555	–	–
	Outpatient	0.81	2,377	0.81	2,377	0.04	320
Large multifamily	Midrise apartment	0.88	1,209	0.88	1,209	–	–
Lodging	Large hotel	0.63	1,701	0.63	1,701	0.21	440
	Nursing home	0.88	1,228	0.88	1,228	–	–
	Small hotel/motel	0.63	1,921	0.63	1,921	0.06	185
Mercantile	Stand-alone retail	0.80	904	0.80	904	0.26	384
	24-hour retail	0.86	1,228	0.86	1,228	0.28	808
	Strip and enclosed mall	0.83	931	0.83	931	0.27	448
Office	Large office	0.98	2,423	0.98	2,423	–	–
	Medium office	0.77	1,173	0.77	1,173	0.27	256
	Small office	0.84	1,037	0.84	1,037	0.15	146
Public assembly	Public assembly	0.91	1,339	0.91	1,339	–	–
Religious worship	Religious worship	0.63	478	0.63	478	–	–
Service	Service: Excluding food	0.76	988	0.76	988	–	–
Warehouse	Warehouse	0.75	324	0.75	324	–	–
Other	Other	0.38	324	0.38	324	0.04	146

¹²⁸ For heat pump projects without explicit heating factors, implementers may use the listed heating factors from the *other* building type for heating energy/demand savings.

Claimed Peak Demand Savings

A summer peak-period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Upstream/Midstream Delivery

For upstream/midstream program delivery, use the EFLH and CF assumptions outlined in Table 41. Assumed values have been weighted based on building-type survey data from 2012¹²⁹ ~~2018~~ <https://www.eia.gov/consumption/commercial/> and 2014 ~~2018~~ [Manufacturing Energy Consumption Survey \(MECS\)](https://www.eia.gov/consumption/manufacturing/).¹³⁰

For upstream/midstream program designs where the building type is known, use the savings coefficients from Table 36 through Table 40. For program designs where the building type is unknown, you may use the savings coefficients from Table 41. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

Table 41. DX HVAC—Upstream/Midstream Input Assumptions¹³¹

Savings coefficient	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
EFLH _C	1,042 1,062	1,517 1,543	1,723 1,752	1,918 1,947	1,314 1,338
EFLH _H	524504	260245	139130	8579	259243
CF _S	0.68	0.92	0.91	0.84	0.84
CF _W	0.360-37	0.400-39	0.280-27	0.150-14	0.13

Measure Life and Lifetime Savings

The EUL and RULs for this HVAC equipment are provided below. The reader should refer to the definitions of estimated useful life (EUL) and remaining useful life in the glossary in Volume 1 for guidance on how to determine the decision type for system installations.

Estimated Useful Life

The EUL for split and packaged ACs and HPs is 15 years.¹³²

¹²⁹ ~~2018-12~~ Commercial Building Energy Consumption Survey (CBECS). <https://www.eia.gov/consumption/commercial/>. ~~2018 version not available until mid-2020.~~

¹³⁰ ~~2018~~ 2014 Manufacturing Energy Consumption Survey (MECS). <https://www.eia.gov/consumption/manufacturing/>.

¹³¹ ~~2018~~ 2012 CBECS and ~~2014~~ MECS.

¹³² The EUL of 15 years has been cited in several places - PUCT Docket No. 36779, DOE 77 FR 28928, 10 CFR Part 431, and in the DEER 2014 update.

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 42. If individual system components were installed at different times, use the condenser age as a proxy for the entire system. For ER units of unknown age, assume a default value equal to the EUL. This corresponds to a default RUL of 2.8 years. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Both the RUL and EUL are needed to estimate savings for ER projects for two distinct periods: The ER period (RUL) and the ROB period (EUL – RUL). The calculations for ER projects are extensive, and as such, are provided in Appendix A.

Table 42. DX HVAC—RUL of Early Retirement Systems^{133,134}

Age of replaced system (years)	Split/package AC/HP systems RUL (years)	Age of replaced system (years)	Split/package AC/HP systems RUL (years)
1	14.0	10	5.7
2	13.0	11	5.0
3	12.0	12	4.4
4	11.0	13	3.8
5	10.0	14	3.3
6	9.1	15	2.8
7	8.2	16	2.0
8	7.3	17	1.0
9	6.5	18 ¹³⁵	0.0

¹³³ PUCT Docket No. 40083, Attachment A describes the process in which the RUL of replaced systems has been calculated.

¹³⁴ Current new construction baseline matches the baseline for existing systems manufactured in 2023. Existing systems manufactured after 1/1/2023 are not eligible to use the early retirement baseline and should use the ROB baseline instead. These values are greyed out in the table and displayed for informational purposes only.

¹³⁵ RULs are capped at the 75th percentile of equipment age, 18 years, as determined based on DOE survival curves. Systems older than 18 years should use the ROB baseline. See the January 2015 memo, “Considerations for early replacement of residential equipment,” for further detail.

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data is recommended to be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Decision/action type: ER, ROB, NC, system type conversion
- Building type (except for upstream/midstream programs)
- Climate zone or county
- Baseline number of units
- Baseline equipment type
- Baseline rated cooling and heating capacities
- **For ER only:** Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- **For ER only:** Photograph of retired unit nameplate demonstrating model number, serial number, and manufacturer if blueprints are not provided; if photograph of nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator's discretion)
- Installed number of units
- Installed equipment type
- Installed equipment rated cooling and heating capacities
- Installed cooling and heating efficiency ratings
- Installed manufacturer and model
- Installed unit AHRI/DOE CCMS certificate or reference number
 - For exempted HPs < 5.4 tons referencing the previous federal standard, a copy of the AHRI certificate or manufacturer specification sheet with date corresponding to time of application or purchase demonstrating that unit does not have a SEER2 efficiency rating is required.
- **For retrofit only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging or installed unit(s); OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging or installed unit(s); as-built design drawings; HVAC specifications package that provides detailed make and model information on installed unit(s); OR an evaluator pre-approved inspection approach
- **For Other building types only:** A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 36779—Provides EUL for HVAC equipment.
- PUCT Docket 40083—Provides incorporation of ER savings for existing commercial HVAC SOP designs and updates for baseline equipment efficiency levels for ROB and new construction projects involving package and split systems.
- PUCT Docket 40885—Provides a petition to revise deemed savings values for commercial HVAC replacement measures. Items covered by this petition include the following:
 - Updated baseline efficiencies use for estimating deemed savings for commercial PTAC/PTHP’s, room air conditioners, and chilled water systems.
 - Approved estimates of RUL of working chilled water systems.
 - Updated demand and energy coefficients for all commercial HVAC systems.
 - Updated EUL of centrifugal chilled water systems installed in ROB or new construction projects.
 - Provide a method for utilizing the ER concept developed in the petition in Docket No. 40083 for packaged and split DX systems and applied to chilled water systems when the age of the system being replaced cannot be ascertained.
- PUCT Docket 41070—Provides energy and demand savings coefficients for an additional climate zone, El Paso, Texas. Prior to this filing, savings for the Dallas-Fort Worth area were used for El Paso, but Dallas-Fort Worth has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.
- PUCT Docket 43681—Updated the approach for calculating early replacement energy and demand savings using a Net Present Value (NPV) method. Documented in Appendix A

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 43. DX HVAC—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Modified ER savings calculations and added references to Appendix A, which details those calculations. Added heat pump minimum required heating efficiencies for reference. Revised baseline efficiency standards based on updates to federal standards.

TRM version	Date	Description of change
v2.1	01/30/2015	TRM v2.1 update. Minor text updates and clarification of ER requirements.
v3.0	04/10/2015	TRM v3.0 update. Update of savings method to allow for part-load efficiency calculations. For heat pumps: Added heating efficiencies and split EFLH into cooling and heating components.
v3.1	11/05/2015	TRM v3.1 update. Update the building type definitions and descriptions. Added "Other" building type for when building type is not explicitly listed.
v4.0	10/10/2016	TRM v4.0 update. Used modeling approach to update DF and EFLH for applicable building types and climate zones. Updated baseline efficiency values for split and packaged units less than 5.4 tons to be consistent with updated federal standards.
v5.0	10/2017	TRM v5.0 update. Updated baseline efficiency values for IECC 2015 and added 24-hour building load shapes. Updated RUL table based on DOE survival curves. Updated baseline efficiency tables to include "Electric Resistance (or None)" heating section type EER/IEER values. Modified baseline cooling efficiency tables for heat pumps to assume Electric Resistance supplemental; corrected an error on the 11.3 to 20 tons category for the EER to IEER conversion.
v6.0	10/2018	TRM v6.0 update. Revised ER criteria for systems with an overall capacity change. Added Data Center as a new building type. Created methodology for heat pump projects without explicitly building type modeling.
v7.0	10/2019	TRM v7.0 update. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Clarified use of post capacity for ROB baselines. Verify M&V plan requirement for VRF and documentation requirements. Added unknown age defaults for ER.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits. Removed baseline efficiency splits between heating section types for air conditioners and defaulted to "All Other" efficiencies. Clarified approach for system types conversion to split/package AC systems. Updated EUL methodology. Incorporated building type weighted savings coefficients for upstream/midstream. Incremented RUL table for code compliance.
v10.0	10/2022	TRM v10.0 update. Added additional guidance for selection of building types for complex projects. Incremented RUL table for code compliance.
v11.0	10/2023	TRM v11.0 update. Removed < 5.4 ton HP sell-through exception. Updated ER baselines for compliance with updated federal standard. Updated NC/ROB 5.4+ ton baselines to incorporate current federal standard. Clarified pre- and post-capacity limits. Aligned building type names across all commercial measures. Incremented RUL table for code compliance.

TRM version	Date	Description of change
v12.0	10/2024	<u>TRM v12.0 update. Updated midstream building type weighting assumptions, defined grade levels for primary and secondary schools, updated early retirement age eligibility and criteria related to downsizing, and noted new federal standard and compliance date.</u>

2.2.3 HVAC Chillers Measure Overview

TRM Measure ID: NR-HV-CH

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See Table 57 through Table 61.

Fuels Affected: Electricity

Decision/Action Type: Replace-on-burnout, early retirement, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

This document presents the deemed savings methodology for the installation of chillers. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) based on the age of the replaced equipment and replace-on-burnout (ROB) and new construction (NC) situations based on efficiency standards.

Savings calculations incorporate the use of both full-load and part-load efficiency values. For ER, the actual age of the baseline system should be determined from the equipment nameplate or other physical documentation, whenever possible. Default values are provided for when the actual age of the unit is unknown. Minimum efficiencies are defined in units of kW/ton, the ratio of input power in kW to the cooling capacity in tons, or EER, the ratio of cooling capacity in Btu/h to input power in Watts.

Two paths are currently available for chiller compliance through the IECC and ASHRAE rating standards. Path A requires higher efficiency ratings for full-load operation, with lower ratings for part-load efficiency, and is most applicable to units that are expected to operate at or near full-load conditions. Path B requires higher efficiency ratings for part-load operation, with lower ratings for full-load efficiency, and is most applicable to units that are expected to operate primarily at part-load conditions with variable frequency drives. Either Path can be used for compliance on any particular chiller, but the chiller must meet the minimum requirements for both full and part-load efficiency that are set forth in the following sections.

Applicable efficient measure types include:¹³⁶

- Compressor types: centrifugal or positive-displacement (screw, scroll, or reciprocating)
- Condenser/heat rejection type: air-cooled or water-cooled system type conversions. Retrofits involving a change from a chiller-based system to a packaged/split system are also covered under this measure. If this type of retrofit is performed, reference the tables from the split/single packaged air conditioners and heat pumps measure.
- Chiller type conversions: from an air-cooled chiller system to a water-cooled chiller system is also addressed in this measure. An additional adjustment is made to the basic chiller savings to account for the auxiliary equipment associated with a water-cooled chiller.

Eligibility Criteria

For a measure to be eligible for this deemed savings approach, the following conditions must be met:

- The existing and proposed cooling equipment is electric.
- The building falls into one of the categories listed in Table 57 through Table 61. Building type descriptions and examples are provided in Table 34 and Table 35.
- For early retirement projects: ER projects involve the replacement of a working system before natural burnout. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. A ROB approach should be used for these scenarios.
- For redundant chiller configurations, the installed chiller must not be exclusively sequenced as a standby chiller. As an example, for N+1 configurations where the redundant chiller is rotated, the deemed savings approach should only be used for N chillers, where N is the total number of chillers in the redundant chiller configuration minus one. Multiple chillers sequenced in a lead-lag or base-trim configuration are eligible to use the deemed savings.

If one of these conditions is not met, the deemed savings approach cannot be used, and the Simplified M&V Methodology or the Full M&V Methodology must be used.

Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.^{137, 138}

¹³⁶ Savings can also be claimed by a retrofit involving a change in equipment type (e.g., air-cooled packaged DX system to a water-cooled centrifugal chiller, or a split system air-cooled heat pump to an air-cooled non-centrifugal chiller). If this type of retrofit is performed, reference the tables from the following HVAC measure templates: HVAC-Chillers, Split System/Single Packaged Heat Pumps, and Air Conditioners

¹³⁷ Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: <https://www.ahridirectory.org/>.

¹³⁸ Department of Energy Compliance Certification Management System (DOE CCMS): <https://www.regulations.doe.gov/certification-data/>.

Baseline Condition

Early Retirement

Early retirement systems involve the replacement of a working system prior to natural burnout. The early retirement baseline cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred.

Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is the same as for a ROB/NC scenario. For the ER period, the baseline efficiency should be estimated using the values from Table 44 through Table 55 according to the capacity, chiller type, and age (based on year manufactured) of the replaced system.¹³⁹ When the chiller age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 44 through Table 55 should be used. When the system age is unknown, assume a default value equal to the EUL. This corresponds to 20 years for non-centrifugal chillers and 25 years for centrifugal chillers. A default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

ER baseline efficiency values represent the code-specified efficiency in effect at the time the chiller was installed. Prior to 2002, code-specified efficiencies from ASHRAE 90.1-1989 were in effect. Code-specified efficiencies increased in 2002, approximating the effective date of ASHRAE 90.1-1999, which went into effect on October 29, 2001. Code-specified efficiencies increased again in 2010 and 2018,¹⁴⁰ coinciding with the IECC 2009 and IECC 2015 code increases.

PUCT Docket 40885 provided baseline efficiencies for chillers replaced via early retirement programs and included a category for 1990-2001. However, the common practice for energy efficiency programs in Texas is to allow systems older than 1990 to use the same baseline efficiencies as those listed for 1990-2001. This practice is reflected in the baseline efficiency tables, by showing the Year Installed as ≤ 2001 rather than 1990-2001.

¹³⁹ The actual age should be determined from the nameplate, building prints, equipment inventory list, etc. and whenever possible the actual source used should be identified in the project documentation.

¹⁴⁰ IECC 2015 not enforced in Texas until program year 2018.

ER Baseline: Air-Cooled Chillers

Table 44. Chillers—Air-Cooled Path A ER Baseline Full-Load Efficiency¹⁴¹

Year installed (replaced system)	< 75 tons (EER)	≥ 75 to 150 tons (EER)	≥ 150 to 300 tons (EER)	≥ 300 to 600 tons (EER)	≥ 600 tons (EER)
≤ 2001	<i>9.212</i>	<i>9.212</i>	<i>8.530</i>	<i>8.530</i>	<i>8.530</i>
2002–2009	9.562	9.562	9.562	9.562	9.562
2010–2017	9.562	9.562	9.562	9.562	9.562
≥ 2018	10.100	10.100	10.100	10.100	10.100

Table 45. Chillers—Air-Cooled Path B ER Baseline Full-Load Efficiency¹⁴²

Year installed (replaced system)	< 75 tons (EER)	≥ 75 to 150 tons (EER)	≥ 150 to 300 tons (EER)	≥ 300 to 600 tons (EER)	≥ 600 tons (EER)
≤ 2001	<i>9.212</i>	<i>9.212</i>	<i>8.530</i>	<i>8.530</i>	<i>8.530</i>
2002–2009	9.562	9.562	9.562	9.562	9.562
2010–2017	9.562	9.562	9.562	9.562	9.562
≥ 2018	9.700	9.700	9.700	9.700	9.700

Table 46. Chillers—Air-Cooled Path A ER Baseline Part-Load Efficiency (IPLV)¹⁴³

Year installed (replaced system)	< 75 tons (EER)	≥ 75 to 150 tons (EER)	≥ 150 to 300 tons (EER)	≥ 300 to 600 tons (EER)	≥ 600 tons (EER)
≤ 2001	<i>9.554</i>	<i>9.554</i>	<i>8.530</i>	<i>8.530</i>	<i>8.530</i>
2002–2009	10.416	10.416	10.416	10.416	10.416
2010–2017	12.500	12.500	12.500	12.500	12.500
≥ 2018	13.700	13.700	14.000	14.000	14.000

¹⁴¹ Code-specified efficiencies in effect prior to 2002 were given in COP and have been converted to EER using $EER = COP \times 3.412$. Values in the “≤ 2001” row have been converted and are expressed in italics.

¹⁴² Ibid.

¹⁴³ Ibid.

Table 47. Chillers—Air-Cooled Path B ER Baseline Part-Load Efficiency (IPLV)¹⁴⁴

Year installed (replaced system)	< 75 tons (EER)	≥ 75 to 150 tons (EER)	≥ 150 to 300 tons (EER)	≥ 300 to 600 tons (EER)	≥ 600 tons (EER)
≤ 2001	9.554	9.554	8.530	8.530	8.530
2002–2009	10.416	10.416	10.416	10.416	10.416
2010–2017	12.500	12.500	12.500	12.500	12.500
≥ 2018	15.800	15.800	16.100	16.100	16.100

ER Baseline: Centrifugal Water-Cooled Chillers

Table 48. Chillers—Water-Cooled Centrifugal Path A ER Baseline Full-Load Efficiency¹⁴⁵

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to 150 tons (kW/ton)	≥ 150 to 300 tons (kW/ton)	≥ 300 to 400 tons (kW/ton)	≥ 400 to 600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.925	0.925	0.837	0.748	0.748	0.748
2002–2009	0.703	0.703	0.634	0.576	0.576	0.576
2010–2017	0.634	0.634	0.634	0.576	0.576	0.570
≥ 2018	0.610	0.610	0.610	0.560	0.560	0.560

Table 49. Chillers—Water-Cooled Centrifugal Path B ER Baseline Full-Load Efficiency¹⁴⁶

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to 150 tons (kW/ton)	≥ 150 to 300 tons (kW/ton)	≥ 300 to 400 tons (kW/ton)	≥ 400 to 600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.925	0.925	0.837	0.748	0.748	0.748
2002–2009	0.703	0.703	0.634	0.576	0.576	0.576
2010–2017	0.639	0.639	0.639	0.600	0.600	0.590
≥ 2018	0.695	0.695	0.635	0.595	0.585	0.585

¹⁴⁴ Ibid.

¹⁴⁵ Ibid.

¹⁴⁶ Ibid.

Table 50. Chillers—Water-Cooled Centrifugal Path A ER Baseline Part-Load Efficiency (IPLV)¹⁴⁷

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to 150 tons (kW/ton)	≥ 150 to 300 tons (kW/ton)	≥ 300 to 400 tons (kW/ton)	≥ 400 to 600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.902	0.902	0.781	0.733	0.733	0.733
2002–2009	0.670	0.670	0.596	0.549	0.549	0.549
2010–2017	0.596	0.596	0.596	0.549	0.549	0.539
≥ 2018	0.550	0.550	0.550	0.520	0.500	0.500

Table 51. Chillers—Water-Cooled Centrifugal Path B ER Baseline Part-Load Efficiency (IPLV)¹⁴⁸

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to 150 tons (kW/ton)	≥ 150 to 300 tons (kW/ton)	≥ 300 to 400 tons (kW/ton)	≥ 400 to 600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.902	0.902	0.781	0.733	0.733	0.733
2002–2009	0.670	0.670	0.596	0.549	0.549	0.549
2010–2017	0.450	0.450	0.450	0.400	0.400	0.400
≥ 2018	0.440	0.440	0.400	0.390	0.380	0.380

ER Baseline: Positive-Displacement (Screw, Scroll, or Reciprocating) Water-Cooled Chillers

Table 52. Chillers—Water-Cooled Screw/Scroll/Recip. Path A ER Baseline Full-Load Efficiency¹⁴⁹

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to <150 tons (kW/ton)	≥ 150 to <300 tons (kW/ton)	≥ 300 to <600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.925	0.925	0.837	0.748	0.748
2002–2009	0.790	0.790	0.718	0.639	0.639
2010–2017	0.780	0.775	0.680	0.620	0.620
≥ 2018	0.750	0.720	0.660	0.610	0.560

¹⁴⁷ Ibid.

¹⁴⁸ Ibid.

¹⁴⁹ Ibid.

Table 53. Chillers—Water-Cooled Screw/Scroll/Recip. Path B ER Baseline Full-Load Efficiency¹⁵⁰

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to <150 tons (kW/ton)	≥ 150 to <300 tons (kW/ton)	≥ 300 to <600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.925	0.925	0.837	0.748	0.748
2002–2009	0.790	0.790	0.718	0.639	0.639
2010–2017	0.800	0.790	0.718	0.639	0.639
≥ 2018	0.780	0.750	0.680	0.625	0.585

Table 54. Chillers—Water-Cooled Screw/Scroll/Recip. Path A ER Baseline Part-Load Efficiency (IPLV)¹⁵¹

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to <150 tons (kW/ton)	≥ 150 to <300 tons (kW/ton)	≥ 300 to <600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.902	0.902	0.781	0.733	0.733
2002–2009	0.676	0.676	0.628	0.572	0.572
2010–2017	0.630	0.615	0.580	0.540	0.540
≥ 2018	0.600	0.560	0.540	0.520	0.500

Table 55. Chillers—Water-Cooled Screw/Scroll/Recip. Path B ER Baseline Part-Load Efficiency (IPLV)¹⁵²

Year installed (replaced system)	< 75 tons (kW/ton)	≥ 75 to <150 tons (kW/ton)	≥ 150 to <300 tons (kW/ton)	≥ 300 to <600 tons (kW/ton)	≥ 600 tons (kW/ton)
≤ 2001	0.902	0.902	0.781	0.733	0.733
2002–2009	0.676	0.676	0.628	0.572	0.572
2010–2017	0.600	0.586	0.540	0.490	0.490
≥ 2018	0.500	0.490	0.440	0.410	0.380

Replace-on-Burnout and New Construction

New baseline efficiency levels for chillers are provided in Table 56, which includes both full load and integrated part load value (IPLV) ratings. The IPLV accounts for chiller efficiency at part-load operation for a given duty cycle. These baseline efficiency levels reference standard ASHRAE 90.1-2010. This standard contains two paths for compliance, Path A or Path B. According to ASHRAE 90.1-2007 Addenda M, Path A is intended for applications where significant operating time is expected at full-load conditions, while Path B is an alternative set of efficiency levels for chillers intended for applications where significant time is spent at part-load operation (such as with a VSD chiller). Path A chillers are eligible to claim savings using the full-

¹⁵⁰ Ibid.

¹⁵¹ Ibid.

¹⁵² Ibid.

load efficiency conditions in the energy and demand savings algorithms.¹⁵³ Path B chillers are eligible to claim savings using the Path B chiller part-load baseline efficiencies with the demand and energy coefficients defined in this measure.

Table 56. Chillers—NC/ROB Baseline Efficiencies¹⁵⁴

System type (efficiency units)		Efficiency type	Capacity (tons)	Path A		Path B	
				Full-load	IPLV	Full-load	IPLV
Air-cooled chiller		EER	< 150	≥ 10.100	≥ 13.700	≥ 9.700	≥ 15.800
			≥ 150	≥ 10.100	≥ 14.000	≥ 9.700	≥ 16.100
Water-cooled chiller	Screw/ scroll/ recip.	kW/ton	< 75	≤ 0.750	≤ 0.600	≤ 0.780	≤ 0.500
			≥ 75 and < 150	≤ 0.720	≤ 0.560	≤ 0.750	≤ 0.490
			≥ 150 and < 300	≤ 0.660	≤ 0.540	≤ 0.680	≤ 0.440
			≥ 300 and < 600	≤ 0.610	≤ 0.520	≤ 0.625	≤ 0.410
			≥ 600	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380
	Centrifugal		< 150	≤ 0.610	≤ 0.550	≤ 0.695	≤ 0.440
			≥ 150 and < 300	≤ 0.610	≤ 0.550	≤ 0.635	≤ 0.400
			≥ 300 and < 400	≤ 0.560	≤ 0.520	≤ 0.595	≤ 0.390
		≥ 400	≤ 0.560	≤ 0.500	≤ 0.585	≤ 0.380	

High-Efficiency Condition

Chillers must exceed the minimum efficiencies specified in Table 56 for either Path A or Path B. For whichever path is used, the chiller must exceed the minimum baseline efficiency for both full-load and IPLV of that path to qualify. Additional conditions for replace-on-burnout, early retirement, and new construction are as follows:

New Construction and Replace-on-Burnout

This scenario includes chillers used for new construction and retrofit/replacements that are not covered by early retirement, such as units that are replaced after natural failure.

Early Retirement

The high-efficiency retrofits must meet the following criteria:¹⁵⁵

- For early retirement projects only, when downsizing, the pre-installed cooling capacity is limited to a maximum of 120 percent of the new installed equipment's cooling capacity must be within 80 percent to 120 percent of the replaced electric cooling capacity when

¹⁵³ According to ASHRAE 90.1-2007 Addenda M, Path A is intended for applications where significant operating time is expected at full-load conditions, while Path B is an alternative set of efficiency levels for water-cooled chillers intended for applications where significant time is spent at part-load operation (such as with a VSD chiller).

¹⁵⁴ IECC 2015 Table C403.2.3(7).

¹⁵⁵ From PUCT Docket #41070.

downsizing. There is no cap on upsizing because the savings are calculated using the lower pre-capacity.

- For scenarios involving the replacement of a combination of systems by an alternate combination of systems of varying capacities, early retirement savings can still be claimed if the overall pre- and post-capacities for the total combination of systems are compliant with the guidance in the previous bullet within ± 20 percent. In these cases, a custom calculation should be performed to establish the following weighted savings factors to be applied over the early retirement portion of the savings calculation: manufacturer year, EUL, RUL, path A/B full and part-load baseline efficiency, coincidence factor, and EFLH. These factors should be weighted based on contribution to overall capacity.

No additional measures are being installed that directly affect the operation of the cooling equipment (e.g., control sequences, cooling towers, and condensers).

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Path A and B Air and Water-Cooled Chillers

$$\text{Summer Peak Demand Savings [kW]} = (Cap_{C,pre} \times \eta_{baseline} - Cap_{C,post} \times \eta_{installed}) \times DF_S$$

Equation 24

$$\text{Energy Savings [kWh]} = (Cap_{C,pre} \times \eta_{baseline} - Cap_{C,post} \times \eta_{installed}) \times EFLH_C$$

Equation 25

Where:

$Cap_{C,pre}$ = For ER and ROB, rated equipment cooling capacity of the existing equipment at AHRI_{standard} conditions with a maximum of 20 percent larger than the post-capacity; for ROB & NC, rated equipment cooling capacity of the new equipment at AHRI-standard conditions [tons]

$Cap_{C,post}$ = Rated equipment cooling capacity of the newly installed equipment at AHRI-standard conditions with a maximum equal to the baseline pre-capacity [tons]

Note: The capacity in the equations may not always match the capacity of the units.

$\eta_{baseline}$ = Efficiency of existing equipment (ER) or standard equipment (ROB/NC) [kW/ton] – default values, based on system type, are given in Table 44 through Table 56; for efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 26 [kW/ton]

$\eta_{installed}$ = Rated efficiency of the newly installed equipment – must exceed efficiency standards, shown in Table 56; for efficiencies given in EER instead of kW/ton, convert to kW/ton using Equation 26 [kW/ton]

Note: Use full-load efficiency (kW/ton) for kW demand savings calculations and part-load efficiency (IPLV) for kWh energy savings calculations.

$$\frac{kW}{Ton} = \frac{12}{EER}$$

Equation 26

CF_s = Summer peak coincidence factor (see Table 57 through Table 61)
 $EFLH_c$ = Cooling equivalent full-load hours [hours] (see Table 57 through Table 61)

Air- to Water-Cooled Replacement: Adjustments for Auxiliary Equipment¹⁵⁶

The equipment efficiency for an air-cooled chiller includes condenser fans, but the equipment efficiency for a water-cooled chiller does not include the condenser water pump and cooling tower (auxiliary equipment). Therefore, when an air-cooled chiller is replaced with a water-cooled chiller, the savings must be reduced to account for the impact of the water-cooled system’s additional equipment. This type of retrofit is only applicable for ER situations. The following equations are used:

$$kW_{adjust} = (HP_{CW\ pump} + HP_{CT\ fan}) \times \frac{0.746}{0.86} \times 0.80$$

Equation 27

$$kWh_{adjust} = kW \times 8,760$$

Equation 28

Where:

$HP_{CW\ pump}$ = Horsepower of the condenser water pump
 $HP_{CT\ fan}$ = Horsepower of the cooling tower fan
0.746 = Conversion from HP to kW [kW/HP]
0.86 = Assumed equipment efficiency
0.80 = Assumed load factor
8,760 = Annual run-time hours

¹⁵⁶ This extra adjustment is noted in PUCT Docket No. 41070.

The energy and demand of the condenser water pump and cooling tower fans are subtracted from the final savings, to reach the net savings:

$$kW_{savings,net} = kW_{Chiller} - kW_{adjust}$$

Equation 29

$$kWh_{savings,net} = kWh_{Chiller} - kWh_{adjust}$$

Equation 30

Early Retirement Savings

The first-year savings algorithms in the above equations are used for all HVAC projects, across NC, ROB, and ER projects. However, ER projects require weighted savings calculated over both the ER period and the ROB period, accounting for the EUL and the RUL. The final reported savings for ER projects are not actually a “first-year” savings, but an “average annual savings over the lifetime (EUL) of the measure.” These savings calculations are explained in Appendix A. Table 57 through Table 61 present the demand and energy coefficients as well as the Part Load Factor. These HVAC coefficients vary by climate zone, building type, and equipment type. A description of the calculation method can be found in Docket No. 40885, Attachment B.

Deemed Energy and Demand Savings Tables

Deemed peak coincidence factor (CF) and equivalent full-load hour (EFLH) values are presented by building type and climate zone. A description of the building types that are used for HVAC systems is presented in Table 34 and Table 35. These building types are derived from the EIA CBECS study.¹⁵⁷

Deemed peak CF and EFLH values are presented by building type and climate zone for chillers in Table 57 through Table 61. These tables also include an “Other” building type, which can be used for business types that are not explicitly listed. The CF and EFLH values used for Other are the most conservative values from the explicitly listed building types. Alternately, with evaluator pre-approval, a deemed building type specified in Table 57 through Table 61 can be used in lieu of Other if it has a similar building type activity or operating schedule. For example, healthcare outpatient is not listed in the deemed tables, but the “Office” building could be used if its typical operating schedule aligns closely with that of an office building. When the “Other” building type is used, or if a non-listed building type is mapped to another deemed option, a description of the actual building type, the primary business activity, the business operating hours, and the HVAC schedule must be collected for the project site and stored in the utility tracking data system.

¹⁵⁷ The Commercial Building Energy Consumption Survey (CBECS) implemented by the US Energy Information Administration includes a principal building activity categorization scheme that separates the Commercial sector into 29 categories and 51 subcategories based on principal building activity (PBA). For its purposes, the CBECS defines Commercial buildings as those buildings greater than 1,000 square feet that devote more than half of their floorspace to activity that is neither residential, manufacturing, industrial, nor agricultural. The high-level building types adopted for the TRM are adapted from this CBECS categorization, with some building types left out and one additional building type—Large Multifamily—included. <https://www.eia.gov/consumption/commercial/>.

For those combinations of technology, climate zone, and building type where no values are present, a project with that specific combination cannot use the deemed approach. A description of the calculation method can be found in Docket No. 40885, Attachment B.

Table 57. Chillers—CF and EFLH for Climate Zone 1: Amarillo

Building type	Principal building activity	Chiller ¹⁵⁸			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
Data center	Data center	0.56	2,807	0.73	5,100
Education	College/university	0.87	1,115	0.68	1,243
	Primary school	0.44	576	0.53	971
	Secondary school	0.70	802	0.58	1,772
Healthcare	Inpatient	0.70	2,006	0.65	2,711
Large multifamily	Midrise apartment	0.41	421	0.50	1,098
Lodging	Large hotel	0.58	1,283	0.59	1,553
	Nursing home	0.41	428	0.50	1,115
Mercantile	Stand-alone retail	0.52	489	0.54	719
	24-hour retail	0.67	681	0.62	974
Office	Large office	0.70	1,208	0.61	1,506
Public assembly	Public assembly	0.44	774	0.53	1,306
Religious worship	Religious worship	0.52	294	0.54	433
Other	Other	0.41	294	0.50	433

Table 58. Chillers—CF and EFLH for Climate Zone 2: Dallas

Building type	Principal building activity	Chiller ¹⁵⁹			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
Data center	Data center	0.54	2,791	0.77	4,906
Education	College/university	0.89	1,587	0.81	1,761
	Primary school	0.48	726	0.60	1,412
	Secondary school	0.84	1,170	0.54	2,234
Healthcare	Inpatient	0.90	2,784	0.81	3,683
Large multifamily	Midrise apartment	0.68	1,060	0.66	2,053
Lodging	Large hotel	0.80	2,086	0.71	2,627
	Nursing home	0.68	1,077	0.66	2,085
Mercantile	Stand-alone retail	0.79	936	0.72	1,328
	24-hour retail	0.89	1,307	0.79	1,975
Office	Large office	0.92	1,711	0.70	2,062
Public assembly	Public assembly	0.48	976	0.60	1,898

¹⁵⁸ Coefficient values are derived from the petitions filed in Docket 40885 and Docket 30331. Coefficients were updated with Docket 40885, but not all building types (herein “principal building activities,” or PBAs) that were originally available in Docket 30331 were updated in Docket 40885. Coefficient values for those PBAs that were not updated in Docket 40885 remain valid.

¹⁵⁹ Ibid.

Building type	Principal building activity	Chiller ¹⁵⁹			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
Religious worship	Religious worship	0.79	563	0.72	799
Other	Other	0.48	563	0.54	799

Table 59. Chillers—CF and EFLH for Climate Zone 3: Houston

Building type	Principal building activity	Chiller ¹⁶⁰			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
Data center	Data center	0.53	2,824	0.76	5,075
Education	College/university	0.80	1,858	0.84	2,099
	Primary school	0.45	818	0.60	1,627
	Secondary school	0.77	1,306	0.55	2,404
Healthcare	Inpatient	0.85	3,116	0.79	4,171
Large multifamily	Midrise apartment	0.65	1,295	0.66	2,467
Lodging	Large hotel	0.71	2,499	0.73	3,201
	Nursing home	0.65	1,315	0.66	2,506
Mercantile	Stand-alone retail	0.83	1,224	0.78	1,712
	24-hour retail	0.80	1,513	0.74	2,427
Office	Large office	0.92	1,820	0.71	2,312
Public assembly	Public assembly	0.45	1,100	0.60	2,188
Religious worship	Religious worship	0.83	737	0.78	1,031
Other	Other	0.45	737	0.55	1,031

Table 60. Chillers—CF and EFLH for Climate Zone 4: Corpus Christi

Building type	Principal building activity	Chiller ¹⁶¹			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
Data center	Data center	0.48	2,881	0.77	5,266
Education	College/university	0.80	2,340	0.87	2,583
	Primary school	0.45	937	0.61	1,845
	Secondary school	0.68	1,503	0.55	2,577
Healthcare	Inpatient	0.79	3,455	0.82	4,637
Large multifamily	Midrise apartment	0.61	1,534	0.67	2,840
Lodging	Large hotel	0.74	2,908	0.73	3,713
	Nursing home	0.61	1,558	0.67	2,884
Mercantile	Stand-alone retail	0.75	1,394	0.76	1,953
	24-hour retail	0.70	1,725	0.73	2,768
Office	Large office	0.82	2,027	0.72	2,570
Public assembly	Public assembly	0.45	1,260	0.61	2,481

¹⁶⁰ Ibid.

¹⁶¹ Ibid.

Building type	Principal building activity	Chiller ¹⁶¹			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
Religious worship	Religious worship	0.75	839	0.76	1,176
Other	Other	0.45	839	0.55	1,176

Table 61. Chillers—CF and EFLH for Climate Zone 5: El Paso

Building type	Principal building activity	Chiller ¹⁶²			
		Air-cooled		Water-cooled	
		CF	EFLH _c	CF	EFLH _c
Data center	Data center	0.56	2,950	0.71	5,137
Education	College/university	0.93	1,278	0.96	1,458
	Primary school	0.61	751	0.53	1,113
	Secondary school	0.77	1,039	0.54	2,196
Healthcare	Inpatient	0.71	2,355	0.59	2,992
Large multifamily	Midrise apartment	0.56	841	0.52	1,553
Lodging	Large hotel	0.63	1,815	0.58	2,038
	Nursing home	0.56	854	0.52	1,577
Mercantile	Stand-alone retail	0.64	722	0.55	948
	24-hour retail	0.61	884	0.60	1,371
Office	Large office	0.77	1,442	0.60	1,683
Public assembly	Public assembly	0.61	1,010	0.53	1,496
Religious worship	Religious worship	0.64	435	0.55	571
Other	Other	0.56	435	0.52	571

Claimed Peak Demand Savings

A summer peak-period value is used for this measure. Refer to Volume 1, Section 4 for further details on peak demand savings and methodology.

Upstream/Midstream ~~Lighting~~

For upstream/midstream program delivery, use the EFLH and CF assumptions outlined in Table 59 and Table 60. Assumed values have been weighted based on building type survey data from 2012 CBECS¹⁶³ and 2014 MECS¹⁶⁴.

For upstream/midstream program designs where building type is known, use the savings coefficients from Table 57 through Table 61. For program designs where building type is unknown, you may use the savings coefficients from Table 62 and Table 63. However, calculations of savings in program implementation should not switch between savings coefficient methods over the implementation period.

¹⁶² Ibid.

¹⁶³ 2012 Commercial Building Energy Consumption Survey (CBECS).

<https://www.eia.gov/consumption/commercial/>. 2018 version not available until mid-2020.

¹⁶⁴ 2014 Manufacturing Energy Consumption Survey (MECS).

<https://www.eia.gov/consumption/manufacturing/>.

Table 62. Chillers—Air-Cooled Upstream/Midstream Input Assumptions¹⁶⁵

Savings coefficient	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
EFLH _c	<u>982967</u>	<u>1,440</u> <u>1,408</u>	<u>1,605</u> <u>1,575</u>	<u>1,820</u> <u>1,789</u>	<u>1,234</u> <u>1,211</u>
CF _s	<u>0.630-62</u>	<u>0.820-80</u>	<u>0.790-78</u>	0.72	0.71

Table 63. Chillers—Water-Cooled Upstream/Midstream Input Assumptions¹⁶⁶

Savings coefficient	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
EFLH _c	<u>1,405</u> <u>1,349</u>	<u>2,013</u> <u>1,941</u>	<u>2,303</u> <u>2,232</u>	<u>2,578</u> <u>2,511</u>	<u>1,661</u> <u>1,578</u>
CF _s	<u>0.590-58</u>	<u>0.670-68</u>	<u>0.690-70</u>	<u>0.690-70</u>	<u>0.580-59</u>

Measure Life and Lifetime Savings

Estimated Useful Life (EUL)

The EUL of HVAC equipment is provided below:

- Screw/scroll/reciprocating chillers: 20 years¹⁶⁷
- Centrifugal chillers: 25 years.¹⁶⁸

Remaining Useful Life (RUL)

The RUL of replaced systems is provided according to system age in Table 64. For ER units of unknown age, a default value of 20 years for non-centrifugal chillers and 25 years for centrifugal chillers should be used (equal to the EUL). This corresponds to a default RUL of 3.6 years for non-centrifugal chillers and 5.4 years for centrifugal chillers. Default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Both the RUL and EUL are needed to estimate savings for early retirement projects for two distinct periods: The ER period (RUL) and the ROB period (EUL-RUL). The calculations for early retirement projects are extensive, and as such, are provided in Appendix A

¹⁶⁵ 2012 CBECS and 2014 MECS.

¹⁶⁶ Ibid.

¹⁶⁷ PUCT Docket No. 36779. The original source was DEER 2008, but DEER 2014 provides the same value of 20 years for “High Efficiency Chillers”. DEER does not differentiate between centrifugal and non-centrifugal chillers.

¹⁶⁸ PUCT Docket No. 40885, review of multiple studies looking at the lifetime of centrifugal chillers as detailed in petition workpapers.

Table 64. Chillers—RUL of Early Retirement Systems^{169,170}

Age of replaced system (years)	Non-centrifugal chillers RUL (years)	Centrifugal chillers RUL (years)	Age of replaced system (years)	Non-centrifugal chillers RUL (years)	Centrifugal chillers RUL (years)
1	18.7	23.9	17	5.0	8.7
2	17.7	22.9	18	4.5	8.1
3	16.7	21.9	19	4.0	7.5
4	15.7	20.9	20	3.6	7.1
5	14.7	19.9	21	3.0	6.6
6	13.7	18.9	22	2.0	6.3
7	12.7	17.9	23	1.0	5.9
8	11.8	16.9	24 ¹⁷¹	0.0	5.6
9	10.9	15.9	25	–	5.4
10	10.0	14.9	26	–	5.0
11	9.1	13.9	27	–	4.0
12	8.3	12.9	28	–	3.0
13	7.5	11.9	29	–	2.0
14	6.8	10.9	30	–	1.0
15	6.2	10.1	31 ¹⁷²	–	0.0
16	5.5	9.3			

¹⁶⁹ PUCT Docket No. 40885, Attachment A describes the process in which the RUL of replaced systems has been calculated.

¹⁷⁰ Current New Construction baseline matches the baseline for existing systems manufactured in 2018. Existing systems manufactured after 1/1/2018 are not eligible to use the early retirement baseline and should use the ROB baseline instead. These values are greyed out in the table and displayed for informational purposes only.

¹⁷¹ RULs are capped at the 75th percentile of non-centrifugal equipment age, 24 years, as determined based on DOE survival curves. Non-centrifugal systems older than 24 years should use the ROB baseline. See the January 2015 memo, “Considerations for early replacement of residential equipment,” for further detail.

¹⁷² Ibid.

Program Tracking Data and Evaluation Requirements

The below list of primary inputs and contextual data is recommended to be specified and tracked by the program database to inform the evaluation and apply the savings properly.

- Decision/action type: ER, ROB, NC, system type conversion
- Building type (except for upstream/midstream programs)
- Climate zone or county
- Baseline number of units
- Baseline equipment type (compressor/condenser type)
- Baseline equipment rated cooling capacity
- **For ER only:** Baseline age of system and method of determination (e.g., nameplate, blueprints, customer reported, not available)
- **For ER only:** Photograph of retired unit nameplate demonstrating model number, serial number, and manufacturer if blueprints are not provided; if photograph of nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator's discretion)
- Installed number of units
- Installed equipment type (compressor/condenser type)
- Installed path (Path A or Path B)
- Is the installed chiller a standby unit in a redundant chiller configuration? (yes, no)
- Installed rated cooling capacity
- Installed cooling efficiency rating
- Installed manufacturer and model
- Installed unit AHRI/DOE CCMS certificate or reference number
- **For retrofit only:** Proof of purchase: invoice showing model number; photos of the model number on product packaging or installed unit(s); OR an evaluator pre-approved inspection approach
- **For new construction only:** Proof of purchase: invoice showing model number; a photo of the model number on product packaging or installed unit(s); as-built design drawings; HVAC specifications package that provides detailed make and model information on installed unit(s); OR an evaluator pre-approved inspection approach
- **For chiller type conversion only:** Condenser water pump HP and cooling tower fan HP
- **For other building type only:** A description of the actual building type, the primary business activity, the business hours, and the HVAC schedule.

References and Efficiency Standards

Petitions and Rulings

- PUCT Docket 30331—Established rules for energy efficiency programs, including factors for principal building activities (PBAs). Most PBA values were superseded by Docket 40885; however, some values from this docket remain valid.
- PUCT Docket 36779—Provides EUL for HVAC equipment.
- PUCT Docket 40083—Provides incorporation of early retirement savings for existing commercial HVAC SOP designs and updates for baseline equipment efficiency levels for ROB and new construction projects involving package and split systems.
- PUCT Docket 40885—Provides a petition to revise deemed savings values for commercial HVAC replacement measures. Items covered by this petition include the following:
 - Updated baseline efficiencies use for estimating deemed savings for commercial PTAC/PTHP's, room air conditioners, and chilled water systems.
 - Approved estimates of RUL of working chilled water systems.
 - Updated demand and energy coefficients for all commercial HVAC systems.
 - Updated EUL of centrifugal chilled water systems installed in ROB or new construction projects.
 - Provide a method for utilizing the early retirement concept developed in the petition in Docket No. 40083 for packaged and split DX systems and applied to chilled water systems when the age of the system being replaced cannot be ascertained.
- PUCT Docket 41070—Provides energy and demand savings coefficients for an additional climate zone, El Paso, Texas. Previously these savings were taken from the Dallas-Fort Worth area, which has a colder winter, somewhat more moderate summer, more sunshine, and less precipitation than El Paso.
- PUCT Docket 43681—Updated the approach for calculating early replacement energy and demand savings using a Net Present Value (NPV) method. Documented in Appendix A.

Relevant Standards and Reference Sources

Please refer to measure citations for relevant standards and reference sources.

Document Revision History

Table 65. Chillers—Revision History

TRM version	Date	Description of change
v1.0	11/25/2013	TRM v1.0 origin.
v2.0	04/18/2014	TRM v2.0 update. Modified savings calculations surrounding early retirement programs, and revised details surrounding RUL and Measure Life. Added references to Appendix A for EUL and RUL discussion, and Net Present Value (NPV) equations.
v2.1	01/30/2015	TRM v2.1 update. Minor text updates and clarification of early retirement requirements.
v3.0	04/10/2015	TRM v3.0 update. Update of savings method to allow for part-load efficiency calculations.
v3.1	11/05/2015	TRM v3.1 update. Updated table references to clarify building types and RUL references. Added “Other” building type for when building type is not explicitly listed. Added Religious Worship building type to Climate Zone 5 for consistency with other zones.
v4.0	10/10/2016	TRM v4.0 update. Used modeling approach to update DF and EFLH for applicable building types and climate zones.
v5.0	10/2017	TRM v5.0 update. Included Path A and Path B compliance options for chillers. Added 24-hour Retail load shape. Updated RUL table based on DOE survival curves.
v6.0	10/2018	TRM v6.0 update. Revised Path A and B savings methodology for mid-year guidance memo. Added Data Center as a new building type. Updated early retirement guidance for projects with a total capacity change.
v7.0	10/2019	TRM v7.0 update. Program tracking requirements updated.
v8.0	10/2020	TRM v8.0 update. General reference checks and text edits. Clarified use of post capacity for ROB baselines. Added unknown age defaults for early retirement.
v9.0	10/2021	TRM v9.0 update. General reference checks and text edits. Updated default age of system to match EUL. Incorporated upstream/midstream building-type weighting for savings coefficients. Incremented RUL table for code compliance.
v10.0	10/2022	TRM v10.0 update. Added guidance for redundant chiller configurations. Incremented RUL table for code compliance.
v11.0	10/2023	TRM v11.0 update. Aligned building type names across all commercial measures. Incremented RUL table for code compliance.
<u>v12.0</u>	<u>10/2024</u>	<u>TRM v12.0 update. Updated early retirement age eligibility and criteria related to downsizing, updated midstream building type weighting assumptions, and provided guidance for building types.</u>

2.2.4 Packaged Terminal Air Conditioners/Heat Pumps, Single Package Vertical Air Conditioners/Heat Pumps, and Room Air Conditioners Measure Overview

TRM Measure ID: NR-HV-PT

Market Sector: Commercial

Measure Category: HVAC

Applicable Building Types: See ~~Table 70 through Table 74~~ All commercial

Fuels Affected: Electricity

Decision/Action Type: Replace-on-burnout, early retirement, new construction

Program Delivery Type: Prescriptive

Deemed Savings Type: Deemed savings calculation

Savings Methodology: Energy modeling, engineering algorithms, and estimates

Measure Description

This section presents the deemed savings methodology for the installation of packaged terminal air conditioners (PTAC), packaged terminal heat pumps (PTHP), single package vertical air conditioners (SPVAC), single package vertical heat pumps (SPVHP), and room AC (RAC) systems. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) of PTAC/PTHPs, replace-on-burnout (ROB), and new construction (NC) situations based current and previous on efficiency standards. For ER, the actual age of the baseline system should be determined from the equipment nameplate or other physical documentation whenever possible. Default values are provided for when the actual age of the unit is unknown.

Applicable efficient measure types include:

Packaged Terminal Air Conditioners and Heat Pumps. Both standard and non-standard size equipment types are covered. Standard size refers to equipment with wall sleeve dimensions having an external wall opening greater than or equal to 16 inches high or greater than or equal to 42 inches wide and a cross-sectional area greater than 670 in². Non-standard size refers to equipment with existing wall sleeve dimensions having an external wall opening of less than 16 inches high or less than 42 inches wide and a cross-sectional area less than 670 in².

Single Package Vertical Air Conditioners and Heat Pumps. All cooling capacities less than 240,000 Btu/hr are covered.

Room Air Conditioners include all equipment configurations covered by the federal appliance standards, including with or without a reverse cycle, louvered or non-louvered sides, casement-only, and casement-slide.

Eligibility Criteria

For a measure to be eligible for this deemed savings approach, the following conditions will be met:

- The existing and proposed cooling equipment is electric.
- The PTAC, PTHP, SPVAC, SPVHP, or RAC must be the primary cooling source for the space.
- For early retirement PTAC/PTHP projects: ER projects involve the replacement of a working system before natural burnout. Additionally, the ER approach cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. An ROB approach should be used for these scenarios.

If one of these conditions is not met, the deemed savings approach cannot be used, and the Simplified M&V Methodology or the Full M&V Methodology must be used.

Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.^{173,174}

Baseline Condition

Early Retirement for PTAC/PTHP Systems

Early retirement systems involve the replacement of a working system prior to natural burnout. The early retirement baseline cannot be used for projects involving a renovation where a major structural change or internal space remodel has occurred. Two baseline condition efficiency values are required for an ER scenario, one for the ER (RUL) period and one for the ROB (EUL-RUL) period. For the ROB period, the baseline efficiency is the same as for a ROB/NC scenario. For the ER period, the baseline efficiency should be estimated according to the capacity, system type (PTAC or PTHP), and age (based on year manufactured) of the replaced system.¹⁷⁵ When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 66, reflecting ASHRAE Standard 90.1-2001 through 90.1-2007, should be used. PTHPs replacing PTACs with built-in electric resistance heat should use a baseline heating efficiency of 1.0 COP.

¹⁷³ Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: <https://www.ahridirectory.org/>.

¹⁷⁴ Department of Energy Compliance Certification Management System (DOE CCMS): <https://www.regulations.doe.gov/certification-data/>.

¹⁷⁵ The actual age should be determined from the nameplate, building prints, equipment inventory list, etc. and whenever possible the actual source used should be identified in the project documentation.

When the system age is unknown, assume a default value equal to the EUL. This corresponds to an age of 15 years.¹⁷⁶ A default RUL may be used exclusively if applied consistently for all projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

Existing standard size PTAC systems manufactured as of January 1, 2017 and standard size PTHP systems manufactured as of October 8, 2012, are not eligible for early retirement. All non-standard size PTAC/PTHPs are not eligible for early retirement.

Table 66. PTAC/PTHPs—ER Baseline Efficiency Levels for Standard Size Units¹⁷⁷

Equipment	Cooling capacity (Btuh)	Baseline cooling efficiency (EER)	Baseline heating efficiency (COP) (No built-in ER heat)	Baseline heating efficiency (COP) (with built-in ER heat)
PTAC	<7,000	11.0	–	1.0
	7,000-15,000	$12.5 - (0.213 \times \text{Cap}/1,000)$		
	>15,000	9.3		
PTHP	<7,000	10.8	3.0	–
	7,000-15,000	$12.3 - (0.213 \times \text{Cap}/1,000)$	$3.2 - (0.026 \times \text{Cap}/1,000)$	
	>15,000	9.1	2.8	

Replace-on-Burnout and New Construction

Table 67 provides federal minimum efficiency standards for PTAC/PTHP units reflected in 10 CFR 431. The effective date for standard size PTACs is January 1, 2017, and the effective date for standard size PTHPs is October 8, 2012. The effective date for all non-standard PTAC/PTHPs is October 7, 2010.

Table 67. PTAC/PTHPs—NC/ROB Baseline Efficiency Levels^{178,179}

Equipment	Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)
PTAC		<7,000	11.9	–

¹⁷⁶ As noted in Docket 40885, page 14-15: Failure probability weights are established by assuming that systems for which age information will be unavailable are likely to be older, setting a minimum age threshold, and using the survival functions for the relevant system type to estimate the likelihood that an operational system is of a given age beyond that threshold. Baseline efficiency for each year of system age is established relative to program year. Baseline efficiency levels can be estimated for the next ten program years, considering increments in efficiency standards that took place in the historical period.

¹⁷⁷ ER only applies to standard size units because the minimum efficiency requirements for non-standard systems have never changed, making the ER baseline efficiency the same as for ROB.

¹⁷⁸ IECC 2015 Table C403.2.3(3).

¹⁷⁹ Cap refers to the rated cooling capacity in Btuh. If the capacity is less than 7,000 Btuh, use 7,000 Btuh in the calculation. If the capacity is greater than 15,000 Btuh, use 15,000 Btuh in the calculation.

Equipment	Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)
	Standard Size	7,000-15,000	14.0 – (0.300 x Cap/1,000)	–
		>15,000	9.5	–
	Non-Standard Size	<7,000	9.4	–
		7,000-15,000	10.9 – (0.213 x Cap/1,000)	–
		>15,000	7.7	–
PTHP	Standard Size	<7,000	11.9	3.3
		7,000-15,000	14.0 – (0.300 x Cap/1,000)	3.7 – (0.052 x Cap/1,000)
		>15,000	9.5	2.9
	Non-Standard Size	<7,000	9.3	2.7
		7,000-15,000	10.8 – (0.213 x Cap/1,000)	2.9 – (0.026 x Cap/1,000)
		>15,000	7.6	2.5

Table 68 provides federal minimum efficiency standards for SPVAC/SPVHP units reflected in 10 CFR 431. The effective date for the Final Rule was November 23, 2015. Compliance with the standards for SPVAC/SPVHPs with cooling capacities less than 65,000 Btu/hr was September 23, 2019; compliance with the standard for SPVAC/SPVHPs with cooling capacities between 65,000 and 135,000 Btu/hr was October 9, 2015; and compliance with the standard for SPVAC/SPVHPs with cooling capacities between 135,000 and 240,000 Btu/hr was October 9, 2016.

Table 68. SPVAC/SPVHPs—NC/ROB Baseline Efficiency Levels¹⁸⁰

Equipment Type	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)	Minimum heating efficiency (COP)
Single package vertical air conditioners	< 65,000	11.0	–
	≥ 65,000 and <240,000	10.0	–
Single package vertical air heat pumps	< 65,000	11.0	3.3
	≥ 65,000 and <240,000	10.0	3.0

Table 69 reflects the standards for room air conditioners, specified in 10 CFR 430.32(b). A new federal standard went into effect on August 30, 2023. However, this standard does not require manufacturer compliance until May 26, 2026.¹⁸¹

¹⁸⁰ Table 11 to 10 CFR 431.97.

¹⁸¹ Current DOE minimum efficiency standard for residential room air conditioners.

<https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0057>.

Table 69. Room ACs—NC/ROB Baseline Efficiency Levels¹⁸²

Category	Cooling capacity (Btuh)	Minimum cooling efficiency (EER)
Without reverse cycle, with louvered sides	< 8,000	11.0
	≥ 8,000 and < 14,000	10.9
	≥ 14,000 and < 20,000	10.7
	≥ 20,000 and < 25,000	9.4
	≥ 25,000	9.0
Without reverse cycle, without louvered sides	< 8,000	10.0
	≥ 8,000 and < 11,000	9.6
	≥ 11,000 and < 14,000	9.5
	≥ 14,000 and < 20,000	9.3
	≥ 20,000	9.4
With reverse cycle, with louvered sides	< 20,000	9.8
	≥ 20,000	9.3
With reverse cycle, without louvered sides	< 14,000	9.3
	≥ 14,000	8.7
Casement-only	All capacities	9.5
Casement-slider	All capacities	10.4

High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 67 ~~and through~~ Table 69.

The high-efficiency retrofits must also meet the following criteria:¹⁸³

- For early retirement projects only, when downsizing, the pre-installed cooling capacity is limited to a maximum of 120 percent of the new equipment's cooling capacity. the newly installed equipment cooling capacity must be within 80 percent to 120 percent of the replaced electric cooling capacity when downsizing. There is no cap on upsizing because the savings are calculated using the lower pre-capacity.
- For scenarios involving the replacement of a combination of systems by an alternate combination of systems of varying capacities, early retirement savings can still be claimed if the overall pre- and post-capacities for the total combination of systems are compliant with the guidance in the previous bullet within ± 20 percent. In these cases, a

¹⁸² Direct final rule for new Room Air Conditioner Standards was published on April 21st, 2011 (76 FR 22454), effective August 19th, 2011, and are required starting June 1st, 2014. These are found in 10 CFR Part 430.

¹⁸³ Modified from PUCT Docket #41070 for TRMv3 to limit replacement of only smaller-sized units and extend Early Retirement to cover PTAC/PTHP.

custom calculation should be performed to establish the following weighted savings factors to be applied over the early retirement portion of the savings calculation: manufacturer year, EUL, RUL, full and part-load baseline, coincidence factor, and EFLH. These factors should be weighted based on contribution to overall capacity.

- Non-standard size PTAC/PTHPs cannot be used for new construction
- No additional measures are being installed that directly affect the operation of the cooling equipment (e.g., control sequences)

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

$$\text{Summer Peak Demand Savings [kW]} = \left(\frac{\text{Cap}_{C,pre}}{\eta_{baseline,C}} - \frac{\text{Cap}_{C,post}}{\eta_{installed,C}} \right) \times DF_S \times \frac{1 \text{ kW}}{1,000 \text{ W}}$$

Equation 31

$$\text{Winter Peak Demand Savings [kW]} = \left(\frac{\text{Cap}_{C,pre}}{\eta_{baseline,C}} - \frac{\text{Cap}_{C,post}}{\eta_{installed,C}} \right) \times DF_W \times \frac{1 \text{ kW}}{3,412 \text{ Btuh}}$$

Equation 32

$$\text{Total Energy Savings [kWh]} = kWh_C + kWh_H$$

Equation 33

$$\text{Cooling Energy Savings [kWh}_C] = \left(\frac{\text{Cap}_{C,pre}}{\eta_{baseline,C}} - \frac{\text{Cap}_{C,post}}{\eta_{installed,C}} \right) \times EFLH_C \times \frac{1 \text{ kW}}{1,000 \text{ W}}$$

Equation 34

$$\text{Heating Energy Savings [kWh}_H] = \left(\frac{\text{Cap}_{H,pre}}{\eta_{baseline,H}} - \frac{\text{Cap}_{H,post}}{\eta_{installed,H}} \right) \times EFLH_H \times \frac{1 \text{ kWh}}{3,412 \text{ Btu}}$$

Equation 35

Where:

$\text{Cap}_{C/H,pre}$ = For ER and ROB, rated equipment cooling/heating capacity of the existing equipment at AHRI-standard conditions with a maximum of 20 percent larger than the post-capacity; for ROB & NC, rated equipment cooling/heating capacity of the new equipment at AHRI-standard conditions [BTUH]; 1 ton = 12,000 Btuh

$\text{Cap}_{C/H,post}$ = Rated equipment cooling/heating capacity of the newly installed equipment at AHRI-standard conditions with a maximum equal to the baseline pre-capacity [Btuh]; 1 ton = 12,000 Btuh

Note: The capacity in the equations may not always match the capacity of the units.

$\eta_{baseline,C}$ = Cooling efficiency of existing (ER) or standard (ROB/NC) equipment [EER, Btu/W-h] (Table 66 through Table 69)

$\eta_{baseline,H}$	=	Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 66 and Table 67) ¹⁸⁴
$\eta_{installed,C}$	=	Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h]—(Must exceed minimum federal standards found in Table 67 and Table 69) ¹⁸⁵
$\eta_{installed,H}$	=	Rated heating efficiency of the newly installed equipment [COP] (Must exceed minimum federal standards found in Table 67)
$CF_{S/W}$	=	Summer/winter seasonal peak coincidence factor (see Table 36 through Table 40)
$EFLH_{C/H}$	=	Cooling/heating equivalent full-load hours [hours] (see Table 70 through Table 74)

The first-year savings algorithms in the above equations are used for all HVAC projects, across NC, ROB, and ER projects. However, ER projects require a weighted savings calculated over both the ER and ROB periods taking the EUL and RUL into account. The ER savings are applied over the remaining useful life (RUL) period, and the ROB savings are applied over the remaining period (EUL-RUL). The final reported savings for ER projects are not actually a “first-year” savings, but an “average annual savings over the lifetime (EUL) of the measure.” These savings calculations are explained in Appendix A.

Deemed Energy and Demand Savings Tables

Table 70 through Table 74 present the deemed peak coincidence factor (CF) and equivalent full-load hour (EFLH) values for PTAC/PTHPs, SPVAC/SPVHPs, and RACs. These values are calculated by climate zone, building type, and equipment type. A description of the calculation method can also be found in Docket No. 40885, Attachment B.

These tables also include an *other* building type, which can be used for business types that are not explicitly listed. The CF and EFLH values used for Other are the most conservative values from the explicitly listed building types. When the Other building type is used, a description of the actual building type, the primary business activity, the business hours, and the HVAC schedule must be collected for the project site and stored in the utility tracking data system. For those combinations of technology, climate zone, and building type where no values are present, a project with that specific combination should use the “Other” building type.

¹⁸⁴ Rated efficiency is commonly reported at both 230V and 208V. Savings calculations should reference efficiency at 230V, as AHRI rating conditions specify that voltage.

¹⁸⁵ Ibid.

Table 70. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF/EFLH Values for Climate Zone 1: Amarillo

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _h
Education	Primary school	0.56	686	0.56	686	0.43	322
	Secondary school	0.61	496	0.61	496	0.43	338
Food sales	Convenience store	0.64	820	0.64	820	0.48	410
Food service	Full-service restaurant	0.73	946	0.73	946	0.43	516
	24-hour full-service restaurant	0.71	1,014	0.71	1,014	0.43	619
	Quick-service restaurant	0.64	710	0.64	710	0.48	473
	24-hour quick-service restaurant	0.65	758	0.65	758	0.48	598
Lodging	Large hotel	0.51	1,248	0.51	1,248	0.86	504
	Nursing home	0.60	635	0.60	635	0.50	256
	Small hotel	0.50	1,442	0.50	1,442	0.36	218
Mercantile	Strip mall	0.66	637	0.66	637	0.39	346
Office	Small office	0.63	660	0.63	660	0.29	156
Other	Other	0.50	496	0.50	496	0.29	156

Table 71. PTAC/PTHPs, SPVAC/SPVHPs, & RACs—CF/EFLH Values for Climate Zone 2: Dallas

Building types	Principal building activity	Packaged terminal unit					
		Air conditioner		Heat pump			
		CF _s	EFLH _c	CF _s	EFLH _c	CF _w	EFLH _h
Education	Primary school	0.85	1,016	0.85	1,016	0.66	231
	Secondary school	0.99	912	0.99	912	0.59	285
Food sales	Convenience store	1.05	1,544	1.05	1,544	0.61	318
Food service	Full-service restaurant	1.06	1,534	1.06	1,534	0.50	401
	24-hour full-service restaurant	1.06	1,734	1.06	1,734	0.49	509
	Quick-service restaurant	1.05	1,336	1.05	1,336	0.61	368
	24-hour quick-service restaurant	1.05	1,485	1.05	1,485	0.60	463
Lodging	Large hotel	0.68	1,749	0.68	1,749	0.82	270
	Nursing home	1.01	1,460	1.01	1,460	0.61	226