# Public Utility Commission of Texas

**Texas Technical Reference Manual**

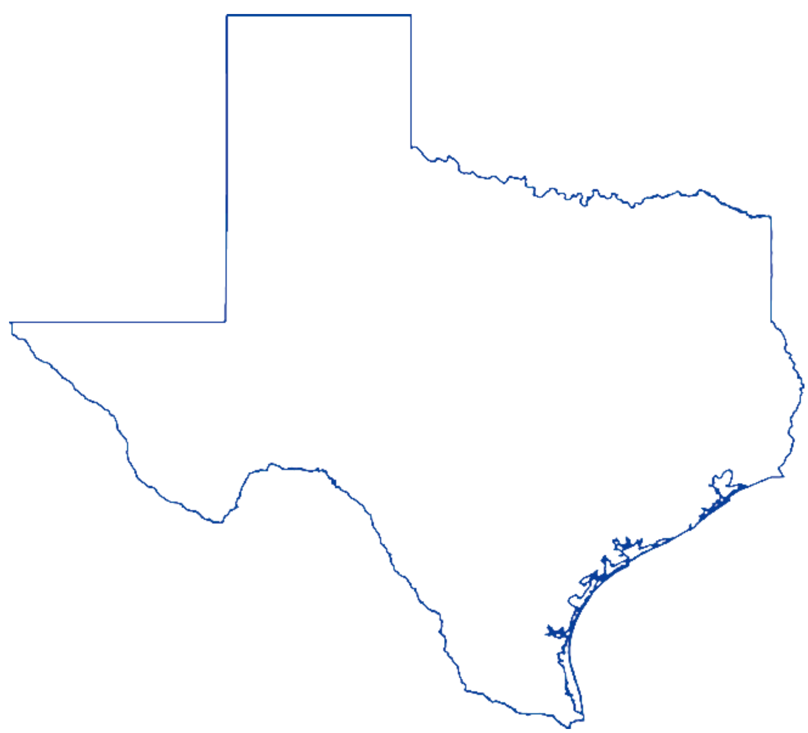
**Version 11.0**

**Volume 2: Residential Measures**

**Program Year 2024**

**Last Revision Date:**

**November 2023**



# Public Utility Commission of Texas

**Texas Technical Reference Manual**

**Version 11.0**

**Volume 2: Residential Measures**

**Program Year 2024**

**Last Revision Date:**

**November 2023**

## Table of Contents


1 Introduction ........ 1

2 Residential Measures ........ 6

2.1 RESIDENTIAL: LIGHTING ........ 6

2.1.1 ENERGY STAR® General Service LED Lamps Measure Overview ........ 6

2.1.2 ENERGY STAR® Specialty LED Lamps Measure Overview ........ 17

2.1.3 LED Nightlights Measure Overview ........ 27

2.2 RESIDENTIAL: HEATING, VENTILATION, AND AIR CONDITIONING ........ 34

2.2.1 Air Conditioner and Heat Pump Tune-Ups Measure Overview ........ 34

2.2.2 Central and Mini-Split Air Conditioners and Heat Pumps Measure Overview ........ 42

2.2.3 ENERGY STAR® Room Air Conditioners Measure Overview ........ 57

2.2.4 Packaged Terminal Heat Pumps Measure Overview ........ 67

2.2.5 ENERGY STAR® Ground Source Heat Pumps Measure Overview ........ 77

2.2.6 Large Capacity Split and Packaged Air Conditioners and Heat Pumps Measure Overview ........ 85

2.2.7 Evaporative Cooling Measure Overview ........ 92

2.2.8 ENERGY STAR® Connected Thermostats Measure Overview ........ 96

2.2.9 Smart Thermostat Load Management Measure Overview ........ 105

2.2.10 Duct Sealing Measure Overview ........ 110

2.3 RESIDENTIAL: BUILDING ENVELOPE ........ 128

2.3.1 Air Infiltration Measure Overview ........ 128

2.3.2 Ceiling Insulation Measure Overview ........ 138

2.3.3 Attic Encapsulation Measure Overview ........ 152

2.3.4 Wall Insulation Measure Overview ........ 169

2.3.5 Floor Insulation Measure Overview ........ 182

2.3.6 Duct Insulation Measure Overview ........ 190

2.3.7 Radiant Barriers Measure Overview ........ 196

2.3.8 Cool Roofs Measure Overview ........ 203

2.3.9 Solar Screens Measure Overview ........ 233

2.3.10 ENERGY STAR® Windows Measure Overview ........ 239

2.3.11 ENERGY STAR® Low-E Storm Windows Measure Overview ........ 247

2.4 RESIDENTIAL: WATER HEATING ........ 255

2.4.1 Water Heater Installations—Electric Tankless and Fuel Substitution Measure Overview ........ 255

2.4.2 ENERGY STAR® Heat Pump Water Heaters Measure Overview ........ 264

2.4.3 ENERGY STAR® Solar Water Heaters Measure Overview ........ 271

2.4.4 Water Heater Tank Insulation Measure Overview ........ 278

2.4.5 Water Heater Pipe Insulation Measure Overview ........ 285

2.4.6 Faucet Aerators Measure Overview ........ 290

2.4.7 Low-Flow Showerheads Measure Overview ........ 296

2.4.8 Showerhead Temperature Sensitive Restrictor Valves Measure Overview ......302
2.4.9 Tub Spout and Showerhead Temperature Sensitive Restrictor Valves Measure Overview ......309
2.4.10 Water Heater Temperature Setback Measure Overview ......317
**2.5 RESIDENTIAL: APPLIANCES** ......321
2.5.1 ENERGY STAR® Ceiling Fans Measure Overview ......321
2.5.2 ENERGY STAR® Clothes Washers Measure Overview ......329
2.5.3 ENERGY STAR® Clothes Dryers Measure Overview ......338
2.5.4 ENERGY STAR® Dishwashers Measure Overview ......344
2.5.5 ENERGY STAR® Refrigerators Measure Overview ......350
2.5.6 ENERGY STAR® Freezers Measure Overview ......364
2.5.7 Refrigerator/Freezer Recycling Measure Overview ......376
2.5.8 ENERGY STAR® Air Purifiers Measure Overview ......381
2.5.9 ENERGY STAR® Pool Pumps Measure Overview ......387
2.5.10 Advanced Power Strips Measure Overview ......397
2.5.11 ENERGY STAR® Electric Vehicle Supply Equipment ......407
2.5.12 Induction Cooking ......411

## List of Figures

Figure 1. Central and Mini-Split AC/HPs—AC Survival Function ............................................. 52
Figure 2. Central and Mini-Split AC/HPs—HP Survival Function ............................................. 53
Figure 3. RACs—Survival Function ............................................. 62
Figure 4. Faucet Aerators—Shower, Bath, and Sink Hot Water Use Profile ............................ 293
Figure 5. Low-Flow Showerheads—Shower, Bath, and Sink Hot Water Use Profile ............... 299
Figure 6. Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile ..................... 306
Figure 7. Tub Spout/Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile .... 315
Figure 8. Refrigerators—Survival Function ............................................. 355
Figure 9. Freezers—Survival Function ............................................. 369

## List of Tables


Table 1. Residential Deemed Savings by Measure Category ....... 1

Table 2. GSL LEDs—Baseline and Default Wattages for A-Shaped Lamps, ....... 8

Table 3. GSL LEDs—Baseline and Default Wattages for Other Lamp Shapes, ....... 8

Table 4. GSL LEDs—Interactive Effects for Cooling Energy Savings and Heating Energy Penalties ....... 10

Table 5. GSL LEDs—In-Service Rates by Program Type ....... 11

Table 6. GSL LEDs—Coincidence Factors ....... 12

Table 7. GSL LEDs—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties ....... 12

Table 8. GSL LEDs—Estimated Useful Life ....... 14

Table 9. GSL LEDs—Revision History ....... 16

Table 10. Specialty LEDs—Baseline and Default Wattages ....... 18

Table 11. Specialty LEDs—Interactive Effects for Cooling Energy Savings and Heating Energy Penalties ....... 20

Table 12. Specialty LEDs—In-Service Rates by Program Type ....... 21

Table 13. Specialty LEDs—Coincidence Factors ....... 21

Table 14. Specialty LEDs—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties ....... 22

Table 15. Specialty LEDs—Estimated Useful Life ....... 24

Table 16. Specialty LEDs—Revision History ....... 25

Table 17. LED Nightlights—Interactive Effects for Cooling Energy Savings and Heating Energy Penalties ....... 28

Table 18. LED Nightlights—In-Service Rates by Program Type ....... 29

Table 19. LED Nightlights—Coincidence Factors ....... 30

Table 20. LED Nightlights—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties ....... 30

Table 21. LED Nightlights—Revision History ....... 33

Table 22. AC/HP Tune-Ups—Equivalent Full Load Cooling/Heating Hours ....... 37

Table 23. AC/HP Tune-Ups—Coincidence Factors ....... 38

Table 24. AC/HP Tune-Ups—Energy Savings (kWh/ton) ....... 39

Table 25. AC/HP Tune-Ups—Summer Peak Demand Savings (kW/ton) ....... 39

Table 26. AC/HP Tune-Ups—Peak Demand Savings (kW/ton) ....... 39

Table 27. AC/HP Tune-Ups—History ....... 41

Table 28. Central and Mini-Split ACs—Baseline Efficiencies ....... 46

Table 29. Central and Mini-Split HPs—Baseline Efficiencies ....... 46

Table 30. Central and Mini-Split AC/HPs—Equivalent Full Load Cooling/Heating Hours ....... 50

Table 31. Central and Mini-Split AC/HPs—Coincidence Factors....50
Table 32. Central and Mini-Split AC/HPs—RUL of Replaced AC....51
Table 33. Central and Mini-Split AC/HPs—RUL of Replaced HP....51
Table 34. Central and Mini-Split AC/HPs—Revision History....56
Table 35. RACs—Baseline Efficiencies for ER, ROB, and NC....58
Table 36. RACs—Efficient Condition Requirements....59
Table 37. RACs—Annual Operating Hours for Cooling....60
Table 38. RACs—Coincidence Factor....60
Table 39. RACs—RUL of Replaced Unit....61
Table 40. RACs—Revision History....65
Table 41. PTHPs—ER Baseline Efficiency Levels for Standard Size PTACs....68
Table 42. PTHPs—ROB Minimum Efficiency Levels,....69
Table 43. PTHPs—Coincidence Factors....72
Table 44. PTHPs—Cooling/Heating EFLHs....72
Table 45. PTHPs—RUL of Replaced PTAC,....74
Table 46. PTHPs—Revision History....76
Table 47. GSHPs—Baseline Efficiencies....78
Table 48. GSHPs—ENERGY STAR Requirements....78
Table 49. GSHPs—Equivalent Full Load Cooling/Heating Hours....80
Table 50. GSHPs—Coincidence Factors....81
Table 51. GSHPs—Energy Savings for Desuperheaters per Cooling Tonnage....82
Table 52. GSHPs—Summer Peak Demand Savings for Desuperheaters per Cooling Tonnage....82
Table 53. GSHPs—Revision History....84
Table 54. Large Capacity AC/HPs—NC/ROB Baseline Efficiency Levels for AC/HPs....86
Table 55. Large Capacity AC/HPs—NC/ROB Baseline Efficiency Levels for GSHPs....87
Table 56. Large Capacity AC/HPs—Coincidence Factors....89
Table 57. Large Capacity AC/HPs—Equivalent Full Load Cooling/Heating Hours....89
Table 58. Large Capacity AC/HPs—Revision History....91
Table 59. Evaporative Cooling—Deemed Savings per System....94
Table 60. Evaporative Cooling—Revision History....95
Table 61. Connected Thermostats—Baseline Efficiency of Existing ACs....97
Table 62. Connected Thermostats—Baseline Efficiency of Existing HPs....97
Table 63. Connected Thermostats—Runtime Reduction Criteria for ENERGY STAR Certification....99
Table 64. Connected Thermostats—Equivalent Full Load Cooling/Heating Hours....100

Table 65. Connected Thermostats—Baseline for Various Equipment Replacement Scenarios ... 100
Table 66. Connected Thermostats—Energy Savings for Thermostats Installed on Unspecified Existing HVAC (kWh/thermostat) ... 101
Table 67. Connected Thermostats—Revision History ... 104
Table 68. Smart Thermostat Load Management—Deemed kW Savings per Device ... 107
Table 69. Smart Thermostat Load Management—Example Total Program Year Savings Calculation ... 107
Table 70. Smart Thermostat Load Management—Revision History ... 109
Table 71. Duct Sealing—Leakage Categorization Guide ... 113
Table 72. Duct Sealing—Energy Savings $V_E$ per $CFM_{25}$ Reduction ... 115
Table 73. Duct Sealing—Summer Demand Savings $V_S$ per $CFM_{25}$ Reduction ... 115
Table 74. Duct Sealing—Winter Demand Savings $V_W$ per $CFM_{25}$ Reduction ... 116
Table 75. Duct Sealing—Climate Zone 1: Amarillo—Energy Savings (kWh), HTR Alternate Approach ... 117
Table 76. Duct Sealing—Climate Zone 2: Dallas—Energy Savings (kWh), HTR Alternate Approach ... 117
Table 77. Duct Sealing—Climate Zone 3: Houston—Energy Savings (kWh), HTR Alternate Approach ... 117
Table 78. Duct Sealing—Climate Zone 4: Corpus Christi—Energy Savings (kWh), HTR Alternate Approach ... 117
Table 79. Duct Sealing—Climate Zone 5: El Paso—Energy Savings (kWh), HTR Alternate Approach ... 118
Table 80. Duct Sealing—Climate Zone 1: Amarillo—Summer Peak Demand Savings (kW), HTR Alternate Approach ... 118
Table 81. Duct Sealing—Climate Zone 2: Dallas—Summer Peak Demand Savings (kW), HTR Alternate Approach ... 118
Table 82. Duct Sealing—Climate Zone 3: Houston—Summer Peak Demand Savings (kW), HTR Alternate Approach ... 118
Table 83. Duct Sealing—Climate Zone 4: Corpus Christi—Summer Peak Demand Savings (kW), HTR Alternate Approach ... 118
Table 84. Duct Sealing—Climate Zone 5: El Paso—Summer Peak Demand Savings (kW), HTR Alternate Approach ... 119
Table 85. Duct Sealing—Climate Zone 1: Amarillo—Winter Peak Demand Savings (kW), HTR Alternate Approach ... 119
Table 86. Duct Sealing—Climate Zone 2: Dallas—Winter Peak Demand Savings (kW), HTR Alternate Approach ... 119
Table 87. Duct Sealing—Climate Zone 3: Houston—Winter Peak Demand Savings (kW), HTR Alternate Approach ... 119

Table 88. Duct Sealing—Climate Zone 4: Corpus Christi—Winter Peak Demand Savings (kW), HTR Alternate Approach ........ 120
Table 89. Duct Sealing—Climate Zone 5: El Paso—Winter Peak Demand Savings (kW), HTR Alternate Approach ........ 120
Table 90. Duct Sealing—Climate Zone 1: Amarillo—Energy Savings (kWh), Alternate Approach ........ 120
Table 91. Duct Sealing—Climate Zone 2: Dallas—Energy Savings (kWh), Alternate Approach ........ 120
Table 92. Duct Sealing—Climate Zone 3: Houston—Energy Savings (kWh), Alternate Approach ........ 121
Table 93. Duct Sealing—Climate Zone 4: Corpus Christi—Energy Savings (kWh), Alternate Approach ........ 121
Table 94. Duct Sealing—Climate Zone 5: El Paso—Energy Savings (kWh), Alternate Approach ........ 121
Table 95. Duct Sealing—Climate Zone 1: Amarillo—Summer Peak Demand Savings (kW), Alternate Approach ........ 121
Table 96. Duct Sealing—Climate Zone 2: Dallas—Summer Peak Demand Savings (kW), Alternate Approach ........ 122
Table 97. Duct Sealing—Climate Zone 3: Houston—Summer Peak Demand Savings (kW), Alternate Approach ........ 122
Table 98. Duct Sealing—Climate Zone 4: Corpus Christi—Summer Peak Demand Savings (kW), Alternate Approach ........ 122
Table 99. Duct Sealing—Climate Zone 5: El Paso—Summer Peak Demand Savings (kW), Alternate Approach ........ 122
Table 100. Duct Sealing—Climate Zone 1: Amarillo—Winter Peak Demand Savings (kW), Alternate Approach ........ 122
Table 101. Duct Sealing—Climate Zone 2: Dallas—Winter Peak Demand Savings (kW), Alternate Approach ........ 123
Table 102. Duct Sealing—Climate Zone 3: Houston—Winter Peak Demand Savings (kW), Alternate Approach ........ 123
Table 103. Duct Sealing—Climate Zone 4: Corpus Christi—Winter Peak Demand Savings (kW), Alternate Approach ........ 123
Table 104. Duct Sealing—Climate Zone 5: El Paso—Winter Peak Demand Savings (kW), Alternate Approach ........ 123
Table 105. Duct Sealing—Revision History ........ 126
Table 106. Air Infiltration—N Factors ........ 131
Table 107. Air Infiltration—Energy Savings $V_E$ per $CFM_{50}$ Reduction ........ 133
Table 108. Air Infiltration—Peak Summer Demand Savings $V_S$ per $CFM_{50}$ Reduction ........ 133
Table 109. Air Infiltration—Peak Winter Demand Savings $V_W$ per $CFM_{50}$ Reduction ........ 134
Table 110. Air Infiltration—Revision History ........ 136

Table 111. Ceiling Insulation—Prototypical Home Characteristics ........................................140
Table 112. Ceiling Insulation—Climate Zone 1: Amarillo, R-30 Energy Savings (kWh/sq. ft.)........................................140
Table 113. Ceiling Insulation—Climate Zone 2: Dallas, R-30 Energy Savings (kWh/sq. ft.).....141
Table 114. Ceiling Insulation—Climate Zone 3: Houston, R-30 Energy Savings (kWh/sq. ft.)........................................141
Table 115. Ceiling Insulation—Climate Zone 4: Corpus Christi, R-30 Energy (kWh/sq. ft.)......141
Table 116. Ceiling Insulation—Climate Zone 5: El Paso, R-30 Energy Savings (kWh/sq. ft.) ..141
Table 117. Ceiling Insulation—Energy Scale-Down Factors for Insulating to Less than R-30 (kWh/sq. ft./ΔR) ........................................142
Table 118. Ceiling Insulation—Energy Scale-Up Factors for Insulating to Greater than R-30 (kWh/sq. ft./ΔR) ........................................143
Table 119. Ceiling Insulation—Climate Zone 1: Amarillo, R-30 Summer Peak Demand Savings (kW/sq. ft.) ........................................143
Table 120. Ceiling Insulation—Climate Zone 2: Dallas, R-30 Summer Peak Demand Savings (kW/sq. ft.) ........................................143
Table 121. Ceiling Insulation—Climate Zone 3: Houston, R-30 Summer Peak Demand Savings (kW/sq. ft.) ........................................144
Table 122. Ceiling Insulation—Climate Zone 4: Corpus Christi, R-30 Summer Peak Demand Savings (kW/sq. ft.)........................................144
Table 123. Ceiling Insulation—Climate Zone 5: El Paso, R-30 Summer Peak Demand Savings (kW/sq. ft) ........................................144
Table 124. Ceiling Insulation—Summer Peak Demand Scale-Down Factors for Insulating to Less than R-30 (kW/sq. ft./ΔR)........................................144
Table 125. Ceiling Insulation—Summer Peak Demand Scale-Up Factors for Insulating to Greater than R-30 (kW/sq. ft./ΔR) ........................................145
Table 126. Ceiling Insulation—Climate Zone 1: Amarillo,  R-30 Winter Peak Demand Savings (kW/sq. ft.) ........................................145
Table 127. Ceiling Insulation—Climate Zone 2: Dallas, R-30 Winter Peak Demand Savings (kW/sq. ft.) ........................................145
Table 128. Ceiling Insulation—Climate Zone 3: Houston, R-30 Winter Peak Demand Savings (kW/sq. ft.) ........................................146
Table 129. Ceiling Insulation—Climate Zone 4: Corpus Christi, R-30 Winter Peak Demand Savings (kW/sq. ft.)........................................146
Table 130. Ceiling Insulation—Climate Zone 5: El Paso, R-30 Winter Peak Demand Savings (kW/sq. ft.) ........................................146
Table 131. Ceiling Insulation—Winter Peak Demand Scale-down Factors for Insulating to Less than R-30 (kW/sq. ft./ΔR)........................................147
Table 132. Ceiling Insulation—Winter Peak Demand Scale-up Factors for Insulating to Greater than R-30(kW/sq. ft./ ΔR) ........................................147
Table 133. Ceiling Insulation—Revision History ........................................150

Table 134. Attic Encapsulation—Prototypical Home Characteristics ......154
Table 135. Attic Encapsulation—Climate Zone 1: Amarillo, R-30 Energy Savings for Insulation Component (kWh/sq. ft) ......155
Table 136. Attic Encapsulation—Climate Zone 2: Dallas, R-30 Energy Savings for Insulation Component (kWh/sq. ft) ......155
Table 137. Attic Encapsulation—Climate Zone 3: Houston, R-30 Energy Savings for Insulation Component (kWh/sq. ft) ......155
Table 138. Attic Encapsulation—Climate Zone 4: Corpus Christi, R-30 Energy Savings for Insulation Component (kWh/sq. ft) ......156
Table 139. Attic Encapsulation—Climate Zone 5: El Paso, R-30 Energy Savings for Insulation Component (kWh/sq. ft) ......156
Table 140. Attic Encapsulation—Energy Scale-down Factors for Insulating to Less than R-30 (kWh/sq. ft./ΔR) ......157
Table 141. Attic Encapsulation—Energy Scale-up Factors for Insulating to Greater than R-30 (kWh/sq. ft./ΔR) ......157
Table 142. Attic Encapsulation—Climate Zone 1: Amarillo, R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.) ......158
Table 143. Attic Encapsulation—Climate Zone 2: Dallas, R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.)......158
Table 144. Attic Encapsulation—Climate Zone 3: Houston, R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.) ......158
Table 145. Attic Encapsulation—Climate Zone 4: Corpus Christi, R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.) ......158
Table 146. Attic Encapsulation—Climate Zone 5: El Paso, R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.) ......159
Table 147. Attic Encapsulation—Summer Peak Demand Scale-down Factors for Insulating to Less than R-30 (kW/sq. ft./ΔR)......159
Table 148. Attic Encapsulation—Summer Peak Demand Scale-up Factors for Insulating to Greater than R-30 (kW/sq. ft./ΔR) ......159
Table 149. Attic Encapsulation—Climate Zone 1: Amarillo, R-30 Winter Peak Demand Savings for Insulation Component (kW/sq. ft.)......160
Table 150. Attic Encapsulation—Climate Zone 2: Dallas, R-30 Winter Peak Demand Savings for Insulation Component (kW/sq. ft.)......160
Table 151. Attic Encapsulation—Climate Zone 3: Houston, R-30 Winter Peak Demand Savings for Insulation Component (kW/sq. ft.)......160
Table 152. Attic Encapsulation—Climate Zone 4: Corpus Christi, R-30 Winter Peak Demand Savings for Insulation Component (kW/sq. ft.) ......161
Table 153. Attic Encapsulation—Zone 5: El Paso, R-30 Winter Peak Demand Savings for Insulation Component (kW/sq. ft.)......161
Table 154. Attic Encapsulation—Winter Peak Demand Scale-down Factors for Insulating to Less than R-30 (kW/sq. ft./ΔR)......162

Table 155. Attic Encapsulation—Winter Peak Demand Scale-cp Factors for Insulating to Greater than R-30 (kW/sq. ft./ΔR) ....... 162
Table 156. Attic Encapsulation—Prototypical Home Characteristics ....... 163
Table 157. Attic Encapsulation—Energy Savings for Infiltration Reduction Component, 18 Percent Air Infiltration Reduction (kWh/home) ....... 164
Table 158. Attic Encapsulation—Summer Peak Demand Savings for Infiltration Reduction Component, 18 Percent Air Infiltration Reduction (kW/home) ....... 164
Table 159. Attic Encapsulation—Winter Peak Demand Savings for the Infiltration Reduction Component, 18 Percent Air Infiltration Reduction (kW/home) ....... 165
Table 160. Attic Encapsulation—Revision History ....... 168
Table 161. Wall Insulation—High-Efficiency Condition R-Values for 2x4 and 2x6 Walls ....... 170
Table 162. Wall Insulation—Prototypical Home Characteristics ....... 171
Table 163. Wall Insulation—Energy Savings (kWh/sq. ft.), Insulation of 2x4 Walls to R- 13 ....... 172
Table 164. Wall Insulation—Energy Savings (kWh/sq. ft.), Insulation of 2x4 Walls to R-21 ....... 172
Table 165. Wall Insulation—Energy Savings (kWh/sq. ft.), Insulation of 2x6 Walls to R-17 ....... 173
Table 166. Wall Insulation—Energy Savings (kWh/sq. ft.), Insulation of 2x6 Walls to R-33 ....... 173
Table 167. Wall Insulation—Summer Peak Demand Savings (kW/sq. ft.), Insulation of 2x4 Walls to R-13 ....... 174
Table 168. Wall Insulation—Summer Peak Demand Savings, Insulation of 2x4 Walls to R-21 (kW/sq. ft.) ....... 174
Table 169. Wall Insulation—Summer Peak Demand Savings (kW/sq. ft.), Insulation of 2x6 Walls to R-17 ....... 175
Table 170. Wall Insulation—Summer Peak Demand Savings (kW/sq. ft.), Insulation of 2x6 Walls to R-33 ....... 176
Table 171. Wall Insulation—Winter Peak Demand Savings (kW/sq. ft.), Insulation of 2x4 Walls to R-13 ....... 177
Table 172. Wall Insulation—Winter Peak Demand Savings (kW/sq. ft.), Insulation of 2x4 Walls to R-21 ....... 177
Table 173. Wall Insulation—Winter Peak Demand Savings (kW/sq. ft.), Insulation of 2x6 Walls to R-17 ....... 178
Table 174. Wall Insulation—Winter Peak Demand Savings (kW/sq. ft.), Insulation of 2x6 Walls to R-33 ....... 178
Table 175. Wall Insulation—Revision History ....... 180
Table 176. Floor Insulation—Prototypical Home Characteristics ....... 184
Table 177. Floor Insulation—Climate Zone 1: Amarillo, Energy Savings (kWh/sq. ft.) ....... 184
Table 178. Floor Insulation—Climate Zone 2: Dallas, Energy Savings (kWh/sq. ft.) ....... 184
Table 179. Floor Insulation—Climate Zone 3: Houston, Energy Savings (kWh/sq. ft.) ....... 185
Table 180. Floor Insulation—Climate Zone 4: Corpus Christi, Energy Savings (kWh/sq. ft.) ....... 185
Table 181. Floor Insulation—Climate Zone 5: El Paso, Energy Savings (kWh/sq. ft.) ....... 185

Table 182. Floor Insulation—Climate Zone 1: Amarillo, Summer Peak Demand Savings (kW/sq. ft.) 185
Table 183. Floor Insulation—Climate Zone 2: Dallas, Summer Peak Demand Savings (kW/sq. ft.) 185
Table 184. Floor Insulation—Climate Zone 3: Houston, Summer Peak Demand Savings (kW/sq. ft.) 186
Table 185. Floor Insulation—Climate Zone 4: Corpus Christi, Summer Peak Demand Savings (kW/sq. ft.) 186
Table 186. Floor Insulation—Climate Zone 5: El Paso, Summer Peak Demand Savings (kW/sq. ft.) 186
Table 187. Floor Insulation—Climate Zone 1: Amarillo, Winter Peak Demand Savings (kW/sq. ft.) 186
Table 188. Floor Insulation—Climate Zone 2: Dallas, Winter Peak Demand Savings (kW/sq. ft.) 186
Table 189. Floor Insulation—Climate Zone 3: Houston, Winter Peak Demand Savings (kW/sq. ft.) 187
Table 190. Floor Insulation—Climate Zone 4: Corpus Christi, Winter Peak Demand Savings (kW/sq. ft.) 187
Table 191. Floor Insulation—Climate Zone 5: El Paso, Winter Peak Demand Savings (kW/sq. ft.) 187
Table 192. Floor Insulation—Revision History 189
Table 193. Duct Insulation—Cooling and Heating Adjustment Factors (AF) 191
Table 194. Duct Insulation—Climate Zone 1: Amarillo, Energy Savings (kWh/sq. ft.) 192
Table 195. Duct Insulation—Climate Zone 2: Dallas, Energy Savings (kWh/sq. ft.) 192
Table 196. Duct Insulation—Climate Zone 3: Houston, Energy Savings (kWh/sq. ft.) 192
Table 197. Duct Insulation—Climate Zone 4: Corpus Christi, Energy (kWh/sq. ft.) 192
Table 198. Duct Insulation—Climate Zone 5: El Paso, Energy Savings (kWh/sq. ft.) 193
Table 199. Duct Insulation—Climate Zone 1: Amarillo, Summer Peak Demand Savings (kW/sq. ft.) 193
Table 200. Duct Insulation—Climate Zone 2: Dallas, Summer Peak Demand Savings (kW/sq. ft.) 193
Table 201. Duct Insulation—Climate Zone 3: Houston, Summer Peak Demand Savings (kW/sq. ft.) 194
Table 202. Duct Insulation—Climate Zone 4: Corpus Christi, Summer Peak Demand Savings (kW/sq. ft.) 194
Table 203. Duct Insulation—Climate Zone 5: El Paso, Summer Peak Demand Savings (kW/sq. ft) 194
Table 204. Duct Insulation—Revision History 195
Table 205. Radiant Barriers—RIMA-I Product Testing Requirements 197
Table 206. Radiant Barriers—Cooling and Heating Adjustment Factors (AF) 198

Table 207. Radiant Barriers—Climate Zone 1: Amarillo, Energy Savings (kWh/sq. ft.)............199
Table 208. Radiant Barriers—Climate Zone 2: Dallas, Energy Savings (kWh/sq. ft.) ..............199
Table 209. Radiant Barriers—Climate Zone 3: Houston, Energy Savings (kWh/sq. ft.) ...........199
Table 210. Radiant Barriers—Climate Zone 4: Corpus Christi, Energy Savings (kWh/sq. ft.)..200
Table 211. Radiant Barriers—Climate Zone 5: El Paso, Energy Savings (kWh/sq. ft.)............200
Table 212. Radiant Barriers—Summer Peak Demand Savings for Residences with Refrigerated Air (kWh/sq. ft.)........200
Table 213. Radiant Barriers—Revision History ........202
Table 214. Cool Roofs—ENERGY STAR Specification........204
Table 215. Cool Roofs—Prototypical Home Characteristics........205
Table 216. Cool Roofs—Climate Zone 1: Amarillo, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)........206
Table 217. Cool Roofs—Climate Zone 2: Dallas, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)........207
Table 218. Cool Roofs—Climate Zone 3: Houston, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)........209
Table 219. Cool Roofs—Climate Zone 4: Corpus Christi, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.) ........210
Table 220. Cool Roofs—Climate Zone 5: El Paso, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)........211
Table 221. Cool Roofs—Climate Zone 1: Amarillo, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)........212
Table 222. Cool Roofs—Climate Zone 2: Dallas, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)........213
Table 223. Cool Roofs—Climate Zone 3: Houston, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)........214
Table 224. Cool Roofs—Climate Zone 4: Corpus Christi, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.) ........215
Table 225. Cool Roofs—Climate Zone 5: El Paso, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)........215
Table 226. Cool Roofs—Climate Zone 1: Amarillo, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)........216
Table 227. Cool Roofs—Climate Zone 2: Dallas, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ........217
Table 228. Cool Roofs—Climate Zone 3: Houston, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ........218
Table 229. Cool Roofs—Climate Zone 4: Corpus Christi, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)........219
Table 230. Cool Roofs—Climate Zone 5: El Paso, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ........219

Table 231. Cool Roofs—Climate Zone 1: Amarillo, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....220

Table 232. Cool Roofs—Climate Zone 2: Dallas, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....221

Table 233. Cool Roofs—Climate Zone 3: Houston, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....221

Table 234. Cool Roofs—Climate Zone 4: Corpus Christi, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)....222

Table 235. Cool Roofs—Climate Zone 5: El Paso, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....222

Table 236. Cool Roofs—Climate Zone 1: Amarillo, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....223

Table 237. Cool Roofs—Climate Zone 2: Dallas, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....224

Table 238. Cool Roofs—Climate Zone 3: Houston, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....225

Table 239. Cool Roofs—Climate Zone 4: Corpus Christi, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....226

Table 240. Cool Roofs—Climate Zone 5: El Paso, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....226

Table 241. Cool Roofs—Climate Zone 1: Amarillo, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....227

Table 242. Cool Roofs—Climate Zone 2: Dallas, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....228

Table 243. Cool Roofs—Climate Zone 3: Houston, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....228

Table 244. Cool Roofs—Climate Zone 4: Corpus Christi, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....229

Table 245. Cool Roofs—Climate Zone 5: El Paso, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.) ....229

Table 246. Cool Roofs—Revision History ....232

Table 247. Solar Screens—Energy Savings (kWh) per Square Foot of Solar Screen ....236

Table 248. Solar Screens—Summer Peak Demand Savings (kW) per Square Foot of Solar Screen ....236

Table 249. Solar Screens—Winter Peak Demand Savings (kW) per Square Foot of Solar Screen ....237

Table 250. Solar Screens—Revision History....238

Table 251. Windows—Baseline Window Specification ....240

Table 252. Windows—ENERGY STAR Requirements....240

Table 253. Windows—TRM and ENERGY STAR Climate Zones....241

Table 254. Windows—Energy Savings (kWh/sq. ft.), Single-Pane Baseline....242
Table 255. Windows—Energy Savings (kWh/sq. ft.), Double-Pane Baseline....242
Table 256. Windows—Energy Savings (kWh/sq. ft.), Weighted-Pane Baseline....242
Table 257. Windows—Summer Peak Demand Savings (kW/sq. ft.), Single-Pane Baseline....243
Table 258. Windows—Summer Peak Demand Savings (kW/sq. ft.), Double-Pane Baseline....243
Table 259. Windows—Summer Peak Demand Savings (kW/sq. ft.), Weighted-Pane Baseline....243
Table 260. Windows—Winter Peak Demand Savings (kW/sq. ft.), Single-Pane Baseline....244
Table 261. Windows—Winter Peak Demand Savings (kW/sq. ft.), Double-Pane Baseline....244
Table 262. Windows—Winter Peak Demand Savings (kW/sq. ft.), Weighted-Pane Baseline....244
Table 263. Windows—Revision History....246
Table 264. Low-E Storm Windows—ENERGY STAR Requirements....249
Table 265. Low-E Storm Windows—Window Assembly Properties....249
Table 266. Low-E Storm Windows—Modeled Building Characteristics....249
Table 267. Low-E Storm Windows—Energy Savings (kWh/sq. ft.), Single-Pane Baseline....250
Table 268. Low-E Storm Windows—Energy Savings (kWh/sq. ft.), Double-Pane Baseline....250
Table 269. Low-E Storm Windows—Energy Savings (kWh/sq. ft.), Weighted-Pane Baseline....251
Table 270. Low-E Storm Windows—Summer Peak Demand Savings (kW/sq. ft.), Single-Pane Baseline....251
Table 271. Low-E Storm Windows—Summer Peak Demand Savings (kW/sq. ft.), Double-Pane Baseline....251
Table 272. Low-E Storm Window—Summer Peak Demand Savings (kW/sq. ft.), Weighted-Pane Baseline....252
Table 273. Low-E Storm Windows—Winter Peak Demand Savings (kW/sq. ft.), Single-Pane Baseline....252
Table 274. Low-E Storm Windows—Peak Demand Savings (kW/sq. ft.), Double-Pane Baseline....252
Table 275. Low-E Storm Windows—Winter Peak Demand Savings (kW/sq. ft.), Weighted-Pane Baseline....253
Table 276. Low-E Storm Windows—Revision History....254
Table 277. DHW Replacements—Federal Standard for Residential Electric Storage Water Heaters....256
Table 278. DHW Replacements—Efficiency Standards....257
Table 279. DHW Replacements—Water Heater Consumption (Gal/Year)....258
Table 280. DHW Replacements—Water Mains Temperature (°F)....259
Table 281. DHW Replacements—Coincidence Factors....260
Table 282. DHW Replacements—Revision History....263
Table 283. HPWHs—Federal Standard for Residential Water Heaters....265

Table 284. HPWHs—ENERGY STAR Specification ............................................................265
Table 285. HPWHs—Water Heater Consumption (Gal/Year) ................................................267
Table 286. HPWHs—Water Mains Temperature (°F)............................................................268
Table 287. HPWHs—Coincidence Factors.........................................................................268
Table 288. HPWHs—Revision History ...............................................................................270
Table 289. Solar DHW—Federal Standard for Residential Electric Storage Water Heaters ....272
Table 290. Solar DHW—Water Heater Consumption (Gal/Year) ..........................................274
Table 291. Solar DHW—Water Mains Temperature (°F).......................................................274
Table 292. Solar DHW—Coincidence Factors .....................................................................275
Table 293. Solar DHW—Revision History ...........................................................................276
Table 294. DHW Tank Insulation—Estimated Tank Area.......................................................280
Table 295. DHW Tank Insulation—Ambient Temperature (°F)..............................................281
Table 296. DHW Tank Insulation—Energy Savings ..............................................................281
Table 297. DHW Tank Insulation—Energy Savings ..............................................................282
Table 298. DHW Tank Insulation—Energy Savings ..............................................................282
Table 299. DHW Tank Insulation—Revision History .............................................................283
Table 300. DHW Pipe Insulation—Estimated Pipe Surface Area ...........................................286
Table 301. DHW Pipe Insulation—Ambient Temperature (°F)................................................287
Table 302. DHW Pipe Insulation—Revision History ..............................................................289
Table 303. Faucet Aerators—Water Mains Temperature (°F) ................................................292
Table 304. Faucet Aerators—Coincidence Factors ...............................................................293
Table 305. Faucet Aerators—Revision History.......................................................................295
Table 306. Low-Flow Showerheads—Water Mains Temperature (°F)....................................298
Table 307. Low-Flow Showerheads—Coincidence Factors ..................................................299
Table 308. Low-Flow Showerheads—Revision History .........................................................301
Table 309. Showerhead TSRVs—Hot Water Usage Reduction .............................................304
Table 310. Showerhead TSRVs—Water Mains Temperature (°F) ........................................306
Table 311. Showerhead TSRVs—Coincidence Factors ........................................................306
Table 312. Showerhead TSRVs—Revision History................................................................308
Table 313. Tub Spout/Showerhead TSRVs—Hot Water Usage Reduction ............................312
Table 314. Tub Spout/Showerhead TSRVs—Water Mains Temperature (°F) .........................314
Table 315. Tub Spout/Showerhead TSRVs—Coincidence Factors........................................314
Table 316. Tub Spout/Showerhead TSRVs—Revision History..............................................316
Table 317. DHW Temperature Setback—Estimated Tank Area.............................................318
Table 318. DHW Temperature Setback—Revision History ....................................................320

Table 319. Ceiling Fans—Fan Definitions ....... 322
Table 320. Ceiling Fans—Efficiency Requirements....... 322
Table 321. Ceiling Fans—Light Kit Efficacy Requirements....... 322
Table 322. Ceiling Fans—Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties....... 324
Table 323. Ceiling Fans— Motor Wattages....... 324
Table 324. Ceiling Fans—Operating Percentages ....... 325
Table 325. Ceiling Fans—Lighting Coincidence Factors ....... 326
Table 326. Ceiling Fans—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties....... 326
Table 327. Ceiling Fans—Energy Savings (kWh)....... 326
Table 328. Ceiling Fans—Summer Peak Demand Savings (kW) ....... 326
Table 329. Ceiling Fans—Winter Peak Demand Savings (kW) ....... 327
Table 330. Ceiling Fans—Revision History ....... 328
Table 331. Clothes Washers—Federal Standard ....... 330
Table 332. Clothes Washers—ENERGY STAR Requirements....... 330
Table 333. Clothes Washers—ENERGY STAR Characteristics....... 333
Table 334. Clothes Washers—Coincidence Factors ....... 333
Table 335. Clothes Washers—Energy Savings (kWh) ....... 334
Table 336. Clothes Washers—Summer Peak Demand Savings (kW)....... 334
Table 337. Clothes Washers—Winter Peak Demand Savings (kW)....... 335
Table 338. Clothes Washers—Revision History....... 336
Table 339. Clothes Dryers—Federal Standard....... 339
Table 340. Clothes Dryers—ENERGY STAR Requirements ....... 339
Table 341. Clothes Dryers—Default Average Load....... 340
Table 342. Clothes Dryers—Coincidence Factors....... 341
Table 343. Clothes Dryers—Energy Savings (kWh)....... 341
Table 344. Clothes Dryers—Summer Peak Demand Savings (kW) ....... 341
Table 345. Clothes Dryers—Winter Peak Demand Savings (kW)....... 342
Table 346. Clothes Dryers—Revision History ....... 343
Table 347. Dishwashers—Federal Standard....... 344
Table 348. Dishwashers—ENERGY STAR Requirements ....... 345
Table 349. Dishwashers—Coincidence Factors....... 347
Table 350. Dishwashers—Energy Savings (kWh)....... 347
Table 351. Dishwashers—Summer Peak Demand Savings (kW)....... 347
Table 352. Dishwashers—Winter Peak Demand Savings (kW)....... 347

Table 353. Dishwashers—Revision History....349
Table 354. Refrigerators—ENERGY STAR Requirements....351
Table 355. Refrigerators—Formulas to Calculate the Energy Usage by Product Class....352
Table 356. Refrigerators—Coincidence Factors....353
Table 357. Refrigerators—RUL of Replaced Unit....354
Table 358. Refrigerators—Energy Savings (kWh)....357
Table 359. Refrigerators—Replace-on-Burnout – Summer Peak Demand Savings (kW)....358
Table 360. Refrigerators—Early Retirement—Summer Peak Demand Savings (kW)....359
Table 361. Refrigerators—Replace-on-Burnout—Winter Peak Demand Savings (kW)....360
Table 362. Refrigerators—Early Retirement—Winter Peak Demand Savings (kW)....361
Table 363. Refrigerators—Revision History....363
Table 364. Freezers—ENERGY STAR Requirements....365
Table 365. Freezers—Formulas to Calculate the Energy Usage by Product Class....366
Table 366. Freezers—Coincidence Factors....367
Table 367. Freezers—RUL of Replaced Unit....368
Table 368. Freezers—Savings (kWh)....371
Table 369. Freezers—Replace-on-Burnout—Summer Peak Demand Savings (kW)....372
Table 370. Freezers—Early Retirement—Summer Peak Demand Savings (kW)....372
Table 371. Freezers—Replace-on-Burnout—Winter Peak Demand Savings (kW)....372
Table 372. Freezers—Early Retirement—Winter Peak Demand Savings (kW)....373
Table 373. Freezers—Revision History....375
Table 374. Refrigerator/Freezer Recycling—Average Annual Energy Consumption....377
Table 375. Refrigerator/Freezer Recycling—Coincidence Factors....378
Table 376. Refrigerator/Freezer Recycling—Revision History....380
Table 377. Air Purifiers—Federal Standard....381
Table 378. Air Purifiers—ENERGY STAR Requirements....382
Table 379. Air Purifiers—Coincidence Factors....384
Table 380. Air Purifiers—Energy Savings (kWh)....384
Table 381. Air Purifiers—Summer Peak Demand Savings (kW)....384
Table 382. Air Purifiers—Winter Peak Demand Savings (kW)....385
Table 383. Air Purifiers—Revision History....386
Table 384. Baseline Condition—Federal Standard Effective July 19, 2021....388
Table 385. ENERGY STAR Pool Pumps – Energy Efficiency Level....389
Table 386. Pool Pumps—Baseline Assumptions....391
Table 387. Pool Pumps—ENERGY STAR Assumptions....391

Table 388. Pool Pumps—Coincidence Factors ....................................................................392
Table 389. Pool Pumps—Energy Savings (kWh) ...................................................................392
Table 390. Pool Pumps—Summer Peak Demand Savings (kW) for Inground Pools ...............393
Table 391. Pool Pumps—Summer Peak Demand Savings (kW) for Above Ground Pools ......393
Table 392. Pool Pumps—Winter Peak Demand Savings (kW) for Inground Pools ..................394
Table 393. Pool Pumps—Peak Demand Savings (kW) for Above Ground Pools ....................394
Table 394. Pool Pumps—Revision History ............................................................................396
Table 395. APS—Peripheral Watt Consumption Breakdown..................................................399
Table 396. APS—In-Service Rates by Program Type ............................................................402
Table 397. APS—Coincidence Factors ..................................................................................402
Table 398. APS—Tier 1 Unadjusted Savings Before Applying ISR ........................................404
Table 399. APS—Tier 2 Unadjusted Savings Before Applying ISR ........................................404
Table 400. APS—Revision History .........................................................................................406
Table 401. EVSE—Coincidence Factors .................................................................................408
Table 402. EVSE—Energy Savings (kWh) ..............................................................................409
Table 403. EVSE—Summer/Winter Peak Demand Savings (kW) ..........................................409
Table 404. EVSE—Revision History .......................................................................................410
Table 405. Induction Cooking—Baseline Electric Resistance Cooktop Energy Consumption ....................................................................................................412
Table 406. Induction Cooking—Coincidence Factors .............................................................413
Table 407. Induction Cooking—Energy Savings (kWh) ..........................................................414
Table 408. Induction Cooking—Summer Peak Demand Savings (kW) ...................................414
Table 409. Induction Cooking—Winter Peak Demand Savings (kW) ......................................414
Table 410. Induction Cooking—Revision History ....................................................................416

## Acknowledgments

The Texas Technical Reference Manual is maintained by the Public Utility Commission of Texas' independent evaluation, measurement, and verification (EM&V) team led by Tetra Tech. This version of the Texas Technical Reference Manual was primarily developed from program documentation and measure savings calculators used by the Texas Electric Utilities and their Energy Efficiency Services Providers (EESPs) to support their energy efficiency efforts, and original source material from petitions filed with the Public Utility Commission of Texas by the utilities, their consultants and EESPs such as Frontier Energy (TXu 1-904-705), ICF, CLEAResult, and Nexant. Portions of the Technical Reference Manual are copyrighted 2001-2017 by the Electric Utility Marketing Managers of Texas (EUMMOT), while other portions are copyrighted 2001-2018 by Frontier Energy. Certain technical content and updates were added by the EM&V team to provide further explanation and direction as well as a consistent structure and level of information.

## TRM Technical Support

Technical support and questions can be emailed to the EM&V project manager, Lark.Lee@tetratech.com, and the PUCT, Therese.Harris@puc.texas.gov.

# 1 INTRODUCTION

This volume of the TRM contains the deemed savings for residential measures that have been approved for use in Texas by the Public Utility Commission of Texas (PUCT). This volume includes instructions regarding various savings calculators and reference sources of the information. The TRM serves as a centralized source of deemed savings values. Where appropriate, measurement and verification (M&V) methods by measure category are noted for informational purposes only regarding the basis of projected and claimed savings.

Table 1 provides an overview of the residential measures contained within this program year (PY) 2024 TRM 11.0 Volume 2 and the types of deemed savings estimates available for each one. There are five types of deemed savings estimates identified:

- *Point estimates* that provided a single deemed savings value correspond to a single measure or type of technology.
- *Deemed saving tables* that provide energy and peak savings as a function of size, capacity, building type, efficiency level, or other inputs.
- *Savings algorithms* that require specified primary inputs that must be gathered on site and the identification of default inputs where primary data could not be collected. In many cases, these algorithms are provided as references to deemed savings tables, point estimates, or calculator explanations.
- *Calculators* are used by different utilities and implementers to calculate energy savings for different measures. In many cases, there are several different calculators available for a single measure. Sometimes their background calculators are similar, and in other cases, estimates can vary greatly between each calculator.
- *M&V methods* are also used for some measures to calculate savings in the event that standard equipment is not used, or the specified building types do not apply. For some of these measures, both a simplified M&V approach and a full M&V approach may be allowed by the utility. M&V methods as a source of claimed and projected savings are noted for informational purposes only.

Please consult Volume 1: Overview and User Guide, Section 5: Structure and Content, for details on the organization of the measure templates presented in this volume.

**Table 1. Residential Deemed Savings by Measure Category**

| Measure category | Measure description | Point estimates | Deemed savings tables | Savings algorithm | Calculator | M&V | 11.0 update |
|---|---|---|---|---|---|---|---|
| Lighting | ENERGY STAR® general service LED lamps | – | – | X | – | – | Added in-service rates by program type and clarification of lamp types. |

| Measure category | Measure description | Point estimates | Deemed savings tables | Savings algorithm | Calculator | M&V | 11.0 update |
|---|---|---|---|---|---|---|---|
| | ENERGY STAR® specialty and directional LED lamps | – | – | X | – | – | Added in-service rates by program type. |
| | LED nightlights | – | – | X | – | – | Added in-service rates by program type. |
| HVAC | Air conditioner or heat pump tune-up | – | – | X | – | – | Updated demand savings. Clarified eligibility for PTACs and PTHPs. |
| | Central heat pumps without SEER2 ratings | – | X | – | – | – | Measure and Appendix A retired. |
| | Mini-split heat pumps without SEER2 ratings | – | X | – | – | – | Measure and Appendix B retired. |
| | Central mini-split air conditioners and heat pumps with SEER2 ratings | – | – | X | – | – | Defined rightsizing and documentation requirements. Updated early retirement age eligibility. |
| | Room air conditioners | – | – | X | – | – | Incorporated updated DOE final rule and ENERGY STAR specification v5.0. Updated early retirement age eligibility. |
| | Packed terminal heat pumps | – | – | X | – | – | Updated early retirement age eligibility. |
| | Ground source heat pumps | – | X | X | – | – | Integrated federal standard change and SEER2 test procedure. |
| | Large capacity split system and single-package air conditioners and heat pumps | – | – | X | – | – | Updated GSHP EUL. |
| | Evaporative cooling | – | X | – | – | – | No revision. |
| | ENERGY STAR® connected thermostats | – | X | – | – | – | Incorporated algorithm approach. Incorporated new SEER2 test procedure. |
| | Smart thermostat load management | – | X | – | – | – | No revision. |
| | Duct sealing | – | – | X | – | X | No revision. |

| Measure category | Measure description | Point estimates | Deemed savings tables | Savings algorithm | Calculator | M&V | 11.0 update |
|---|---|---|---|---|---|---|---|
| Building envelope | Air infiltration | – | X | – | – | X | Added electric resistance documentation adjustment factor. |
| | Ceiling insulation | – | X | – | – | – | Added electric resistance documentation adjustment factor. |
| | Attic encapsulation | – | X | – | – | – | Added electric resistance documentation adjustment factor. |
| | Wall insulation | – | X | – | – | – | Added electric resistance documentation adjustment factor. |
| | Floor insulation | – | X | – | – | – | Added electric resistance documentation adjustment factor. |
| | Duct insulation | – | X | – | – | – | Measure origin. |
| | Radiant barriers | – | X | – | – | – | Clarified savings normalization by area. Added electric resistance documentation adjustment factor. |
| | Cool roofs | – | X | – | – | – | No revision. |
| | Solar screens | – | X | – | – | – | No revision. |
| | ENERGY STAR® windows | – | X | – | – | – | Updated ENERGY STAR specification. Added electric resistance documentation adjustment factor. |
| | ENERGY STAR® low-e storm windows | | X | – | – | – | Added electric resistance documentation adjustment factor. |

| Measure category | Measure description | Point estimates | Deemed savings tables | Savings algorithm | Calculator | M&V | 11.0 update |
|---|---|---|---|---|---|---|---|
| Domestic water heating | Water heater installation—electric tankless and fuel substitution | – | – | X | – | – | Removed requirement to install HPWH for DHW > 55 gallons. Incorporated updated ENERGY STAR specification v5.0. Updated documentation requirements. |
| | Heat pump water heaters | – | X | – | – | – | Incorporated updated ENERGY STAR specification v5.0. Updated documentation requirements. |
| | Solar water heaters | – | X | – | – | – | Incorporated updated ENERGY STAR specification v5.0. Updated documentation requirements. |
| | Water heater tank insulation | – | X | – | – | – | Clarified baseline and added deemed savings. Updated documentation requirements. |
| | Water heater pipe insulation | – | – | X | – | – | No revision. |
| | Faucet aerators | – | – | X | – | – | No revision. |
| | Low-flow showerheads | – | – | X | – | – | No revision. |
| | Showerhead temperature sensitive restrictor valves | – | – | X | – | – | No revision. |
| | Tub spout and showerhead temperature-sensitive restrictor valves | – | – | X | – | – | No revision. |
| | Water heater temperature setback | – | – | X | – | – | No revision. |

| Measure category | Measure description | Point estimates | Deemed savings tables | Savings algorithm | Calculator | M&V | 11.0 update |
|---|---|---|---|---|---|---|---|
| Appliances | ENERGY STAR® ceiling fans | – | – | X | – | – | No revision. |
| | ENERGY STAR® clothes washers | – | X | – | – | – | No revision. |
| | ENERGY STAR® clothes dryers | – | X | – | – | – | No revision. |
| | ENERGY STAR® dishwashers | – | X | – | – | – | No revision. |
| | ENERGY STAR® refrigerators | – | – | X | – | X | Updated early retirement age eligibility. |
| | ENERGY STAR® freezers | – | X | – | – | – | Updated early retirement age eligibility. |
| | Refrigerator/ freezer recycling | X | – | X | – | – | No revision. |
| | ENERGY STAR® air purifiers | – | X | – | – | – | Updated baseline to Tier 1 federal standard. |
| | ENERGY STAR® pool pumps | – | – | X | – | – | Updated baseline to current federal standard. Added new savings tiers. Updated documentation requirements. |
| | Advanced power strips | – | X | – | – | – | Added in-service rates. |
| | ENERGY STAR® electric vehicle supply equipment | – | X | – | – | – | Updated algorithm with days coefficient. Updated documentation requirements. |
| | Induction cooking | – | X | – | – | – | Updated documentation requirements. |

# 2 RESIDENTIAL MEASURES

## 2.1 RESIDENTIAL: LIGHTING

### 2.1.1 ENERGY STAR® General Service LED Lamps Measure Overview

**TRM Measure ID:** R-LT-GS

**Market Sector:** Residential

**Measure Category:** Lighting

**Applicable Building Types:** Single-family, multifamily; manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive and direct install

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

#### Measure Description

This measure provides a method for calculating savings for the replacement of a standard-efficiency lamp with an ENERGY STAR-compliant LED general service lamp (GSL) in a residential application.[1] This measure applies to all lamps not included in the subsequent measure for Specialty LED Lamps. All lamp types not defined in the Specialty LED Lamps measure should be treated as GSLs.

#### Eligibility Criteria

These savings values rely on usage patterns specific to both indoor and outdoor applications. In lieu of collecting lamp location, a default weighting of 90.5 percent indoor and 9.5 percent outdoor may be assumed.[2]

New homes must exceed the lighting equipment requirements of the current state building code (IECC 2015) to be eligible for prescriptive lighting savings.

Fixtures with integrated LEDs may be eligible under this measure using a modified baseline.

[1] DOE Final Rule: Definitions for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0012-0022.

[2] 2015 US Lighting Market Characterization, Department of Energy. November 2017. Table 4.11. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

## Baseline Condition

On May 8, 2022, the Department of Energy (DOE) issued two final rules relating to GSLs:

- Energy Conservation Program: Definitions for General Service Lamps, effective July 8, 2022, which expanded the definition of GSLs.[3]
- Energy Conservation Program: Energy Conservation Standards for General Service Lamps, effective July 25, 2022, which shifted the baseline to 45 lumens/watt efficacy.[4]

The baseline is assumed to be the second-tier Energy Independence and Security Act of 2007 (EISA)-mandated efficiency for a GSL. The EISA regulations dictate that GSLs must comply with a 45 lumen/watt efficacy standard at time of sale beginning January 1, 2023. However, due to the DOE enforcement schedule, savings may be claimed against the first-tier EISA baseline through February 28, 2023, at the utility's discretion.

For low-income and hard-to-reach direct install programs, utilities may claim additional savings for early retirement of incandescent and halogen lamps with LEDs when documentation requirements are met. It is assumed that the remaining useful life (RUL) of the existing lamps is two years. This is when the incandescent or halogen lamp baseline bulbs will be at the end of their useful life and need to be replaced. First year savings are weighted using the dual baseline methodology for the first-tier and second-tier baselines found in Table 2 and Table 3. The first-tier baseline may only be used in this scenario.

New construction applications use the same baselines; however, savings can only be claimed for efficient lighting installed above the minimum amount required by code. Current code dictates 75 percent high-efficacy lighting. Therefore, if 100 percent of installed lighting is high-efficacy, savings can be claimed for the remaining 25 percent of installed lamps.

Due to the variability among fixture types compared to screw-in lamps, qualified fixtures with integrated LEDs should use the rated installed wattage and equivalent wattage, or other approved custom methodology, in lieu of the deemed values outlined in Table 2 and Table 3. These wattages are available on the ENERGY STAR certificate and can be used in combination with the deemed savings methodologies provided in this measure.

[3] DOE Final Rule: Definitions for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0012-0022.

[4] DOE Final Rule: Energy Conservation Standards for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0005-0070.

**Table 2. GSL LEDs—Baseline and Default Wattages for A-Shaped Lamps[5,6]**

| Minimum lumens | Maximum lumens | Incandescent equivalent wattage | 1st tier EISA 2007 ($W_{Base}$)[7] | 2nd tier EISA 2007 ($W_{Base}$)[8] | Default $W_{Post}$ (if unknown)[9] |
|---|---|---|---|---|---|
| 250 | 309 | 25 | Exempt | Exempt | 3.5 |
| 310 | 749 | 40 | 29 | 12 | 5.5 |
| 750 | 1,049 | 60 | 43 | 20 | 9.0 |
| 1,050 | 1,489 | 75 | 53 | 28 | 11.5 |
| 1,490 | 2,600 | 100 | 72 | 45 | 15.0 |
| 2,601 | 3,300 | 150 | Exempt | 66 | 22.5 |

**Table 3. GSL LEDs—Baseline and Default Wattages for Other Lamp Shapes[10,11]**

| Minimum lumens | Maximum lumens | Incandescent equivalent wattage[12] | 1st tier EISA 2007 ($W_{Base}$)[13] | 2nd tier EISA 2007 ($W_{Base}$)[14] | $W_{Post}$ (if unknown)[15] |
|---|---|---|---|---|---|
| 250 | 309 | Qualified Products List (QPL) | Exempt | Exempt | QPL |
| 310 | 749 | – | 29 | 12 | |
| 750 | 1,049 | – | 43 | 20 | |
| 1,050 | 1,489 | – | 53 | 28 | |
| 1,490 | 2,600 | – | 72 | 45 | |
| 2,601 | 3,300 | QPL | Exempt | 66 | |

[5] Federal standard for General Service Incandescent Lamps (GSIL): https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=20.

[6] If exempt, refer to the incandescent equivalent wattage.

[7] 1st tier baseline is only applicable to low-income and hard-to-reach direct install programs. This baseline is only applicable for two years, equivalent to the expected life of an incandescent lamp.

[8] Non-exempt baseline wattages are calculated by dividing the midpoint of the specified lumen range by the 45 lumens/watt efficacy standard.

[9] Average rated wattage from the ENERGY STAR QPL rounded to nearest half-watt: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

[10] Federal standard for General Service Incandescent Lamps (GSIL): https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=20.

[11] If exempt, refer to incandescent equivalent wattage.

[12] Due to large variation in lamp types, use rated value from the ENERGY STAR QPL: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

[13] 1st tier baseline is only applicable to low-income and hard-to-reach direct install programs. This baseline is only applicable for two years, equivalent to the expected life of an incandescent lamp.

[14] Non-exempt baseline wattages are calculated by dividing the midpoint of the specified lumen range by the 45 lumens/watt efficacy standard.

[15] Due to large variation in lamp types, use rated value from ENERGY STAR: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

## High-Efficiency Condition

The high-efficiency condition is the wattage of the replacement lamp. LEDs must be ENERGY STAR-compliant[16] for the relevant lamp shape being installed as outlined in the latest ENERGY STAR specification.[17] Alternatively, lab testing reports (e.g., LM-79, LM-80, TM-21, ISTMT) are also accepted as a method of certification.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Wattage reduction is defined as the difference between the wattage of a standard baseline lamp, according to EISA 2007 (see Table 2 and Table 3) and the wattage of a comparable GSL LED. An LED is considered comparable to the baseline lamp if they are aligned on the lumen output ranges set out in EISA 2007.

For new construction projects, programs should calculate savings using the methodology in this section for all efficient lamps installed in the home. The program should claim savings for the percentage of installed high-efficacy lamps that exceed the minimum required by code, which is currently 75 percent of lamps. For example, if a new home is built with high-efficacy lamps in 85 percent of the permanently installed fixtures, the program would claim 10 percent of the total calculated savings.

### *Energy Savings*

Annual energy (kWh) savings are calculated as follows.

$$Energy\ Savings\ [\Delta kWh] = \frac{\left(W_{base} - W_{post}\right)}{1{,}000} \times Hours \times ISR \times IEF_E$$

**Equation 1**

*Where:*

| | | |
|---|---|---|
| $W_{base}$ | = | *Baseline wattage corresponding with the lumen output of the purchased LED lamp for the year purchased/installed; reduced baselines are provided for EISA-compliant lamps in Table 2* |
| $W_{post}$ | = | *Actual wattage of LED purchased/installed (if unknown, use default wattages from Table 2)* |

[16] ENERGY STAR QPL: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.
[17] http://www.energystar.gov/products/certified-products/detail/light-bulbs.

| | | |
|---|---|---|
| *HOU* | = | *Average hours of use per year = 803 hours (for interior/exterior applications calculated based on an average daily usage of 2.2 hours per day*[18]*)* |
| *$IEF_E$* | = | *Interactive effects factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 4)* |
| *ISR* | = | *In-service rate, the percentage of incentivized units that are installed and in use (rather than removed, stored, or burnout) to account for units incentivized but not operating (see Table 5)* |
| *1,000* | = | *Constant to convert from W to kW* |

**Table 4. GSL LEDs—Interactive Effects for Cooling Energy Savings and Heating Energy Penalties**[19]

| $IEF_E$ | | | | | |
|---|---|---|---|---|---|
| **Heating/cooling type*** | **Climate Zone 1: Amarillo** | **Climate Zone 2: Dallas** | **Climate Zone 3: Houston** | **Climate Zone 4: Corpus Christi** | **Climate Zone 5: El Paso** |
| Gas heat with AC | 1.06 | 1.13 | 1.17 | 1.15 | 1.12 |
| Gas heat with no AC | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heat pump | 0.91 | 1.00 | 1.05 | 1.11 | 0.97 |
| Electric resistance heat with AC | 0.65 | 0.80 | 0.90 | 1.00 | 0.75 |
| Electric resistance heat with no AC | 0.57 | 0.69 | 0.76 | 0.83 | 0.65 |
| No heat with AC | 1.06 | 1.13 | 1.17 | 1.15 | 1.12 |
| Unconditioned space | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heating/cooling unknown[20] | 0.88 | 0.98 | 1.04 | 1.07 | 0.95 |

* IEF for homes with no AC is most appropriate for customers with evaporative cooling or room air conditioners.

[18] The average daily usage of 2.2 hours per day is a blended value for indoor and outdoor lamps. Source: Evaluation of 2008 Texas 'Make Your Mark' Statewide CFL Program Report. Frontier Energy. June 2009.

[19] Extracted from BEopt energy models used to estimate savings for envelope measures. Referencing the EISA baseline table, the typical lumen output was determined by taking the midpoint for the 60-watt equivalent lamp (900 lumens), which was assumed to be the most typical installation. The resulting lumens were divided by the default wattage for incandescents (43 W), CFLs (13 W), and LEDs (10 W) resulting in an assumed efficacy for incandescents (21 lm/W), CFLs (70 lm/W), and LEDs (90 lm/W). IEF values were calculated using the following formula: $1 + HVAC_{savings}/Lighting_{savings}$.

[20] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16 percent outdoor lighting except for upstream defaults. Cadmus report: Cadmus. Entergy Energy-Efficiency Portfolio Evaluation Report 2013 Program Year. Prepared for Entergy Arkansas, Inc. March 14, 2014. Docket No. 07-082-TF.

**Table 5. GSL LEDs—In-Service Rates by Program Type**

| Program type | ISR |
|---|---|
| Low-income community kits[21] | 0.88 |
| All other kit programs[22] | 0.60 |
| Retail (time of sale)[23] | 0.76 |
| Midstream/upstream | |
| Direct install[24] | 0.97 |

## *Demand Savings*

Summer and winter demand savings are determined by applying a coincidence factor associated with each season.

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{(W_{base} - W_{post})}{1{,}000} \times CF_S \times ISR \times IEF_{D,S}$$

**Equation 2**

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{(W_{base} - W_{post})}{1{,}000} \times CF_W \times ISR \times IEF_{D,W}$$

**Equation 3**

*Where:*

| | | |
|---|---|---|
| $CF_{S/W}$ | = | *Seasonal peak coincidence factor (see Table 6)* |
| $IEF_D$ | = | *Interactive effects factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 7)* |

[21] Kits targeting low-income qualified communities. From Illinois TRM v10, based on 2018 Ameren Illinois income-qualified participant survey. Representative of first-year installations.

[22] From Illinois TRM v10 based on evaluation of ComEd PY9 Elementary Energy Education program. Representative of first-year installations.

[23] From Illinois TRM v10 based on evaluations of ComEd PY8, PY9, and CY2018 and Ameren PY8 programs. Representative of first-year installations.

[24] Dimetrosky, S., Parkinson, K. and Lieb, N. "Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures." January 2015. ISR for upstream programs, including storage lamps installed within four years of purchase. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf.

**Table 6. GSL LEDs—Coincidence Factors[25]**

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 0.060 | 0.053 | 0.063 | 0.059 | 0.032 |
| Winter | 0.275 | 0.232 | 0.199 | 0.263 | 0.358 |

**Table 7. GSL LEDs—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[26]**

| $IEF_{D,S}$ | | | | | |
|---|---|---|---|---|---|
| Heating/cooling type* | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
| Gas heat with AC | 1.45 | 1.33 | 1.68 | 1.23 | 1.44 |
| Gas heat with no AC | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heat pump | 1.45 | 1.33 | 1.68 | 1.23 | 1.44 |
| Electric resistance heat with AC | 1.45 | 1.33 | 1.68 | 1.23 | 1.44 |
| Electric resistance heat with no AC | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| No heat with AC | 1.45 | 1.33 | 1.68 | 1.23 | 1.44 |
| Unconditioned space | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heating/cooling unknown[27] | 1.39 | 1.28 | 1.58 | 1.20 | 1.38 |
| $IEF_{D,W}$ | | | | | |
| Heating/cooling type* | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4 Corpus Christi | Climate Zone 5 El Paso |
| Gas heat with AC | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| Gas heat with no AC | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heat pump | 0.71 | 0.67 | 0.65 | 0.74 | 0.81 |
| Electric resistance heat with AC | 0.44 | 0.36 | 0.38 | 0.42 | 0.52 |
| Electric resistance heat with no AC | 0.44 | 0.36 | 0.38 | 0.42 | 0.52 |
| No heat with AC | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| Unconditioned space | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heating/cooling unknown[28] | 0.76 | 0.72 | 0.73 | 0.75 | 0.80 |

* IEF for homes with no AC is most appropriate for customers with evaporative cooling or room air conditioners.

[25] See Volume 1.
[26] Refer to Table 4.
[27] Ibid.
[28] Ibid.

### *Low-Income and Hard-to-Reach Direct Install Programs*

Annual energy (kilowatt-hours, kWh) and peak demand (kilowatts, kW) may be calculated separately for two time periods:

- The estimated remaining life of the equipment that is being removed (incandescent or halogen lamp), designated the remaining useful life (RUL), and
- The remaining time in the EUL period (EUL – RUL).

Annual energy and peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in the Volume 3 appendices.

*Where:*

| | | |
|---|---|---|
| *RUL* | = | *Remaining useful life = 2 years* |
| *EUL* | = | *Estimated useful life = 16 or 20 years (see Measure Life and Lifetime Savings section)* |

### *Upstream/Midstream Program Assumptions*

All GSLs with an equivalent wattage of 100 W or lower distributed though 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 five percent of savings allocated to the commercial sector.[29] 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.

## 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.

[29] Weighting assumptions based on statewide evaluator review of LED purchasing behavior for similar program designs as referenced in the 2018 EM&V Upstream Lighting memo.

## 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

Historically, the average measure life is based upon the rated lamp life of the LED. The measure life assumes an average use of 2.2 hours per day based on blended usage for indoor/outdoor applications and applies a 0.85 degradation factor to indoor/outdoor LEDs.

$$EUL_{Total} = \frac{Rated\ Life \times DF}{HOU \times 365.25}$$

**Equation 4**

*Where:*

*Rated Life* = *10,000 hours, 12,000 hours, 15,000 hours, or 20,000 hours, as specified by the manufacture; if unknown, assume a 10,000-hour lifetime*[30]

*DF* = *0.85 degradation factor*[31]

*HOU* = *2.2 hours per day*[32]

**Table 8. GSL LEDs—Estimated Useful Life**

| Range of rated measure life (hours) | Assumed rated measure life (hours) | Rated product lifetime (years) |
|---:|---:|---:|
| $\leq$ 17,500 | 15,000 | 16 |
| > 17,500 | 20,000 | 20* |

* Measure life capped at 20 years. EUL may be deemed at 16 years in lieu of documenting the customer baseline.

[30] Minimum lifetime requirement under ENERGY STAR Lamps Specification V2.1, effective January 2, 2017. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf.

[31] ENERGY STAR CFL Third Party Testing and Verification Off-the-Shelf CFL Performance: Batch 3. Figure 27, p. 47.

[32] The average daily usage of 2.2 hours per day is a blended value for indoor and outdoor lamps. Source: Evaluation of 2008 Texas 'Make Your Mark' Statewide CFL Program Report. Frontier Energy. June 2009.

## 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
- Program delivery type (low-income targeted kits, non-low-income targeted kits, retail, direct install)
- Number of LEDs installed
- Wattage of each replacement LED
- Lumen output of each replacement LED
- Manufacturer-rated lifetime of each replacement LED in hours
- Heating system type (gas, electric resistance, heat pump, none, unknown)
- Cooling system type (air conditioner, evaporative, none, unknown)
- Location of replacement lamp (conditioned, unconditioned, or outdoor); only required when not assuming default weighting
- Proof of purchase – with date of purchase and quantity
    - Alternative: representative photos of replacement units or another pre-approved method of installation verification
- ENERGY STAR certificate matching replacement model number
    - Alternative: another pre-approved method of certification (e.g., LM-79, LM-80, TM-21 ISTMT lap reports)
- For low-income and hard-to-reach direct install programs, photo documentation clearly showing the lamp type and approximate quantity replaced or other pre-approved method of verification
- For new construction projects only, these data points must be gathered for all permanently installed fixtures in the home to document the percentage that are high-efficacy.

## 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 9. GSL LEDs—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v3.0 | 4/10/2015 | TRM v3.0 origin. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Modification of in-service rate, revision of interactive effects factors to reflect indoor-specific values for additional heating and cooling equipment types. Provided default input assumptions for upstream lighting programs. Capped estimated measure life. |
| v3.1 | 3/28/2016 | TRM v3.1 March revision. Updated summer and winter coincidence factors. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Updated IEF values and useful life estimates. |
| v5.0 | 10/2017 | TRM v5.0 update. Updated EUL algorithm to account for baseline change beginning in 2021. Included language to deem EUL. |
| v6.0 | 11/2018 | TRM v6.0 update. Updated useful life estimates. Updated interactive effects factors. |
| v7.0 | 10/2019 | TRM v7.0 update. Removed dual baseline and updated useful life estimates. Added invoice and certificate requirements. Added option for new construction savings. |
| v8.0 | 10/2020 | TRM v8.0 update. Defined midstream methodology and clarified default wattages by lumen range. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated midstream methodology and added path for fixtures. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated for compliance with new DOE GSL definition and reinstatement of EISA 45 lumens/watt backstop. |
| v11.0 | 10/2023 | TRM v11.0 update. Added in-service rates by program type. |

## 2.1.2 ENERGY STAR® Specialty LED Lamps Measure Overview

**TRM Measure ID:** R-LT-SP

**Market Sector:** Residential

**Measure Category:** Lighting

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive and direct install

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This measure provides a method for calculating savings for replacement of an incandescent or halogen reflector or decorative lamp with an ENERGY STAR-compliant LED specialty lamp in a residential application. These lamps are limited to the following lamp types, defined by the current federal standard[33] and further reduced to only include lamps that are common to utility rebate programs.

- G-shape lamps that have a first number symbol less than or equal to 12.5 (diameter less than or equal to 1.5625 inches)
- G-shape lamps with a diameter of five inches or more
- MR-shape lamps that have a first symbol equal to 16 (diameter equal to two inches) and have a lumen output greater than or equal to 800 lumens
- Reflector lamps that have a first number symbol less than 16 (diameter less than two inches) and that do not have E26/E24, E26d, E26/50x39, E26/53x39, E29/28, E29/53x39, E39, E39d, EP39, or EX39 bases

## Eligibility Criteria

These savings values rely on usage patterns specific to both indoor and outdoor applications. In lieu of collecting lamp location, a default weighting of 90.5 percent indoor and 9.5 percent outdoor may be assumed.[34]

New homes must exceed the lighting equipment requirements of the current state building code (IECC 2015) to be eligible for prescriptive lighting savings.

[33] DOE Final Rule: Definitions for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0012-0022.

[34] 2015 US Lighting Market Characterization, Department of Energy. November 2017. Table 4.11. https://www.energy.gov/sites/prod/files/2017/12/f46/lmc2015_nov17.pdf.

Fixtures with integrated LEDs may be eligible under this measure using a modified baseline.

## Baseline Condition

On May 8, 2022, the Department of Energy (DOE) issued two final rules relating to general service lamps:

- Energy Conservation Program: Definitions for General Service Lamps (GSL), effective July 8, 2022, which expanded the definition of general service lamp.[35]
- Energy Conservation Program: Energy Conservation Standards for General Service Lamps, effective July 25, 2022, which shifted the baseline to 45 lumens per watt efficacy.[36]

For all products not defined as GSLs, the baseline is assumed to be the incandescent equivalent wattage. The baseline wattage will be determined based on the bulb shape of the installed lamp, as outlined below. New construction applications use the same baselines. However, savings can only be claimed for efficient lighting installed above the minimum amount required by code. Current code dictates 75 percent high-efficacy lighting. Therefore, if 100 percent of installed lighting is high-efficacy, savings can be claimed for the remaining 25 percent of installed lamps.

Due to the variability among fixture types compared to screw-in lamps, qualified fixtures with integrated LEDs should use the rated installed wattage and equivalent wattage, or other approved custom methodology, in lieu of the deemed values outlined in this section. These wattages are available on the ENERGY STAR certificate and can be used in combination with the deemed savings methodologies provided in this measure.

**Table 10. Specialty LEDs—Baseline and Default Wattages[37]**

| Lamp type[38] | Minimum lumens | Maximum lumens | $W_{Base}$ |
|---|---|---|---|
| G-shape with diameter $\geq$ 5 in.[39] | – | – | Qualified Products List (QPL) |
| MR16/MRX16 | 800 | – | 75 |
| R14 | 250 | 299 | 25 |

[35] DOE Final Rule: Definitions for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0012-0022.

[36] DOE Final Rule: Energy Conservation Standards for General Service Lamps. https://www.regulations.gov/document/EERE-2021-BT-STD-0005-0070.

[37] Due to large variation in lamp types, use rated value from ENERGY STAR QPL where not specified: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.

[38] Lamp types excluded from this table were not included on the ENERGY STAR QPL. For missing lamp types, refer to the equivalent and rated wattages from the ENERGY STAR certification.

[39] G-shape lamps are not included because there were very few ENERGY STAR-qualified products with a diameter of 5 inches or more. For these products, use the equivalent and rated wattages from the ENERGY STAR certification.

## High- Efficiency Condition

The high-efficiency condition is the wattage of the replacement lamp. LEDs must be ENERGY STAR-compliant[40] for the relevant lamp shape being removed as outlined in the latest ENERGY STAR specification.[41] Alternatively, lab testing reports (e.g., LM-79, LM-80, TM-21, ISTMT) are also accepted as a method of certification.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Wattage reduction is defined as the difference between the wattage of a specialty baseline lamp and the wattage of a directional or specialty LED.

For new construction projects, programs should calculate savings using the methodology in this section for all efficient lamps installed in the home. The program should claim savings for the percentage of installed high-efficacy lamps that exceed the minimum required by code, which is currently 75 percent of lamps. For example, if a new home is built with high-efficacy lamps in 85 percent of the permanently installed fixtures, the program would claim 10 percent of the total calculated savings.

### *Energy Savings Algorithms*

Annual energy (kWh) savings are calculated as follows:

$$Energy\ Savings\ [\Delta kWh] = \frac{(W_{base} - W_{post})}{1{,}000} \times HOU \times ISR \times IEF_E$$

**Equation 5**

*Where:*

| | | |
|---|---|---|
| $W_{base}$ | = | *EISA-exempt specialty lamp or a DOE-ruling-exempt reflector (see Table 10)* |
| $W_{post}$ | = | *Actual wattage of LED purchased/installed* |
| *HOU* | = | *Average hours of use per year = 803 hours (for interior/exterior applications calculated based on an average daily usage of 2.2 hours per day[42])* |

[40] ENERGY STAR QPL: https://www.energystar.gov/productfinder/product/certified-light-bulbs/results.
[41] ENERGY STAR specification: http://www.energystar.gov/products/certified-products/detail/light-bulbs.
[42] The average daily usage of 2.2 hours per day is a blended value for indoor and outdoor lamps. Source: Evaluation of 2008 Texas 'Make Your Mark' Statewide CFL Program Report. Frontier Energy (formerly Associates). June 2009.

| | | |
|---|---|---|
| *$IEF_E$* | = | *Interactive effects factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 11)* |
| *ISR* | = | *In-service rate, the percentage of incentivized units that are installed and in use (rather than removed, stored, or burnt out) to account for units incentivized but not operating (see Table 12)* |
| *1,000* | = | *Constant to convert from W to kW* |

**Table 11. Specialty LEDs—Interactive Effects for Cooling Energy Savings and Heating Energy Penalties**[43]

| | $IEF_E$ | | | | |
|---|---|---|---|---|---|
| **Heating/cooling type*** | **Climate Zone 1: Amarillo** | **Climate Zone 2: Dallas** | **Climate Zone 3: Houston** | **Climate Zone 4: Corpus Christi** | **Climate Zone 5: El Paso** |
| Gas heat with AC | 1.06 | 1.13 | 1.17 | 1.15 | 1.12 |
| Gas heat with no AC | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heat pump | 0.91 | 1.00 | 1.05 | 1.11 | 0.97 |
| Electric resistance heat with AC | 0.65 | 0.80 | 0.90 | 1.00 | 0.75 |
| Electric resistance heat with no AC | 0.57 | 0.69 | 0.76 | 0.83 | 0.65 |
| No heat with AC | 1.06 | 1.13 | 1.17 | 1.15 | 1.12 |
| Unconditioned space | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heating/cooling unknown[44] | 0.88 | 0.98 | 1.04 | 1.07 | 0.95 |

* IEF for homes with no AC is most appropriate for customers with evaporative cooling or room air conditioners.

[43] Extracted from BEopt energy models used to estimate savings for envelope measures. Referencing the EISA baseline table, the typical lumen output was determined by taking the midpoint for the 60-watt equivalent lamp (900 lm), which was assumed to be the most typical installation. The resulting lumens were divided by the default wattage for incandescents (43 W), CFLs (13 W), and LEDs (10 W) resulting in an assumed efficacy for incandescents (21 lm/W), CFLs (70 lm/W), and LEDs (90 lm/W). IEF values were calculated using the following formula: $1 + HVAC_{savings}/Lighting_{savings}$.

[44] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16 percent outdoor lighting except for upstream defaults. Cadmus report: Cadmus. Entergy Energy-Efficiency Portfolio Evaluation Report 2013 Program Year. Prepared for Entergy Arkansas, Inc. March 14, 2014. Docket No. 07-082-TF.

**Table 12. Specialty LEDs—In-Service Rates by Program Type**

| Program type | ISR |
|---|---|
| Low-income community kits[45] | 0.88 |
| All other kit programs[46] | 0.60 |
| Retail (time of sale)[47] | 0.76 |
| Direct install[48] | 0.97 |

### *Demand Savings Algorithms*

Summer and winter demand savings are determined by applying a coincidence factor associated with each season.

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{(W_{base} - W_{post})}{1{,}000} \times CF_S \times ISR \times IEF_{D,S}$$

**Equation 6**

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{(W_{base} - W_{post})}{1{,}000} \times CF_W \times ISR \times IEF_{D,W}$$

**Equation 7**

*Where:*

$CF_{S/W}$ = *Seasonal peak coincidence factor (Table 13)*

$IEF_D$ = *Interactive effects factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 14)*

**Table 13. Specialty LEDs—Coincidence Factors[49]**

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 0.060 | 0.053 | 0.063 | 0.059 | 0.032 |
| Winter | 0.275 | 0.232 | 0.199 | 0.263 | 0.358 |

[45] Kits targeting low-income qualified communities. From Illinois TRM v10, based on 2018 Ameren Illinois income-qualified participant survey. Representative of first-year installations.

[46] From Illinois TRM v10 based on evaluation of ComEd PY9 Elementary Energy Education program. Representative of first-year installations.

[47] From Illinois TRM v10 based on evaluations of ComEd PY8, PY9, and CY2018 and Ameren PY8 programs. Representative of first-year installations.

[48] Dimetrosky, S., Parkinson, K. and Lieb, N. “Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures.” January 2015. ISR for upstream programs, including storage lamps installed within four years of purchase. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf.

[49] See Volume 1

**Table 14. Specialty LEDs—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties**[50]

| $IEF_{D,S}$ | | | | | |
|---|---|---|---|---|---|
| Heating/cooling type* | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
| Gas heat with AC | 1.45 | 1.33 | 1.68 | 1.23 | 1.44 |
| Gas heat with no AC | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heat pump | 1.45 | 1.33 | 1.68 | 1.23 | 1.44 |
| Electric resistance heat with AC | 1.45 | 1.33 | 1.68 | 1.23 | 1.44 |
| Electric resistance heat with no AC | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| No heat with AC | 1.45 | 1.33 | 1.68 | 1.23 | 1.44 |
| Unconditioned space | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heating/cooling unknown[51] | 1.39 | 1.28 | 1.58 | 1.20 | 1.38 |
| $IEF_{D,W}$ | | | | | |
| Heating/cooling type* | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
| Gas heat with AC | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| Gas heat with no AC | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heat pump | 0.71 | 0.67 | 0.65 | 0.74 | 0.81 |
| Electric resistance heat with AC | 0.44 | 0.36 | 0.38 | 0.42 | 0.52 |
| Electric resistance heat with no AC | 0.44 | 0.36 | 0.38 | 0.42 | 0.52 |
| No heat with AC | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| Unconditioned space | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heating/cooling unknown[52] | 0.76 | 0.72 | 0.73 | 0.75 | 0.80 |

* IEF for homes with no AC is most appropriate for customers with evaporative cooling or room air conditioners.

[50] Refer to Table 11.

[51] Calculated using IEFs from a Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16 percent outdoor lighting except for upstream defaults. Cadmus report: Cadmus. Entergy Energy-Efficiency Portfolio Evaluation Report 2013 Program Year. Prepared for Entergy Arkansas, Inc. March 14, 2014. Docket No. 07-082-TF.

[52] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16 percent outdoor lighting except for upstream defaults. Cadmus report: Cadmus. Entergy Energy-Efficiency Portfolio Evaluation Report 2013 Program Year. Prepared for Entergy Arkansas, Inc. March 14, 2014. Docket No. 07-082-TF.

### *Upstream/Midstream Program Assumptions*

All general service, decorative, and reflector lamps with an equivalent wattage of 100 W or lower distributed though 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 five percent of savings allocated to the commercial sector.[53] 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.

## 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

Historically, the average measure life is based upon rated lamp life of the LED. The measure life assumes an average use of 2.2 hours per day based on blended usage for indoor/outdoor applications and applies a 0.85 degradation factor to indoor/outdoor LEDs.

$$EUL_{Total} = \frac{Rated\ Life \times DF}{HOU \times 365.25}$$

**Equation 8**

[53] Weighting assumptions based on statewide evaluator review of LED purchasing behavior for similar program designs as referenced in the 2018 EM&V upstream lighting memo.

*Where:*

| | | |
|---|---|---|
| *Rated Life* | = | *10,000 hours, 12,000 hours, 15,000 hours, or 20,000 hours, as specified by the manufacturer; if unknown, assume a 10,000-hour lifetime*[54] |
| *DF* | = | *0.85 degradation factor*[55] |
| *HOU* | = | *2.2 hours per day*[56] |

**Table 15. Specialty LEDs—Estimated Useful Life**

| Range of rated measure life (hours) | Assumed rated measure life (hours) | Specialty measure life (years) |
|---|---|---|
| ≤ 17,500 | 15,000 | 16 |
| > 17,500 | 20,000 | 20* |

* Measure life capped at 20 years. EUL may be deemed at 16 years in lieu of collecting manufacturer rated life or documenting customer baseline.

## 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
- Program delivery type (low-income targeted kits, non-low-income targeted kits, retail, direct install)
- Number of LEDs installed
- ANSI C79.1-2002 nomenclature of LED installed (G40, PAR, etc.)
- Baseline and rated wattages of each replacement LED
- Lumen output of each replacement LED
- Manufacturer-rated lifetime of each replacement LED in hours
- Heating system type (gas, electric resistance, heat pump, none, unknown)
- Cooling system type (air conditioner, evaporative cooler, none, unknown)

54 Minimum lifetime requirement under ENERGY STAR Lamps Specification V2.1, effective January 2, 2017. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V2.1%20Final%20Specification.pdf.

55 ENERGY STAR CFL Third Party Testing and Verification Off-the-Shelf CFL Performance: Batch 3. Figure 27, p. 47.

56 The average daily usage of 2.2 hours per day is a blended value for indoor and outdoor lamps. Source: Evaluation of 2008 Texas 'Make Your Mark' Statewide CFL Program Report. Frontier Energy (formerly Associates). June 2009.

- Location of installed lamp (conditioned, unconditioned, or outdoor); only required when not assuming default weighting
- Baseline calculation methodology (EISA-affected non-reflector, EISA-exempt non-reflector, DOE-ruling-affected reflector, DOE-ruling-exempt reflector, manufacturer-rated equivalent incandescent wattage, or default wattage)
- Proof of purchase – with date of purchase and quantity
  - Alternative: representative photos of installed units or other pre-approved method of installation verification
- ENERGY STAR certificate matching replacement model number
  - Alternative: other pre-approved method of certification (e.g., LM-79, LM-80, TM-21, ISTMT lap reports)
- For new construction projects only, these data points must be gathered for all permanently installed fixtures in the home to document the percentage that are high-efficacy.

## 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 16. Specialty LEDs—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v3.0 | 4/10/2015 | TRM v3.0 origin. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Modification of in-service rate, revision of interactive effects factors to reflect indoor-specific values for additional heating and cooling equipment types. Consolidated default input assumptions for upstream lighting programs. Capped estimated measure life. |
| v3.1 | 3/28/2016 | TRM v3.1 March revision. Updated summer and winter coincidence factors. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Updated IEF values. |
| v5.0 | 10/2017 | TRM v5.0 update. Updated useful life estimates. |
| v6.0 | 11/2018 | TRM v6.0 update. Updated useful life estimates. Updated interactive effects factors. |

| TRM version | Date | Description of change |
|---|---|---|
| v7.0 | 10/2019 | TRM v7.0 update. Removed dual baseline and updated useful life estimates. Added invoice and certificate requirements. Added option for new construction savings. |
| v8.0 | 10/2020 | TRM v8.0 update. Defined midstream methodology and clarified default wattages by lumen range. Updated specialty lamps baselines. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated midstream methodology and added path for fixtures. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated for compliance with new DOE GSL definition. Several lamp types previously considered *specialty lamps* moved to *general service lamp* measure. |
| v11.0 | 10/2023 | TRM v11.0 update. Added in-service rates by program type. |

## 2.1.3 LED Nightlights Measure Overview

**TRM Measure ID:** R-LT-NL

**Market Sector:** Residential

**Measure Category:** Lighting

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive and direct install

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This measure provides a method for calculating savings for the replacement of an incandescent nightlight with an LED or electroluminescent nightlight.

## Eligibility Criteria

This measure applies to all LED nightlights installed in a residential application.

## Baseline Condition

The baseline condition is assumed to be an incandescent/halogen nightlight.

## High-Efficiency Condition

The high-efficiency condition is a qualified LED nightlight.

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Energy Savings*

Annual energy (kilowatt-hours, kWh) savings are calculated as follows.

$$Energy\ Savings\ [\Delta kWh] = \frac{(W_{base} - W_{post})}{1{,}000} \times Hours \times ISR \times IEF_E$$

**Equation 9**

*Where:*

| | | |
|---|---|---|
| $W_{base}$ | = | *Baseline wattage. Use actual wattage if known (default = 7 W)*[57] |
| $W_{post}$ | = | *Actual wattage of LED purchased/installed (default = 1 W for LED)* |
| *HOU* | = | *Average hours of use per year = 4,161 hours*[58] |
| $IEF_E$ | = | *Interactive effects factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 17)* |
| *ISR* | = | *In-service rate, the percentage of incentivized units that are installed and in use (rather than removed, stored, or burnt out) to account for units incentivized but not operating (see Table 18)* |
| *1,000* | = | *Constant to convert from W to kW* |

**Table 17. LED Nightlights—Interactive Effects for Cooling Energy Savings and Heating Energy Penalties**[59]

| $IEF_E$ | | | | | |
|---|---|---|---|---|---|
| **Heating/cooling type*** | **Climate Zone 1: Amarillo** | **Climate Zone 2: Dallas** | **Climate Zone 3: Houston** | **Climate Zone 4: Corpus Christi** | **Climate Zone 5: El Paso** |
| Gas heat with AC | 1.06 | 1.13 | 1.17 | 1.15 | 1.12 |
| Gas heat with no AC | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heat pump | 0.91 | 1.00 | 1.05 | 1.11 | 0.97 |
| Electric resistance heat with AC | 0.65 | 0.80 | 0.90 | 1.00 | 0.75 |
| Electric resistance heat with no AC | 0.57 | 0.69 | 0.76 | 0.83 | 0.65 |
| No heat with AC | 1.06 | 1.13 | 1.17 | 1.15 | 1.12 |

57 Mertz, Stanley. "LED Nightlights Energy Efficiency Retail products programs." March 2018.

58 Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights," Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2 and 3.

59 Extracted from BEopt energy models used to estimate savings for envelope measures. Referencing the EISA baseline table, the typical lumen output was determined by taking the midpoint for the 60-watt equivalent lamp (900 lm), which was assumed to be the most typical installation. The resulting lumens were divided by the default wattage for incandescents (43 W), CFLs (13 W), and LEDs (10 W) resulting in an assumed efficacy for incandescents (21 lm/W), CFLs (70 lm/W), and LEDs (90 lm/W). IEF values were calculated using the following formula: $1 + HVAC_{savings}/Lighting_{savings}$.

| IEF$_E$ | | | | | |
|---|---|---|---|---|---|
| Heating/cooling type* | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
| Unconditioned space | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heating/cooling unknown[60] | 0.88 | 0.98 | 1.04 | 1.07 | 0.95 |

* IEF for homes with no AC is most appropriate for customers with evaporative cooling or room air conditioners.

**Table 18. LED Nightlights—In-Service Rates by Program Type**

| Program type | ISR |
|---|---|
| Low-income community kits[61] | 0.88 |
| All other kit programs[62] | 0.60 |
| Retail (time of sale)[63] | 0.76 |
| Direct install[64] | 0.97 |

## *Demand Savings*

Summer and winter demand savings are determined by applying a coincidence factor associated with each season.

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{(W_{base} - W_{post})}{1{,}000} \times CF_S \times ISR \times IEF_{D,S}$$

**Equation 10**

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{(W_{base} - W_{post})}{1{,}000} \times CF_W \times ISR \times IEF_{D,W}$$

**Equation 11**

[60] Calculated using IEFs from a Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16 percent outdoor lighting except for upstream defaults. Cadmus report: Cadmus. Entergy Energy-Efficiency Portfolio Evaluation Report 2013 Program Year. Prepared for Entergy Arkansas, Inc. March 14, 2014. Docket No. 07-082-TF.

[61] Kits targeting low-income qualified communities. From Illinois TRM v10, based on 2018 Ameren Illinois income-qualified participant survey. Representative of first-year installations.

[62] From Illinois TRM v10 based on evaluation of ComEd PY9 Elementary Energy Education program. Representative of first-year installations.

[63] From Illinois TRM v10 based on evaluations of ComEd PY8, PY9, and CY2018 and Ameren PY8 programs. Representative of first-year installations.

[64] Dimetrosky, S., Parkinson, K. and Lieb, N. “Residential Lighting Evaluation Protocol – The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures.” January 2015. ISR for upstream programs, including storage lamps installed within four years of purchase. http://energy.gov/sites/prod/files/2015/02/f19/UMPChapter21-residential-lighting-evaluation-protocol.pdf.

*Where:*

| | | |
|---|---|---|
| $CF_{S/W}$ | = | *Seasonal peak coincidence factor (see Table 19)* |
| $IEF_D$ | = | *Interactive effects factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 20)* |

**Table 19. LED Nightlights—Coincidence Factors**[65]

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Winter | 0.67 | 0.71 | 0.61 | 0.75 | 1.00 |

**Table 20. LED Nightlights—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties**[66]

| $IEF_{D,S}$ | | | | | |
|---|---|---|---|---|---|
| Heating/cooling type* | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
| Gas heat with AC | 1.45 | 1.33 | 1.68 | 1.23 | 1.44 |
| Gas heat with no AC | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heat pump | 1.45 | 1.33 | 1.68 | 1.23 | 1.44 |
| Electric resistance heat with AC | 1.45 | 1.33 | 1.68 | 1.23 | 1.44 |
| Electric resistance heat with no AC | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| No heat with AC | 1.45 | 1.33 | 1.68 | 1.23 | 1.44 |
| Unconditioned space | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heating/cooling unknown[67] | 1.39 | 1.28 | 1.58 | 1.20 | 1.38 |

[65] From TX TRM *commercial lamps & fixtures* measure for dusk-to-dawn operation.
[66] Refer to Table 20.
[67] Ibid.

| IEF$_{D,W}$ | | | | | |
|---|---|---|---|---|---|
| Heating/cooling type* | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
| Gas heat with AC | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| Gas heat with no AC | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heat pump | 0.71 | 0.67 | 0.65 | 0.74 | 0.81 |
| Electric resistance heat with AC | 0.44 | 0.36 | 0.38 | 0.42 | 0.52 |
| Electric resistance heat with no AC | 0.44 | 0.36 | 0.38 | 0.42 | 0.52 |
| No heat with AC | 0.98 | 0.98 | 0.98 | 0.98 | 0.98 |
| Unconditioned space | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Heating/cooling unknown[68] | 0.76 | 0.72 | 0.73 | 0.75 | 0.80 |

* IEF for homes with no AC is most appropriate for customers with evaporative cooling or room air conditioners.

### *Upstream/Midstream Program Assumptions*

All general service lamps with an equivalent wattage of 100 W or lower distributed though 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.[69] 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.

## 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.

[68] Ibid.

[69] Weighting assumptions based on statewide evaluator review of LED purchasing behavior for similar program designs as referenced in the 2018 EM&V upstream lighting memo.

## Additional Calculators and Tools

Not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) for LED nightlights is 8 years.[70]

## 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
- Program delivery type (low-income targeted kits, non-low-income targeted kits, retail, direct install)
- Number of LED nightlights installed
- LED nightlight wattage
- Heating system type (gas, electric resistance, heat pump, none, unknown)
- Cooling system type (air conditioner, evaporative, none, unknown)
- Proof of purchase – with date of purchase and quantity
    - Alternative: representative photos of replacement units or another pre-approved method of installation verification

## References and Efficiency Standards

Not applicable.

## Petitions and Rulings

Not applicable.

## Relevant Standards and Reference Sources

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

[70] Southern California Edison Company, "LED, Electroluminescent & Fluorescent Night Lights," Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2 and 3.

## Document Revision History

**Table 21. LED Nightlights—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v10.0 | 10/2022 | TRM v10.0 origin. |
| v11.0 | 10/2023 | TRM v11.0 update. Added in-service rates by program type. |

## 2.2 RESIDENTIAL: HEATING, VENTILATION, AND AIR CONDITIONING

### 2.2.1 Air Conditioner and Heat Pump Tune-Ups Measure Overview

**TRM Measure ID:** R-HV-TU

**Market Sector:** Residential

**Measure Category:** HVAC

**Applicable Building Types:** Single-family, multifamily, manufactured

**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 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, on average, closer to as-new performance. This measure applies to all residential 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.

Air conditioner inspection and tune-up checklist:[71]

- Tighten all electrical connections, measure motor voltage and current
- Lubricate all moving parts, including motor and fan bearings
- Inspect and clean the condensate drain
- Inspect controls of the system to ensure proper and safe operation. Check the startup/shutdown cycle of the equipment to assure the system starts, operates, and shuts off properly.
- Clean evaporator and condenser coils

[71] Based on ENERGY STAR HVAC Maintenance Checklist. www.energystar.gov/index.cfm?c=heat_cool.pr_maintenance.

- Clean indoor blower fan components
- 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.[72] All residential customers are eligible for this measure if they have refrigerated air conditioning 65,000 Btu/hr or less in cooling capacity that has not been serviced through a utility program in the last five years.

This measure is also applicable to packaged terminal air conditioners and heat pumps (PTAC/PTHPs).

## Baseline Condition

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

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

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

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

**Equation 12**

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

**Equation 13**

[72] 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.

*Where:*

| | | |
|---|---|---|
| $EER_{pre}$ | = | *Efficiency of the cooling equipment before tune-up* |
| $EL$ | = | *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 = 11.2 EER* |
| $HSPF_{pre}$ | = | *Heating efficiency of the air source heat pump before tune-up* |
| $HSPF_{post}$ | = | *Deemed heating efficiency of air source heat pumps after tune-up = 7.7 HSPF* |

### High-Efficiency Condition

After the tune-up, the equipment must be clean with airflows and refrigerant charges adjusted as appropriate and set forth above, with the added specification that 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 majority of existing, functioning units were installed under the federal standard in place between January 23, 2006, and January 1, 2015, which set a baseline of 13 SEER and 7.7 HSPF[73]. A 13 SEER is equivalent to approximately 11.2 EER[74] using the conversion developed by Lawrence Berkeley Lab and US DOE: $EER = -0.02 \times SEER^2 + 1.12 \times SEER$.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

Savings are based on an assumed efficiency loss factor of 5 percent due to dirty coils, dirty filters, improper airflow, and/or incorrect refrigerant charge.[75]

[73] Code specified HSPF from federal standard effective January 23, 2006 through January 1, 2015.

[74] 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.” US Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[75] Energy Center of Wisconsin, May 2008; “Central Air Conditioning in Wisconsin, A Compilation of Recent Field Research.”

## *Energy Savings Algorithms*

Heating energy savings are only applicable to heat pumps.

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

**Equation 14**

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

**Equation 15**

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

**Equation 16**

*Where:*

| | | |
|---|---|---|
| $Cap_C$ | = | *Rated cooling capacity of the equipment based on model number [Btuh] (1 ton = 12,000 Btuh)* |
| $Cap_H$ | = | *Rated heating capacity of the equipment based on model number [Btuh] (1 ton = 12,000 Btuh)* |
| $EER_{pre}$ | = | *Cooling efficiency of the equipment pre-tune-up using Equation 12 [Btuh/W]* |
| $EER_{post}$ | = | *Cooling efficiency of the equipment after the tune-up [Btuh/W]; assume 11.2* |
| $HSPF_{pre}$ | = | *Heating efficiency of the equipment pre-tune-up using Equation 13 [Btuh/W]* |
| $HSPF_{post}$ | = | *Heating efficiency of the equipment after the tune-up [Btuh/W]; assume 7.7* |
| $EFLH_{C/H}$ | = | *Cooling/heating equivalent full-load hours for appropriate climate zone [hours]* |

**Table 22. AC/HP Tune-Ups—Equivalent Full Load Cooling/Heating Hours[76]**

| Climate zone | $EFLH_C$ | $EFLH_H$ |
|---|---|---|
| Zone 1: Amarillo | 1,142 | 1,880 |
| Zone 2: Dallas | 1,926 | 1,343 |
| Zone 3: Houston | 2,209 | 1,127 |

[76] ENERGY STAR Central AC/HP Savings Calculator. April 2009 update. https://www.energystar.gov/sites/default/files/asset/document/ASHP_Sav_Calc.xls.

| Climate zone | $EFLH_C$ | $EFLH_H$ |
|---|---|---|
| Zone 4: Corpus Christi | 2,958 | 776 |
| Zone 5: El Paso | 1,524 | 1,559 |

### *Demand Savings Algorithms*

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = Cap_C \times \left(\frac{1}{EER_{pre}} - \frac{1}{EER_{post}}\right) \times CF_S \times \frac{1\ kW}{1{,}000\ W}$$

**Equation 17**

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = Cap_H \times \left(\frac{1}{HSPF_{pre}} - \frac{1}{HSPF_{post}}\right) \times CF_W \times \frac{1\ kW}{1{,}000\ W}$$

**Equation 18**

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.

*Where:*

$CF_{S/W}$ = *Summer/winter peak coincidence factor (see Table 23)*

**Table 23. AC/HP Tune-Ups—Coincidence Factors[77]**

| Season | CF |
|---|---|
| Summer[78] | 0.87 |
| Winter[79] | 0.83 |

## Deemed Energy Savings Tables

Applying the above algorithms results in the deemed energy savings per ton in Table 24. Heating savings are only applicable for heat pumps.

[77] Coincidence factors calculated in accordance with the current peak definition are lower than expected for the Texas climate. Residential HVAC measures will temporarily revert to the coincidence factors used in TX TRM v4.0 before the change to the peak definition. These values will be reevaluated in upcoming TRM cycles to better align with the current peak definition.

[78] Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent of the maximum cooling requirement of the residence (for cooling-dominated climates). Assuming that maximum cooling occurs during the peak period, the guideline leads to a coincidence factor of 1 / 1.15 = 0.87.

[79] ACCA Manual S recommends that residential heat pumps be sized at 115 percent of the maximum cooling requirement of the residence (for cooling dominated climates). Based on AHRI data for 1.5–5 ton HVAC systems, the average ratio of rated heating capacity to cooling capacity is 0.96. Assuming that maximum heating occurs during the peak period and adjusting for the average ratio of heating-to-cooling capacity, the guideline leads to a coincidence factor of 0.96 / 1.15 = 0.83.

**Table 24. AC/HP Tune-Ups—Energy Savings (kWh/ton)**

| Climate zone | Cooling (kWh/ton) | Heating (kWh/ton) |
|---|---|---|
| Zone 1: Amarillo | 64.4 | 154.2 |
| Zone 2: Dallas | 108.6 | 110.2 |
| Zone 3: Houston | 124.6 | 92.4 |
| Zone 4: Corpus Christi | 166.8 | 63.7 |
| Zone 5: El Paso | 85.9 | 127.9 |

## Deemed Summer Demand Savings Tables

Applying the above algorithms results in the deemed summer demand savings per ton in Table 25.

**Table 25. AC/HP Tune-Ups—Summer Peak Demand Savings (kW/ton)**

| Climate zone | Summer kW/ton |
|---|---|
| Zone 1: Amarillo | 0.049 |
| Zone 2: Dallas | |
| Zone 3: Houston | |
| Zone 4: Corpus Christi | |
| Zone 5: El Paso | |

## Deemed Winter Demand Savings Tables

Applying the above algorithms results in the deemed winter demand savings per ton in Table 26. Winter peak demand savings are only applicable for heat pumps.

**Table 26. AC/HP Tune-Ups—Peak Demand Savings (kW/ton)**

| Climate zone | Winter kW/ton |
|---|---|
| Zone 1: Amarillo | 0.068 |
| Zone 2: Dallas | |
| Zone 3: Houston | |
| Zone 4: Corpus Christi | |
| Zone 5: El Paso | |

## 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 five years.[80]

## 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:

- 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, model number, and serial number
- Cooling and heating capacity of the serviced unit (tons)
- Heating capacity of the serviced unit if applicable (tons)
- Refrigerant type
- Target superheat or subcooling
- Post tune-up superheat or subcooling
- Amount of refrigerant added or removed
- Static pressures before and after 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 name plates are useful).

## References and Efficiency Standards

## Petitions and Rulings

Not applicable.

---

[80] 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. https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf.

## Relevant Standards and Reference Sources

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

## Document Revision History

**Table 27. AC/HP Tune-Ups—History**

| TRM version | Date | Description of change |
|---|---|---|
| v4.0 | 10/10/2015 | TRM v4.0 origin. |
| v5.0 | 10/2017 | TRM v5.0 update. No revision. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. No revision. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated coincidence factors. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated EUL reference. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated coincidence factors. |
| v11.0 | 10/2023 | TRM v11.0 update. Updated demand savings. Clarified eligibility for PTACs and PTHPs. |

## 2.2.2 Central and Mini-Split Air Conditioners and Heat Pumps Measure Overview

**TRM Measure ID:** R-HV-CM

**Market Sector:** Residential

**Measure Category:** HVAC

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Replace-on-burnout, early retirement, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

Residential replacement of existing heating and cooling equipment with a new central or mini-split air-source air conditioner (AC) or heat pump (HP) in an existing building, or the installation of a new central AC or HP in a new residential construction. Downsized systems that are rightsized per heat-load calculation are also eligible. A new central system includes an entire packaged unit or a split system consisting of an indoor unit with a matching remote condensing unit. This measure also applies to the installation of dual-fuel HPs and DC inverter systems that meet all existing measure eligibility criteria.

Additional savings may be available for duct removal in combination with the installation of a ductless mini-split. In these cases, refer to the *duct sealing* measure and follow the savings methodology (standard approach) using a value of 0 cubic feet per minute (CFM) as the post-improvement duct leakage. Leakage testing must be performed on the existing ductwork to claim savings for duct removal.

### Eligibility Criteria

The deemed savings apply to units with a capacity of ≤ 65,000 Btu/hour (5.4 tons).

Equipment shall be properly sized to the dwelling based on ASHRAE or ACCA Manual J standards. Manufacturer datasheets for installed equipment or documentation of AHRI or DOE CCMS certification must be provided.[81,82] Savings should be calculated using rated capacities whenever possible. Reported system capacities and efficiencies should always match those verified by AHRI or DOE as tested under AHRI operating conditions for a specific combination

[81] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[82] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

of equipment, including condenser, coil, and furnace (or condenser only for packaged units). Savings should never be calculated using efficiency ratings for individual system components.

Customers should be advised against using the emergency heat (EM HEAT) setting on heat pump thermostats. This setting is meant only for use in emergency situations when the heat pump is damaged or malfunctioning. Supplemental heating automatically kicks on in below-freezing conditions using the regular HEAT setting. Contractors installing a new heat pump thermostat with equipment install shall advise the customer of correct thermostat usage.

For early retirement projects, to receive savings, the unit to be replaced must be functioning at the time of removal with a maximum age of 24 years for ACs and 20 years for HPs. Otherwise, claim savings for a replace-on-burnout project. Additional guidance for systems applying the default age is provided in the Savings Algorithms and Input Variables section.

The replacement of an evaporative cooler with a refrigerated system is eligible where the decision to change equipment types predates or is independent of the decision to install efficient equipment and should be claimed against the new construction baseline.

The replacement of a room AC with a central or mini-split AC or HP is eligible and should be claimed against the new construction baseline. Refer to the Replace-on-Burnout or Early Retirement of an Electric Resistance Furnace section for guidance about the appropriate heating baseline for residences with electric resistance heat. Under this scenario, no savings should be awarded for rightsizing.

System rightsizing refers to installing an HVAC system that has been sized in accordance with a load calculation, such as a Manual J, considering specific home characteristics. Rightsizing retrofit projects could include upsizing or downsizing by one-half ton or more from the existing system. New construction projects are not eligible to receive deemed savings for system rightsizing.[83]

For system downsizing, savings may be claimed against the applicable replace-on-burnout or early retirement scenario using the existing higher system pre-capacity with the lower system post-capacity if a Manual J load calculation is completed and included with project documentation.

For system upsizing, savings should generally be claimed against the new construction baseline. However, optional rightsizing savings are available for upsizing up to one ton for the scenarios outlined below. In these cases, savings may be claimed against the applicable replace-on-burnout or early retirement scenario if the specified conditions are met. For these scenarios, savings must be determined using the lower pre-tonnage. These exceptions should be applied consistently at the program level for the duration of the program year.

- Replacing a single larger capacity system with multiple smaller capacity systems.[84] If the multiple installed units do not share the same efficiency value, savings should be determined using the most conservative efficiency value.

[83] For projects using a custom baseline, see TRM Volume 4.

[84] This exception is allowed to account for efficiency improvements due to zoning that are not reflected in the current savings methodology.

- Replacing a single-stage system with a variable-speed system.[85] This scenario only applies to the replacement of a single-stage system.
- If a Manual J load calculation is completed and included with project documentation.[86]

Additionally, low-income or hard-to-reach programs may use the electric resistance baseline for the following two scenarios:

- The electric resistance baseline may be used for systems upsized by no more than a half-ton in lieu of the new construction baseline. Under this scenario, cooling savings should be claimed against the new construction baseline using the installed (higher) capacity. Heating savings should be claimed against the electric resistance baseline using the existing (lower) capacity. Documentation should be aligned with the rightsizing and electric resistance baseline requirements outlined in this measure.
- The second scenario is for a major multifamily renovation when a centralized system, such as a boiler, is replaced with individual heat pumps. For this scenario, the electric resistance baseline may be claimed in lieu of new construction only if the building owner can document intent to install electric-resistance furnaces without program intervention. The cooling savings should still be claimed against the new construction baseline. Documentation should follow early retirement and electric-resistance baseline requirements.

When replacing a single unit with multiple units where the capacity is the same or has been downsized, savings should be calculated using the total system pre- and post-capacity. Again, if the multiple installed units do not share the same efficiency value, savings should be looked up using the most conservative efficiency value.

## Baseline Condition

### *New Construction, Replace-on-Burnout, or Early Retirement of an Air-Source AC or HP*

New construction baseline efficiency values for ACs or HPs are compliant with the current federal standard,[87,88] effective January 1, 2023. The baseline is assumed to be a new system with an AHRI-listed SEER2 rating consistent with the values listed in Table 28 and Table 29. These baselines are also applicable to central ACs with gas, electric resistance, or unknown heating replacing an HP; evaporative coolers with central, space, or no heating; and room/window ACs with central, space, or no heating.

---

[85] This exception is allowed to account for efficiency improvements due to operating at variable speeds that are not reflected in the current savings methodology.

[86] This exception is allowed to account for efficiency improvements due to replacing a unit that was operating longer than designed to keep up with actual site load conditions.

[87] DOE minimum efficiency standard for residential air conditioners/heat pumps. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive.

[88] Walter-Terrinoni, Helen, "New US Energy Efficiency Standards and Refrigerants for Residential ACs and Heat Pumps." Air-Conditioning, Heating, & Refrigeration Institute (AHRI). February 1, 2022.

For replace-on-burnout projects, the cooling baselines are reduced by 4.3 percent. This value is based on Energy Systems Laboratory (ESL) survey data and incorporates an adjustment to the baseline SEER2/EER2 value to reflect the percentage of current replacements that do not include the installation of an AHRI-matched system.[89,90] Heating baselines were not included in original ESL survey data and are not adjusted.

For early retirement projects, baselines are defined in Table 28 and Table 29 based on the applicable federal standard base on manufacture year. These baselines have been converted to SEER2, EER2, and HSPF2 by extrapolating from known values referenced in the current federal standard. Systems manufactured as of January 1, 2023, are not eligible for early retirement.

For early retirement projects involving an HP replacing an AC with gas heat, early retirement cooling baselines should be used in combination with new construction heating baselines.

For all systems with a part-load efficiency rating of 15.2 SEER2 or higher, the full-load efficiency baseline is reduced to 9.8 EER2, consistent with the EER2 federal standard specified for the Southwest region. While this standard does not directly apply to Texas, it is used here to recognize a reduced full-load allowance for systems achieving higher part-load efficiency ratings. This value is not reduced based on ESL survey data. Where applicable, the reduced 9.8 EER2 baseline should be applied in lieu of the EER2 baseline value presented in Table 28 and Table 29 except where the specified baseline EER2 value is lower than 9.8 EER2.

### *Replace-on-Burnout or Early Retirement of an Electric Resistance Furnace*

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[91] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[92] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters should calculate savings using a HP baseline.

By the nature of the technology, all electric resistance furnaces have the same efficiency with HSPF = 3.412.[93] Projects in which an electric resistance furnace is replaced, either in replace-on-burnout or early retirement scenarios, use this baseline for heating-side savings.

---

[89] Frontier Energy on behalf of the Electric Utility Marketing Managers of Texas (EUMMOT). "Petition to revise Existing Commission-Approved Deemed Savings Values for Central Air Conditioning and Heat Pump Systems: Docket No. 36780." Public Utility Commission of Texas. Approved August 27, 2009. https://interchange.puc.texas.gov/. Adapted for new 14 SEER baseline.

[90] The original petition defines the reduced baseline as 12.44 SEER compared to a 13 SEER federal standard. This deemed value was converted to a percentage reduction to accommodate a transition from SEER to SEER2. No EER adjustment is discussed in the original petition because the previous deemed savings structure only awarded savings based on SEER ratings. However, supporting documentation of the original filing makes it clear that the adjustment is appropriate for both part- and full-load cooling efficiency values. Therefore, the deemed percentage reduction is applied to both SEER2 and EER2 ROB baselines.

[91] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[92] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

[93] COP = HSPF × 1,055 J/BTU / 3,600 J/W-hr. For Electric Resistance, heating efficiency is 1 COP. Therefore, HSPF = 1 × 3,600 / 1,055 = 3.412.

**Table 28. Central and Mini-Split ACs—Baseline Efficiencies**

| Project type | Capacity (Btu/hr) | Cooling mode |
|---|---|---|
| New construction, split air conditioners | < 45,000 | 14.3 SEER2<br>11.7 EER2 |
| | ≥ 45,000 | 13.8 SEER2<br>11.2 EER2 |
| New construction, packaged air conditioners | All | 13.4 SEER2<br>10.9 EER2 |
| Replace-on-burnout, split air conditioners | < 45,000 | 13.7 SEER2<br>11.2 EER2 |
| | ≥ 45,000 | 13.2 SEER2<br>10.7 EER2 |
| Replace-on-burnout, packaged air conditioners | All | 12.8 SEER2<br>10.4 EER2 |
| Early retirement, air conditioners (manufactured 1/1/2015 through 12/31/2022) | All | 12.8 SEER2<br>10.4 EER2 |
| Early retirement, air conditioners (when applying default age)[94] | All | 12.3 SEER2<br>10.0 EER2 |
| Early retirement, air conditioners (manufactured 1/23/2006 through 12/31/2014) | All | 11.9 SEER2<br>9.7 EER2 |
| Early retirement, air conditioners (manufactured before 1/23/2006) | All | 9.1 SEER2<br>7.4 EER2 |
| All systems rated at 15.2 SEER2 or higher[95] | All | 9.8 EER2 |

**Table 29. Central and Mini-Split HPs—Baseline Efficiencies**

| Project type | Cooling mode | Heating mode |
|---|---|---|
| New construction, split heat pumps | 14.3 SEER2<br>11.7 EER2 | 7.5 HSPF2 |
| New construction, packaged heat pumps | 13.4 SEER2<br>10.9 EER2 | 6.7 HSPF2 |
| Replace-on-burnout, split heat pumps | 13.7 SEER2<br>11.2 EER2 | 7.5 HSPF2 |
| Replace-on-burnout, packaged heat pumps | 12.8 SEER2<br>10.4 EER2 | 6.7 HSPF2 |

[94] Baseline efficiencies are calculated by taking the average the early retirement categories for 2006-2014 and 2015-2022.

[95] 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.

| Project type | Cooling mode | Heating mode |
|---|---|---|
| Early retirement, split heat pumps (manufactured 1/1/2015 through 12/31/2022) | 12.8 SEER2<br>10.4 EER2 | 6.9 HSPF2 |
| Early retirement, packaged heat pumps (manufactured 1/1/2015 through 12/31/2022) | 12.8 SEER2<br>10.4 EER2 | 6.7 HSPF2 |
| Early retirement, split heat pumps (when applying default age)[96] | 12.3 SEER2<br>10.0 EER2 | 6.7 HSPF2 |
| Early retirement, packaged heat pumps (when applying default age)[97] | 12.3 SEER2<br>10.0 EER2 | 6.6 HSPF2 |
| Early retirement, heat pumps (manufactured 1/23/2006 through 12/31/2014) | 11.9 SEER2<br>9.7 EER2 | 6.5 HSPF2 |
| Early retirement, heat pumps (manufactured before 1/23/2006) | 9.1 SEER2<br>7.4 EER2 | 5.7 HSPF2 |
| All systems rated at 15.2 SEER2 or higher[98] | 9.8 EER2 | – |
| Replace-on-burnout or early retirement, electric resistance furnace[99] | – | 3.412 HSPF2 |

## High-Efficiency Condition

Rated system cooling (SEER2) and heating (HSPF2) efficiencies must meet or exceed the federal standard specified in Table 28 and Table 29. HVAC equipment with SEER2 meeting federal standard minimum requirements is eligible for early retirement cooling savings with verification of age of existing equipment and removal of functional inefficient equipment. HPs with HSPF2 meeting the minimum federal standard replacing electric resistance furnaces should follow the electric resistance documentation requirements.

Since there is no full-load efficiency requirement specified in the current federal standard, systems that comply with SEER2 and HSPF2 requirements but do not comply with the EER2 requirements outlined in Table 28 and Table 29 may still be eligible to claim savings. Systems with qualifying SEER2 and HSPF2 energy ratings are permitted to claim cooling energy savings, heating energy savings, and winter demand savings for systems, but not summer demand savings where the EER2 rating does not comply with the minimum requirement.

[96] Baseline efficiencies are calculated by taking the average the early retirement categories for 2006–2014 and 2015–2022.

[97] Ibid.

[98] 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.

[99] When installing a heat pump replacing a split air conditioner with an electric resistance furnace, the reduced 3.412 HSPF2 heating baseline efficiency should be applied in lieu of the applicable value presented earlier in the table.

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.

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Energy and demand savings algorithms and associated input variables are listed below.

For early retirement or rightsizing projects, attempt to determine the rated capacity of the existing unit. The rated capacity may be found on the manufacturer specification sheet for the existing unit if the new system is not available on the AHRI or DOE CCMS directories. If the model number of the existing unit is unobtainable or if the manufacturer specification sheet cannot be found, use nominal tonnage for both the existing and new unit. Never use nominal tonnage for the existing unit in combination with rated tonnage for the new unit, which can lead to overstated savings. Additionally, never use nominal tonnage to determine savings for projects where no early retirement or rightsizing has occurred.

For early retirement, if age is unknown, assume a default age equal to the replaced unit estimated useful life (EUL) resulting in a remaining useful life (RUL) of 7 (ACs) or 6 years (HPs). Default age may be used exclusively if applied consistently for all early retirement projects. This is the only scenario where an early retirement baseline can be applied to systems older than 24 years for ACs and 20 years for HPs. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible. Default early retirement baselines are specified in Table 28 and Table 29 for use with the default age.

### *Energy Savings Algorithms*

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

**Equation 19**

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

**Equation 20**

$$Heating\ Energy\ Savings\ [kWh_H] = \left(\frac{Cap_{H,pre}}{\eta_{baseline,H}} - \frac{Cap_{H,post}}{\eta_{installed,H}}\right) \times EFLH_H \times \frac{1\ kW}{1{,}000\ W}$$

**Equation 21**

### *Demand Savings Algorithms*

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

**Equation 22**

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = \left(\frac{Cap_{H,pre}}{\eta_{baseline,H}} - \frac{Cap_{H,post}}{\eta_{installed,H}}\right) \times CF_W \times \frac{1\ kW}{1{,}000\ W}$$

**Equation 23**

*Where:*

$Cap_{C/H,pre}$ = *For early retirement (ER), cooling/heating capacity of the existing equipment; for replace-on-burnout (ROB) and new construction (NC), rated cooling/heating capacity of the new equipment [Btuh]; 1 ton = 12,000 Btuh*

$Cap_{C/H,post}$ = *Cooling/heating capacity of the new equipment [Btuh]; 1 ton = 12,000 Btuh*

*Note: When claiming early retirement or rightsizing savings, pre- and post-capacity should be expressed as a nominal tonnage multiplied by 12,000 Btuh/ton. In all other cases, pre- and post-capacity should be set equal to the rated post-capacity at AHRI standard conditions.*

$\eta_{baseline,C}$ = *Baseline 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 28 and Table 29) [Btuh/W]*

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

$\eta_{installed,H}$ = *Rated heating efficiency of the newly installed equipment (must exceed baseline efficiency standards in Table 29) [Btuh/W]*

*Note: Use SEER2 for cooling kWh, EER2 for summer kW, and HSPF2 for heating kWh and winter kW savings calculations.*

$EFLH_{C/H}$ = *Cooling/heating equivalent full-load hours (Table 30)*

$CF_{S/W}$ = *Summer/winter seasonal peak coincidence factor (Table 31)*

**Table 30. Central and Mini-Split AC/HPs—Equivalent Full Load Cooling/Heating Hours**[100]

| Climate zone | $EFLH_C$ | $EFLH_H$ |
|---|---|---|
| Zone 1: Amarillo | 1,142 | 1,880 |
| Zone 2: Dallas | 1,926 | 1,343 |
| Zone 3: Houston | 2,209 | 1,127 |
| Zone 4: Corpus Christi | 2,958 | 776 |
| Zone 5: El Paso | 1,524 | 1,559 |

**Table 31. Central and Mini-Split AC/HPs—Coincidence Factors**[101]

| Season | CF |
|---|---|
| Summer[102] | 0.87 |
| Winter[103] | 0.83 |

## *Early Retirement*

Annual energy (kWh) and summer peak demand (kW) savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period (EUL – RUL)

Annual energy and summer peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in the Volume 3 appendices.

---

100 ENERGY STAR Central AC/HP Savings Calculator.

101 Coincidence factors calculated in accordance with the current peak definition are lower than expected for the Texas climate. Residential HVAC measures will temporarily revert to the coincidence factors used in TX TRM v4.0 before the change to the peak definition. These values will be reevaluated in upcoming TRM cycles to better align with the current peak definition.

102 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent of the maximum cooling requirement of the residence (for cooling-dominated climates). Assuming that maximum cooling occurs during the peak period, the guideline leads to a coincidence factor of 1 / 1.15 = 0.87.

103 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent of the maximum cooling requirement of the residence (for cooling-dominated climates). Based on AHRI data for 1.5–5 ton HVAC systems, the average ratio of rated heating capacity to cooling capacity is 0.96. Assuming that maximum heating occurs during the peak period and adjusting for the average ratio of heating to cooling capacity, the guideline leads to a coincidence factor of 0.96 / 1.15 = 0.83.

*Where:*

| | | |
|---|---|---|
| *RUL* | = | *Remaining useful life (see Table 32 or Table 33). If individual system components were installed at separate times, use the condenser age as a proxy for the entire system. For HPs replacing an AC with an electric resistance furnace, use the AC RUL table.* |
| *EUL* | = | *Estimated useful life = 18 years (AC); 15 years (HP)* |

**Table 32. Central and Mini-Split AC/HPs—RUL of Replaced AC**

| Age of replaced unit (years) | Remaining useful life (years) | Age of replaced unit (years) | Remaining useful life (years) |
|---|---|---|---|
| 1 | 16.8 | 14 | 8.6 |
| 2 | 15.8 | 15 | 8.2 |
| 3 | 14.9 | 16 | 7.9 |
| 4 | 14.1 | 17 | 7.6 |
| 5 | 13.3 | 18 | 7.0 |
| 6 | 12.6 | 19 | 6.0 |
| 7 | 11.9 | 20 | 5.0 |
| 8 | 11.3 | 21 | 4.0 |
| 9 | 10.8 | 22 | 3.0 |
| 10 | 10.3 | 23 | 2.0 |
| 11 | 9.8 | 24 | 1.0 |
| 12 | 9.4 | 25[104,105] | 0.0 |
| 13 | 9.0 | | |

**Table 33. Central and Mini-Split AC/HPs—RUL of Replaced HP**

| Age of replaced unit (years) | Remaining useful life (years) | Age of replaced unit (years) | Remaining useful life (years) |
|---|---|---|---|
| 1 | 13.7 | 12 | 7.9 |
| 2 | 12.7 | 13 | 7.6 |
| 3 | 12.0 | 14 | 7.0 |
| 4 | 11.3 | 15 | 6.0 |
| 5 | 10.7 | 16 | 5.0 |
| 6 | 10.2 | 17 | 4.0 |
| 7 | 9.7 | 18 | 3.0 |

104 RULs are capped at the seventy-fifth percentile as determined based on DOE survival curves (see Figure 1). Systems older than this age should use the ROB baseline. See the January 2015 memo, "Considerations for Early Replacement of Residential Equipment," for further detail.

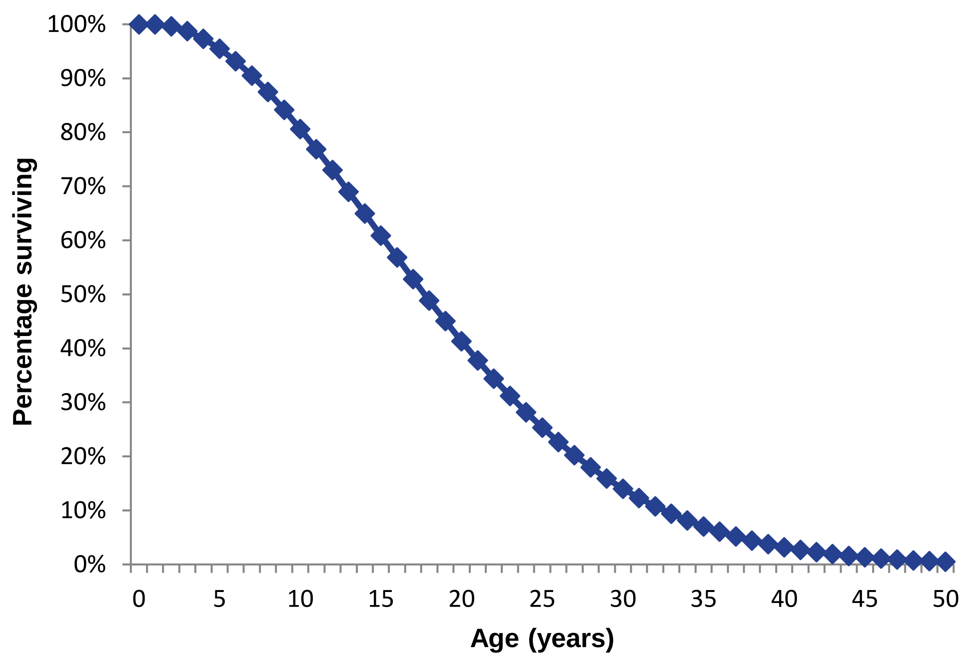
105 Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. "Considerations for Early Replacement of Residential Equipment." Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to Texas investor-owned utilities through the EM&V team's SharePoint.

| Age of replaced unit (years) | Remaining useful life (years) |
|---|---|
| 8 | 9.3 |
| 9 | 8.9 |
| 10 | 8.5 |
| 11 | 8.2 |
| 19 | 2.0 |
| 20 | 1.0 |
| 21[106] | 0.0 |

## *Derivation of RULs*

ACs have an estimated useful life of 18 years, and HPs have an estimated useful life of 15 years. This estimate is consistent with the age at which approximately 50 percent of ACs and HPs installed in a given year will no longer be in service, as described by the survival function in Figure 1 and Figure 2.

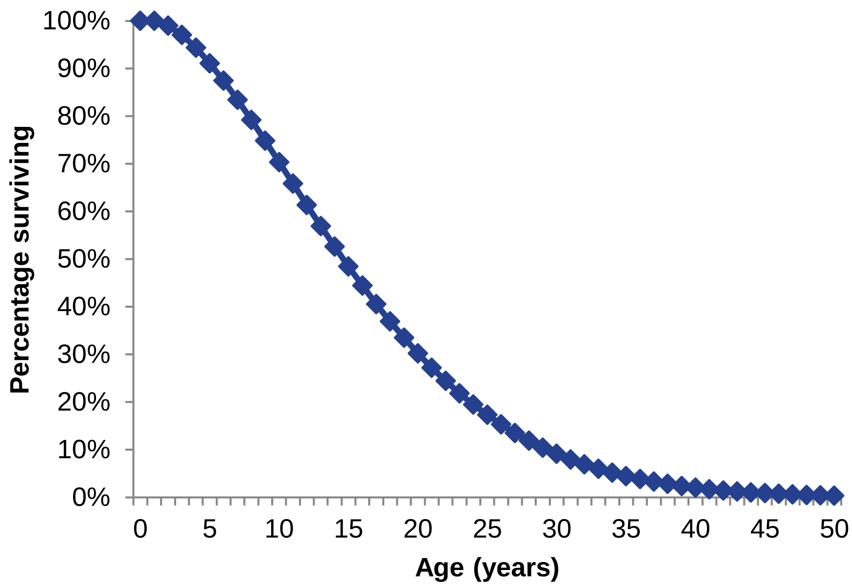
**Figure 1. Central and Mini-Split AC/HPs—AC Survival Function[107]**




[106] See footnotes on default age from previous table.

[107] Department of Energy, Federal Register, 76 FR 37408, Technical Support Document: 8.2.3.5 Lifetime. June 2011. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

**Figure 2. Central and Mini-Split AC/HPs—HP Survival Function**[108]




The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 1 and Figure 2. The age of the system being replaced is found on the horizontal axis, and the corresponding percentage of surviving system is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. The age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

## 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.

[108] Ibid.

## Additional Calculators and Tools

Not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 18 years for an AC and 15 years for a HP unit based on the current DOE Final Rule standards for ACs and HPs.[109]

This value is consistent with the EUL reported in the Department of Energy 76 Final Rule 37408 Technical Support Document for Energy Conservation Standards for Air Conditioners and Heat Pumps.[110]

## 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 (early retirement, replace-on-burnout, new construction)
- Manufacturer, model, and serial number of newly installed unit
    - AHRI/DOE CCMS certificate or reference number matching manufacturer and model number
- Cooling capacity of the newly installed unit (Btuh)
- Heating capacity of the newly installed unit (Btuh) (HPs only)
- Seasonal energy efficiency ratio (SEER2) and energy efficiency ratio (EER2) of the newly installed unit
- Heating seasonal performance factor (HSPF2) of the newly installed unit (HPs only)
- Type of unit replaced (AC with gas furnace, AC with electric resistance furnace, air-source HP)
    - Baseline equipment used for savings (if different from unit replaced)
- Type of unit installed (central AC, central HP, dual-fuel HP, mini-split AC, mini-split HP, DC inverter AC, DC inverter HP)
- Unit type subcategory (split, packaged)

---

[109] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0011-0012.

[110] Department of Energy, Federal Register, 76 FR 37408, Technical Support Document: 8.2.3.5 Lifetime. June 2011.

- Compressor type for newly installed unit (single-stage, multi-stage, variable speed)
    - Recommended to assist with development of future deemed savings for variable-speed systems
- Age of the replaced unit (early retirement only unless default EUL is applied consistently across the program)
- Retired or replaced heating unit model number, serial number, manufacturer, and heating capacity (electric resistance only)
    - Photograph of retired heating unit nameplate, utility inspection, recording nameplate information, or other evaluator-approved approach. Sampling is allowed for multifamily complexes
    - If documentation is not provided, an adjustment factor of 0.75 will be applied to the heating energy and winter demand savings
- Retired cooling unit model number, serial number, manufacturer, and cooling capacity (rightsizing or early retirement unless default EUL is applied consistently across the program)
- Manual J load calculation (rightsizing). See the Eligibility Criteria section for applicable scenarios.
- Photograph of retired cooling unit nameplate (required for all rightsizing projects and early retirement projects unless default age is applied consistently across the program)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (early retirement only)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide estimated square footage of conditioned area served by the retired unit (rightsizing only)
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only). This requirement also applies to projects using the default age.
- For installed HVAC systems meeting minimum federal standard SEER2 efficiency:
    - Age of existing equipment
    - Proof of functionality of existing equipment
    - Rated SEER, if available
- If replacing an evaporative cooler, application should include a statement that the customer decision to change equipment types predates or is independent of the decision to install efficient equipment

- Proof of purchase with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification

# 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 34. Central and Mini-Split AC/HPs—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v10.0 | 10/2022 | TRM v10.0 origin. |
| v11.0 | 10/2023 | TRM v11.0 update. Defined rightsizing and documentation requirements. Updated early retirement age eligibility. |

## 2.2.3 ENERGY STAR® Room Air Conditioners Measure Overview

**TRM Measure ID:** R-HV-RA

**Market Sector:** Residential

**Measure Category:** HVAC

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Replace-on-burnout, early retirement, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

The following deemed savings values are applicable to the installation of a high-efficiency room air conditioner.

### Eligibility Criteria

Installed room air conditioners (RACs) must be compliant with the current ENERGY STAR specification for RACs.

To claim early retirement savings, the replaced unit must be functioning at the time of removal with a maximum age of 12 years, coinciding with the point at which there is no assumed remaining useful life.

### Baseline Condition

For new construction and replace-on-burnout, the baseline is assumed to be a new room air conditioning unit that is compliant with the current federal standard,[111] effective June 1, 2014. The standard refers to a revised efficiency rating, Combined Energy Efficiency Ratio (CEER), which accounts for standby/off-mode energy usage.

For early retirement, the baseline efficiency is assumed to match the minimum federal standard efficiencies in place prior to June 1, 2014. Since the effective date occurred mid-year, existing systems manufactured as of 2015 are not eligible for early retirement.

[111] Legacy DOE minimum efficiency standard for residential room air conditioners effective during current federal standard manufacturer lag period.https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32.

A new federal standard went into effect on August 30, 2023. However, this standard does not require manufacturer compliance until May 26, 2026.[112]

**Table 35. RACs—Baseline Efficiencies for ER, ROB, and NC**

| Reverse cycle (yes/no) | Louvered sides (yes/no) | Capacity (Btu/hr) | Federal standard prior to June 1, 2014 | Federal standard as of June 1, 2014 |
|---|---|---|---|---|
| | | | ER baseline EER | ROB/NC baseline CEER |
| No | Yes | < 6,000 | 9.7 | 11.0 |
| | | 6,000-7,999 | 9.7 | 11.0 |
| | | 8,000-13,999 | 9.8 | 10.9 |
| | | 14,000-19,999 | 9.7 | 10.7 |
| | | 20,000-27,999 | 8.5 | 9.4 |
| | | ≥ 28,000 | 8.5 | 9.0 |
| No | No | < 6,000 | 9.0 | 10.0 |
| | | 6,000-7,999 | 9.0 | 10.0 |
| | | 8,000-10,999 | 8.5 | 9.6 |
| | | 11,000-13,999 | 8.5 | 9.5 |
| | | 14,000-19,999 | 8.5 | 9.3 |
| | | ≥ 20,000 | 8.5 | 9.4 |
| Yes | Yes | < 20,000 | 9.0 | 9.8 |
| | | ≥ 20,000 | 8.5 | 9.3 |
| Yes | No | < 14,000 | 8.5 | 9.3 |
| | | ≥ 14,000 | 8.0 | 8.7 |
| Casement-only | | All capacities | 8.7 | 9.5 |
| Casement-slider | | All capacities | 9.5 | 10.4 |

## High-Efficiency Condition

The table below displays the ENERGY STAR Final Version 5.0 Requirements for eligible room air conditioners effective October 30, 2023.[113] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

---

[112] Current DOE minimum efficiency standard for residential room air conditioners. https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0057.

[113] ENERGY STAR Room Air Conditioners Final Version 5.0 Program Requirements. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%205.0%20Room%20Air%20Conditioners%20Specification%20and%20Partner%20Commitments.pdf.

Table 36. RACs—Efficient Condition Requirements

| Reverse cycle (Yes/No) | Louvered sides (Yes/No) | Capacity (Btu/hr) | Minimum CEER[114] |
|---|---|---|---|
| No | Yes | < 6,000 | 13.1 |
| | | 6,000-7,999 | 13.7 |
| | | 8,000-13,999 | 14.7 |
| | | 14,000-19,999 | 14.4 |
| | | 20,000-27,999 | 12.7 |
| | | ≥ 28,000 | 12.2 |
| No | No | < 6,000 | 12.8 |
| | | 6,000-7,999 | 12.8 |
| | | 8,000-10,999 | 13.0 |
| | | 11,000-13,999 | 12.8 |
| | | 14,000-19,999 | 12.6 |
| | | ≥ 20,000 | 12.7 |
| Yes | Yes | < 20,000 | 13.2 |
| | | ≥ 20,000 | 12.6 |
| Yes | No | < 14,000 | 12.6 |
| | | ≥ 14,000 | 11.7 |
| Casement-only | | All capacities | 12.8 |
| Casement-slider | | All capacities | 14.0 |

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Energy and demand savings algorithms and associated input variables are listed below.

### *New Construction or Replace-on-Burnout*

#### Energy Savings Algorithms

$$Energy\ Savings\ [\Delta kWh] = Cap \times \frac{1\ kW}{1{,}000\ W} \times AOH_C \times \left(\frac{1}{CEER_{Base}} - \frac{1}{CEER_{RAC}}\right)$$

**Equation 24**

[114] The updated ENERGY STAR specification discontinues the five percent energy credit for "connected functionality".

*Where:*

| | | |
|---|---|---|
| *Cap* | = | *Rated equipment cooling capacity of the installed (Btu/hr)* |
| $AOH_C$ | = | *Annual operating hours for cooling (Table 37)* |
| $CEER_{Base}$ | = | *Combined energy efficiency ratio of the baseline cooling equipment (Table 35)* |
| $CEER_{RAC}$ | = | *Combined energy efficiency ratio of the installed RAC* |

**Table 37. RACs—Annual Operating Hours for Cooling**[115]

| Climate Zone | $AOH_C$ |
|---|---|
| Zone 1: Amarillo | 820 |
| Zone 2: Dallas | 1,374 |
| Zone 3: Houston | 1,308 |
| Zone 4: Corpus Christi | 2,150 |
| Zone 5: El Paso | 1,204 |

## Demand Savings Algorithms

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = Cap \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{CEER_{Base}} - \frac{1}{CEER_{RAC}}\right) \times CF_S$$

**Equation 25**

*Where:*

| | | |
|---|---|---|
| $CF_S$ | = | *Summer peak coincidence factor (Table 38)* |

**Table 38. RACs—Coincidence Factor**[116]

| Season | CF |
|---|---|
| Summer[117] | 0.87 |

[115] Association of Home Appliance Manufacturers (AHAM) Room Air Conditioner Cooling Calculator.

[116] Coincidence factors calculated in accordance with the current peak definition are lower than expected for the Texas climate. Residential HVAC measures will temporarily revert to the coincidence factors used in TX TRM v4.0 before the change to the peak definition. These values will be reevaluated in upcoming TRM cycles to better align with the current peak definition.

[117] Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent of the maximum cooling requirement of the residence (for cooling dominated climates). Assuming that maximum cooling occurs during the peak period, the guideline leads to a coincidence factor of 1 / 1.15 = 0.87.

### *Early Retirement*

Annual energy (kWh) and summer peak demand (kW) savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period (EUL – RUL).

Annual energy (kWh) savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in the Volume 3 appendices.

*Where:*

| | | |
|---|---|---|
| *RUL* | = | *Remaining useful life (see Table 39); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 3 years* |
| *EUL* | = | *Estimated useful life = 10 years* |

**Table 39. RACs—RUL of Replaced Unit[118]**

| Age of replaced unit (years) | RUL (years) |
|---|---|
| 1 | 8.0 |
| 2 | 7.2 |
| 3 | 6.2 |
| 4 | 5.2 |
| 5 | 5.2 |
| 6 | 5.2 |
| 7 | 5.2 |
| 8 | 5.0 |
| 9 | 4.0 |
| 10 | 3.0 |
| 11 | 2.0 |
| 12 | 1.0 |
| 13[119,120] | 0.0 |

118 Current federal standard effective date is 6/1/2014. Since the effective date occurred mid-year, existing systems installed as of 2015 are not eligible to use the early retirement baseline and should instead use the ROB baseline.

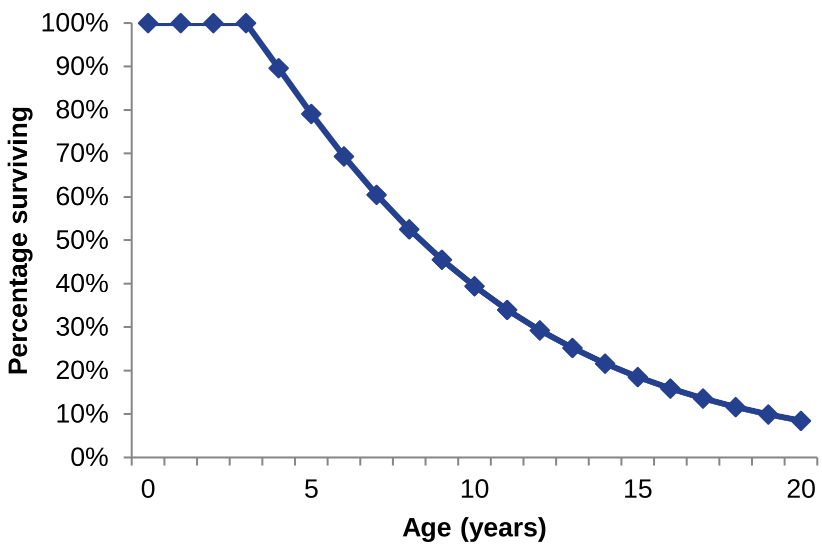
119 RULs are capped at the seventy-fifth percentile of equipment age as determined based on DOE survival curves (see Figure 3). Systems older than this age should use the ROB baseline. See the January 2015 memo, "Considerations for Early Replacement of Residential Equipment," for further detail.

120 Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. "Considerations for Early Replacement of Residential Equipment." Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to all Texas investor-owned utilities through the EM&V team's SharePoint.

## *Derivation of RULs*

RACs have an estimated useful life of 10 years. This estimate is consistent with the age at which approximately 50 percent of the RACs installed in a given year will no longer be in service, as described by the survival function in Figure 3.

**Figure 3. RACs—Survival Function[121]**




The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 3. The age of the system being replaced is found on the horizontal axis, and the corresponding percentage of surviving system is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. The age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 3. The age of the room air conditioner being replaced is found on the horizontal axis, and the corresponding percentage of surviving RACs is determined from the chart. The surviving percentage value is then divided in half, creating a new percentage. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

[121] Department of Energy, Federal Register, 76 FR 22454, Technical Support Document: 8.2.2.6 Product Lifetime. April 2011. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41. Download TSD at: https://www.regulations.gov/document/EERE-2007-BT-STD-0010-0053.

## *Energy Savings Algorithms*

For the RUL time period:

$$kWh_{savings,ER} = CAP \times \frac{1\ kW}{1{,}000\ W} \times AOH_C \times \left(\frac{1}{EER_{ER}} - \frac{1}{CEER_{RAC}}\right)$$

**Equation 26**

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

$$kWh_{savings,ROB} = Cap \times \frac{1\ kW}{1{,}000\ W} \times AOH_C \times \left(\frac{1}{CEER_{ROB}} - \frac{1}{CEER_{RAC}}\right)$$

**Equation 27**

*Where:*

$EER_{ER}$ = *Energy efficiency ratio of the early retirement baseline cooling equipment (Table 35)*

## *Summer Demand Savings Algorithms*

To calculate demand savings for the early retirement of a RAC, a similar methodology is used as for replace-on-burnout installations, with separate savings calculated for the remaining useful life of the unit, and the remainder of the EUL as outlined in the section above.

For the RUL time period:

$$kW_{Savings,ER} = CAP \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{EER_{ER}} - \frac{1}{CEER_{RAC}}\right) \times CF_S$$

**Equation 28**

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

$$kW_{Savings,ROB} = CAP \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{CEER_{ROB}} - \frac{1}{CEER_{RAC}}\right) \times CF_S$$

**Equation 29**

*Where:*

$CF_S$ = *Summer peak coincidence factor (Table 38)*

## 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) of a room air conditioning unit is 10 years based on the Technical Support Document for the current DOE Final Rule standards for RACs.

This value is consistent with the EUL reported in the DOE Technical Support Document for RACs.[122]

# 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 (early retirement, replace-on-burnout, new construction)
- New unit manufacturer, model, and serial number
- ENERGY STAR certificate matching model
- Cooling capacity of the installed unit (Btu/hr)
- Combined energy efficiency ratio (CEER) of the new unit

[122] Technical Support Document: Room Air Conditioners, June 2020, p. ES-14. https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0013.

- Age of the replaced unit (early retirement only)
- Photograph of retired unit nameplate (early retirement)
    - If a photograph of the retired unit nameplate is unavailable or not legible, provide a photo and/or description documenting the reason why the nameplate photo was unobtainable (early retirement only)
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

## 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 40. RACs—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Low-income and hard-to-reach Market Transformation section merged with main measure as “early retirement” option. Updated by Frontier Energy, March 2014, based on new federal standards. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. early retirement savings may be claimed through any appropriately designed program in accordance with EM&V team’s memo, “Considerations for early replacement of residential equipment.” Remaining useful lifetimes updated. Updated EUL to align with median lifetime. New construction permitted to claim savings. New ENERGY STAR standards incorporated. |
| v3.1 | 11/05/2015 | TRM v3.1 update. No revision. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Added RUL values for units with an age of one to three years. Added a default RUL value for when the age of the unit is unknown. Eliminated the eligibility requirement of the existing unit to have a minimum age of five years. |

| TRM version | Date | Description of change |
|---|---|---|
| v5.0 | 10/2017 | TRM v5.0 update. Updated peak coincidence factors for compliance with current Texas peak definition. Single coincidence factor replaced with individual factors for each climate zone. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. Update to documentation requirements. |
| v8.0 | 10/2020 | TRM v8.0 update. Clarified early retirement age eligibility. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated early retirement age eligibility. Clarified eligibility for units with connected functionality. |
| v10.0 | 10/2022 | TRM v10.0 update. Update minimum CEER requirement for units with connected functionality. Updated coincidence factors, early retirement age eligibility, and documentation requirements. |
| v11.0 | 10/2023 | TRM v11.0 update. Incorporated updated DOE final rule and ENERGY STAR specification v5.0. Updated early retirement age eligibility. |

## 2.2.4 Packaged Terminal Heat Pumps Measure Overview

**TRM Measure ID:** R-HV-PT

**Market Sector:** Residential

**Measure Category:** HVAC

**Applicable Building Types:** Multifamily

**Fuels Affected:** Electricity

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

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This section presents the deemed savings methodology for the installation of packaged terminal heat pumps (PTHP) replacing packaged terminal air conditioners (PTAC) with electric resistance heat. This document covers assumptions made for baseline equipment efficiencies for early retirement (ER) and replace-on-burnout (ROB), 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 are restricted to packaged terminal 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, equal to 16 inches high or greater than, or equal to 42 inches wide and a cross-sectional area greater than 670 in$^2$. *Non-standard size* refers to equipment with existing wall sleeve dimensions having an external wall opening of fewer than 16 inches high or fewer than 42 inches wide and a cross-sectional area less than 670 in$^2$.

## Eligibility Criteria

Existing PTAC and installed PTHP must be the primary cooling source in the residence. Installed PTHPs must be compliant with the current commercial code.

ER projects must involve the replacement of a working system before natural burnout. Additionally, the ER approach cannot be used for projects involving a simultaneous renovation where a major structural change or internal space remodel has occurred. A ROB approach should be used for these scenarios.

Manufacturer datasheets for new equipment or documentation of AHRI or DOE CCMS certification must be provided.[123,124]

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

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

## Baseline Condition

### *Early Retirement*

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 scenario. For the ER period, the baseline efficiency should be estimated according to the capacity, system type (PTAC), and age (based on year of manufacture) of the replaced system.[125] When the system age can be determined (from a nameplate, building prints, equipment inventory list, etc.), the baseline efficiency levels provided in Table 41, 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.

When the system age is unknown, assume 15 years.[126] A default RUL may be used exclusively if applied consistently for all eligible early retirement projects. Otherwise, the default should only be used when a project is reported and documented as having a nameplate that is illegible.

Existing systems manufactured as of February 2013 are not eligible for early retirement.

**Table 41. PTHPs—ER Baseline Efficiency Levels for Standard Size PTACs[127]**

| Equipment | Cooling capacity (Btuh) | Baseline cooling efficiency (EER) | Baseline heating efficiency (COP) (no built-in resistance heat) | Baseline heating efficiency (COP) (replacing built-in resistance heat) |
|---|---|---|---|---|
| PTAC | < 7,000 | 11.0 | – | 1.0 |
| | 7,000-15,000 | 12.5 – (0.213 x Cap/1,000) | | |
| | > 15,000 | 9.3 | | |

[125] 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.

[126] 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.

[127] 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.

### *Replace-on-Burnout*

Table 42 provides minimum efficiency standards for PTAC/PTHP units and reflects the federal standards for packaged terminal air-conditioners and heat pumps effective February 2013 and reflected in 10 CFR 431.

**Table 42. PTHPs—ROB Minimum Efficiency Levels[128,129]**

| Equipment | Category | Cooling capacity (Btuh) | Minimum cooling efficiency (EER) | Minimum heating efficiency (COP) | Baseline heating efficiency (COP) (replacing built-in resistance heat) |
|---|---|---|---|---|---|
| PTHP | Standard size | < 7,000 | 11.9 | 3.3 | 1.0 |
| | | 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 | |

128 IECC 2015 Table C403.2.3(3).

129 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.

## High-Efficiency Condition

The high-efficiency retrofits must exceed the minimum federal standards found in Table 42.

The high-efficiency retrofits must also meet the following criteria:[130]

- For ER projects only, the installed equipment cooling capacity must be within 80 percent to 120 percent of the replaced electric cooling capacity.
- No additional measures are being installed that directly affect the operation of the cooling equipment (i.e., control sequences).

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

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

**Equation 30**

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

**Equation 31**

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

**Equation 32**

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

**Equation 33**

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

**Equation 34**

[130] Modified from PUCT Docket #41070 for TRMv3 to limit replacement of only smaller-sized units and extend early retirement to cover PTAC/PTHP.

*Where:*

| | | |
|---|---|---|
| $Cap_{C/H,pre}$ | = | *For ER, rated equipment cooling/heating*[131] *capacity of the existing equipment at AHRI standard conditions*; for ROB & NC, rated equipment cooling/heating capacity of the new equipment at AHRI standard conditions *[BTUH]; 1 ton = 12,000 Btuh* |
| $Cap_{C/H,post}$ | = | *Rated equipment cooling/heating capacity of the newly installed equipment at AHRI standard conditions [Btuh]; 1 ton = 12,000 Btuh* |
| $\eta_{baseline,C}$ | = | *Cooling efficiency of existing (ER) or standard (ROB/NC) equipment [EER, Btu/W-h] (Table 41 through Table 42)* |
| $\eta_{installed,C}$ | = | *Rated cooling efficiency of the newly installed equipment [EER, Btu/W-h] (must exceed minimum requirements from Table 42)*[132] |
| $\eta_{baseline,H}$ | = | *Heating efficiency of existing (ER) or standard (ROB/NC) equipment [COP] (Table 41 through Table 42)* |
| $\eta_{installed,H}$ | = | *Rated heating efficiency of the newly installed equipment [COP] (must exceed minimum requirements from Table 42)*[133] |
| $CF_{S/W}$ | = | *Summer/winter seasonal peak coincidence factor (Table 43)* |
| $EFLH_{C/H}$ | = | *Cooling/heating equivalent full-load hours for newly installed equipment based on appropriate climate zone, building type, and equipment type [hours] (Table 44)* |

[131] Baseline cooling capacity refers to the rated cooling capacity of the existing PTAC. Assume baseline heating capacity is equal to rated heating capacity for newly installed PTHP.
[132] Rated efficiency is commonly reported at both 230 V and 208 V. Savings calculations should reference efficiency at 230 V, as AHRI rating conditions specify that voltage.
[133] Ibid.

**Table 43. PTHPs—Coincidence Factors**[134]

| Season | CF |
|---|---|
| Summer[135] | 0.87 |
| Winter[136] | 0.83 |

**Table 44. PTHPs—Cooling/Heating EFLHs**[137]

| Climate zone | $EFLH_C$ | $EFLH_H$ |
|---|---|---|
| Zone 1: Amarillo | 1,142 | 1,880 |
| Zone 2: Dallas | 1,926 | 1,343 |
| Zone 3: Houston | 2,209 | 1,127 |
| Zone 4: Corpus Christi | 2,958 | 776 |
| Zone 5: El Paso | 1,524 | 1,559 |

The first-year savings algorithms in the above equations are used for all HVAC projects, across ROB and ER projects. However, ER projects require 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 Volume 3, Appendix A.

## Claimed Peak Demand Savings

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

[134] Coincidence factors calculated in accordance with the current peak definition are lower than expected for the Texas climate. Residential HVAC measures will temporarily revert to the coincidence factors used in TX TRM v4.0 before the change to the peak definition. These values will be reevaluated in upcoming TRM cycles to better align with the current peak definition.

[135] Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent of the maximum cooling requirement of the residence (for cooling dominated climates). Assuming that maximum cooling occurs during the peak period, the guideline leads to a coincidence factor of 1 / 1.15 = 0.87.

[136] Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent of the maximum cooling requirement of the residence (for cooling dominated climates). Based on AHRI data for 1.5–5 ton HVAC systems, the average ratio of rated heating capacity to cooling capacity is 0.96. Assuming that maximum heating occurs during the peak period and adjusting for the average ratio of heating to cooling capacity, the guideline leads to a coincidence factor of 0.96 / 1.15 = 0.83.

[137] ENERGY STAR Central AC/HP Savings Calculator. April 2009 update. https://www.energystar.gov/sites/default/files/asset/document/ASHP_Sav_Calc.xls.

## Deemed Energy and 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.

## Measure Life and Lifetime Savings

### *Estimated Useful Life (EUL)*

The EUL is 15 years, as specified in as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HVAC-PTHP.[138]

### *Remaining Useful Life (RUL) for PTHP Systems*

Annual energy (kWh) and summer peak demand (kW) savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period (EUL – RUL).

Annual energy (kWh) savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in the Volume 3 appendices.

*Where:*

| | | |
|---|---|---|
| *RUL* | = | *Remaining useful life (see Table 45); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 2.8 years* |
| *EUL* | = | *Estimated useful life = 15 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.

[138] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

**Table 45. PTHPs—RUL of Replaced PTAC[139,140]**

| Age of replaced system (years) | PTAC RUL (Years) | Age of replaced system (years) | PTAC 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[141] | 0.0 |

## 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: ROB or ER
- Climate zone or county
- Equipment configuration category: standard/non-standard
- Baseline equipment rated cooling capacity (Btuh)
- Baseline number of units
- Installed equipment rated cooling and heating capacities
- Installed number of units
- Installed cooling and heating efficiency rating
- Installed make and model
- AHRI/DOE CCMS certificate or reference number matching manufacturer and model number
- Baseline age and method of determination (e.g., nameplate, blueprints, customer reported, not available) (early retirement only)

---

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

[140] Current federal standard effective date is 2/2013. Existing systems manufactured after this date are not eligible to use the early retirement baseline and should instead use the ROB baseline.

[141] RULs are capped at the seventy-fifth percentile of equipment age as determined based on DOE survival curves. Systems older than this age should use the ROB baseline. See the January 2015 memo, “Considerations for Early Replacement of Residential Equipment,” for further detail.

- A representative sample of photographs of retired unit nameplate demonstrating model number, serial number, and manufacturer if blueprints are not provided (early retirement only)
    - If a photograph of the nameplate is unavailable or not legible, provide documentation demonstrating reason why the nameplate photo was unobtainable, including but not limited to a photo or description documenting the reason why the nameplate photo was unobtainable (alternate forms of documentation can be approved at the evaluator's discretion)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- Documentation demonstrating the functionality of existing equipment, including but not limited to photograph demonstrating the functionality of existing equipment or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)

## References and Efficiency Standards

### Petitions and Rulings

- 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. This petition updated demand and energy coefficients for all commercial HVAC systems.

### Relevant Standards and Reference Sources

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

## Document Revision History

**Table 46. PTHPs—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v7.0 | 10/2019 | TRM v7.0 origin. |
| v8.0 | 10/2020 | TRM v8.0 update. Clarified early retirement age eligibility. Added winter demand algorithm. Updated coincidence factors and documentation requirements |
| v9.0 | 10/2021 | TRM v9.0 update. Clarified early retirement age eligibility. Updated EUL reference. |
| v10.0 | 10/2022 | TRM v10.0 update. Clarified electric resistance baseline. Updated coincidence factors and early retirement age eligibility. |
| v11.0 | 10/2023 | TRM v11.0 update. Updated early retirement age eligibility. |

## 2.2.5 ENERGY STAR® Ground Source Heat Pumps Measure Overview

**TRM Measure ID:** R-HV-GH

**Market Sector:** Residential

**Measure Category:** HVAC

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Replace-on-burnout, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This measure requires the installation of a ground-source heat pump (GSHP) meeting the minimum requirements of ENERGY STAR geothermal heat pump key product criteria. Savings calculations are presented for systems with and without desuperheaters.

### Eligibility Criteria

The deemed savings apply to units with a capacity of ≤ 65,000 Btu/hour.

Energy savings for desuperheaters only apply if the desuperheater is attached to an electric storage water heater. The electric storage water heating cannot replace a gas water heater in a retrofit installation.

### Baseline Condition

The baseline unit is assumed to be an air-source heat pump (ASHP) for new construction, and either an ASHP or an air conditioner with an electric resistance furnace for replace-on-burnout projects. New construction baseline efficiency values for ASHPs are compliant with the current federal minimum standard, effective January 1, 2023.[142]

[142] DOE minimum efficiency standard for residential air conditioners/heat pumps. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive

For replace-on-burnout (ROB) projects, the cooling baseline is reduced to 13.7 SEER2. This value incorporates an adjustment to the baseline SEER2 value to reflect the percentage of current replacements that do not include the installation of an AHRI-matched system.[143] The heating baseline for replace-on-burnout projects is dependent on the heating type of the baseline equipment.

**Table 47. GSHPs—Baseline Efficiencies**

| Project type | Cooling mode[144] | Heating mode[145] |
|---|---|---|
| New construction | 9.8 EER2 (14.3 SEER2) | 2.2 COP (7.5 HSPF2) |
| ROB—air source heat pump baseline | 9.8 EER2 (13.7 SEER2) | 2.2 COP (7.5 HSPF2) |
| ROB—air conditioner with electric resistance furnace baseline | | 1 COP (3.412 HSPF2) |

## High-Efficiency Condition

The table below displays the ENERGY STAR Final Version 3.2 requirements for eligible geothermal heat pumps effective January 1, 2012.[146] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

**Table 48. GSHPs—ENERGY STAR Requirements**

| Product type | Cooling mode (EER) | Heating mode (COP) |
|---|---|---|
| Closed loop water-to-air | 17.1 | 3.6 |
| Open loop water-to-air | 21.1 | 4.1 |
| Closed loop water-to-water | 16.1 | 3.1 |
| Open loop water-to-water | 20.1 | 3.5 |
| Direct geoexchange (DGX) | 16.0 | 3.6 |

143 Frontier Energy on behalf of the Electric Utility Marketing Managers of Texas (EUMMOT). "Petition to revise Existing Commission-Approved Deemed Savings Values for Central Air Conditioning and Heat Pump Systems: Docket No. 36780." Public Utility Commission of Texas. Approved August 27, 2009. https://interchange.puc.texas.gov/. Adapted for new 14 SEER baseline.

144 The Central HP EER2 baseline is reduced to 9.8 EER2 for systems rated at 15.2 SEER2 or higher. While GSHPs do not have a SEER2 rating, all full-load EER minimum efficiency requirements exceed that threshold. Therefore, the reduced EER2 baseline is extended to all GSHP installations.

145 Code specified HSPF value converted to COP using COP = HSPF x 1,055 J/Btu ÷ 3,600 J/W-h = HSPF ÷ 3.412.

146 ENERGY STAR Program Requirements Product Specification for Geothermal Heat Pumps, v3.2. https://www.energystar.gov/sites/default/files/Geothermal%20Heat%20Pump%20Version%203.2%20Final%20Specification.pdf.

The specifications in the charts above apply to single-stage models. Multi-stage models may be qualified based on:[147]

$$EER = (highest\ rated\ capacity\ EER + lowest\ rated\ capacity\ EER)\ /\ 2$$

**Equation 35**

$$COP = (highest\ rated\ capacity\ COP + lowest\ rated\ capacity\ COP)\ /\ 2$$

**Equation 36**

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Peak demand and annual energy savings for GSHP systems should be calculated, as shown below. Where a desuperheater is also installed, please see the Deemed Energy Savings Tables section for additional energy savings and the Deemed Summer Demand Savings Tables for additional demand savings.

Energy and demand savings for desuperheaters were adapted from a 2001 study conducted by Oak Ridge National Laboratory (ORNL) on GSHPs in Texas.[148] Desuperheater savings were calculated for each climate zone by taking the difference in savings between GSHPs with and without desuperheaters and averaging the savings between low and high-efficiency units. Savings for GSHP systems with desuperheaters should be calculated using the algorithms below with an additional energy credit based on the system capacity and efficiency.

The ORNL study draws from a 1998 analysis based on a study conducted at the Fort Polk Joint Readiness Training Center in Leesville, Louisiana. The Fort Polk study used calibrated simulations of 200 multifamily residences in the complex to estimate energy savings attributable to the replacement of air source heat pumps with GSHPs. These estimates were found to be within 5 percent of actual post-retrofit savings. Building models were developed using TRNSYS.[149]

Using the Fort Polk models, the ORNL study assumed a baseline of a 1.5-ton, 10-SEER air source heat pump. Simulations of low-, medium-, and high-efficiency GSHPs with and without desuperheaters were compared against the baseline unit. The models were run using TMY-2 weather profiles for Climate Zones 1-4. Energy and demand differences between the pre- and post-retrofit models were used to estimate average savings per ton of cooling capacity.

[147] Geothermal Heat Pumps Key Product Criteria, https://www.energystar.gov/products/heating_cooling/heat_pumps_geothermal/key_product_criteria.

[148] Shonder, J. A., Hughes, P., and Thornton, J. Development of Deemed Energy and Demand Savings for Residential Ground Source Heat Pump Retrofits in the State of Texas. Transactions-American Society of Heating, Refrigerating, and Air Conditioning Engineers. 108, no. 1: 953-961, 2001.

[149] Klein, S. A. TRNSYS Manual: A Transient Simulation Program. Solar Engineering Laboratory, University of Wisconsin-Madison, Version 14.2 for Windows, September 1996.

In the 1998 analysis, low-efficiency GSHPs were assumed to be units with an EER of 12.4 and capacity of 19 kBtuh, while medium-efficiency units had an EER of 16.8 and capacity of 21 kBtuh. High-efficiency units had an EER or 18.3, with a capacity of 22 kBtuh.

These models were used to derive the energy and demand savings associated with installation of a desuperheater along with a GSHP, as shown in Table 51 and Table 52, respectively.

## *Energy Savings Algorithms*

$$Total\ Energy\ Savings\ [\Delta kWh] = kWh_{Savings,C} + kWh_{Savings,H} + kWh_{DSH}$$

**Equation 37**

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

**Equation 38**

$$Heating\ Energy\ Savings\ [kWh_H] = Cap_H \times \frac{1\ kWh}{3{,}412\ Btu} \times EFLH_H \times \left(\frac{1}{COP_{Base}} - \frac{1}{COP_{GSHP}}\right)$$

**Equation 39**

*Where:*

| | | |
|---|---|---|
| $kWh_{DSH}$ | = | *Energy savings (kWh) associated with installation of a desuperheater (see Table 51); these savings should only be added if a desuperheater is installed* |
| $Cap_{C/H}$ | = | *Rated equipment cooling/heating capacity of the installed GSHP (Btu/hr)* |
| $EFLH_{C/H}$ | = | *Equivalent full load hours for cooling/heating (Table 49)* |
| $SEER2_{Base}$ | = | *Energy efficiency ratio of the baseline cooling equipment (Table 47)* |
| $EER_{GSHP}$ | = | *Energy efficiency ratio of the installed GSHP* |
| $COP_{Base}$ | = | *Coefficient of performance of the baseline heating equipment converted from HSPF2 (Table 47)* |
| $COP_{GSHP}$ | = | *Coefficient of performance of the installed GSHP* |

**Table 49. GSHPs—Equivalent Full Load Cooling/Heating Hours[150]**

| Climate zone | $EFLH_C$ | $EFLH_H$ |
|---|---|---|
| Zone 1: Amarillo | 1,142 | 1,880 |
| Zone 2: Dallas | 1,926 | 1,343 |
| Zone 3: Houston | 2,209 | 1,127 |

[150] ENERGY STAR Central AC/HP Savings Calculator.

| Climate zone | $EFLH_C$ | $EFLH_H$ |
|---|---|---|
| Zone 4: Corpus Christi | 2,958 | 776 |
| Zone 5: El Paso | 1,524 | 1,559 |

### Demand Savings Algorithms

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = Cap_C \times \frac{1\ kW}{1{,}000\ W} \times \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{GSHP}}\right) \times CF_S + kW_{DSH}$$

**Equation 40**

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = Cap_H \times \frac{1\ kWh}{3{,}412\ Btu} \times \left(\frac{1}{COP_{Base}} - \frac{1}{COP_{GSHP}}\right) \times CF_W$$

**Equation 41**

*Where:*

| | | |
|---|---|---|
| $EER2_{Base}$ | = | *Energy efficiency ratio of the baseline cooling equipment (see Table 47)* |
| $CF_{S/W}$ | = | *Summer/winter peak coincidence factor (see Table 50)* |
| $kW_{DSH}$ | = | *Summer demand savings (kW) associated with installation of a desuperheater (see Table 52); these savings should only be added if a desuperheater is installed* |

**Table 50. GSHPs—Coincidence Factors[151]**

| Season | CF |
|---|---|
| Summer[152] | 0.87 |
| Winter[153] | 0.83 |

[151] Coincidence factors calculated in accordance with the current peak definition are lower than expected for the Texas climate. Residential HVAC measures will temporarily revert to the Coincidence factors used in TX TRM v4.0 before the change to the peak definition. These values will be reevaluated in upcoming TRM cycles to better align with the current peak definition.

[152] Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent of the maximum cooling requirement of the residence (for cooling-dominated climates). Assuming that maximum cooling occurs during the peak period, the guideline leads to a coincidence factor of 1 / 1.15 = 0.87.

[153] Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent of the maximum cooling requirement of the residence (for cooling-dominated climates). Based on AHRI data for 1.5–5 ton HVAC systems, the average ratio of rated heating capacity to cooling capacity is 0.96. Assuming that maximum heating occurs during the peak period and adjusting for the average ratio of heating to cooling capacity, the guideline leads to a coincidence factor of 0.96 / 1.15 = 0.83.

## Deemed Energy Savings Tables

**Table 51. GSHPs—Energy Savings for Desuperheaters per Cooling Tonnage**

| Climate zone | kWh/ton |
|---|---|
| Zone 1: Amarillo | 612 |
| Zone 2: Dallas | 791 |
| Zone 3: Houston | 802 |
| Zone 4: Corpus Christi | 847 |
| Zone 5: El Paso | 791 |

## Deemed Summer Demand Savings Tables

**Table 52. GSHPs—Summer Peak Demand Savings for Desuperheaters per Cooling Tonnage**

| Climate zone | kW/ton |
|---|---|
| Zone 1: Amarillo | 0.440 |
| Zone 2: Dallas | 0.405 |
| Zone 3: Houston | 0.405 |
| Zone 4: Corpus Christi | 0.410 |
| Zone 5: El Paso | 0.405 |

## 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.

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

## 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) of a GSHP unit is 24 years.

This value is consistent with the life expectancy of the heat pump components reported in multiple Department of Energy GSHP guides. Underground ground-loop infrastructure is expected to last 25–50 years. [154,155]

## 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:

- Climate zone or county
- Decision/action type (new construction, replace-on-burnout)
- Replaced unit heating type (heat pump, electric resistance furnace)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
- Manufacturer, model number, and serial number
- ENERGY STAR certificate matching installed model number
- Installed GSHP type (closed loop water-to-air, open loop water-to-air, closed loop water-to-water, open loop water-to-water, direct geoexchange)
- Energy efficiency ratio (EER) of the new unit
- Coefficient of performance (COP) of the new unit
- Product specification sheet
- Rated cooling and heating capacity of the new unit (Btu/hr)[156]
- Whether a desuperheater was also installed or present
- Proof of purchase with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification

## References and Efficiency Standards

### Petitions and Rulings

Not applicable.

[154] Department of Energy. Geothermal Heat Pump Energy Saver article. https://www.energy.gov/energysaver/geothermal-heat-pumps.
[155] Department of Energy. "Guide to Geothermal Heat Pumps. February 2011. http://www.energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf.
[156] Rated capacities are not specified on the ENERGY STAR certificate and should be taken from the product specification sheet.

## Relevant Standards and Reference Sources

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

## Document Revision History

**Table 53. GSHPs—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Updated by Frontier Energy, March 2014, based on new federal standards and alternative methodology. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. No revision. |
| v3.1 | 11/05/2015 | TRM v3.1 update. No revision. |
| v4.0 | 10/10/2016 | TRM v4.0 update. No revision. |
| v5.0 | 10/2017 | TRM v5.0 update. Updated peak coincidence factors for compliance with current Texas peak definition. Single coincidence factor replaced with individual factors for each climate zone. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. Updates to tracking requirements. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated algorithms to make units consistent. |
| v9.0 | 10/2021 | TRM v9.0 update. Added clarifying language and updated algorithm units. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated coincidence factors and EUL. |
| v11.0 | 10/2023 | TRM v11.0 update. Integrated federal standard change and SEER2 test procedure. |

## 2.2.6 Large Capacity Split and Packaged Air Conditioners and Heat Pumps Measure Overview

**TRM Measure ID:** R-HV-LC

**Market Sector:** Residential

**Measure Category:** HVAC

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This measure applies to the installation of a split/packaged air conditioner (AC) or heat pump (HP) with a capacity exceeding that of a typical residential system (greater than or equal to 65,000 Btu/hr) in a retrofit or new construction application. This measure also applies to the installation of ground-source heat pumps (GSHP) with a capacity exceeding 65,000 Btu/hr.

## Eligibility Criteria

- The deemed savings apply to central AC/HPs with a capacity of 65,000-240,000 Btu/hr (5.4-20 tons) and GSHPs with a capacity of 65,000-135,000 Btu/hr (5.4-11.3 tons).
- Equipment shall be properly sized to dwelling based on ASHRAE or ACCA Manual J standards.
- Manufacturer datasheets for new equipment or documentation of AHRI or DOE CCMS certification must be provided.[157,158]

## Baseline Condition

New construction and replace-on-burnout baseline efficiency levels are provided in Table 54 and Table 55. These baseline efficiency levels reflect the latest minimum efficiency requirements from the current federal manufacturing standard, IECC 2015, and ASHRAE 90.1-2013.

[157] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory: https://www.ahridirectory.org/.

[158] Department of Energy Compliance Certification Management System (DOE CCMS): https://www.regulations.doe.gov/certification-data/.

**Table 54. Large Capacity AC/HPs—NC/ROB Baseline Efficiency Levels for AC/HPs**[159]

| System type | Capacity (tons) | Heating section type | Baseline efficiencies | Source[160] |
|---|---|---|---|---|
| Air conditioners | > 5.4 to < 11.3 | None or<br>Electric resistance | 11.2 EER<br>12.8 IEER | DOE Standards/<br>IECC 2015 |
| | | All Other | 11.0 EER<br>12.6 IEER | |
| | ≥ 11.3 to ≤ 20 | None or<br>Electric resistance | 11.0 EER<br>12.4 IEER | |
| | | All other | 10.8 EER<br>12.2 IEER | |
| Heat pump (cooling)[161] | 5.4 to < 11.3 | Heat pump | 11.0 EER<br>12.0 IEER | DOE Standards/<br>IECC 2015 |
| | ≥ 11.3 to ≤ 20 | | 10.6 EER<br>11.6 IEER | |
| Heat pump (heating)[162] | 5.4 to < 11.3 | Heat pump | 3.3 COP | DOE Standards/<br>IECC 2015 |
| | ≥ 11.3 to ≤ 20 | | 3.2 COP | |

[159] IECC 2015 Table C403.2.3(1) and C403.2.3(2).
[160] These baseline efficiency standards noted as "DOE Standards" are cited in the Code of Federal Regulations, 10 CFR 431.97. http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec431-97.pdf.
[161] 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".
[162] Heat pump retrofits must also exceed the baseline efficiency levels for heating efficiencies.

Table 55. Large Capacity AC/HPs—NC/ROB Baseline Efficiency Levels for GSHPs[163]

| System type | Capacity (Btuh) | Cooling EWT rating condition | Minimum cooling EER | Heating EWT rating condition | Minimum heating COP |
|---|---|---|---|---|---|
| Water-to-air (water loop) | ≥ 65,000 and < 135,000 | 86°F | 13.0 | 68°F | 4.3 |
| Water-to-air (groundwater) | | 59°F | 18.0 | 50°F | 3.7 |
| Brine-to-air (ground loop) | | 77°F | 14.1 | 32°F | 3.2 |
| Water-to-water (water loop) | | 86°F | 10.6 | 68°F | 3.7 |
| Water-to-water (groundwater) | | 59°F | 16.3 | 50°F | 3.1 |
| Brine-to-water (ground loop) | | 77°F | 12.1 | 32°F | 2.5 |

## High-Efficiency Condition

Split and packaged systems must exceed the minimum efficiencies specified in Table 54 and Table 55.

For reference, both ENERGY STAR and the Consortium for Energy Efficiency (CEE) offer suggested guidelines for high-efficiency equipment.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

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

**Equation 42**

$$Cooling\ Energy\ Savings\ [kWh_C] = Cap_C \times \left(\frac{1}{\eta_{baseline,C}} - \frac{1}{\eta_{installed,C}}\right) \times EFLH_C \times \frac{1\ kW}{1{,}000\ W}$$

**Equation 43**

$$Heating\ Energy\ Savings\ [kWh_H] = Cap_H \times \left(\frac{1}{\eta_{baseline,H}} - \frac{1}{\eta_{installed,H}}\right) \times EFLH_H \times \frac{1\ kWh}{3{,}412\ Btu}$$

**Equation 44**

163 Values from ASHRAE 90.1-2013.

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

**Equation 45**

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

**Equation 46**

*Where:*

| | | |
|---|---|---|
| $Cap_{C/H}$ | = | *Rated equipment cooling/heating capacity of the installed equipment at AHRI standard conditions (Btu/hr); 1 ton = 12,000 Btu/hr* |
| $\eta_{baseline,C}$ | = | *Cooling efficiency of standard equipment (Btuh/W)* |
| $\eta_{installed,C}$ | = | *Rated cooling efficiency of the newly installed equipment (Btuh/W)* |
| $\eta_{baseline,H}$ | = | *Heating efficiency of standard equipment (Btuh/W or COP)* |
| $\eta_{installed,H}$ | = | *Rated heating efficiency of the newly installed equipment (Btuh/W or COP)* |

Note: Use EER for cooling kW and COP for heating kW and kWh savings calculations. SEER/IEER should be used to calculate cooling kWh for central ACs and HPs. EER should be used to calculate cooling kWh for GSHPs. Heating efficiencies expressed as HSPF will be approximated as a seasonal COP and should be converted using the following equation:

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

**Equation 47**

| | | |
|---|---|---|
| $CF_{S/W}$ | = | *Summer/winter peak coincidence factor (Table 56)* |
| $EFLH_{C/H}$ | = | *Cooling/heating equivalent full-load hours (Table 57)* |

**Table 56. Large Capacity AC/HPs—Coincidence Factors**[164]

| Season | CF |
|---|---|
| Summer[165] | 0.87 |
| Winter[166] | 0.83 |

**Table 57. Large Capacity AC/HPs—Equivalent Full Load Cooling/Heating Hours**[167]

| Climate zone | $EFLH_C$ | $EFLH_H$ |
|---|---|---|
| Zone 1: Amarillo | 1,142 | 1,880 |
| Zone 2: Dallas | 1,926 | 1,343 |
| Zone 3: Houston | 2,209 | 1,127 |
| Zone 4: Corpus Christi | 2,958 | 776 |
| Zone 5: El Paso | 1,524 | 1,559 |

## 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.

---

164 Coincidence factors calculated in accordance with the current peak definition are lower than expected for the Texas climate. Residential HVAC measures will temporarily revert to the coincidence factors used in TX TRM v4.0 before the change to the peak definition. These values will be reevaluated in upcoming TRM cycles to better align with the current peak definition.

165 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent of the maximum cooling requirement of the residence (for cooling-dominated climates). Assuming that maximum cooling occurs during the peak period, the guideline leads to a coincidence factor of 1 / 1.15 = 0.87.

166 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent of the maximum cooling requirement of the residence (for cooling-dominated climates). Based on AHRI data for 1.5–5 ton HVAC systems, the average ratio of rated heating capacity to cooling capacity is 0.96. Assuming that maximum heating occurs during the peak period and adjusting for the average ratio of heating to cooling capacity, the guideline leads to a coincidence factor of 0.96 / 1.15 = 0.83.

167 ENERGY STAR Central AC/HP Savings Calculator. April 2009 update. https://www.energystar.gov/sites/default/files/asset/document/ASHP_Sav_Calc.xls.

## 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) is 18 years for a large-capacity air conditioner and 15 years for a large capacity heat pump based on the current DOE Final Rule standards for central heat pumps.[168] The EUL of a high-efficiency ground source heat pump unit is 24 years, consistent with the EUL reported in the DOE GSHP guide.[169]

These values are consistent with the life expectancy of the heat pump components reported in multiple DOE GSHP guides. Underground ground-loop infrastructure is expected to last 25–50 years. [170,171]

# 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:

- Climate zone or county
- Decision/action type (new construction, retrofit)
- Cooling and heating capacities (Btu/hr)
- Full-load efficiency rating (EER) of the installed unit
- Part-load efficiency rating (SEER/IEER) of the installed unit (if applicable)
- Coefficient of Performance (COP) of the unit installed (heat pumps and GSHPs only)
- Proof of purchase – with date of purchase and quantity
- Alternative: photo of unit installed or other pre-approved method of installation verification

[168] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=75.

[169] Department of Energy. "Guide to Geothermal Heat Pumps. February 2011. http://www.energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf.

[170] Department of Energy. Geothermal Heat Pump Energy Saver article. https://www.energy.gov/energysaver/geothermal-heat-pumps.

[171] Department of Energy. "Guide to Geothermal Heat Pumps. February 2011. http://www.energy.gov/sites/prod/files/guide_to_geothermal_heat_pumps.pdf.

- Manufacturer, model, capacity, and serial number
- AHRI/DOE CCMS certificate or reference number matching manufacturer and model number

# 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 58. Large Capacity AC/HPs—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Measure removed from TRM. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. No revision. |
| v3.1 | 11/05/2015 | TRM v3.1 update. No revision. |
| v4.0 | 10/10/2016 | TRM v4.0 update. No revision. |
| v5.0 | 10/2017 | TRM v5.0 update. No revision. |
| v6.0 | 11/2018 | TRM v6.0 update. Consolidated AC and HP measures and reintroduced to TRM. Extended measure applicability to GSHPs. Updated from deemed savings to algorithm approach. |
| v7.0 | 10/2019 | TRM v7.0 update. Updated documentation requirements. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated coincidence factors |
| v9.0 | 10/2021 | TRM v9.0 update. Updated baseline efficiency table to remove categories applicable to larger capacity ranges. Added GSHP coincidence factors. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated coincidence factors. |
| v11.0 | 10/2023 | TRM v11.0 update. Updated GSHP EUL. |

### 2.2.7 Evaporative Cooling Measure Overview

**TRM Measure ID:** R-HV-EC

**Market Sector:** Residential

**Measure Category:** HVAC

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculations

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

The following deemed savings values are applicable in calculating an incentive for the installation of a direct evaporative cooler instead of a refrigerated air system in an existing or new construction home in a dwelling occupied by a residential energy consumer.

## Eligibility Criteria

Direct whole-house evaporative cooling systems with a saturation efficiency of 0.85 or greater are eligible for this measure. Portable, window, indirect, and hybrid systems are not eligible.

## Baseline Condition

The baseline condition is a new refrigerated air conditioner with a rated efficiency at 14 SEER, the federal minimum standard.[172] The system being replaced is likely to be a less efficient evaporative cooling system, but the alternative to the new evaporative cooling unit is a minimally efficient refrigerated air conditioning system.

## High-Efficiency Condition

The high efficiency condition is a direct evaporative cooling system with a saturation efficiency of at least 0.85.

[172] DOE minimum efficiency standard for residential air conditioners/heat pumps. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=48&action=viewlive.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Deemed savings for this measure were derived using a reference metering study of evaporative cooling projects for Xcel Energy.[173] The energy savings from the Xcel study are adjusted for climate using a cooling degree day (CDD) ratio derived from TMY 2020 weather data.[174] Demand savings are calculated using the coincidence factor for the room air conditioner measure and an EFLH estimation simulated in a calibrated BEopt model that is used for other modeled measures in the Texas TRM.

### Energy Savings Algorithms

$$kWh_{Savings} = kWh_{Ref} \times \left(\frac{CDD_{Site}}{CDD_{Ref}}\right)$$

**Equation 48**

*Where:*

| | | |
|---|---|---|
| $kWh_{Ref}$ | = | *Reference kWh savings from Xcel Energy metering evaluation of evaporative cooling project in Grand Junction, CO: 2,041* |
| $CDD_{Ref}$ | = | *Cooling degree days for the reference location of Grand Junction, CO: 1,452* |
| $CDD_{Site}$ | = | *Cooling degree days for the project site location, El Paso, TX: 2,446* |

### Demand Savings Algorithms

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{kWh_{Savings}}{EFLH_{Site}} \times CF_S$$

**Equation 49**

[173] Evaporative Cooling Rebate Program Evaluation by The Cadmus Group, Inc., January 2010, Page 64, Table 23, Savings kWh value for Grand Junction Tier 2. https://www.xcelenergy.com/staticfiles/xe/Regulatory/Regulatory%20PDFs/EvaporativeCoolingProgramEvaluation.pdf.

[174] NSRDB Viewer: https://nsrdb.nrel.gov/.

*Where:*

| | | |
|---|---|---|
| $EFLH_{Site}$ | = | *Equivalent full-load hours of an evaporative cooling system for the project site location, El Paso, TX: 1,288*[175] |
| $CF_S$ | = | *Summer coincidence factor*[176] *= 0.87* |

## Deemed Savings Tables

**Table 59. Evaporative Cooling—Deemed Savings per System**

| Climate zone | kWh savings | Summer kW savings | Winter kW savings |
|---|---|---|---|
| 5 | 3,438 | 2.46 | 0 |

## 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) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HV-Evap.[177]

# 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
- Retired system model number and serial number (if applicable)
- Installed evaporative cooler model number and serial number
- Installed evaporative cooler saturation effectiveness

---

175 EFLH are calculated as the total annual kilowatt-hours divided by the max kilowatt value output by the BEopt model.

176 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential heat pumps be sized at 115 percent of the maximum cooling requirement of the residence (for cooling-dominated climates). Assuming that maximum cooling occurs during the peak period, the guideline leads to a coincidence factor of 1 / 1.15 = 0.87.

177 DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- Proof of purchase with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification

## 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 60. Evaporative Cooling—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v7.0 | 10/2019 | TRM v7.0 origin. |
| v8.0 | 10/2020 | TRM v8.0 update. No revision |
| v9.0 | 10/2021 | TRM v9.0 update. Updated EUL reference. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated CDD reference. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision |

## 2.2.8 ENERGY STAR® Connected Thermostats Measure Overview

**TRM Measure ID:** R-HV-CT

**Market Sector:** Residential

**Measure Category:** HVAC

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering spreadsheets and estimates

## Measure Description

Deemed savings are provided for the replacement of a standard or programmable thermostat with an ENERGY STAR connected thermostat.

## Eligibility Criteria

All residential customers with refrigerated air conditioning are eligible to claim cooling savings for this measure. Customers must have electric central heating (either an electric resistance furnace or a heat pump) to claim heating savings.

The connected thermostats measure is primarily a residential retrofit measure; savings are presented for the average efficiency ratings of installed HVAC systems. Deemed savings are also presented for new construction efficiency ratings (minimum efficiency set by Federal standards).

Customers should be advised against using the emergency heat (EM HEAT) setting on heat pump thermostats. This setting is meant only for use in emergency situations when the heat pump is damaged or malfunctioning. Supplemental heating automatically kicks on in below-freezing conditions using the regular HEAT setting. Contractors installing a new heat pump thermostat with equipment install shall advise customer of correct thermostat usage.

Customers that receive incentives for purchasing a thermostat device through an energy efficiency program may be able to enroll in the load management program offered by the utility at the point of purchase. Deemed demand savings can only be claimed for those customers if they participate in the peak demand events. Otherwise, these devices are only eligible for the deemed energy efficiency savings.

## Baseline Condition

The baseline condition is a residential central HVAC system controlled by a thermostat that does not meet the criteria for a connected thermostat (see high efficiency condition). For connected thermostats installed in conjunction with an existing HVAC unit, the baseline condition is an HVAC unit controlled by a manual or programmable thermostat with an average efficiency for existing HVAC units in Texas estimated as shown in Table 61.

**Table 61. Connected Thermostats—Baseline Efficiency of Existing ACs**

| Project type | Capacity (Btu/hr) | Cooling mode |
|---|---|---|
| Split air conditioners (manufactured as of 1/1/2023) | < 45,000 | 14.3 SEER2 |
| | ≥ 45,000 | 13.8 SEER2 |
| Packaged air conditioners (manufactured as of 1/1/2023) | All | 13.4 SEER2 |
| Split/packaged air conditioners (manufactured 1/1/2015 through 12/31/2022) | All | 12.8 SEER2 |
| Split/packaged air conditioners (when age is unknown)[178] | All | 12.3 SEER2 |
| Split/packaged air conditioners (manufactured 1/23/2006 through 12/31/2014) | All | 11.9 SEER2 |
| Split/packaged air conditioners (manufactured before 1/23/2006) | All | 9.1 SEER2 |

**Table 62. Connected Thermostats—Baseline Efficiency of Existing HPs**

| Project type | Cooling mode | Heating mode |
|---|---|---|
| Split heat pumps (manufactured as of 1/1/2023) | 14.3 SEER2 | 7.5 HSPF2 |
| Packaged heat pumps (manufactured as of 1/1/2023) | 13.4 SEER2 | 6.7 HSPF2 |
| Split heat pumps (manufactured 1/1/2015 through 12/31/2022) | 12.8 SEER2 | 6.9 HSPF2 |
| Packaged heat pumps (manufactured 1/1/2015 through 12/31/2022) | 12.8 SEER2 | 6.7 HSPF2 |
| Split heat pumps (when age is unknown)[179] | 12.3 SEER2 | 6.7 HSPF2 |
| Packaged heat pumps (when applying default age)[180] | 12.3 SEER2 | 6.6 HSPF2 |

[178] Baseline efficiencies are calculated by taking the average the early retirement categories for 2006–2014 and 2015–2022.
[179] Baseline efficiencies are calculated by taking the average the early retirement categories for 2006–2014 and 2015–2022.
[180] Ibid.

| Project type | Cooling mode | Heating mode |
|---|---|---|
| Split/packaged heat pumps (manufactured 1/23/2006 through 12/31/2014) | 11.9 SEER2 | 6.5 HSPF2 |
| Split/packaged heat pumps (manufactured before 1/23/2006) | 9.1 SEER2 | 5.7 HSPF2 |
| Electric resistance furnace | – | 3.412 HSPF2 |

For connected thermostats installed in conjunction with a new HVAC unit (for both retrofit and new construction applications), the baseline condition is an HVAC unit controlled by a manual or programmable thermostat with the baseline HVAC unit efficiency being equal to the efficiency of the installed system. The efficiency ratings of newly installed HVAC units should meet or exceed minimum values set by the federal manufacturing standards in effect at the time of the installation.

## High-Efficiency Condition

The high-efficiency condition is an HVAC unit being controlled by a connected thermostat compliant with the ENERGY STAR Final Version 1.0 requirements for eligible connected thermostats effective December3, 2016.[181] A list of eligible thermostats is available on the ENERGY STAR website.[182] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

## Energy and Demand Savings Methodology

Energy savings are estimated according to the program requirements established by the ENERGY STAR program for thermostat service providers seeking certification. In addition to a series of other technical and programmatic requirements, providers must demonstrate that their thermostat services result in significant run-time reductions for the controlled cooling and heating equipment. Specifically, ENERGY STAR provides the runtime reduction criteria reproduced in Table 63.

ENERGY STAR runtime reductions are translated to energy savings using the methodologies defined in the Central and Mini-Split Air Conditioners and Heat Pumps measure.

Demand (kW) savings are not estimated for the Connected Thermostats measure.

[181] ENERGY STAR Program Requirements Product Specification for Connected Thermostats, v1.0. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Program%20Requirements%20for%20Connected%20Thermostats%20Version%201.0.pdf.
[182] ENERGY STAR Certified Products: ENERGY STAR Certified Smart Thermostats. Online. Available: https://www.energystar.gov/productfinder/product/certified-connected-thermostats/results.

**Table 63. Connected Thermostats—Runtime Reduction Criteria for ENERGY STAR Certification**

| Metric | Statistical measure | Performance requirement |
|---|---|---|
| Annual percentage run time reduction, cooling | Lower 95 percent confidence limit of weighted national average | $\geq$ 10 percent |
| | Weighted national average of 20th percentiles | $\geq$ 5 percent |
| Annual percentage run time reduction, heating | Lower 95 percent confidence limit of weighted national average | $\geq$ 8 percent |
| | Weighted national average of 20th percentiles | $\geq$ 4 percent |
| Average resistance heat utilization for heat pump installations | National mean in 5°F outdoor temperature bins from 0 to 60°F | Reporting requirement |

## Savings Algorithms and Input Variables

Energy and demand savings algorithms and associated input variables are listed below.

### *Energy Savings Algorithms*

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

**Equation 50**

$$Cooling\ Energy\ Savings\ [kWh_C] = \frac{Cap_C}{\eta_C} \times EFLH_C \times \frac{1\ kW}{1{,}000\ W} \times CRF$$

**Equation 51**

$$Heating\ Energy\ Savings\ [kWh_H] = \frac{Cap_H}{\eta_H} \times EFLH_H \times \frac{1\ kW}{1{,}000\ W} \times HRF$$

**Equation 52**

*Where:*

$Cap_{C/H}$ = *HVAC equipment cooling/heating capacity. For thermostats installed on existing equipment, use the nominal tonnage converted to nominal capacity. For thermostats installed with a new HVAC system, use the AHRI rated capacity of the new equipment. [Btuh]; 1 ton = 12,000 Btuh*

$\eta_C$ = *HVAC equipment cooling efficiency. For thermostats installed on existing equipment, default to the code SEER2 rating from Table 61 for ACs and Table 62 for HPs. For thermostats installed with a new HVAC system, use the AHRI SEER2 rating of the new equipment. [Btuh/W]*

| | | |
|---|---|---|
| $\eta_H$ | = | *HVAC equipment heating efficiency. For thermostats installed on existing equipment, default to the code HSPF2 from Table 62. For thermostats installed with a new HVAC system, use the AHRI HSPF2 rating of the new equipment. [Btuh/W]* |
| $EFLH_{C/H}$ | = | *Cooling/heating equivalent full-load hours (Table 64)* |
| $CRF$ | = | *Cooling hours reduction factor = 10% (Table 63)* |
| $HRF$ | = | *Heating hours reduction factor = 8% (Table 63)* |

**Table 64. Connected Thermostats—Equivalent Full Load Cooling/Heating Hours[183]**

| Climate zone | $EFLH_C$ | $EFLH_H$ |
|---|---|---|
| Zone 1: Amarillo | 1,142 | 1,880 |
| Zone 2: Dallas | 1,926 | 1,343 |
| Zone 3: Houston | 2,209 | 1,127 |
| Zone 4: Corpus Christi | 2,958 | 776 |
| Zone 5: El Paso | 1,524 | 1,559 |

## Deemed Energy Savings Tables

Deemed savings tables are only provided for connected thermostats installations where the cooling and heating equipment is unspecified. Savings are presented in kWh per thermostat, assuming a default of 3.7 tons.[184]

The following table describes various equipment replacement scenarios that may be encountered and specifies which baseline should be used in each case.

**Table 65. Connected Thermostats—Baseline for Various Equipment Replacement Scenarios**

| Equipment replacement scenario | Baseline | |
|---|---|---|
| | Cooling | Heating |
| No HVAC equipment replacement | Existing | Existing |
| Non-condenser replacements (e.g., coil or furnace ONLY) | Existing | Existing |
| Air conditioner condenser replacement with gas furnace | New | No savings |
| Air conditioner condenser replacement with electric heat | New | Existing |
| Heat pump condenser replacement | New | New |

[183] ENERGY STAR Central AC/HP Savings Calculator.

[184] Based on review of average reported cooling capacity for central air conditioners and heat pumps installed in Texas utility programs in previous program years.

For upstream programs, assume a heating type weighting of 41.8 percent gas, 49.3 percent electric resistance, and 9.0 percent heat pump heat.[185]

**Table 66. Connected Thermostats—Energy Savings for Thermostats Installed on Unspecified Existing HVAC[186] (kWh/thermostat)**

| Climate zone | Total energy savings |
|---|---|
| Zone 1: Amarillo | 1,549 |
| Zone 2: Dallas | 1,507 |
| Zone 3: Houston | 1,479 |
| Zone 4: Corpus Christi | 1,537 |
| Zone 5: El Paso | 1,493 |

## Deemed Summer Demand Savings Tables

Summer demand savings shall not be claimed for the connected thermostats measure.

## Deemed Winter Demand Savings Tables

Winter demand savings shall not be claimed for the connected thermostats measure.

## Claimed Peak Demand Savings

Not applicable.

## Example Deemed Savings Calculation

**Example 1.** A direct installed connected thermostat is installed on an existing 3.5 ton split air conditioner manufactured in 2015 in Climate Zone 2.

$$Cooling\ Energy\ Savings = \frac{3.5 \times 12{,}000 \times 1{,}926 \times 0.10}{12.8 \times 1{,}000} = 632\ kWh$$

$$Heating\ Energy\ Savings = 0\ kWh$$

$$Total\ kWh\ Savings = 632 + 0 = 632\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 0\ kW$$

$$Winter\ Peak\ Demand\ Savings = 0\ kW$$

185 Residential Energy Consumption Survey (RECS) 2015: Space heating in homes in the South and West Regions (HC6.8), February 27, 2017. https://www.eia.gov/consumption/residential/data/2015/.

186 Assuming smart thermostat is installed in conjunction with an existing 3.7-ton HVAC unit.

**Example 2.** A direct install connected thermostat is installed with a new 5 ton split heat pump rated at 56,000 cooling Btuh, 55,000 heating Btuh, 15.2 SEER2 and 8 HSPF2 in Climate Zone 3.

$$Cooling\ Energy\ Savings\ = \frac{56{,}000 \times 2{,}209 \times 0.10}{15.2\ \times 1{,}000} = 814\ kWh$$

$$Heating\ Energy\ Savings\ = \frac{55{,}000 \times 1{,}127 \times 0.08}{8\ \times 1{,}000} = 620\ kWh$$

$$Total\ kWh\ Savings = 814 + 620 = 1{,}434\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 0\ kW$$

$$Winter\ Peak\ Demand\ Savings = 0\ kW$$

**Example 3.** A midstream/upstream connected thermostat is installed in Climate Zone 4.

$$Total\ kWh\ Savings = 1{,}537\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 0\ kW$$

$$Winter\ Peak\ Demand\ Savings = 0\ kW$$

### Additional Calculators and Tools

Not applicable.

### Measure Life and Lifetime Savings

The estimated useful life (EUL) is 11 years as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HV-ProgTstat.[187]

## 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:

All program types:

- Climate zone or county
- Thermostat quantity sold/installed
- Thermostat manufacturer and model number
- Copy of ENERGY STAR certificate matching model number

[187] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

Additional requirements for all program types other than upstream/midstream:

- HVAC system type (AC/HP)
- Determine whether HVAC condenser was replaced in conjunction with the thermostat
- If installed with existing HVAC equipment:
  - HVAC capacity (Btuh): Nominal tons converted to capacity
  - Manufacture year
- If installed with new HVAC system:
  - HVAC capacity (Btuh): AHRI rated capacity
  - Part-load cooling efficiency (SEER2)
  - Full-load cooling efficiency (EER2)
  - Heating efficiency (HSPF2) – HPs only
  - Heating type (gas, electric resistance, heat pump, none)
- Proof of purchase with date of purchase and quantity
  - Alternative: photo of unit installed or another pre-approved method of installation verification

## References and Efficiency Standards

### Petitions and Rulings

- Docket No. 48265. Petition of AEP Texas Inc., CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company. Petition to Approve Deemed Savings for New Nonresidential Door Air Infiltration, Nonresidential Door Gaskets, and Residential ENERGY STAR Connected Thermostats. Public Utility Commission of Texas.

### Relevant Standards and Reference Sources

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

## Document Revision History

**Table 67. Connected Thermostats—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v6.0 | 11/2018 | TRM v6.0 origin. |
| v7.0 | 10/2019 | TRM v7.0 revision. Updated documentation requirement. |
| v8.0 | 10/2020 | TRM v8.0 update. No revision. |
| v9.0 | 10/2021 | TRM v9.0 update. Provided guidance about emergency heat settings and updated EUL reference. Added clarification to prevent double counting of savings with smart thermostat load management measure. |
| v10.0 | 10/2022 | TRM v10.0 update. No revision. |
| v11.0 | 10/2023 | TRM v11.0 update. Incorporated algorithm approach. Incorporated new SEER2 test procedure. |

### 2.2.9 Smart Thermostat Load Management Measure Overview

**TRM Measure ID:** R-HV-TD

**Market Sector:** Residential

**Measure Category:** HVAC

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Measurement and verification

## Measure Description

Deemed demand savings are provided for calling load management events on smart thermostats[188] in summer afternoons. A load management event is a process through which a utility may optimize available resources by sending a signal to customers' smart thermostats. The signal modifies the smart thermostats temperature setting to reduce overall load demand from central refrigerated air conditioning.

## Eligibility Criteria

All Texas residential customers with smart thermostats participating in Climate Zone 5 load management events are eligible to claim demand savings for this measure.

Customers that receive incentives for purchasing a thermostat device through an energy efficiency program may be able to enroll in the load management program offered by the utility at the point of purchase. Deemed demand savings can only be claimed for those customers if they participate in the peak demand events. Otherwise, these devices are only eligible for the deemed energy efficiency savings.

## Baseline Condition

The baseline condition is a heating, ventilation, and air conditioning (HVAC) unit operating in the absence of the load management event and subsequent load management activities.

## High-Efficiency Condition

The high-efficiency condition is an HVAC unit being controlled by a smart thermostat and participating in a load management event.

[188] In this case, smart thermostats are internet-enabled devices that control a home's heating and air conditioning and can be remotely controlled by El Paso Electric Company for load management events.

## Energy and Demand Savings Methodology

Demand savings were calculated using the “High 3 of 5 Baseline with Day-of Adjustment” method adopted in the Texas Technical Reference Manual Version 5.0 (TRM 5.0). This method considered the five most recent non-event non-holiday weekdays preceding an event and used data from the three days with the highest load within those five days to establish the baseline. “Day-of” adjustments were used to scale the baseline load estimate to the load conditions on the day of the event using data from the two hours prior to the time on the event day when participants were notified of the pending call for curtailment. In this specific program, customers were likely to experience a pre-cool period lasting up to one hour prior to the event. Therefore, the adjustment period was set as the two-hour period three hours prior to the event.

Interval metering devices were installed on a sample of households to record 15-minute interval kW demand of each house. Consumption data were recorded for a total of 50 homes in Texas. Among these 50 homes, 43 have un-anonymized thermostat run-time data, which allow linking interval consumption data with run-time data for each home. Data for customers in the sample was recorded beginning June 23, 2017. The deemed demand savings presented below were derived from these 43 homes in the summer 2018 data.

Event-level savings are calculated by multiplying kW savings per device by the number of participating devices for each event. Devices that participated no less than 50 percent of the total event duration are identified as participating devices. The average of the events’ savings represents the program year savings.

Energy savings are not estimated through this specific measure.

## Savings Algorithms and Input Variables

The demand algorithms and associated input variables are listed below:

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = Baseline\ Period\ kW - Curtailment\ kW$$

**Equation 53**

*Where:*

| | | |
|---|---|---|
| *Baseline Period kW* | = | *Baseline average demand calculated according to the High 3 of 5 Baseline Method* |
| *Curtailment kW* | = | *Average demand measured during the curtailment period* |

## Deemed Energy Savings Tables

Energy savings shall not be claimed using the methodology described in this measure.

## Deemed Summer Demand Savings Tables

**Table 68. Smart Thermostat Load Management—Deemed kW Savings per Device**

| Climate zone | kW/device |
|---|---|
| 5 | 1.45 |

## Deemed Winter Demand Savings Tables

Winter demand savings shall not be claimed using the methodology described in this measure.

## Claimed Peak Demand Savings

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

## Example Deemed Savings Calculation

**Example 1.** A smart thermostat is installed in a home participating in summer load management events:

$$Summer\ kWsavings = 1.45\ kW$$

$$Winter\ kW\ savings = 0\ kW$$

$$kWh\ savings = 0\ kWh$$

**Example 2.** Suppose ten events were called in an entire summer with participation counts listed in the table below. The total program year demand savings would be the average of the event-level savings.

**Table 69. Smart Thermostat Load Management—Example Total Program Year Savings Calculation**

| Event number | Texas | | Event-level demand savings (kW) |
|---|---|---|---|
| | Deemed savings per device (kW) | Participating device number | |
| Event 1 | 1.45 | 600 | 870 |
| Event 2 | 1.45 | 671 | 973 |
| Event 3 | 1.45 | 744 | 1,079 |
| Event 4 | 1.45 | 819 | 1,188 |
| Event 5 | 1.45 | 868 | 1,259 |
| Event 6 | 1.45 | 975 | 1,414 |
| Event 7 | 1.45 | 826 | 1,198 |
| Event 8 | 1.45 | 910 | 1,320 |
| Event 9 | 1.45 | 804 | 1,166 |
| Event 10 | 1.45 | 704 | 1,021 |
| **Total program year demand savings (kW):** | | | 1,149 |

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is one year for smart thermostat load management.

## 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
- A list of all load management events affecting residential participants, describing their date, the time the event started, and the time the event ended.
- List of targeted smart thermostats in each event and unique identifier for each device.
- Participation status for targeted thermostats (e.g., participant and non-participant as described below), runtime data, or other information to assign participation status (e.g., duration of participation, offline, opted-out).
    - Participants are smart thermostats that participated no less than 50 percent of the total event duration.
    - Devices that opted out after participating for no less than 50 percent of the total event duration may be included in the participants list for that specific event.
    - All other devices that participated for less than 50 percent of the total event duration or were offline are considered non-participants and should be excluded from the participants list and savings calculation for that event.

Summary of savings calculations and rounding practices.

- Data rounding to the nearest whole number should only occur at the event and program levels for residential load management programs (NOT at the customer level). Utilities that prefer not to round the savings should document that in their calculations and inform the EM&V team (see Volume 5 section 3.1 for more details).

## 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 70. Smart Thermostat Load Management—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v6.0 | 11/2018 | TRM v6.0 origin. |
| v7.0 | 10/2019 | TRM v7.0 update. Updates to calculated savings. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated description and tracking requirements. |
| v9.0 | 10/2021 | TRM v9.0 update. Added clarification to prevent double counting of savings with smart thermostat load management measure. |
| v10.0 | 10/2022 | TRM v10.0 update. No revision. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision. |

## 2.2.10 Duct Sealing Measure Overview

**TRM Measure ID:** R-HV-DS

**Market Sector:** Residential

**Measure Category:** HVAC

**Applicable Building Types:** Single-family, manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Building simulation modeling

## Measure Description

This measure involves sealing leaks in supply and return ducts of the HVAC distribution systems in homes or converted residences with central air conditioning. The standard approach to estimate savings in this measure is based on the results obtained via pre- and post-leakage testing as defined in this measure. In lieu of leakage testing, savings for eligible duct sealing projects may be claimed using the alternate approach specified in this measure.

## Eligibility Criteria

All single-family customers with ducted central refrigerated air conditioning or evaporative cooling are eligible to claim cooling savings for this measure. Customers must have ducted central heating with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. The specified deemed savings are not applicable to multifamily customers or to residences with space (non-central or ducted) air conditioning or heating.

For the standard approach with leakage testing, duct leakage should be assessed following the Building Performance Institute (BPI) standards. Duct leakage testing should not be conducted in homes where either evidence of asbestos or mold is present or suspected due to the age of the home.[189]

[189] "Technical Standards for the Building Analyst Professional", Building Performance Institute (BPI), v1/4/12, Page 1 of 17, states:
"Health and Safety: Where the presence of asbestos, lead, mold and/or other potentially hazardous material is known or suspected, all relevant state and federal (EPA) guidelines must be followed to ensure technician and occupant safety. Blower door depressurization tests may not be performed in homes *where there is a risk of asbestos becoming airborne and being drawn into the dwelling."* http://www.bpi.org/sites/default/files/Technical%20Standards%20for%20the%20Building%20Analyst%20Professional.pdf.

Utility program manuals should be consulted for health and safety considerations related to the implementation of duct efficiency measures and/or testing procedures.

Duct sealing is a residential retrofit measure only and does not apply to new construction.

## Baseline Condition

The savings calculation methods for this measure (when implemented with duct leakage testing) are valid up to a maximum pre-installation leakage rate of 35 percent of total fan flow.[190] For homes with an initial leakage rate greater than 35 percent of total fan flow, savings will be awarded with respect to this cap rather than the initial leakage. Data from nearly 28,000 single-family and mobile home duct blaster tests conducted for duct efficiency improvements in Texas between 2003 and 2006 show that more than 70 percent of all pre-retrofit leakage rates fall below 38 percent total leakage.[191]

Engineering calculations show that the interior temperature in those settings that exceed 38 percent total leakage would be above the thermally acceptable comfort levels published by ASHRAE in its 2009 Fundamentals publication. The proposed pre-installation leakage limits will help ensure that the deemed savings are an accurate reflection of the program's impacts and that the program focuses its efforts on scenarios where leakage conditions are likely to persist if unaddressed for several years.

Low-income customers[192] are exempt from the cap limiting the maximum pre-installation leakage rate to 35 percent of total fan flow.

While these baseline criteria were applied in deriving the deemed savings for the alternate approach (without duct leakage testing), it is not necessary to determine the pre-installation leakage rate for projects claiming the alternate deemed savings.

## High-Efficiency Condition

Materials used should be long-lasting materials, such as mastics, UL 181A or UL 181B approved foil tape or aerosol-based sealants. Fabric-based duct tape is not allowed.

The selected methodology for estimating duct sealing deemed savings according to the standard approach requires duct leakage-to-outside testing using a combination duct pressurization and house pressurization.

[190] Total Fan Flow = Cooling Capacity (tons) x 400 cfm/ton.
[191] Based on data collected by Frontier Energy for investor-owned utilities in Texas.
[192] Low-income customers are income-eligible customers served through a targeted low-income energy efficiency program as described in 25.181(r). This may also apply to income-eligible customers served through a hard-to-reach program that is also delivered following the guidelines in 25.181(r). https://www.puc.texas.gov/agency/rulesnlaws/subrules/electric/25.181/25.181.pdf.

## *Duct Leakage Testing (Standard Approach)*

Measurements to determine pre-installation and post-installation leakage rates must be performed in accordance with utility-approved procedures. For this measure, leakage-to-outside must be directly measured. The project sponsor shall use the Combination Duct Blaster™ (or equivalent) and blower door method. Prior to beginning any installations, the project sponsor must submit the intended method(s) and may be required to provide the utility with evidence of competency, such as RESNET certification, North American Technician Excellence (NATE) certification, or other certification by evaluator approved EPA-recognized ENERGY STAR Home Certification Organization (HCO). Leakage rates must be measured and reported at the average air distribution system operating pressure (25 Pa).[193]

## *Categorizing Achieved Duct Leakage Reduction (Absent Leakage Testing)*

Participating energy efficiency service providers (EESPs) electing not to perform leakage testing should nevertheless provide an estimate of the expected outcome of the leakage reduction work performed: projects should be characterized according to contractor estimation of whether the work required should result in a ***low***, ***average***, or ***high reduction*** in duct system leakage. EESPs should take the following considerations into account in assessing the likely leakage reduction achieved in a given project:

- The number and size of repaired leaks
- Leak location: a leak in an attic joint will cause more energy loss than a joint that leaks to conditioned space
- Supply/return: supply-side leaks, particularly in the return air plenum and near the air handling unit can be especially problematic, as they tend to draw additional unconditioned air into the system.

Systems that were not initially very leaky and in which few joints and supply vents were sealed should be characterized as low reduction. Jobs with a typical number of supply vents and joints sealed, and in which the supply air return or the return air plenum were sealed, should be characterized as average reduction. Jobs requiring significant interventions to eliminate large or numerous leaks should be considered high reduction.

The following table provides a guideline for selecting an appropriate leakage category. How the category is determined may fluctuate on a per-home basis.

[193] See ANSI/RESNET/ICC 380, Chapter 4 Procedure for Measuring Airtightness of Building or Dwelling Unit Enclosure and Chapter 5 Procedure for Measuring Airtightness of Duct Systems.

**Table 71. Duct Sealing—Leakage Categorization Guide**[194]

| Category | Duct location | Duct insulation value | Leakage characteristics[195] |
|---|---|---|---|
| Low | > 90 percent conditioned | > R7 | Some observable leaks |
| | | | Substantial leaks |
| | | R4 - R7 | Some observable leaks |
| | | | Substantial leaks |
| | | < R4 | Some observable leaks |
| | | | Substantial leaks |
| | 50-90 percent conditioned | > R7 | Some observable leaks |
| | | R4 - R7 | Some observable leaks |
| | | < R4 | Some observable leaks |
| Average | > 90 percent conditioned | > R7 | Catastrophic leaks |
| | | R4 - R7 | Catastrophic leaks |
| | | < R4 | Catastrophic leaks |
| | 50-90 percent conditioned | > R7 | Substantial leaks |
| | | | Catastrophic leaks |
| | | R4 - R7 | Substantial leaks |
| | | < R4 | Substantial leaks |
| | < 50 percent conditioned | > R7 | Some observable leaks |
| | | R4 - R7 | Some observable leaks |
| | | < R4 | Some observable leaks |
| High | 50-90 percent conditioned | R4 - R7 | Catastrophic leaks |
| | | < R4 | Catastrophic leaks |
| | < 50 percent conditioned | > R7 | Substantial leaks |
| | | | Catastrophic leaks |
| | | R4 - R7 | Substantial leaks |
| | | | Catastrophic leaks |
| | | < R4 | Substantial leaks |
| | | | Catastrophic leaks |

## Energy and Demand Savings Methodology

Savings may be claimed according to either the standard approach (with duct leakage testing) or the alternate approach, according to the following sections.

194 Based on typical distribution efficiency assumptions from the Building Performance Institute (BPI) Technical Standards for the Heating Professional, November 20, 2007, page 7. http://www.bpi.org/sites/default/files/Technical%20Standards%20for%20the%20Heating%20Professional.pdf.

195 Catastrophic leaks are defined by BPI as disconnected ducts, missing end-caps, and other catastrophic holes.

### *Standard Approach (with Duct Leakage Testing)*

The annual energy and summer and winter peak demand savings to be claimed according to the standard approach for this measure shall be calculated as a function of the reduction in duct leakage achieved, using the energy and demand savings coefficients from Table 72 through Table 74 for the climate zone in which the project was implemented and the type of heating equipment in the project home.

## Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings, which are expressed as linear functions of the reduction in duct leakage achieved (in $CFM_{25}$). Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: the base case duct leakage rate was set to 8 $CFM_{25}$ per 100 square feet. Results from running the base case model provide estimated hourly energy use for the prototypical home prior to treatment. Post-treatment conditions were simulated by setting the leakage rate to 6 $CFM_{25}$ per 100 square feet. Results from running the change case model provide estimated hourly energy use for the prototypical home after treatment. A comparison of these two runs provides the deemed savings estimates.

Deemed savings are presented as a function of the $CFM_{25}$ reduction achieved, as demonstrated by leakage to outside testing using the Combination Duct Blaster™ (or equivalent) and Blower Door method. The kWh and kW per $CFM_{50}$ values represented by the $V_E$, $V_S$, and $V_W$ coefficients are derived by taking the difference between annual energy use and summer and winter peak demand, as estimated by the two model runs and normalizing to the $CFM_{25}$ reduction achieved.

## Deemed Energy Savings Tables

Table 72 presents the annual energy savings per $CFM_{25}$ reduction for a residential duct sealing project. The following formula shall be used to calculate annual energy savings for duct leakage reduction:

$$Energy\ Savings\ [\Delta kWh] = \left(DL_{pre} - DL_{post}\right) \times V_E$$

**Equation 54**

*Where:*

| | | |
|---|---|---|
| $DL_{pre}$ | = | *Pre-improvement duct leakage at 25 Pa (cu. ft./min)* |
| $DL_{post}$ | = | *Post-improvement duct leakage at 25 Pa (cu. ft./min)* |
| $V_{E,C}$ | = | *Cooling Energy Savings Coefficient in Table 72* |
| $V_{E,H}$ | = | *Heating Energy Savings Coefficient in Table 72* |

**Table 72. Duct Sealing—Energy Savings $V_E$ per $CFM_{25}$ Reduction**

| Climate zone | $V_{E,C}$: Cooling savings | | $V_{E,H}$: Heating savings | | |
|---|---|---|---|---|---|
| | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | 0.82 | 0.21 | 0.07 | 2.75 | 0.71 |
| Zone 2: Dallas | 1.05 | – | 0.03 | 1.19 | 0.31 |
| Zone 3: Houston | 1.23 | – | 0.02 | 0.85 | 0.26 |
| Zone 4: Corpus Christi | 1.46 | – | 0.01 | 0.61 | 0.19 |
| Zone 5: El Paso | 1.20 | 0.38 | 0.03 | 1.44 | 0.37 |

## Deemed Summer Demand Savings Tables

Table 73 presents the summer peak demand savings per $CFM_{25}$ reduction for a residential duct sealing project. The following formula shall be used to calculate deemed summer demand savings for duct leakage reduction:

$$Summer\ Pek\ Demand\ Savings\ [\Delta kW] = \left(DL_{pre} - DL_{post}\right) \times V_S$$

**Equation 55**

*Where:*

$V_S$ = *Summer Demand Savings Coefficient (see Table 73)*

**Table 73. Duct Sealing—Summer Demand Savings $V_S$ per $CFM_{25}$ Reduction**

| Climate zone | Summer kW impact per $CFM_{25}$ reduction | |
|---|---|---|
| | Refrigerated | Evaporative |
| Zone 1: Amarillo | 9.28E-04 | 2.29E-04 |
| Zone 2: Dallas | 8.47E-04 | – |
| Zone 3: Houston | 1.06E-03 | – |
| Zone 4: Corpus Christi | 6.72E-04 | – |
| Zone 5: El Paso | 7.66E-04 | 1.86E-04 |

## Deemed Winter Demand Savings Tables

Table 74 presents the winter peak demand savings per $CFM_{25}$ reduction for a residential duct sealing project. The following formula shall be used to calculate deemed winter demand savings for duct leakage reduction:

$$Deemed\ Winter\ Demand\ Savings\ (kW) = \left(DL_{pre} - DL_{post}\right) \times V_W$$

**Equation 56**

*Where:*

$V_W$ = *Winter Demand Savings Coefficient (see Table 74)*

**Table 74. Duct Sealing—Winter Demand Savings $V_W$ per $CFM_{25}$ Reduction**

| Climate zone | kWh impact per $CFM_{25}$ reduction | | |
|---|---|---|---|
| | Gas | Resistance | Heat pump |
| Zone 1: Amarillo | 4.38E-06 | 8.49E-04 | 1.46E-04 |
| Zone 2: Dallas | 1.22E-06 | 9.96E-04 | 6.98E-04 |
| Zone 3: Houston | 8.60E-06 | 8.61E-04 | 5.02E-04 |
| Zone 4: Corpus Christi | 1.18E-05 | 6.71E-04 | 4.06E-04 |
| Zone 5: El Paso | 6.68E-06 | 2.81E-04 | 6.69E-05 |

### *Alternate Approach (No Duct Leakage Testing)*

The following savings tables are provided for projects implemented without performing leakage testing, accounting for the application of pre-retrofit leakage caps to not hard-to-reach (HTR) projects. The annual energy and summer and winter peak demand savings to be claimed according to the alternate approach for this measure shall be taken from Table 72 through Table 74 for the climate zone in which the project was implemented and the type of heating equipment in the project home.

While savings for multiple duct systems are additive for the standard approach, the following savings are specified per home when using the alternate approach and should not be multiplied by the number of treated duct systems.

NOTE: This approach is only available to programs with an incentive structure that does not vary by leakage category. Additionally, energy efficiency service providers (EESPs) should not alternate between the standard and alternative approaches during the same program year. Utilities should either restrict all participants within an individual program to one approach or the other, or they should restrict individual EESPs to one approach or the other across all program types.

## *Hard-to-Reach (HTR) and Targeted Low-Income Programs*

## *Deemed Energy Savings Tables (Alternate Approach)*

**Table 75. Duct Sealing—Climate Zone 1: Amarillo—Energy Savings (kWh), HTR Alternate Approach**

| Category | Assessed leakiness | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| 1 | Low | 204 | 52 | 17 | 685 | 177 |
| 2 | Average | 323 | 83 | 28 | 1,083 | 280 |
| 3 | High | 514 | 132 | 44 | 1,725 | 445 |

**Table 76. Duct Sealing—Climate Zone 2: Dallas—Energy Savings (kWh), HTR Alternate Approach**

| Category | Assessed leakiness | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| 1 | Low | 262 | – | 7 | 297 | 77 |
| 2 | Average | 413 | – | 12 | 468 | 122 |
| 3 | High | 659 | – | 19 | 746 | 194 |

**Table 77. Duct Sealing—Climate Zone 3: Houston—Energy Savings (kWh), HTR Alternate Approach**

| Category | Assessed leakiness | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| 1 | Low | 307 | – | 5 | 212 | 65 |
| 2 | Average | 484 | – | 8 | 335 | 102 |
| 3 | High | 771 | – | 13 | 533 | 163 |

**Table 78. Duct Sealing—Climate Zone 4: Corpus Christi—Energy Savings (kWh), HTR Alternate Approach**

| Category | Assessed leakiness | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| 1 | Low | 364 | – | 2 | 152 | 47 |
| 2 | Average | 575 | – | 4 | 240 | 75 |
| 3 | High | 916 | – | 6 | 383 | 119 |

Table 79. Duct Sealing—Climate Zone 5: El Paso—Energy Savings (kWh), HTR Alternate Approach

| Category | Assessed leakiness | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| 1 | Low | 299 | 95 | 7 | 359 | 92 |
| 2 | Average | 472 | 150 | 12 | 567 | 146 |
| 3 | High | 753 | 238 | 19 | 903 | 232 |

### *Deemed Summer Demand Savings Tables (Alternate Approach)*

Table 80. Duct Sealing—Climate Zone 1: Amarillo—Summer Peak Demand Savings (kW), HTR Alternate Approach

| Category | Refrigerated | Evaporative |
|---|---|---|
| Low | 0.23 | 0.06 |
| Average | 0.37 | 0.09 |
| High | 0.58 | 0.14 |

Table 81. Duct Sealing—Climate Zone 2: Dallas—Summer Peak Demand Savings (kW), HTR Alternate Approach

| Category | Refrigerated | Evaporative |
|---|---|---|
| Low | 0.21 | – |
| Average | 0.33 | – |
| High | 0.53 | – |

Table 82. Duct Sealing—Climate Zone 3: Houston—Summer Peak Demand Savings (kW), HTR Alternate Approach

| Category | Refrigerated | Evaporative |
|---|---|---|
| Low | 0.26 | – |
| Average | 0.42 | – |
| High | 0.66 | – |

Table 83. Duct Sealing—Climate Zone 4: Corpus Christi—Summer Peak Demand Savings (kW), HTR Alternate Approach

| Category | Refrigerated | Evaporative |
|---|---|---|
| Low | 0.17 | – |
| Average | 0.26 | – |
| High | 0.42 | – |

**Table 84. Duct Sealing—Climate Zone 5: El Paso—Summer Peak Demand Savings (kW), HTR Alternate Approach**

| Category | Refrigerated | Evaporative |
|---|---|---|
| Low | 0.19 | 0.05 |
| Average | 0.30 | 0.07 |
| High | 0.48 | 0.12 |

### *Deemed Winter Demand Savings Tables (Alternate Approach)*

**Table 85. Duct Sealing—Climate Zone 1: Amarillo—Winter Peak Demand Savings (kW), HTR Alternate Approach**

| Category | Heating system type | | |
|---|---|---|---|
| | Gas | Electric resistance | Heat pump |
| Low | 0.00 | 0.21 | 0.04 |
| Average | 0.00 | 0.33 | 0.06 |
| High | 0.00 | 0.53 | 0.09 |

**Table 86. Duct Sealing—Climate Zone 2: Dallas—Winter Peak Demand Savings (kW), HTR Alternate Approach**

| Category | Heating system type | | |
|---|---|---|---|
| | Gas | Electric resistance | Heat pump |
| Low | 0.00 | 0.25 | 0.17 |
| Average | 0.00 | 0.39 | 0.27 |
| High | 0.00 | 0.62 | 0.44 |

**Table 87. Duct Sealing—Climate Zone 3: Houston—Winter Peak Demand Savings (kW), HTR Alternate Approach**

| Category | Heating system type | | |
|---|---|---|---|
| | Gas | Electric resistance | Heat pump |
| Low | 0.00 | 0.21 | 0.13 |
| Average | 0.00 | 0.34 | 0.20 |
| High | 0.01 | 0.54 | 0.31 |

**Table 88. Duct Sealing—Climate Zone 4: Corpus Christi—Winter Peak Demand Savings (kW), HTR Alternate Approach**

| Category | Heating system type | | |
|---|---|---|---|
| | Gas | Electric resistance | Heat pump |
| Low | 0.00 | 0.17 | 0.10 |
| Average | 0.00 | 0.26 | 0.16 |
| High | 0.01 | 0.42 | 0.25 |

**Table 89. Duct Sealing—Climate Zone 5: El Paso—Winter Peak Demand Savings (kW), HTR Alternate Approach**

| Category | Heating system type | | |
|---|---|---|---|
| | Gas | Electric resistance | Heat pump |
| Low | 0.00 | 0.07 | 0.02 |
| Average | 0.00 | 0.11 | 0.03 |
| High | 0.00 | 0.18 | 0.04 |

### *All Other Programs*

### *Deemed Energy Savings Tables (Alternate Approach)*

**Table 90. Duct Sealing—Climate Zone 1: Amarillo—Energy Savings (kWh), Alternate Approach**

| Category | Assessed leakiness | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| 1 | Low | 187 | 48 | 16 | 628 | 162 |
| 2 | Average | 300 | 77 | 26 | 1,005 | 259 |
| 3 | High | 428 | 110 | 37 | 1,437 | 371 |

**Table 91. Duct Sealing—Climate Zone 2: Dallas—Energy Savings (kWh), Alternate Approach**

| Category | Assessed leakiness | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| 1 | Low | 240 | – | 7 | 272 | 71 |
| 2 | Average | 384 | – | 11 | 435 | 113 |
| 3 | High | 549 | – | 16 | 622 | 162 |

Table 92. Duct Sealing—Climate Zone 3: Houston—Energy Savings (kWh), Alternate Approach

| Category | Assessed leakiness | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| 1 | Low | 281 | – | 5 | 194 | 59 |
| 2 | Average | 449 | – | 7 | 310 | 95 |
| 3 | High | 643 | – | 10 | 444 | 136 |

Table 93. Duct Sealing—Climate Zone 4: Corpus Christi—Energy Savings (kWh), Alternate Approach

| Category | Assessed leakiness | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| 1 | Low | 333 | – | 2 | 139 | 43 |
| 2 | Average | 533 | – | 4 | 223 | 69 |
| 3 | High | 763 | – | 5 | 319 | 99 |

Table 94. Duct Sealing—Climate Zone 5: El Paso—Energy Savings (kWh), Alternate Approach

| Category | Assessed leakiness | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| 1 | Low | 274 | 87 | 7 | 329 | 84 |
| 2 | Average | 438 | 139 | 11 | 526 | 135 |
| 3 | High | 627 | 199 | 16 | 752 | 193 |

### *Deemed Summer Demand Savings Tables (Alternate Approach)*

Table 95. Duct Sealing—Climate Zone 1: Amarillo—Summer Peak Demand Savings (kW), Alternate Approach

| Category | Refrigerated | Evaporative |
|---|---|---|
| Low | 0.21 | 0.05 |
| Average | 0.34 | 0.08 |
| High | 0.48 | 0.12 |

**Table 96. Duct Sealing—Climate Zone 2: Dallas—Summer Peak Demand Savings (kW), Alternate Approach**

| Category | Refrigerated | Evaporative |
|---|---|---|
| Low | 0.19 | – |
| Average | 0.31 | – |
| High | 0.44 | – |

**Table 97. Duct Sealing—Climate Zone 3: Houston—Summer Peak Demand Savings (kW), Alternate Approach**

| Category | Refrigerated | Evaporative |
|---|---|---|
| Low | 0.24 | – |
| Average | 0.39 | – |
| High | 0.55 | – |

**Table 98. Duct Sealing—Climate Zone 4: Corpus Christi—Summer Peak Demand Savings (kW), Alternate Approach**

| Category | Refrigerated | Evaporative |
|---|---|---|
| Low | 0.15 | – |
| Average | 0.25 | – |
| High | 0.35 | – |

**Table 99. Duct Sealing—Climate Zone 5: El Paso—Summer Peak Demand Savings (kW), Alternate Approach**

| Category | Refrigerated | Evaporative |
|---|---|---|
| Low | 0.17 | 0.04 |
| Average | 0.28 | 0.07 |
| High | 0.40 | 0.10 |

### *Deemed Winter Demand Savings Tables (Alternate Approach)*

**Table 100. Duct Sealing—Climate Zone 1: Amarillo—Winter Peak Demand Savings (kW), Alternate Approach**

| Category | Heating system type | | |
|---|---|---|---|
| | Gas | Electric resistance | Heat pump |
| Low | 0.00 | 0.19 | 0.03 |
| Average | 0.00 | 0.31 | 0.05 |
| High | 0.00 | 0.44 | 0.08 |

**Table 101. Duct Sealing—Climate Zone 2: Dallas—Winter Peak Demand Savings (kW), Alternate Approach**

| Category | Heating system type | | |
|---|---|---|---|
| | Gas | Electric resistance | Heat pump |
| Low | 0.00 | 0.23 | 0.16 |
| Average | 0.00 | 0.36 | 0.25 |
| High | 0.00 | 0.52 | 0.36 |

**Table 102. Duct Sealing—Climate Zone 3: Houston—Winter Peak Demand Savings (kW), Alternate Approach**

| Category | Heating system type | | |
|---|---|---|---|
| | Gas | Electric resistance | Heat pump |
| Low | 0.00 | 0.20 | 0.11 |
| Average | 0.00 | 0.31 | 0.18 |
| High | 0.00 | 0.45 | 0.26 |

**Table 103. Duct Sealing—Climate Zone 4: Corpus Christi—Winter Peak Demand Savings (kW), Alternate Approach**

| Category | Heating system type | | |
|---|---|---|---|
| | Gas | Electric resistance | Heat pump |
| Low | 0.00 | 0.15 | 0.09 |
| Average | 0.00 | 0.25 | 0.15 |
| High | 0.01 | 0.35 | 0.21 |

**Table 104. Duct Sealing—Climate Zone 5: El Paso—Winter Peak Demand Savings (kW), Alternate Approach**

| Category | Heating system type | | |
|---|---|---|---|
| | Gas | Electric resistance | Heat pump |
| Low | 0.00 | 0.06 | 0.02 |
| Average | 0.00 | 0.10 | 0.02 |
| High | 0.00 | 0.15 | 0.03 |

## Claimed Peak Demand Savings

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

## Example Deemed Savings Calculation

**Example 1.** Using the **standard approach**, a 1,700 square foot home with a 3.5-ton central air conditioner and a gas furnace in Climate Zone 3 is found to have a pre-retrofit duct leakage rate of 600 $CFM_{25}$. After sealing leaks, duct leakage is estimated at 100 $CFM_{25}$. The project is completed in a non-HTR program.

$$Max\ Initial\ Leakage\ Rate\ = \left(400\frac{CFM}{ton}\times 3.5tons\right)\times 35\% = 490\ CFM_{25}$$

$$Reported\ Initial\ Leakage\ = Min\ (600, 490) = 490\ CFM_{25}$$

$$DL_{pre} - DL_{post} = (490 - 100) = 390\ CFM_{25}$$

$$kWh\ savings = (1.23 + 0.02)\times 390 = 488\ kWh$$

$$Summer\ kW\ savings = 1.06\times 10^{-3}\times 390 = 0.41\ kW$$

$$Winter\ kW\ savings = 8.60\times 10^{-6}\times 390 = 0.003\ kW$$

**Example 2.** Using the **alternate approach**, a duct sealing project is completed on a home of any square footage with a central heat pump of any tonnage in Climate Zone 3. The duct system is categorized as 50-90 percent in conditioned space with an existing duct insulation value of R4-R7 and substantial leaks. Therefore, that home is categorized as an average leakage home. No leakage testing is performed. The project is completed in an HTR program. All savings are taken directly from deemed savings lookup tables.

$$kWh\ savings = 484 + 102 = 586\ kWh$$

$$Summer\ kW\ savings = 0.42\ kW$$

$$Winter\ kW\ savings = 0.20\ kW$$

## Additional Calculators and Tools

There is a calculator to estimate the energy and demand savings associated with this measure using the algorithms described in the previous subsection.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) for a duct sealing measure is 18 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID HV-DuctSeal-BW.[196]

[196] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

## 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
- Cooling type (central refrigerated, evaporative cooling, none)
- Heating type (central gas furnace, central electric resistance furnace, heat pump, none)
- Additional documentation is required to validate resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach)
- Cooling capacity of home HVAC units (tons)
- EESPs claiming savings according to duct leakage testing:
    - Pre-improvement duct leakage at 25 Pa (cu. ft./min)
    - Post-improvement duct leakage at 25 Pa (cu. ft./min)
    - Pre- and post-photos of leakage test readings
- EESPs claiming savings without performing leakage testing should provide:
    - Description of the leakage severity in the home (low, average, or high)
    - Description of location and condition of ducts:
        - Duct location (>90 percent conditioned, 50-90 percent conditioned, <50 percent conditioned)
        - Existing duct insulation value (>R7, R4-R7, <R4)
    - Leakage characteristics (some observable leaks, substantial leaks, catastrophic leaks)
    - Other relevant details that may assist with validating claimed leakage category (recommended)
    - Description and photos of interventions taken (both pre- and post-condition), such as newly sealed joints, supply vents, and other relevant leaks sealed
    - Incentive rate structure: incentive should be paid per home and should not vary by leakage category to avoid providing an incentive to overstate the existing leakage category.

## References and Efficiency Standards

### Petitions and Rulings

- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 105. Duct Sealing—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Minor formatting changes, and language introduced to provide further direction for low-income customers and testing procedure. Contractors now required to track cooling capacity of HVAC equipment. Language added to reflect updates to federal standards for central heat pumps and central air conditioners. |
| v2.1 | 1/30/2015 | TRM v2.1 update. Addition of language referring contractors to program manuals for information regarding health and safety precautions. |
| v3.0 | 4/10/2015 | TRM v3.0 update. No revision. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Update of reference sources for air temperatures and densities, heating degree-days. Cooling demand savings required to be claimed. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Approach changed from algorithm-based to deemed savings coefficients estimated using building simulation models. Updated energy and demand savings. Added separate savings for homes with evaporative cooling. Updated measure description to eliminate eligibility for homes without a central AC, but with a ducted heating system. |
| v5.0 | 10/2017 | TRM v5.0 update. Remove PY 2017 option to use energy and demand adjustment factors in combination with algorithm methodology from TRM v3.1. |
| v6.0 | 11/2018 | TRM v6.0 update. Added alternative approach to bypass the need to complete leakage testing based on preceding guidance memo. |

| TRM version | Date | Description of change |
|---|---|---|
| v7.0 | 10/2019 | TRM v8.0 update. Added clarifying language on incentive rate per home. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated eligibility and documentation requirements for electric resistance heat. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated EUL reference. |
| v10.0 | 10/2022 | TRM v10.0 update. Corrected typo in leakage categorization guide. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision. |

# 2.3 RESIDENTIAL: BUILDING ENVELOPE

## 2.3.1 Air Infiltration Measure Overview

**TRM Measure ID:** R-BE-AI

**Market Sector:** Residential low-income and hard-to-reach

**Measure Category:** Building envelope

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Building simulation modeling

### Measure Description

This measure involves the implementation of interventions to reduce the rate of air infiltration into residences. Pre- and post-treatment blower door air pressure readings are required to confirm air leakage reduction. The standard approach for estimating savings in this measure is based on the results obtained via pre- and post-leakage testing as defined in this measure.

### Eligibility Criteria

Savings in this measure apply to low-income (LI) and hard-to-reach (HTR) customers only. Cooling savings apply to customers with central or mini-split electric refrigerated air conditioning in their homes. Heating savings apply to customers with a central furnace (gas or electric resistance) or a heat pump in their homes. Customers who participate in HTR or LI programs are also eligible to claim heating or cooling savings for homes heated with gas or electric resistance space heaters and/or cooled by one or more room air conditioners by applying an adjustment to deemed savings for the specified system.

There is an upper limit of 4.6 $CFM_{50}$ per square foot of house floor area for the pre-retrofit infiltration rate on eligible projects. For homes where the pre-retrofit leakage exceeds this limit, savings will be awarded against the leakage cap.

Utilities may require certification or competency testing of personnel who will perform the blower door tests Air leakage should be assessed through testing following Building Performance Institute (BPI) standards. In some limited cases, where testing is not possible or unsafe (e.g., due to potential presence of asbestos), a visual assessment may be satisfactory. The air leakage testing should not be conducted in homes where either evidence of asbestos or mold is present or suspected due to the age of the home.[197] Utilities' program manuals should be consulted for health and safety considerations related to the implementation of air sealing measures.

Only structures with electric refrigerated air conditioning systems are eligible.

## Baseline Condition

The baseline for this measure is the existing leakage rate of the treated residence. The existing leakage rate should be capped to account for the fact that the deemed savings values per $CFM_{50}$ leakage reduction are only applicable up to a point where the existing HVAC equipment would run continuously. Beyond that point, energy use will no longer increase linearly with an increase in leakage.

Baseline assumptions used in the development of these deemed savings are based on a conversion from $ACH_{Natural}$. ASHRAE Handbook: Fundamentals specifies that more than 80 percent of sampled low-income housing had a pre-leakage rate at or below 1.75 $ACH_{Natural}$.[198] $ACH_{Natural}$ was converted to $CFM_{50}$/sq. ft. using Equation 57.

$$CFM_{50,pre} = \frac{ACH_{Natural,pre} \times h \times N}{60}$$

**Equation 57**

*Where:*

| | | |
|---|---|---|
| $ACH_{Natural,pre}$ | = | *1.75 representing greater than 80 percent of sampled homes* |
| $h$ | = | *Ceiling height (ft.) = 8.5 (default)*[199] |
| $N$ | = | *N factor for single story normal shielding (Table 106) = 18.5* |

Using the above approach, the maximum per-square-foot pre-installation infiltration rate is 4.6 $CFM_{50}$/sq. ft.. Therefore, to avoid incentivizing homes with envelope problems not easily remedied through typical weatherization procedures, or where blower door tests were improperly conducted, these savings should only be applied starting at a baseline $CFM_{50}$/sq. ft. of 4.6 or lower.

---

[197] The Building Performance Institute, Inc. (BPI) Standard Reference: Building Performance Institute Technical Standards for the Building Analyst Professional, v2/28/05mda, Page 1 of 17, states: "Health and Safety*:* Where the presence of asbestos, lead, mold and/or other potentially hazardous material is known or suspected, all relevant state and federal (EPA) guidelines must be followed to ensure technician and occupant safety. Blower door depressurization tests may not be performed in homes *where there is a risk of asbestos becoming airborne and being drawn into the dwelling."*

[198] 2017 ASHRAE Handbook: Fundamentals, Chapter 16, p. 16.19, Fig. 12.

[199] Typical ceiling height of 8 feet adjusted to account for greater ceiling heights in some areas of a typical residence.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[200] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[201] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer/Winter Demand Savings Tables sections.

## High-Efficiency Condition

Blower door air pressure measurements must also be used to ensure that post-treatment air infiltration rates are not less than those set forth by the standard in Equation 58, based on floor area and the number of bedrooms.[202] These calculated minimum $CFM_{50}$ values assume two occupants for a one-bedroom dwelling unit and an additional person for each additional bedroom. At the utility's discretion, this minimum $CFM_{50}$ requirement may be enforced as an eligibility requirement. Otherwise, savings may be claimed for projects where the measured final infiltration rate is less than the minimum allowable ventilation rate if the following conditions are met:

- Mechanical ventilation is present or introduced in compliance with ASHRAE 62.2-2019
- Post-treatment infiltration rate is reported as the actual measured CFM50 result
- Savings are calculated using the TRM minimum allowable ventilation rate with no additional savings claimed for CFM reduction below this amount

Where higher occupant densities are known, the minimum rate shall be increased by 7.5 $CFM_{Nat}$ for each additional person. A $CFM_{Nat}$ value can be converted to $CFM_{50}$ by multiplying by the appropriate N factor (Table 106).

$$Min\ CFM_{50} = [0.03 \times A_{Floor} + 7.5 \times OCC] \times N$$

**Equation 58**

*Where:*

| | | |
|---|---|---|
| *Min $CFM_{50}$* | = | *Minimum final ventilation rate ($CFM_{50}$)* |
| *$A_{Floor}$* | = | *Floor area (sq. ft.)* |
| *OCC* | = | *BR + 1, where BR is the number of bedrooms; if number of home occupants is known to exceed BR + 1, occupancy should be used instead* |
| *N* | = | *N factor (Table 106)* |

200 Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.
201 Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.
202 ASHRAE 62.2-2013. $CFM_{Nat}$ values converted to $CFM_{50}$ values by multiplying by appropriate N factor.

**Table 106. Air Infiltration—N Factors**[203]

| Shielding | Number of stories | | |
|---|---|---|---|
| | 1 story | 2 story | 3+ stories |
| Well shielded | 22.2 | 17.8 | 15.5 |
| Normal | 18.5 | 14.8 | 13.0 |
| Exposed | 16.7 | 13.3 | 11.7 |

The maximum CFM reduction percentage[204] is capped at 30 percent. It is important to note that the minimum ventilation rate specified earlier in this section still applies for cases where the maximum 30 percent CFM reduction cannot be achieved due to the post CFM value being limited by the minimum allowable post CFM value provisioned for safety reasons.

The TRM stipulates an upper limit of 4.6 $CFM_{50}$ per square foot of house floor area for the pre-retrofit infiltration rate as part of eligibility criteria. For homes where the pre-retrofit leakage exceeds this limit, energy and demand savings must be calculated using the pre-measure-installation leakage cap. Therefore, when the pre-retrofit leakage is capped, energy and demand savings can only be claimed for a 30 percent reduction in CFM compared to the capped pre-CFM value. When the pre-retrofit leakage is not capped, energy and demand savings can only be claimed for a 30 percent reduction in CFM compared to the tested, actual pre-retrofit infiltration rate of the home.

The TRM requires all contractors to provide sufficient evidence (e.g., pictures capturing the scope/type of retrofit implemented and blower door test readings) for all homes.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings, which are expressed as linear functions of the leakage reduction achieved (in $CFM_{50}$).[205] Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: the base case air infiltration rate was set to 20 $ACH_{50}$. Results from running the base case model provide estimated hourly energy use for the prototypical home prior to treatment. Post-treatment conditions were simulated by setting the leakage rate to 3 $ACH_{50}$.

[203] Krigger, J. and Dorsi, C.,“Residential Energy: Cost Savings and Comfort for Existing Buildings”. A-11 Building Tightness Limits, p. 284. Use Zone 2 for Texas climate.

[204] CFM reduction percentage is calculated as: (pre-CFM value – post-CFM value) / pre-CFM value

[205] Model testing indicates a straight-line relationship between demand and energy savings achieved and CFM50 reductions is appropriate with beginning and ending leakage rates within the ranges permitted by the measure.

Deemed savings are presented as a function of the $CFM_{50}$ reduction achieved, as demonstrated by blower door testing. The kWh and kW per $CFM_{50}$ values represented by the $V_E$, $V_S$, and $V_W$ coefficients are derived by taking the difference between annual energy use and summer and winter peak demand as estimated by the two model runs and normalizing to the $CFM_{50}$ reduction achieved. The pre- and post-treatment $ACH_{50}$ values (20 and 3, respectively) are converted to $CFM_{50}$ by multiplying the pressurized air-change rate by the volume of the model home and dividing by 60 (minutes/hour).

## Deemed Energy Savings Tables

Table 107 presents the energy savings per $CFM_{50}$ reduction for a residential air sealing project. The following formula shall be used to calculate deemed energy savings for infiltration efficiency improvements.

$$Energy\ Savings\ [\Delta \text{kWh}] = \Delta CFM_{50} \times \left(V_{E,C} \times CAF + V_{E,H} \times HAF\right)$$

**Equation 59**

*Where:*

| | | |
|---|---|---|
| $\Delta CFM_{50}$ | = | *Air infiltration reduction in cubic feet per minute at 50 Pascal* |
| $V_{E,C}$ | = | *Cooling energy savings coefficient (Table 107)* |
| $CAF$ | = | *Cooling savings adjustment factor for homes with room air conditioners; set to 1.0 for homes with refrigerated air or set to 0.6 for homes with one or more room air conditioners* |
| $V_{E,H}$ | = | *Heating energy savings coefficient (Table 107)* |
| $HAF$ | = | *Heating savings adjustment factor for homes with electric resistance space heaters; set to 1.0 for homes with central heating with supplemental space heating or set to 0.24 for homes with primary electric resistance space heating* |

For customers who participate in hard-to-reach (HTR) or low-income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate cooling values in Table 107 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 107 by a factor of 0.24.[206]

[206] This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

**Table 107. Air Infiltration—Energy Savings $V_E$ per $CFM_{50}$ Reduction**

| | $V_{E,C}$: Cooling savings | $V_{E,H}$: Heating savings | | |
|---|---|---|---|---|
| Climate zone | Refrigerated air | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | 0.12 | 0.09 | 1.92 | 0.78 |
| Zone 2: Dallas | 0.27 | 0.04 | 1.10 | 0.45 |
| Zone 3: Houston | 0.22 | 0.02 | 0.63 | 0.25 |
| Zone 4: Corpus Christi | 0.39 | 0.02 | 0.55 | 0.21 |
| Zone 5: El Paso | 0.07 | 0.03 | 0.88 | 0.34 |

## Deemed Summer Demand Savings Tables

Table 108 presents the summer peak demand savings per CFM 50 reduction for a residential air sealing project. The following formula shall be used to calculate deemed summer demand savings for air infiltration improvements:

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = \Delta CFM_{50} \times V_S \times CAF$$

**Equation 60**

*Where:*

$V_S$ = *Summer demand savings coefficient (Table 108)*

For customers who participate in HTR/LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate cooling values in Table 108 by a factor of 0.6.

**Table 108. Air Infiltration—Peak Summer Demand Savings $V_S$ per $CFM_{50}$ Reduction**

| Climate zone | Summer kW impact per $CFM_{50}$ reduction |
|---|---|
| Zone 1: Amarillo | 1.64E-04 |
| Zone 2: Dallas | 2.10E-04 |
| Zone 3: Houston | 1.90E-04 |
| Zone 4: Corpus Christi | 2.24E-04 |
| Zone 5: El Paso | 9.40E-05 |

## Deemed Winter Demand Savings Tables

For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 109 by a factor of 0.24. For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 109 by a factor of 0.24.

Table 109 presents the summer peak demand savings per $CFM_{50}$ reduction for a residential air sealing project. The following formula shall be used to calculate deemed winter demand savings for air infiltration improvement:

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = \Delta CFM_{50} \times V_W \times HAF$$

**Equation 61**

*Where:*

$V_W$ = *Winter demand savings coefficient (Table 109)*

For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 109 by a factor of 0.24.[207]

**Table 109. Air Infiltration—Peak Winter Demand Savings $V_W$ per $CFM_{50}$ Reduction**

| | Winter kW impact per $CFM_{50}$ reduction | |
|---|---|---|
| **Climate zone** | **Electric resistance** | **Heat pump** |
| Zone 1: Amarillo | 9.42E-04 | 5.48E-04 |
| Zone 2: Dallas | 1.25E-03 | 6.93E-04 |
| Zone 3: Houston | 8.61E-04 | 4.41E-04 |
| Zone 4: Corpus Christi | 7.81E-04 | 3.60E-04 |
| Zone 5: El Paso | 2.92E-04 | 1.19E-04 |

## Claimed Peak Demand Savings

Refer to Volume 1, Section 4.

## Example Deemed Savings Calculation

**Example 1.** A contractor uses a blower door test to estimate 12,000 $CFM_{50}$ of pre-retrofit air leakage in a 2,200 square foot, 2-story, 3-bedroom home in Climate Zone 4 with a heat pump. The home is located in a normally shielded area. After identifying and sealing leaks, she performs another blower door test and measures 8,000 $CFM_{50}$ of air leakage.

$$Max\ Initial\ Leakage\ Rate\ = 4.6\ \times\ 2{,}200 = 10{,}120\ CFM_{50}$$

$$Reported\ Initial\ Leakage\ = Min\ (12{,}000, 10{,}120) = 10{,}120 CFM_{50}$$

$$Capped\ Post\ Retrofit\ Leakage\ = 10{,}120\ \times\ (1 -\ 0.3) = 7{,}084\ CFM_{50}$$

$$Reported\ Post\ Retrofit\ Leakage\ = Max\ (8{,}000, 7{,}084) = 8{,}000\ CFM_{50}$$

[207] This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

$$Min.\,Post\ Retrofit\ Leakage\ (safety) = [0.03\ \times\ 2{,}200 + 7.5 \times 4]\ \times\ 14.8 = 1{,}421\ CFM_{50}$$

$$\Delta CFM_{50} = (10{,}120 - 8{,}000) = \mathit{2{,}120}$$

$$Energy\ Savings = (0.39 + 0.21)\ \times\ 2{,}120 = \mathit{1{,}272\ kWh}$$

$$Summer\ Peak\ Demand\ Savings = 2.24\ \times\ 10^{-4}\ \times\ 2{,}120 = 0.47\ kW$$

$$Winter\ Peak\ Demand\ Savings = 3.60\ \times\ 10^{-4}\ \times\ 2{,}120 = 0.76\ kW$$

### Additional Calculators and Tools

Not applicable.

### Measure Life and Lifetime Savings

The estimated useful life (EUL) is 11 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID BS-Wthr.[208]

## 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
- Pre-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Post-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Cooling type (central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); representative sampling is allowed for multifamily complexes
    - If documentation is not provided, an adjustment factor of 0.75 will be applied to the heating energy and winter demand savings
- Square footage of the house
- Shielding level (well shielded, normal, exposed)
- Number of bedrooms
- Number of stories

[208] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- Number of occupants
- Pre- and post-photos of blower door test readings
- Representative photos of leak repairs

## References and Efficiency Standards

### Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Energy for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 27903. Order Adopting New §25.184 as Approved at the August 21, 2003, Open Meeting and Submitted to the Secretary of State. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.
- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 110. Air Infiltration—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Minor edits to language. Added detail on methodology and model characteristics. |
| v2.1 | 1/30/2015 | TRM v2.1 update. Addition of language referring contractors to program manuals for information regarding health and safety precautions. |
| v3.0 | 4/10/2015 | TRM v3.0 update. Revision of minimum ventilation requirements, pre-retrofit cap on infiltration levels, Climate Zone 5 savings values for homes with heat pumps, and tracking number of bedrooms and occupants in a house. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Provided clarification around effects of occupancy on minimum final ventilation. |

| TRM version | Date | Description of change |
|---|---|---|
| v4.0 | 10/10/2016 | TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Introduced new protocols related to maximum CFM reduction percentage and its associated documentation requirements. Added a new example for calculating savings. |
| v5.0 | 10/2017 | TRM v5.0 update. Added alternative approach to bypass the need to complete leakage testing in guidance memo to follow. |
| v6.0 | 11/2018 | TRM v6.0 update. Removed alternative approach allowance at this time. Clarified the eligibility of projects where $CFM_{post}$ falls below the minimum ventilation rate requirement. |
| v7.0 | 10/2019 | TRM v7.0 update. No revision. |
| v8.0 | 10/2020 | TRM v8.0 update. Reduced leakage cap and updated documentation requirements. Updated eligibility to only LI/HTR. Added space heat adjustment factor and electric resistance documentation requirement. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated savings calculation example and EUL reference. |
| v10.0 | 10/2022 | TRM v10.0 update. No revision. |
| v11.0 | 10/2023 | TRM v11.0 update. Added electric resistance documentation adjustment factor. |

## 2.3.2 Ceiling Insulation Measure Overview

**TRM Measure ID:** R-BE-CI

**Market Sector:** Residential

**Measure Category:** Building envelope

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Building simulation modeling

## Measure Description

Savings are estimated for insulation improvements to the ceiling area above a conditioned space in a residence.

## Eligibility Criteria

Cooling savings in this measure apply to customers with central or mini-split electric refrigerated air conditioning in their homes, or to customers in TRM Climate Zones 1 and 5 who have evaporative cooling systems. Homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Customers who participate in hard-to-reach (HTR) or low-income (LI) programs are eligible to claim reduced heating savings for homes heated with gas or electric resistance space heaters by applying an adjustment to deemed savings that is specified for that heat type. Customers participating in HTR or LI programs are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that is specified for homes with central refrigerated air.

## Baseline Condition

Ceiling insulation levels encountered in existing homes can vary significantly, depending on factors such as the age of the home, type of insulation installed, and level of attic use (equipment, storage, etc.). Deemed savings have been developed based on different levels of encountered (existing) ceiling insulation in participating homes, ranging from sparsely insulated (R-5) to the equivalent of about 6 inches of fiberglass batt insulation (R-22). The current average ceiling insulation level at participating homes is to be determined and documented by the insulation installer. Degradation due to age and density of the existing insulation should be taken into account.

In the event that existing insulation is or has been removed during measure implementation, the existing R-value for claiming savings shall be based upon the R-value of the existing insulation prior to removal.

In the event there are varying levels of existing insulation, an area-weighted U-factor can be used to find the effective R-value across the treated area. The U-factor should be taken from the existing insulation only. This approach can be used in single attic spaces, and savings should be estimated separately for independent spaces where there are separate heating or cooling methods (e.g., additions).

### *Area-Weighted U-Factor Calculation Method*

$$U_A = [U_1 \times Area_1 + \mathrm{U}_2 \times \mathrm{Area}_2 + \ldots]/\,[\mathrm{Area}_1 + \mathrm{Area}_2 + \ldots]$$

$$Effective\ Rvalue = \frac{1}{U_A}$$

**Equation 62**

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[209] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[210] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer/Winter Demand Savings Tables sections.

## High-Efficiency Condition

A minimum ceiling insulation level of R-30 is recommended throughout Texas as prescribed by the Department of Energy. Accordingly, deemed savings are provided for insulating to R-30. Adjustment factors are provided to allow contractors to estimate savings for installation of higher or lower levels of post-retrofit insulation. Contractors should estimate post-retrofit R-values according to the average insulation depth achieved across the area treated and the R per-inch of the insulation material installed.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone was modified as follows: the default R-value of ceiling insulation (R-15 in most zones) was set at different levels, ranging from R-0 (no ceiling insulation) to R-22. These modifications are shown in Table 111.

The model runs are used to estimate peak demand and energy use in the modeled home at each of the base case ceiling insulation levels. The change-case models were run with the ceiling insulated to R-30.

---

[209] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[210] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

**Table 111. Ceiling Insulation—Prototypical Home Characteristics**

| Shell characteristic | Value | Source |
|---|---|---|
| Base ceiling insulation | < R5<br>R5-R8<br>R9-R14<br>R15-R22 | Existing insulation level |
| Change ceiling insulation | R-30 | R-30 retrofit insulation level consistent with DOE recommendations |

## Deemed Energy Savings Tables

Table 112 through Table 116, present the energy savings (kWh) associated with ceiling insulation for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

For customers who participate in hard-to-reach (HTR) or low-income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying the appropriate cooling value in Table 112 through Table 118 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 112 through Table 118 by a factor of 0.24.[211]

**Table 112. Ceiling Insulation—Climate Zone 1: Amarillo, R-30 Energy Savings (kWh/sq. ft.)**

| Ceiling insulation base R-value | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|
| | Refrigerated air | Evaporative cooling | Gas | Electric resistance | Heat pump |
| < R-5 | 0.41 | 0.12 | 0.12 | 3.07 | 1.31 |
| R-5 to R-8 | 0.28 | 0.08 | 0.08 | 2.16 | 0.92 |
| R-9 to R-14 | 0.15 | 0.04 | 0.05 | 1.17 | 0.50 |
| R-15 to R-22 | 0.06 | 0.02 | 0.02 | 0.51 | 0.22 |

[211] This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

**Table 113. Ceiling Insulation—Climate Zone 2: Dallas, R-30 Energy Savings (kWh/sq. ft.)**

| Ceiling insulation base R-value | Cooling savings | Heating savings | | |
|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump |
| < R-5 | 0.67 | 0.07 | 1.90 | 0.79 |
| R-5 to R-8 | 0.46 | 0.05 | 1.34 | 0.55 |
| R-9 to R-14 | 0.25 | 0.03 | 0.72 | 0.30 |
| R-15 to R-22 | 0.11 | 0.01 | 0.32 | 0.13 |

**Table 114. Ceiling Insulation—Climate Zone 3: Houston, R-30 Energy Savings (kWh/sq. ft.)**

| Ceiling insulation base R-value | Cooling savings | Heating savings | | |
|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump |
| < R-5 | 0.68 | 0.05 | 1.30 | 0.53 |
| R-5 to R-8 | 0.46 | 0.03 | 0.92 | 0.37 |
| R-9 to R-14 | 0.24 | 0.02 | 0.50 | 0.20 |
| R-15 to R-22 | 0.10 | 0.01 | 0.22 | 0.09 |

**Table 115. Ceiling Insulation—Climate Zone 4: Corpus Christi, R-30 Energy (kWh/sq. ft.)**

| Ceiling insulation base R-value | Cooling savings | Heating savings | | |
|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump |
| R-5 | 0.52 | 0.03 | 0.89 | 0.34 |
| R-5 to R-8 | 0.35 | 0.02 | 0.62 | 0.24 |
| R-9 to R-14 | 0.18 | 0.01 | 0.33 | 0.13 |
| R-15 to R-22 | 0.08 | 0.00 | 0.14 | 0.06 |

**Table 116. Ceiling Insulation—Climate Zone 5: El Paso, R-30 Energy Savings (kWh/sq. ft.)**

| Ceiling insulation base R-value | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|
| | Refrigerated air | Evaporative cooling | Gas | Electric resistance | Heat pump |
| < R-5 | 0.63 | 0.21 | 0.07 | 1.96 | 0.81 |
| R-5 to R-8 | 0.43 | 0.15 | 0.05 | 1.40 | 0.57 |
| R-9 to R-14 | 0.23 | 0.08 | 0.03 | 0.75 | 0.31 |
| R-15 to R-22 | 0.10 | 0.03 | 0.01 | 0.33 | 0.13 |

## *Scale-Down/Up Factors for Energy Savings: Insulation to Below or Above R-30*

The factors presented in this section are to be used when the average post-retrofit insulation depth is providing more or less than R-30 insulation. Scale-down factors are provided for the case when average post-retrofit insulation depth is not sufficient to achieve R-30; scale-up factors are provided for the case when insulating to a level greater than R-30. In either case, the following equation should be applied to scale down or scale up the energy savings.

$$Energy\ Savings\ [\Delta kWh] = \left\{R30\ Savings/ft^2 + \left[S_{D/U} \times (R_{Achieved} - 30)\right]\right\} \times A$$

**Equation 63**

*Where:*

| | | |
|---|---|---|
| *R30 Savings/ft²* | = | *Sum of project-appropriate deemed cooling and heating energy savings per square feet taken from Table 112 through Table 116* |
| $S_{D/U}$ | = | *Project-appropriate scale-down or scale-up factor from either Table 117 or Table 118* |
| $R_{Achieved}$ | = | *Achieved R-value of installed insulation (e.g., for R-28, $R_{Achieved}$ = 28)* |
| *A* | = | *Treated area (sq. ft.)* |

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved energy savings per square foot of treated ceiling area.

**Table 117. Ceiling Insulation—Energy Scale-Down Factors for Insulating to Less than R-30 (kWh/sq. ft./ΔR)**

| Climate zone | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|
| | Refrigerated air | Evaporative cooling | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | 4.00E-03 | 1.16E-03 | 1.27E-03 | 3.26E-02 | 1.38E-02 |
| Zone 2: Dallas | 6.66E-03 | – | 7.11E-04 | 2.00E-02 | 8.20E-03 |
| Zone 3: Houston | 6.22E-03 | – | 4.67E-04 | 1.38E-02 | 5.47E-03 |
| Zone 4: Corpus Christi | 4.92E-03 | – | 2.44E-04 | 9.04E-03 | 3.47E-03 |
| Zone 5: El Paso | 4.00E-03 | 1.16E-03 | 1.27E-03 | 3.26E-02 | 1.38E-02 |

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved energy savings per square foot of treated ceiling area.

**Table 118. Ceiling Insulation—Energy Scale-Up Factors for Insulating to Greater than R-30 (kWh/sq. ft./ΔR)**

| Climate zone | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|
| | Refrigerated air | Evaporative cooling | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | 2.66E-03 | 7.63E-04 | 8.45E-04 | 2.18E-02 | 9.18E-03 |
| Zone 2: Dallas | 4.45E-03 | – | 4.82E-04 | 1.33E-02 | 5.47E-03 |
| Zone 3: Houston | 4.00E-03 | – | 2.97E-04 | 9.19E-03 | 3.66E-03 |
| Zone 4: Corpus Christi | 3.24E-03 | – | 1.62E-04 | 5.99E-03 | 2.30E-03 |
| Zone 5: El Paso | 2.66E-03 | 7.63E-04 | 8.45E-04 | 2.18E-02 | 9.18E-03 |

## Deemed Summer Demand Savings Tables

Table 119 through Table 123 present the summer demand savings (kW/sq. ft.) associated with ceiling insulation for the five Texas climate zones.

For customers who participate in HTR/LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying the appropriate cooling value in the refrigerated air column in Table 119 through Table 125 by a factor of 0.6.

**Table 119. Ceiling Insulation—Climate Zone 1: Amarillo, R-30 Summer Peak Demand Savings (kW/sq. ft.)**

| Ceiling insulation base R-value | Refrigerated | Evaporative |
|---|---|---|
| < R-5 | 8.00E-04 | 2.25E-04 |
| R-5 to R-8 | 4.50E-04 | 1.47E-04 |
| R-9 to R-14 | 2.33E-04 | 7.16E-05 |
| R-15 to R-22 | 1.02E-04 | 2.87E-05 |

**Table 120. Ceiling Insulation—Climate Zone 2: Dallas, R-30 Summer Peak Demand Savings (kW/sq. ft.)**

| Ceiling insulation base R-value | Demand savings (kW/sq. ft.) |
|---|---|
| < R-5 | 9.00E-04 |
| R-5 to R-8 | 5.17E-04 |
| R-9 to R-14 | 2.67E-04 |
| R-15 to R-22 | 1.15E-04 |

**Table 121. Ceiling Insulation—Climate Zone 3: Houston, R-30 Summer Peak Demand Savings (kW/sq. ft.)**

| Ceiling insulation base R-value | Demand savings (kW/sq. ft.) |
|---|---|
| < R-5 | 6.25E-04 |
| R-5 to R-8 | 5.51E-04 |
| R-9 to R-14 | 2.87E-04 |
| R-15 to R-22 | 1.22E-04 |

**Table 122. Ceiling Insulation—Climate Zone 4: Corpus Christi, R-30 Summer Peak Demand Savings (kW/sq. ft.)**

| Ceiling insulation base R-value | Demand savings (kW/sq. ft.) |
|---|---|
| < R-5 | 4.75E-04 |
| R-5 to R-8 | 3.40E-04 |
| R-9 to R-14 | 1.79E-04 |
| R-15 to R-22 | 7.95E-05 |

**Table 123. Ceiling Insulation—Climate Zone 5: El Paso, R-30 Summer Peak Demand Savings (kW/sq. ft)**

| Ceiling insulation base R-value | Refrigerated | Evaporative |
|---|---|---|
| < R-5 | 8.00E-04 | 2.23E-04 |
| R-5 to R-8 | 4.72E-04 | 1.53E-04 |
| R-9 to R-14 | 2.38E-04 | 6.25E-05 |
| R-15 to R-22 | 1.03E-04 | 2.09E-05 |

### *Scale-Down/Up Factors: Insulation to Below or Above R-30*

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved summer peak demand savings per square foot of treated ceiling area.

**Table 124. Ceiling Insulation—Summer Peak Demand Scale-Down Factors for Insulating to Less than R-30 (kW/sq. ft./ΔR)**

| Climate zone | Refrigerated air | Evaporative cooling |
|---|---|---|
| Zone 1: Amarillo | 6.41E-06 | 1.97E-06 |
| Zone 2: Dallas | 7.30E-06 | – |
| Zone 3: Houston | 7.91E-06 | – |
| Zone 4: Corpus Christi | 5.20E-06 | – |
| Zone 5: El Paso | 6.41E-06 | 1.97E-06 |

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved summer peak demand savings per square foot of treated ceiling area.

**Table 125. Ceiling Insulation—Summer Peak Demand Scale-Up Factors for Insulating to Greater than R-30 (kW/sq. ft./ΔR)**

| Climate zone | Refrigerated air | Evaporative cooling |
|---|---|---|
| Zone 1: Amarillo | 4.22E-06 | 1.89E-06 |
| Zone 2: Dallas | 4.92E-06 | – |
| Zone 3: Houston | 5.92E-06 | – |
| Zone 4: Corpus Christi | 3.47E-06 | – |
| Zone 5: El Paso | 4.22E-06 | 1.89E-06 |

## Deemed Winter Demand Savings Tables

Table 126 through Table 130 present the winter demand savings associated with ceiling insulation for the five Texas climate zones.

For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 126 through Table 132 by a factor of 0.24.[212]

**Table 126. Ceiling Insulation—Climate Zone 1: Amarillo, R-30 Winter Peak Demand Savings (kW/sq. ft.)**

| Ceiling insulation base R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| < R-5 | 4.25E-05 | 9.75E-04 | 8.00E-04 |
| R-5 to R-8 | 2.51E-05 | 8.74E-04 | 4.53E-04 |
| R-9 to R-14 | 1.37E-05 | 4.56E-04 | 2.38E-04 |
| R-15 to R-22 | 4.72E-06 | 1.95E-04 | 1.01E-04 |

**Table 127. Ceiling Insulation—Climate Zone 2: Dallas, R-30 Winter Peak Demand Savings (kW/sq. ft.)**

| Ceiling insulation base R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| < R-5 | 3.50E-05 | 1.30E-03 | 8.25E-04 |
| R-5 to R-8 | 2.79E-05 | 9.84E-04 | 6.60E-04 |
| R-9 to R-14 | 1.45E-05 | 5.13E-04 | 3.51E-04 |
| R-15 to R-22 | 6.42E-06 | 2.23E-04 | 1.52E-04 |

212 This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

**Table 128. Ceiling Insulation—Climate Zone 3: Houston, R-30 Winter Peak Demand Savings (kW/sq. ft.)**

| Ceiling insulation base R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| < R-5 | 4.25E-05 | 1.15E-03 | 6.75E-04 |
| R-5 to R-8 | 2.91E-05 | 7.71E-04 | 4.49E-04 |
| R-9 to R-14 | 1.39E-05 | 4.01E-04 | 2.35E-04 |
| R-15 to R-22 | 5.36E-06 | 1.74E-04 | 1.03E-04 |

**Table 129. Ceiling Insulation—Climate Zone 4: Corpus Christi, R-30 Winter Peak Demand Savings (kW/sq. ft.)**

| Ceiling insulation base R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| < R-5 | 2.50E-05 | 8.25E-04 | 4.50E-04 |
| R-5 to R-8 | 2.18E-05 | 6.31E-04 | 3.03E-04 |
| R-9 to R-14 | 1.13E-05 | 3.28E-04 | 1.57E-04 |
| R-15 to R-22 | 5.71E-06 | 1.44E-04 | 6.95E-05 |

**Table 130. Ceiling Insulation—Climate Zone 5: El Paso, R-30 Winter Peak Demand Savings (kW/sq. ft.)**

| Ceiling insulation base R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| < R-5 | 2.25E-05 | 5.75E-04 | 2.25E-04 |
| R-5 to R-8 | 1.14E-05 | 3.72E-04 | 1.57E-04 |
| R-9 to R-14 | 5.38E-06 | 1.79E-04 | 7.54E-05 |
| R-15 to R-22 | 2.26E-06 | 7.41E-05 | 3.11E-05 |

### *Scale-Down/Up Factors for Demand Reduction: Insulation to Below or Above R-30*

The factors presented in this section are to be used when the average post-retrofit insulation depth is providing more or less than R-30 insulation. Scale-down factors are provided for the case when average post-retrofit insulation depth is not sufficient to achieve R-30; scale-up factors are provided for the case when insulating to a level greater than R-30. In either case, the following equation should be applied to scale down or scale up the summer peak demand savings.

$$Peak\ Demand\ Savings\ [\Delta kW] = \left\{R30\ Savings/ft^2 + \left[S_{D/U} \times (R_{Achieved} - 30)\right]\right\} \times A$$

**Equation 64**

*Where:*

| | | |
|---|---|---|
| *R30 Savings/ft²* | = | *Sum of project-appropriate deemed cooling and heating energy savings per square feet taken from Table 119 through Table 123 or Table 126 through Table 130* |
| $S_{D/U}$ | = | *Project-appropriate scale-down or scale-up factor from either Table 124 and Table 125 (Summer) or Table 131 and Table 132 (Winter)* |

If the ceiling is insulated to a level less than R-30, the following factors shall be applied to scale down the achieved winter peak demand savings per square foot of treated ceiling area.

**Table 131. Ceiling Insulation—Winter Peak Demand Scale-down Factors for Insulating to Less than R-30 (kW/sq. ft./ΔR)**

| Climate zone | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| Zone 1: Amarillo | 4.29E-07 | 1.21E-05 | 6.30E-06 |
| Zone 2: Dallas | 3.97E-07 | 1.40E-05 | 9.55E-06 |
| Zone 3: Houston | 3.05E-07 | 1.10E-05 | 6.53E-06 |
| Zone 4: Corpus Christi | 3.19E-07 | 9.18E-06 | 4.32E-06 |
| Zone 5: El Paso | 4.29E-07 | 1.21E-05 | 6.30E-06 |

If the ceiling is insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved winter peak demand savings per square foot of treated ceiling area.

**Table 132. Ceiling Insulation—Winter Peak Demand Scale-up Factors for Insulating to Greater than R-30(kW/sq. ft./ ΔR)**

| Climate zone | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| Zone 1: Amarillo | 2.76E-07 | 7.85E-06 | 4.19E-06 |
| Zone 2: Dallas | 2.57E-07 | 8.33E-06 | 4.80E-06 |
| Zone 3: Houston | 2.19E-07 | 7.33E-06 | 4.46E-06 |
| Zone 4: Corpus Christi | 1.72E-07 | 5.79E-06 | 2.72E-06 |
| Zone 5: El Paso | 2.76E-07 | 7.85E-06 | 4.19E-06 |

## Claimed Peak Demand Savings

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

## Example Deemed Savings Calculation

**Example 1 (Scale-Up).** A home in Climate Zone 5 with evaporative cooling and an electric resistance furnace insulates 400 square feet from a baseline of R-1 to an efficient condition of R-38.

$$Cooling\ kWh\ savings\ per\ sq.ft. = 0.21 + 7.63x10^{-4} \times (38 - 30) = \mathit{0.22\ kWh/sq.\ ft.}$$

$$Heating\ kWh\ savings\ per\ sq.ft. = 1.96 + 2.18x10^{-2} \times (38 - 30) = \mathit{2.13\ kWh/sq.\ ft.}$$

$$Energy\ Savings = (0.22 + 2.13) \times 400 = \mathit{940\ kWh}$$

$$Summer\ kW\ savings\ per\ sq.ft. = 2.23 \times 10^{-4} + 1.89 \times 10^{-6} \times (38 - 30) = \mathit{2.38} \times 10^{-4}\ \mathit{kW/sq.\ ft.}$$

$$Summer\ Peak\ Demand\ Savings = 2.38 \times 10^{-4} \times 400 = 0.10\ kW$$

$$Winter\ kWsavings\ per\ sq.ft\ = 5.75 \times 10^{-4} + 7.85 \times 10^{-6} \times (38 - 30) = \mathit{1.20} \times 10^{-3}\ \mathit{kW/sq.\ ft.}$$

$$Winter\ Peak\ Demand\ Savings = 1.20 \times 10^{-3} \times 400 = 0.48\ kW$$

**Example 2 (Scale-Down).** A home in Climate Zone 3 with an air-source heat pump insulates 550 square feet from a baseline of R-5 to an efficient condition of R-28.

$$Cooling\ kWh\ savings\ per\ sq.ft. = 0.46 + 5.47 \times 10^{-3} \times (28 - 30) = 0.45\ kWh/sq.ft.$$

$$Heating\ kWh\ savings\ per\ sq.ft. = 0.37 + 3.66 \times 10^{-3} \times (28 - 30) = 0.36\ kWh/sq.ft.$$

$$Energy\ Savings = (0.45 + 0.36) \times 550 = 446.4\ kWh$$

$$Summer\ kW\ savings\ per\ sq.ft. = 5.51 \times 10^{-4} + 7.91 \times 10^{-6} \times (28 - 30) = 5.35 \times 10^{-4}\ kW/sq.ft.$$

$$Summer\ Peak\ Demand\ Savings = 5.35 \times 10^{-4} \times 550 = 0.29\ kW$$

$$Winter\ kW\ savings\ per\ sq.ft. = 4.49 \times 10^{-4} + 6.53 \times 10^{-6} \times (28 - 30) = 4.36 \times 10^{-4}\ kW/sq.ft.$$

$$Winter\ Peak\ Demand\ Savings = 4.36 \times 10^{-4} \times 550 = 0.24\ kW$$

## Additional Calculators and Tools

Not applicable.

## Measure Life and Lifetime Savings

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007),[213] the estimated useful life is 25 years for ceiling insulation.

## 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:

- Climate zone or county
- Base R-value of original insulation
- R-value of installed insulation
- Cooling type (evaporative cooling, central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes.
    - If documentation is not provided, an adjustment factor of 0.75 will be applied to the heating energy and winter demand savings
- Square footage of ceiling insulation installed above a conditioned space
- Only for homes with a reported baseline R-value that is less than R-5:
    - Two pictures: (1) a picture showing the entire attic floor, and (2) a close-up picture of a ruler that shows the measurement of the depth of the insulation.

      Note: The second photo type is required for each area of insulation where there are varying R-values less than R-5. Additionally, both photo types are required for all separate attic/ceiling areas, even when the installed R-value is the same.

[213] GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007). http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLightsandHVACGDS_1Jun2007.pdf.

# References and Efficiency Standards

## Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Energy for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.
- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

## Relevant Standards and Reference Sources

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

## Document Revision History

**Table 133. Ceiling Insulation—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Added detail on methodology and model characteristics. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. Provided savings tables for installation of insulation up to R-38. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air conditioning. Climate Zone 2 savings values awarded for Climate Zone 5 homes with heat pumps. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Provided example savings calculations. Clarified that no heating demand savings are to be claimed for homes with a gas furnace. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Updated energy and demand savings per new prototype simulation models and introduced new protocols for baseline and post-retrofit R-values, their associated savings estimations and documentation requirements. |
| v5.0 | 10/2017 | TRM v5.0 update. No revision. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |

| TRM version | Date | Description of change |
|---|---|---|
| v7.0 | 10/2019 | TRM v7.0 update. Added clarifying language for U-factor methodology. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated savings tables. Added space heat adjustment factor and electric resistance documentation requirement. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated savings tables for < R-5 baseline category. |
| v10.0 | 10/2022 | TRM v10.0 update. No revision. |
| v11.0 | 10/2023 | TRM v11.0 update. Added electric resistance documentation adjustment factor. |

## 2.3.3 Attic Encapsulation Measure Overview

**TRM Measure ID:** R-BE-AE

**Market Sector:** Residential

**Measure Category:** Building envelope

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Building simulation modeling

## Measure Description

Savings are estimated for bringing the attic into conditioned space by insulating and sealing the attic walls and roofs, eliminating leakage (to outside) and removing ceiling insulation, if present, to enhance airflow between the attic and the conditioned space directly below. Savings are presented according to Insulation Improvement and Infiltration Reduction components. Participants are expected to claim the sum of component savings.

## Eligibility Criteria

Cooling savings in this measure apply to customers with central or mini-split electric refrigerated air conditioning in their homes or to customers in TRM Climate Zones 1 and 5 who have evaporative cooling systems. Homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Customers who participate in hard-to-reach (HTR) or low-income (LI) programs are eligible to claim reduced heating savings for homes heated with gas or electric resistance space heaters by applying an adjustment to deemed savings that is specified for that heat type. Customers participating in HTR or LI programs are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that is specified for homes with central refrigerated air.

## Baseline Condition

The baseline condition is a vented, unfinished attic with some level of ceiling insulation. Ceiling insulation levels in existing construction can vary significantly, depending on the age of the home, type of insulation installed, and activity in the attic (such as using the attic for storage and HVAC equipment). Deemed savings have been developed based on different levels of encountered (existing) ceiling insulation in participating homes, ranging from sparsely insulated (< R-5) to the equivalent of about 6 inches of fiberglass batt insulation (R-22). The average ceiling insulation level prior to the retrofit for at participating homes is to be determined and documented by the contractor. Degradation due to age and density of the existing insulation should be taken into account.

Because existing ceiling insulation must be removed during measure implementation, the existing R-value will be based upon the R-value of the existing insulation prior to removal.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[214] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[215] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer/Winter Demand Savings Tables sections.

### High-Efficiency Condition

A minimum ceiling insulation level of R-30 is recommended throughout Texas as prescribed by the Department of Energy[216]. Accordingly, deemed savings are provided for insulating to R-30. Adjustment factors are provided to allow contractors to estimate savings for installation of higher or lower levels of post-retrofit insulation. Contractors should estimate post-retrofit R-value according to the average insulation depth achieved across the area treated and the R per-inch of the insulation material installed.

Vents, obvious leaks, are to be sealed. Ceiling insulation between the attic and the conditioned space is removed.

## Energy and Demand Savings Methodology

The energy and demand savings produced by the attic encapsulation measures have two components: 1) reduced heat transfer into the attic from the insulation improvement, and 2) reduced leakage of conditioned air to outside by closing off vents and sealing of leaks. Accordingly, deemed energy and demand savings are presented by their insulation and air infiltration components. Both insulation improvement component and infiltration reduction component savings should be claimed for all projects. Insulation improvement component savings shall be claimed using deemed savings derived for the ceiling insulation measure, as explained below. There are two paths for claiming infiltration reduction component savings depending on whether pre- and post-retrofit blower door testing is undertaken when implementing the attic encapsulation measure. If blower door testing is performed, savings for the infiltration reduction component can be estimated according to the Residential Air Infiltration measure (Measure 2.3.1). If blower door testing is not undertaken, savings for the Infiltration Reduction component shall be claimed as presented in the air infiltration reduction component savings presented in this measure (below).

In previous versions of the TRM, energy and demand savings for the attic encapsulation measure have been presented according to the results achieved by directly modeling the attic encapsulation measure according to the best interpretation of how the measure should be represented. The expectation is that this measure should, at a minimum, provide savings commensurate with those obtained from the installation of ceiling insulation. In general, the

---

[214] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[215] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

[216] Department of Energy Insulation R-value recommendations for zone 2/3, https://www.energy.gov/energysaver/weatherize/insulation.

measure is expected to out-perform ceiling insulation. However, modeling results have not reflected this expectation due to complications accounting for reduced infiltration, resulting in lower deemed savings for the attic encapsulation measure than those estimated for ceiling insulation. To encourage implementation of the measure and begin to develop information about the outcomes, the savings presented in this measure for the insulation improvement component of the Attic Encapsulation Measure are equivalent to the ceiling insulation measure savings. After adding air infiltration reduction component savings to the insulation improvement component savings, attic encapsulation measure savings will exceed those of the ceiling insulation measure.

## Insulation Component Savings

### *Savings Algorithms and Input Variables (Insulation Component)*

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed by modeling the ceiling insulation measure using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. For details on the derivation of these savings, refer to the Residential Ceiling Insulation Measure (Measure 2.3.2).

### *Deemed Energy Savings Tables (Insulation Component)*

Table 135 through Table 139 present the energy savings (kWh) associated with attic encapsulation for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types. Savings are specified per square foot of conditioned space directly below the treated attic.

For customers who participate in hard-to-reach (HTR) or low-income (LI) programs, cooling energy savings may be claimed for homes cooled by one or more room air conditioners by multiplying the appropriate cooling savings value from Table 135 through Table 141 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 135 through Table 141 by a factor of 0.24.[217]

**Table 134. Attic Encapsulation—Prototypical Home Characteristics**

| Shell characteristic | Value | Source |
|---|---|---|
| Base attic encapsulation | Vented attic<br>< R5<br>R5-R8<br>R9-R14<br>R15-R22 | Typical construction practice throughout the state |
| Change attic encapsulation with blower door test | Sealed attic with no ceiling insulation and R-30 roof deck insulation | R-30 retrofit insulation level consistent with DOE recommendations |

[217] This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

| Shell characteristic | Value | Source |
|---|---|---|
| Change attic encapsulation without blower door test | Sealed attic with no ceiling insulation and R-30 roof deck insulation<br>18 percent leakage reduction | Insulation: R-30 retrofit insulation level consistent with DOE recommendations<br>Leakage Reduction: mean reduction achieved via attic encapsulation according to ACCA Manual J, 8th Edition, Section 21-14[218] |

**Table 135. Attic Encapsulation—Climate Zone 1: Amarillo, R-30 Energy Savings for Insulation Component (kWh/sq. ft)**

| Ceiling insulation base R-value | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|
| | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| < R-5 | 0.41 | 0.12 | 0.12 | 3.07 | 1.31 |
| R-5 to R-8 | 0.28 | 0.08 | 0.08 | 2.16 | 0.92 |
| R-9 to R-14 | 0.15 | 0.04 | 0.05 | 1.17 | 0.50 |
| R-15 to R-22 | 0.06 | 0.02 | 0.02 | 0.51 | 0.22 |

**Table 136. Attic Encapsulation—Climate Zone 2: Dallas, R-30 Energy Savings for Insulation Component (kWh/sq. ft)**

| Ceiling insulation base R-value | Cooling savings | Heating savings | | |
|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump |
| < R-5 | 0.67 | 0.07 | 1.90 | 0.79 |
| R-5 to R-8 | 0.46 | 0.05 | 1.34 | 0.55 |
| R-9 to R-14 | 0.25 | 0.03 | 0.72 | 0.30 |
| R-15 to R-22 | 0.11 | 0.01 | 0.32 | 0.13 |

**Table 137. Attic Encapsulation—Climate Zone 3: Houston, R-30 Energy Savings for Insulation Component (kWh/sq. ft)**

| Ceiling insulation base R-value | Cooling savings | Heating savings | | |
|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump |
| < R-5 | 0.68 | 0.05 | 1.30 | 0.53 |
| R-5 to R-8 | 0.46 | 0.03 | 0.92 | 0.37 |
| R-9 to R-14 | 0.24 | 0.02 | 0.50 | 0.20 |
| R-15 to R-22 | 0.10 | 0.01 | 0.22 | 0.09 |

[218] Section 21-14 of ACCA Manual J states that, "…a foam encapsulated attic eliminates ceiling leakage to the outdoors (i.e., to a vented attic), which means that the reduction in infiltration Cfm may range from 3 to 30 percent, with an 18 percent mean, as noted above". See Air Conditioning Contractors of America. Manual J, 8th Edition Version 2.10. Nov. 2011, p. 188.

**Table 138. Attic Encapsulation—Climate Zone 4: Corpus Christi, R-30 Energy Savings for Insulation Component (kWh/sq. ft)**

| Ceiling insulation base R-value | Cooling savings | Heating savings | | |
|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump |
| < R-5 | 0.52 | 0.03 | 0.89 | 0.34 |
| R-5 to R-8 | 0.35 | 0.02 | 0.62 | 0.24 |
| R-9 to R-14 | 0.18 | 0.01 | 0.33 | 0.13 |
| R-15 to R-22 | 0.08 | 0.00 | 0.14 | 0.06 |

**Table 139. Attic Encapsulation—Climate Zone 5: El Paso, R-30 Energy Savings for Insulation Component (kWh/sq. ft)**

| Ceiling insulation base R-value | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|
| | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| < R-5 | 0.63 | 0.21 | 0.07 | 1.96 | 0.81 |
| R-5 to R-8 | 0.43 | 0.15 | 0.05 | 1.40 | 0.57 |
| R-9 to R-14 | 0.23 | 0.08 | 0.03 | 0.75 | 0.31 |
| R-15 to R-22 | 0.10 | 0.03 | 0.01 | 0.33 | 0.13 |

## *Scale-Down/Up Factors for Energy Savings: Insulation to Below or Above R-30*

The factors presented in this section are to be used when the average post-retrofit insulation depth is providing either more than or less than R-30 insulation. Scale-down factors are provided for the case when average post-retrofit insulation depth is not sufficient to achieve R-30; scale-up factors are provided for the case when insulating to a level greater than R-30. In either case, the following equation should be applied to scale down or scale up the energy savings.

$$Energy\ Savings\ [\Delta kWh] = \left\{R30\ Savings/ft^2 + \left[S_{D/U} \times (R_{Achieved} - 30)\right]\right\} \times A$$

**Equation 65**

*Where:*

*R30 Savings/ft²* = *Sum of project-appropriate deemed Cooling and Heating Energy Savings per square feet taken from Table 135 through Table 139*

$S_{D/U}$ = *Project-appropriate scale-down or scale-up factor from either Table 140 or Table 141*

| | | |
|---|---|---|
| $R_{Achieved}$ | = | *Achieved R-value of installed insulation (e.g., for R-28, $R_{Achieved}$ = 28)* |
| $A$ | = | *Treated area (sq. ft.)* |

If the roof deck and attic walls are insulated to a level less than R-30, the factors in Table 140 shall be applied to scale down the achieved energy savings per square foot of treated ceiling area.

**Table 140. Attic Encapsulation—Energy Scale-down Factors for Insulating to Less than R-30 (kWh/sq. ft./ΔR)**

| Climate zone | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|
| | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | 4.00E-03 | 1.16E-03 | 1.27E-03 | 3.26E-02 | 1.38E-02 |
| Zone 2: Dallas | 6.66E-03 | – | 7.11E-04 | 2.00E-02 | 8.20E-03 |
| Zone 3: Houston | 6.22E-03 | – | 4.67E-04 | 1.38E-02 | 5.47E-03 |
| Zone 4: Corpus Christi | 4.92E-03 | – | 2.44E-04 | 9.04E-03 | 3.47E-03 |
| Zone 5: El Paso | 4.00E-03 | 1.16E-03 | 1.27E-03 | 3.26E-02 | 1.38E-02 |

If the roof deck and attic walls are insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved energy savings per square foot of treated ceiling area.

**Table 141. Attic Encapsulation—Energy Scale-up Factors for Insulating to Greater than R-30 (kWh/sq. ft./ΔR)**

| Climate zone | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|
| | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | 2.66E-03 | 7.63E-04 | 8.45E-04 | 2.18E-02 | 9.18E-03 |
| Zone 2: Dallas | 4.45E-03 | – | 4.82E-04 | 1.33E-02 | 5.47E-03 |
| Zone 3: Houston | 4.00E-03 | – | 2.97E-04 | 9.19E-03 | 3.66E-03 |
| Zone 4: Corpus Christi | 3.24E-03 | – | 1.62E-04 | 5.99E-03 | 2.30E-03 |
| Zone 5: El Paso | 2.66E-03 | 7.63E-04 | 8.45E-04 | 2.18E-02 | 9.18E-03 |

### *Deemed Summer Demand Savings Tables*

Table 142 through Table 146 present the summer demand savings (kW/sq. ft.) associated with the Insulation Improvement component of the Attic Encapsulation Measure for the five Texas climate zones.

For customers who participate in HTR/LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying the appropriate cooling value in the refrigerated air column in Table 142 through Table 148 by a factor of 0.6.

**Table 142. Attic Encapsulation—Climate Zone 1: Amarillo,**
**R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.)**

| Ceiling insulation base R-value | Refrigerated | Evaporative |
|---|---|---|
| < R-5 | 8.00E-04 | 2.25E-04 |
| R-5 to R-8 | 4.50E-04 | 1.47E-04 |
| R-9 to R-14 | 2.33E-04 | 7.16E-05 |
| R-15 to R-22 | 1.02E-04 | 2.87E-05 |

**Table 143. Attic Encapsulation—Climate Zone 2: Dallas,**
**R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.)**

| Ceiling insulation base R-value | Demand savings |
|---|---|
| < R-5 | 9.00E-04 |
| R-5 to R-8 | 5.17E-04 |
| R-9 to R-14 | 2.67E-04 |
| R-15 to R-22 | 1.15E-04 |

**Table 144. Attic Encapsulation—Climate Zone 3: Houston,**
**R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.)**

| Ceiling insulation base R-value | Demand savings |
|---|---|
| < R-5 | 6.25E-04 |
| R-5 to R-8 | 5.51E-04 |
| R-9 to R-14 | 2.87E-04 |
| R-15 to R-22 | 1.22E-04 |

**Table 145. Attic Encapsulation—Climate Zone 4: Corpus Christi,**
**R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.)**

| Ceiling insulation base R-value | Demand savings |
|---|---|
| < R-5 | 4.75E-04 |
| R-5 to R-8 | 3.40E-04 |
| R-9 to R-14 | 1.79E-04 |
| R-15 to R-22 | 7.95E-05 |

**Table 146. Attic Encapsulation—Climate Zone 5: El Paso, R-30 Summer Peak Demand Savings for Insulation Component (kW/sq. ft.)**

| Ceiling insulation base R-value | Refrigerated | Evaporative |
|---|---|---|
| < R-5 | 8.00E-04 | 2.23E-04 |
| R-5 to R-8 | 4.72E-04 | 1.53E-04 |
| R-9 to R-14 | 2.38E-04 | 6.25E-05 |
| R-15 to R-22 | 1.03E-04 | 2.09E-05 |

### *Scale-Down/Up Factors: Insulation to Below or Above R-30*

If the roof deck and attic walls are insulated to a level less than R-30, the following factors shall be applied to scale down the achieved summer peak demand savings per square foot of treated ceiling area.

**Table 147. Attic Encapsulation—Summer Peak Demand Scale-down Factors for Insulating to Less than R-30 (kW/sq. ft./ΔR)**

| Climate zone | Refrigerated | Evaporative |
|---|---|---|
| Zone 1: Amarillo | 6.41E-06 | 1.97E-06 |
| Zone 2: Dallas | 7.30E-06 | – |
| Zone 3: Houston | 7.91E-06 | – |
| Zone 4: Corpus Christi | 5.20E-06 | – |
| Zone 5: El Paso | 6.41E-06 | 1.97E-06 |

If the roof deck and attic walls are insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved summer peak demand savings per square foot of treated ceiling area.

**Table 148. Attic Encapsulation—Summer Peak Demand Scale-up Factors for Insulating to Greater than R-30 (kW/sq. ft./ΔR)**

| Climate zone | Refrigerated | Evaporative |
|---|---|---|
| Zone 1: Amarillo | 4.22E-06 | 1.89E-06 |
| Zone 2: Dallas | 4.92E-06 | – |
| Zone 3: Houston | 5.92E-06 | – |
| Zone 4: Corpus Christi | 3.47E-06 | – |
| Zone 5: El Paso | 4.22E-06 | 1.89E-06 |

## *Deemed Winter Demand Savings Tables*

Table 149 through Table 153 present the winter demand savings associated with the Insulation Improvement component of the Attic Encapsulation Measure for the five Texas climate zones.

For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 149 through Table 155 by a factor of 0.24.[219]

**Table 149. Attic Encapsulation—Climate Zone 1: Amarillo, R-30 Winter Peak Demand Savings for Insulation Component (kW/sq. ft.)**

| Ceiling insulation base R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| < R-5 | 4.25E-05 | 9.75E-04 | 8.00E-04 |
| R-5 to R-8 | 2.51E-05 | 8.74E-04 | 4.53E-04 |
| R-9 to R-14 | 1.37E-05 | 4.56E-04 | 2.38E-04 |
| R-15 to R-22 | 4.72E-06 | 1.95E-04 | 1.01E-04 |

**Table 150. Attic Encapsulation—Climate Zone 2: Dallas, R-30 Winter Peak Demand Savings for Insulation Component (kW/sq. ft.)**

| Ceiling insulation base R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| < R-5 | 3.50E-05 | 1.30E-03 | 8.25E-04 |
| R-5 to R-8 | 2.79E-05 | 9.84E-04 | 6.60E-04 |
| R-9 to R-14 | 1.45E-05 | 5.13E-04 | 3.51E-04 |
| R-15 to R-22 | 6.42E-06 | 2.23E-04 | 1.52E-04 |

**Table 151. Attic Encapsulation—Climate Zone 3: Houston, R-30 Winter Peak Demand Savings for Insulation Component (kW/sq. ft.)**

| Ceiling insulation base R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| < R-5 | 4.25E-05 | 1.15E-03 | 6.75E-04 |
| R-5 to R-8 | 2.91E-05 | 7.71E-04 | 4.49E-04 |
| R-9 to R-14 | 1.39E-05 | 4.01E-04 | 2.35E-04 |
| R-15 to R-22 | 5.36E-06 | 1.74E-04 | 1.03E-04 |

[219] This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

**Table 152. Attic Encapsulation—Climate Zone 4: Corpus Christi, R-30 Winter Peak Demand Savings for Insulation Component (kW/sq. ft.)**

| Ceiling insulation base R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| < R-5 | 2.50E-05 | 8.25E-04 | 4.50E-04 |
| R-5 to R-8 | 2.18E-05 | 6.31E-04 | 3.03E-04 |
| R-9 to R-14 | 1.13E-05 | 3.28E-04 | 1.57E-04 |
| R-15 to R-22 | 5.71E-06 | 1.44E-04 | 6.95E-05 |

**Table 153. Attic Encapsulation—Zone 5: El Paso, R-30 Winter Peak Demand Savings for Insulation Component (kW/sq. ft.)**

| Ceiling insulation base R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| < R-5 | 2.25E-05 | 5.75E-04 | 2.25E-04 |
| R-5 to R-8 | 1.14E-05 | 3.72E-04 | 1.57E-04 |
| R-9 to R-14 | 5.38E-06 | 1.79E-04 | 7.54E-05 |
| R-15 to R-22 | 2.26E-06 | 7.41E-05 | 3.11E-05 |

### *Scale-Down/Up Factors for Demand Reduction: Insulation to Below or Above R-30*

The factors presented in this section are to be used when the average post-retrofit insulation depth is providing more or less than R-30 insulation. Scale-down factors are provided for the case when average post-retrofit insulation depth is not sufficient to achieve R-30; scale-up factors are provided for the case when insulating to a level greater than R-30. In either case, the following equation should be applied to scale down or scale up the summer peak demand savings.

$$Peak\ Demand\ Savings\ [\Delta kW] = \left\{R30\ Savings/ft^2 + \left[S_{D/U} \times (R_{Achieved} - 30)\right]\right\} \times A$$

**Equation 66**

*Where:*

*R30 Savings/ft²* = *Sum of project-appropriate deemed Cooling and Heating Energy Savings per square feet taken from Table 142 through Table 146 or Table 149 through Table 153*

$S_{D/U}$ = *Project-appropriate scale-down or scale-up factor from either Table 147 and Table 148 (summer) or Table 154 and Table 155 (winter)*

If the roof deck and attic walls are insulated to a level less than R-30, the following factors shall be applied to scale down the achieved winter peak demand savings (per square foot of treated ceiling area).

**Table 154. Attic Encapsulation—Winter Peak Demand Scale-down Factors for Insulating to Less than R-30 (kW/sq. ft./ΔR)**

| Climate zone | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| Zone 1: Amarillo | 4.29E-07 | 1.21E-05 | 6.30E-06 |
| Zone 2: Dallas | 3.97E-07 | 1.40E-05 | 9.55E-06 |
| Zone 3: Houston | 3.05E-07 | 1.10E-05 | 6.53E-06 |
| Zone 4: Corpus Christi | 3.19E-07 | 9.18E-06 | 4.32E-06 |
| Zone 5: El Paso | 4.29E-07 | 1.21E-05 | 6.30E-06 |

If the roof deck/attic walls are insulated to a level greater than R-30, the following factors shall be applied to scale up the achieved winter peak demand savings per square foot of treated ceiling area.

**Table 155. Attic Encapsulation—Winter Peak Demand Scale-cp Factors for Insulating to Greater than R-30 (kW/sq. ft./ΔR)**

| Climate zone | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| Zone 1: Amarillo | 2.76E-07 | 7.85E-06 | 4.19E-06 |
| Zone 2: Dallas | 2.57E-07 | 8.33E-06 | 4.80E-06 |
| Zone 3: Houston | 2.19E-07 | 7.33E-06 | 4.46E-06 |
| Zone 4: Corpus Christi | 1.72E-07 | 5.79E-06 | 2.72E-06 |
| Zone 5: El Paso | 2.76E-07 | 7.85E-06 | 4.19E-06 |

## Air Infiltration Reduction Component Savings

Energy and demand savings for the air infiltration reduction component of the attic encapsulation measure are calculated either using the results of pre- and post-retrofit blower door testing or an average percent infiltration reduction. Regardless of how air infiltration reduction component savings are calculated, they should be added to the insulation improvement component savings to arrive at the total energy and demand savings for implementing the Attic Encapsulation measure.

Homes without refrigerated cooling should not claim air infiltration reduction component savings for attic encapsulation.

### *With Blower Door Testing*

Implementers choosing to perform pre- and post-measure blower door testing should claim the air infiltration reduction component deemed energy and demand savings for the Attic Encapsulation measure using the estimated $CFM_{50}$ reduction from the blower door tests with the equations and coefficients in the Residential Infiltration measure (Measure 2.3.1).

## Without Blower Door Testing

Implementers electing not to perform blower door testing when performing this measure shall claim air infiltration reduction component deemed energy and demand savings for the Attic Encapsulation measure using this section, which presents the annual energy (kWh) and summer and winter demand savings (kW) associated with attic encapsulation for the five Texas climate zones, taking into account a mean leakage reduction of 18 percent.[220] Savings are presented per home.

## Savings Algorithms and Input Variables (Infiltration Reduction Component)

Calibrated simulation modeling was used to develop air infiltration reduction deemed savings, which are expressed in Measure 2.3.1 as linear functions of the leakage reduction achieved (in $CFM_{50}$).[221] For details on the derivation of the air infiltration measure savings, refer to the Residential Air Infiltration measure (Measure 2.3.1).

ACCA Manual J provides an average leakage reduction attributable to attic encapsulation projects of 18 percent.[222] Accordingly, deemed savings attributable to the air infiltration reduction component of an attic encapsulation project implemented without pre- and post-implementation blower door testing are estimated by applying an 18 percent leakage reduction to the infiltration rates embedded in the deemed savings prototype model homes used in the derivation of residential envelope measure deemed savings for the Texas TRM. This 18 percent leakage reduction provides the $CFM_{50}$ reduction input required to estimate air infiltration measure deemed savings with the equations in Measure 2.3.1.

**Table 156. Attic Encapsulation—Prototypical Home Characteristics**

| Shell characteristic | $CFM_{50}$ reduction | Source |
|---|---|---|
| Air infiltration reduction from attic encapsulation (without blower door testing) | 18 percent reduction | Mean reduction achieved via attic encapsulation according to ACCA Manual J, 8th Edition, Section 21-14[223] |

[220] Section 21-14 of ACCA Manual J states that, "…a foam encapsulated attic eliminates ceiling leakage to the outdoors (i.e., to a vented attic), which means that the reduction in infiltration CFM may range from 3 to 30 percent, with an 18 percent mean, as noted above". See Air Conditioning Contractors of America. Manual J, 8th Edition Version 2.10. Nov. 2011, p. 188.

[221] Model testing indicates a straight-line relationship between demand and energy savings achieved and CFM50 reductions is appropriate with beginning and ending leakage rates within the ranges permitted by the measure.

[222] Air Conditioning Contractors of America. Manual J, 8th Edition Version 2.10. Nov. 2011, p. 188.

[223] Section 21-14 of ACCA Manual J states that, "…a foam encapsulated attic eliminates ceiling leakage to the outdoors (i.e., to a vented attic), which means that the reduction in infiltration Cfm may range from 3 to 30 percent, with an 18 percent mean, as noted above". See Air Conditioning Contractors of America. Manual J, 8th Edition Version 2.10. Nov. 2011, p. 188.

## *Deemed Energy Savings Tables (Infiltration Reduction Component)*

Annual energy savings are provided by the space heating equipment type combined with refrigerated cooling. Savings are specified per home based on a deemed 18 percent infiltration reduction. Homes without refrigerated cooling are not eligible to claim these savings.

**Table 157. Attic Encapsulation—Energy Savings for Infiltration Reduction Component, 18 Percent Air Infiltration Reduction (kWh/home)**

| Climate zone | Heating type | | |
|---|---|---|---|
| | Gas/ no heat | Electric resistance | Heat pump |
| Zone 1: Amarillo | 135.0 | 874.5 | 385.8 |
| Zone 2: Dallas | 209.2 | 600.3 | 315.5 |
| Zone 3: Houston | 161.9 | 469.5 | 259.6 |
| Zone 4: Corpus Christi | 179.7 | 411.9 | 262.9 |
| Zone 5: El Paso | 64.3 | 524.7 | 226.5 |

## *Deemed Summer Demand Savings Tables (Infiltration Reduction Component)*

Summer demand savings are specified per home based on a deemed 18 percent infiltration reduction. Homes without refrigerated cooling are not eligible to claim these savings.

**Table 158. Attic Encapsulation—Summer Peak Demand Savings for Infiltration Reduction Component, 18 Percent Air Infiltration Reduction (kW/home)**

| Climate zone | Cooling type | |
|---|---|---|
| | Refrigerated | Evaporative |
| Zone 1: Amarillo | 0.088 | – |
| Zone 2: Dallas | 0.117 | – |
| Zone 3: Houston | 0.117 | – |
| Zone 4: Corpus Christi | 0.098 | – |
| Zone 5: El Paso | 0.056 | – |

## *Deemed Winter Demand Savings Tables (Infiltration Reduction Component)*

Winter demand savings are provided by space heating equipment types. Savings are specified per home based on a deemed 18 percent infiltration reduction.

**Table 159. Attic Encapsulation—Winter Peak Demand Savings for the Infiltration Reduction Component, 18 Percent Air Infiltration Reduction (kW/home)**

| Climate zone | Heating type | | |
|---|---|---|---|
| | Gas/ no heat | Electric resistance | Heat pump |
| Zone 1: Amarillo | – | 0.404 | 0.235 |
| Zone 2: Dallas | – | 0.548 | 0.304 |
| Zone 3: Houston | – | 0.476 | 0.244 |
| Zone 4: Corpus Christi | – | 0.342 | 0.158 |
| Zone 5: El Paso | – | 0.161 | 0.066 |

## Example Deemed Savings Calculation

**Example 1.** A contractor seals the attic and adds R-38 insulation to the underside of the roof to a home with 900 square feet of conditioned space below the treated attic in Climate Zone 3 with refrigerated air and a gas furnace, which has existing ceiling insulation estimated at R-7. No blower door testing is performed.

Insulation component savings:

$$Energy\ Savings/ft^2, Insulation\ to\ R-30 = 0.46 + 0.03 = 0.49\ kWh/ft^2$$

$$Energy\ Savings, Insulation\ to\ R-38 =$$

$$\{0.49 + [(4x10^{-3} + 2.97x10^{-4}) \times (38-30)]\} \times 900 = 471.9\ kWh$$

$$Summer\ Peak\ Demand\ Savings, Insulation\ to\ R-38 =$$

$$\{5.51 \times 10^{-4} + [5.92 \times 10^{-6}\ x\ (38-30)]\} \times 900 = 0.54\ kW$$

$$Winter\ Peak\ Demand\ Savings, Insulation\ to\ R-38 =$$

$$\{2.91 \times 10^{-5} + [2.19x10^{-7} \times (38-30)]\} \times 900 = 0.03\ kW$$

Infiltration reduction component savings:

$$Energy\ Savings, 18\%\ Infiltration\ Reduction = 161.9\ kWh$$

$$Summer\ Peak\ Demand\ Savings, 18\%\ Infiltration\ Reduction = 0.12\ kW$$

$$Winter\ Peak\ Demand\ Savings, 18\%\ Infiltration\ Reduction = 0$$

Measure savings:

$$Energy\ Savings = 471.9 + 161.9 = 633.8\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 0.54 + 0.12 = 0.66\ kW$$

$$Winter\ Peak\ Demand\ Savings = 0.03 + 0 = 0.03\ kW$$

**Example 2.** A contractor seals the attic and adds R-30 insulation to the underside of the roof to a home with 1,200 square feet of conditioned space below the treated attic in Climate Zone 4 with an air-source heat pump in which existing ceiling insulation is demonstrated to be R-9. Blower door testing performed before and after measure implementation demonstrated a 750 $CFM_{50}$ reduction in leakage rate.

Insulation component savings:

$$Energy\ Savings = (0.18 + 0.13) \times 1{,}200 = 372\ kWh$$

$$Summer\ Peak\ Demand\ Savings = (1.79 \times 10^{-4}) \times 1{,}200 = 0.21\ kW$$

$$Winter\ Peak\ Demand\ Savings = (1.57 \times 10^{-4}) \times 1{,}200 = 0.19\ kW$$

Infiltration reduction component savings:

$$Energy\ Savings, 750\ CFM_{50}\ Infiltration\ Reduction = 750 \times (0.39 \times 1 + 0.21) = 450 kWh$$

$$Summer\ Peak\ Demand\ Savings, 750\ CFM_{50}\ Infiltration\ Reducion = 750 \times (2.24x10^{-4} \times 1) = 0.17\ kW$$

$$Winter\ Peak\ Demand\ Savings, 750\ CFM_{50}\ Infiltration\ Reduction = 750 \times (3.60x10^{-4}) = 0.27\ kW$$

Measure savings:

$$Energy\ Savings = 372 + 450 = 822\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 0.21 + 0.17 = 0.38\ kW$$

$$Winter\ Peak\ Demand\ Savings = 0.19 + 0.27 = 0.46\ kW$$

## 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

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007),[224] the Estimated Useful Life is 25 years for ceiling insulation. The measure life specified for ceiling insulation is also appropriate for attic encapsulation.

## 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:

- Climate zone or county
- Base R-value of original insulation
- R-value of installed insulation
- Cooling type (evaporative cooling, central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
    - If documentation is not provided, an adjustment factor of 0.75 will be applied to the heating energy and winter demand savings
- Square footage of conditioned space directly below the treated attic
- Indicate whether blower door testing was performed and whether air infiltration reduction component savings are claimed in this measure or separately using the Air Infiltration measure
- Only for homes with a reported baseline R-value that is less than R-5:
    - Two pictures: (1) a picture showing the entire attic floor, and (2) a close-up picture of a ruler that shows the measurement of the depth of the insulation

      Note: The second photo type is required for each area of insulation where there are varying R-values less than R-5. Additionally, both photo types are required for all separate attic/ceiling areas, even when the installed R-value is the same.

[224] GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007). http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLightsandHVACGDS_1Jun2007.pdf.

## References and Efficiency Standards

### Petitions and Rulings

- 10/2017

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 160. Attic Encapsulation—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. Incorporated alternative savings path that includes savings for infiltration reduction. |
| v6.0 | 11/2018 | TRM v6.0 update. Removed closed cell recommendation. |
| v7.0 | 11/2019 | TRM v7.0 update. Incorporated EM&V guidance memo. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated savings tables. Added space heat adjustment factor and electric resistance documentation requirement. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated savings tables for < R-5 baseline category. |
| v10.0 | 10/2022 | TRM v10.0 update. No revision. |
| v11.0 | 10/2023 | TRM v11.0 update. Added electric resistance documentation adjustment factor. |

## 2.3.4 Wall Insulation Measure Overview

**TRM Measure ID:** R-BE-WI

**Market Sector:** Residential

**Measure Category:** Building envelope

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Building simulation modeling

## Measure Description

Wall insulation is added to the walls surrounding conditioned space in existing homes, either by removing wall enclosures and applying batt or spray insulation or by otherwise filling (e.g., blowing in loose insulation) the cavity space between studs in the walls of existing homes. Walls may be either 2x4 or 2x6 construction. Savings are estimated for filling the wall cavities of 2x4 or 2x6 walls with fiberglass batts, cellulose, or closed-cell spray foam and are presented per square foot of treated wall area (gross wall area less window and door area).

## Eligibility Criteria

Cooling savings in this measure apply to customers with central or mini-split electric refrigerated air conditioning in their homes, or to customers in TRM Climate Zones 1 and 5 who have evaporative cooling systems. Homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Customers who participate in hard-to-reach (HTR) or low-income (LI) programs are eligible to claim reduced heating savings for homes heated with gas or electric resistance space heaters by applying an adjustment to deemed savings that is specified for that heat type. Customers participating in HTR or LI programs are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that is specified for homes with central refrigerated air.

Refer to the Baseline Condition section below for eligibility criteria regarding the pre-retrofit level of wall insulation.

## Baseline Condition

The baseline is a house with little or no wall insulation in the wall cavity. For those homes for which a minimal level of insulation is encountered, the baseline is established at R-4. This baseline should be used to represent homes for which installed insulation covers a very limited amount of the wall area to be treated, is significantly degraded, and/or is less than an inch thick. Homes with more than this base level of insulation are not eligible for the measure.

Baseline homes may have either 2x4 or 2x6 construction.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[225] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[226] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer/Winter Demand Savings Tables sections.

## High-Efficiency Condition

The standard throughout Texas for adding wall insulation to an existing wall cavity is R-13, as prescribed by the United States Department of Energy (DOE) and Texas Department of Housing and Community Affairs (TDHCA) programs. The standard is achieved by filling a 2x4 wall cavity with fiberglass batt or cellulose insulation, which typically provides an R-value per inch (thickness) of between 3 and 4 $ft^2 \cdot °F \cdot hr/Btu$. Other wall insulation materials may be used, such as closed-cell spray foam, which approximately provides R-6 per inch.

As such, deemed savings are provided for insulating 2x4 and 2x6 walls to the levels presented in Table 161.

**Table 161. Wall Insulation—High-Efficiency Condition R-Values for 2x4 and 2x6 Walls**

| Insulation material | 2x4 wall | 2x6 wall |
|---|---|---|
| Fiberglass batt or cellulose | R-13 | R-17 |
| Closed-cell spray foam | R-21 | R-33 |

Wall insulation reduces the ventilation rate in the home, and therefore, a post-installation blower door test must be conducted. Results must comply with the minimum final ventilation rate discussed in the High-Efficiency Condition section found in the Air Infiltration section of this document. This requirement applies to retrofits implemented under the HTR and RSOP programs.

225 Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.
226 Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: the default R-11 insulation was reduced to either R-0 or R-4.

The model runs calculated energy use for the prototypical home prior to the installation of the wall insulation measure. Next, change-case models were run to calculate energy use with the wall insulation measure in place.

**Table 162. Wall Insulation—Prototypical Home Characteristics**

| Shell characteristic | Value | Source |
|---|---|---|
| Base wall insulation | R-0<br>R-4 | BEopt estimates wall assembly R-value for uninsulated walls to be 3.6 for 2x4 construction and 3.7 for 2x6 construction. Assembly R-values for R-4 walls are 6.7 and 7.1 for 2x4 and 2x6 construction, respectively. Listed base levels are for the insulation material only. |
| Change wall insulation 2x4 wall | R-13<br>R-21 | For retrofit with fiberglass batt/cellulose and closed-cell spray foam, respectively. |
| Change wall insulation 2x6 wall | R-17<br>R-33 | EF or retrofit with fiberglass batt/cellulose and closed-cell spray foam, respectively. |

### Deemed Energy Savings Tables

Savings are presented separately for insulating 2x4 wall construction and homes with 2x6 walls. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

For customers who participate in hard-to-reach (HTR) or low-income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying the appropriate cooling value in Table 163 through Table 166 by a factor of 0.6. Similarly for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 163 through Table 166 by a factor of 0.24.[227]

[227] This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

### *2x4 Walls*

Table 163 presents the deemed energy savings values for insulating 2x4 walls to R-13 for all five Texas climate zones.

**Table 163. Wall Insulation—Energy Savings (kWh/sq. ft.), Insulation of 2x4 Walls to R- 13**

| Climate zone | Baseline R-value | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | Uninsulated | 0.50 | 0.17 | 0.18 | 3.96 | 1.67 |
| Zone 2: Dallas | | 0.85 | – | 0.09 | 2.44 | 0.99 |
| Zone 3: Houston | | 0.90 | – | 0.07 | 1.67 | 0.66 |
| Zone 4: Corpus Christi | | 0.53 | – | 0.04 | 1.19 | 0.45 |
| Zone 5: El Paso | | 0.76 | 0.29 | 0.09 | 2.40 | 0.98 |
| Zone 1: Amarillo | R-4 | 0.18 | 0.06 | 0.07 | 1.52 | 0.64 |
| Zone 2: Dallas | | 0.32 | – | 0.04 | 0.93 | 0.38 |
| Zone 3: Houston | | 0.33 | – | 0.03 | 0.64 | 0.25 |
| Zone 4: Corpus Christi | | 0.19 | – | 0.01 | 0.45 | 0.17 |
| Zone 5: El Paso | | 0.28 | 0.11 | 0.03 | 0.92 | 0.37 |

Table 164 presents the deemed energy savings values for insulating 2x4 walls to R-21 for all five Texas climate zones.

**Table 164. Wall Insulation—Energy Savings (kWh/sq. ft.), Insulation of 2x4 Walls to R-21**

| Climate zone | Baseline R-value | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | Uninsulated | 0.56 | 0.18 | 0.20 | 4.44 | 1.87 |
| Zone 2: Dallas | | 0.95 | – | 0.10 | 2.73 | 1.11 |
| Zone 3: Houston | | 1.01 | – | 0.08 | 1.88 | 0.74 |
| Zone 4: Corpus Christi | | 0.59 | – | 0.04 | 1.33 | 0.50 |
| Zone 5: El Paso | | 0.85 | 0.33 | 0.10 | 2.69 | 1.09 |
| Zone 1: Amarillo | R-4 | 0.24 | 0.08 | 0.09 | 2.00 | 0.84 |
| Zone 2: Dallas | | 0.42 | – | 0.05 | 1.23 | 0.50 |
| Zone 3: Houston | | 0.43 | – | 0.03 | 0.84 | 0.33 |
| Zone 4: Corpus Christi | | 0.26 | – | 0.02 | 0.59 | 0.22 |
| Zone 5: El Paso | | 0.37 | 0.14 | 0.05 | 1.20 | 0.49 |

### *2x6 Walls*

Table 165 presents the deemed energy savings values for insulating 2x6 walls to R-17 for all five Texas climate zones.

**Table 165. Wall Insulation—Energy Savings (kWh/sq. ft.), Insulation of 2x6 Walls to R-17**

| Climate zone | Baseline R-value | Cooling savings | | Heating Savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | Uninsulated | 0.53 | 0.18 | 0.19 | 4.27 | 1.80 |
| Zone 2: Dallas | | 0.91 | – | 0.10 | 2.63 | 1.07 |
| Zone 3: Houston | | 0.97 | – | 0.08 | 1.81 | 0.71 |
| Zone 4: Corpus Christi | | 0.56 | – | 0.04 | 1.27 | 0.48 |
| Zone 5: El Paso | | 0.81 | 0.31 | 0.10 | 2.58 | 1.05 |
| Zone 1: Amarillo | R-4 | 0.22 | 0.07 | 0.08 | 1.81 | 0.76 |
| Zone 2: Dallas | | 0.38 | – | 0.04 | 1.11 | 0.45 |
| Zone 3: Houston | | 0.39 | – | 0.03 | 0.76 | 0.30 |
| Zone 4: Corpus Christi | | 0.23 | – | 0.02 | 0.53 | 0.20 |
| Zone 5: El Paso | | 0.33 | 0.13 | 0.04 | 1.08 | 0.44 |

Table 166 presents the deemed energy savings values for insulating 2x6 walls to R-33 for all five Texas climate zones.

**Table 166. Wall Insulation—Energy Savings (kWh/sq. ft.), Insulation of 2x6 Walls to R-33**

| Climate zone | Baseline R-value | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | Uninsulated | 0.59 | 0.20 | 0.22 | 4.79 | 2.01 |
| Zone 2: Dallas | | 1.01 | – | 0.11 | 2.94 | 1.20 |
| Zone 3: Houston | | 1.07 | – | 0.09 | 2.02 | 0.80 |
| Zone 4: Corpus Christi | | 0.62 | – | 0.04 | 1.42 | 0.54 |
| Zone 5: El Paso | | 0.90 | 0.35 | 0.11 | 2.88 | 1.17 |
| Zone 1: Amarillo | R-4 | 0.28 | 0.09 | 0.11 | 2.33 | 0.98 |
| Zone 2: Dallas | | 0.48 | – | 0.05 | 1.42 | 0.58 |
| Zone 3: Houston | | 0.49 | – | 0.04 | 0.98 | 0.38 |
| Zone 4: Corpus Christi | | 0.29 | – | 0.02 | 0.67 | 0.25 |
| Zone 5: El Paso | | 0.42 | 0.16 | 0.05 | 1.38 | 0.56 |

## Deemed Summer Demand Savings Tables

For customers who participate in HTR/LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying the appropriate cooling value in Table 167 through Table 170 by a factor of 0.6.

### *2x4 Walls*

Table 167 presents the deemed summer demand savings values for insulating 2x4 walls to R-13 for all five Texas climate zones.

**Table 167. Wall Insulation—Summer Peak Demand Savings (kW/sq. ft.), Insulation of 2x4 Walls to R-13**

| Climate zone | Baseline R-value | Cooling type | |
|---|---|---|---|
| | | Refrigerated | Evaporative |
| Zone 1: Amarillo | Uninsulated | 6.41E-04 | 2.40E-04 |
| Zone 2: Dallas | | 7.32E-04 | – |
| Zone 3: Houston | | 8.50E-04 | – |
| Zone 4: Corpus Christi | | 4.17E-04 | – |
| Zone 5: El Paso | | 6.52E-04 | 2.00E-04 |
| Zone 1: Amarillo | R-4 | 2.35E-04 | 9.16E-05 |
| Zone 2: Dallas | | 2.70E-04 | – |
| Zone 3: Houston | | 3.02E-04 | – |
| Zone 4: Corpus Christi | | 1.55E-04 | – |
| Zone 5: El Paso | | 2.43E-04 | 7.40E-05 |

Table 168 presents the deemed summer demand savings values for insulating 2x4 walls to R-13 for all five Texas climate zones.

**Table 168. Wall Insulation—Summer Peak Demand Savings, Insulation of 2x4 Walls to R-21 (kW/sq. ft.)**

| Climate zone | Baseline R-value | Cooling type | |
|---|---|---|---|
| | | Refrigerated | Evaporative |
| Zone 1: Amarillo | Uninsulated | 7.34E-04 | 2.66E-04 |
| Zone 2: Dallas | | 8.16E-04 | – |
| Zone 3: Houston | | 9.55E-04 | – |
| Zone 4: Corpus Christi | | 4.69E-04 | – |
| Zone 5: El Paso | | 7.32E-04 | 2.23E-04 |

| Climate zone | Baseline R-value | Cooling type | |
|---|---|---|---|
| | | Refrigerated | Evaporative |
| Zone 1: Amarillo | R-4 | 3.29E-04 | 1.18E-04 |
| Zone 2: Dallas | | 3.55E-04 | – |
| Zone 3: Houston | | 4.08E-04 | – |
| Zone 4: Corpus Christi | | 2.07E-04 | – |
| Zone 5: El Paso | | 3.24E-04 | 9.68E-05 |

### *2x6 Walls*

Table 169 presents the deemed summer demand savings values for insulating 2x6 walls to R-17 for all five Texas climate zones.

**Table 169. Wall Insulation—Summer Peak Demand Savings (kW/sq. ft.), Insulation of 2x6 Walls to R-17**

| Climate zone | Baseline R-value | Cooling type | |
|---|---|---|---|
| | | Refrigerated | Evaporative |
| Zone 1: Amarillo | Uninsulated | 8.00E-04 | 2.59E-04 |
| Zone 2: Dallas | | 7.87E-04 | – |
| Zone 3: Houston | | 9.20E-04 | – |
| Zone 4: Corpus Christi | | 4.56E-04 | – |
| Zone 5: El Paso | | 8.06E-04 | 2.14E-04 |
| Zone 1: Amarillo | R-4 | 2.88E-04 | 1.06E-04 |
| Zone 2: Dallas | | 3.19E-04 | – |
| Zone 3: Houston | | 3.67E-04 | – |
| Zone 4: Corpus Christi | | 1.88E-04 | – |
| Zone 5: El Paso | | 2.91E-04 | 8.44E-05 |

Table 170 presents the deemed summer demand savings values for insulating 2x6 walls to R-33 for all five Texas climate zones.

**Table 170. Wall Insulation—Summer Peak Demand Savings (kW/sq. ft.), Insulation of 2x6 Walls to R-33**

| Climate zone | Baseline R-value | Cooling type | |
|---|---|---|---|
| | | Refrigerated | Evaporative |
| Zone 1: Amarillo | Uninsulated | 7.76E-04 | 2.83E-04 |
| Zone 2: Dallas | | 8.77E-04 | – |
| Zone 3: Houston | | 1.02E-03 | – |
| Zone 4: Corpus Christi | | 5.08E-04 | – |
| Zone 5: El Paso | | 7.80E-04 | 2.38E-04 |
| Zone 1: Amarillo | R-4 | 3.64E-04 | 1.30E-04 |
| Zone 2: Dallas | | 4.09E-04 | – |
| Zone 3: Houston | | 4.64E-04 | – |
| Zone 4: Corpus Christi | | 2.40E-04 | – |
| Zone 5: El Paso | | 3.65E-04 | 1.08E-04 |

## Deemed Winter Demand Savings

For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 171 through Table 174 by a factor of 0.24.[228]

[228] This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

### *2x4 Walls*

Table 171 presents the deemed winter demand savings values for insulating 2x4 walls to R-13 for all five Texas climate zones.

**Table 171. Wall Insulation—Winter Peak Demand Savings (kW/sq. ft.), Insulation of 2x4 Walls to R-13**

| Climate zone | Baseline R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|---|
| Zone 1: Amarillo | Uninsulated | 6.93E-05 | 1.71E-03 | 8.78E-04 |
| Zone 2: Dallas | | 6.66E-05 | 1.96E-03 | 1.30E-03 |
| Zone 3: Houston | | 7.49E-05 | 1.48E-03 | 8.39E-04 |
| Zone 4: Corpus Christi | | 4.28E-05 | 1.22E-03 | 5.78E-04 |
| Zone 5: El Paso | | 2.06E-05 | 6.78E-04 | 2.84E-04 |
| Zone 1: Amarillo | R-4 | 2.58E-05 | 6.20E-04 | 3.19E-04 |
| Zone 2: Dallas | | 2.46E-05 | 7.32E-04 | 4.94E-04 |
| Zone 3: Houston | | 2.61E-05 | 5.50E-04 | 3.20E-04 |
| Zone 4: Corpus Christi | | 1.61E-05 | 4.51E-04 | 2.13E-04 |
| Zone 5: El Paso | | 6.23E-06 | 2.23E-04 | 9.39E-05 |

Table 172 presents the deemed winter demand savings values for insulating 2x4 walls to R-21 for all five Texas climate zones.

**Table 172. Wall Insulation—Winter Peak Demand Savings (kW/sq. ft.), Insulation of 2x4 Walls to R-21**

| Climate zone | Baseline R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|---|
| Zone 1: Amarillo | Uninsulated | 7.69E-05 | 1.89E-03 | 9.75E-04 |
| Zone 2: Dallas | | 7.41E-05 | 2.18E-03 | 1.46E-03 |
| Zone 3: Houston | | 8.19E-05 | 1.65E-03 | 9.40E-04 |
| Zone 4: Corpus Christi | | 4.78E-05 | 1.36E-03 | 6.41E-04 |
| Zone 5: El Paso | | 2.24E-05 | 7.37E-04 | 3.10E-04 |
| Zone 1: Amarillo | R-4 | 3.34E-05 | 8.06E-04 | 4.16E-04 |
| Zone 2: Dallas | | 3.20E-05 | 9.57E-04 | 6.50E-04 |
| Zone 3: Houston | | 3.31E-05 | 7.19E-04 | 4.21E-04 |
| Zone 4: Corpus Christi | | 2.11E-05 | 5.88E-04 | 2.77E-04 |
| Zone 5: El Paso | | 8.01E-06 | 2.83E-04 | 1.20E-04 |

### *2x6 Walls*

Table 173 presents the deemed winter demand savings values for insulating 2x6 walls to R-17 for all five Texas climate zones.

**Table 173. Wall Insulation—Winter Peak Demand Savings (kW/sq. ft.), Insulation of 2x6 Walls to R-17**

| Climate zone | Baseline R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|---|
| Zone 1: Amarillo | Uninsulated | 6.99E-05 | 1.76E-03 | 9.09E-04 |
| Zone 2: Dallas | | 7.01E-05 | 2.07E-03 | 1.40E-03 |
| Zone 3: Houston | | 7.86E-05 | 1.57E-03 | 9.10E-04 |
| Zone 4: Corpus Christi | | 4.58E-05 | 1.29E-03 | 6.08E-04 |
| Zone 5: El Paso | | 1.84E-05 | 6.24E-04 | 2.64E-04 |
| Zone 1: Amarillo | R-4 | 2.68E-05 | 6.93E-04 | 3.58E-04 |
| Zone 2: Dallas | | 2.84E-05 | 8.49E-04 | 5.84E-04 |
| Zone 3: Houston | | 2.96E-05 | 6.40E-04 | 3.82E-04 |
| Zone 4: Corpus Christi | | 1.90E-05 | 5.19E-04 | 2.41E-04 |
| Zone 5: El Paso | | 5.59E-06 | 2.06E-04 | 8.81E-05 |

Table 174 presents the deemed winter demand savings values for insulating 2x6 walls to R-33 for all five Texas climate zones.

**Table 174. Wall Insulation—Winter Peak Demand Savings (kW/sq. ft.), Insulation of 2x6 Walls to R-33**

| Climate zone | Baseline R-value | Gas | Electric resistance | Heat pump |
|---|---|---|---|---|
| Zone 1: Amarillo | Uninsulated | 7.66E-05 | 1.95E-03 | 1.00E-03 |
| Zone 2: Dallas | | 7.77E-05 | 2.31E-03 | 1.56E-03 |
| Zone 3: Houston | | 8.62E-05 | 1.75E-03 | 1.02E-03 |
| Zone 4: Corpus Christi | | 5.11E-05 | 1.43E-03 | 6.73E-04 |
| Zone 5: El Paso | | 1.96E-05 | 6.66E-04 | 2.82E-04 |
| Zone 1: Amarillo | R-4 | 3.35E-05 | 8.76E-04 | 4.53E-04 |
| Zone 2: Dallas | | 3.60E-05 | 1.08E-03 | 7.44E-04 |
| Zone 3: Houston | | 3.72E-05 | 8.17E-04 | 4.92E-04 |
| Zone 4: Corpus Christi | | 2.43E-05 | 6.59E-04 | 3.06E-04 |
| Zone 5: El Paso | | 6.87E-06 | 2.48E-04 | 1.06E-04 |

## Example Deemed Savings Calculation

**Example 1.** A home with uninsulated 2x4 walls in Climate Zone 1 with evaporative cooling and an electric resistance furnace insulates 750 square feet to R-13 with fiberglass batt insulation.

$$Energy\ Savings = (0.17 + 3.96) \times 750 = 3{,}091.5\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 2.40 \times 10^{-4} \times 750 = 0.18\ kW$$

$$Winter\ Peak\ Demand\ Savings = 1.71 \times 10^{-3} \times 750 = 1.28\ kW$$

**Example 2.** A home in Climate Zone 4 with uninsulated 2x6 walls with a central air conditioning unit and a gas furnace insulates 500 square feet to R-21 with closed-cell spray foam.

$$Energy\ Savings = (0.56 + 0.04) \times 500 = 300.0\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 4.56 \times 10^{-4} \times 500 = 0.23\ kW$$

$$Winter\ Peak\ Demand\ Savings = 4.58 \times 10^{-5} \times 500 = 0.02\ kW$$

## 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

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007), the Estimated Useful Life is 25 years for wall insulation.

## 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
- Cooling type (evaporative cooling, central refrigerated cooling, room air conditioner, none)

- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
    - If documentation is not provided, an adjustment factor of 0.75 will be applied to the heating energy and winter demand savings
- Square footage of retrofitted wall area (gross wall area excluding window and door area)

## References and Efficiency Standards

### Petitions and Rulings

- Docket No. 22241, Item 58. Petition by Frontier Energy for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 22241, Item 62. Petition by Frontier Energy for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 175. Wall Insulation—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Added detail on methodology and model characteristics. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air. Climate Zone 2 savings values awarded for Climate Zone 5 homes with heat pumps. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Provided example savings calculations. |
| v4.0 | 8/31/2016 | TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for 2x4 and 2x6 wall framing and for homes with central AC versus evaporative cooling. Added a two-tier baseline definition of R-0 and R-4. |

| TRM version | Date | Description of change |
| --- | --- | --- |
| v5.0 | 10/2017 | TRM v5.0 update. Make an explicit allowance for cellulose insulation. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. No revision. |
| v8.0 | 10/2020 | TRM v8.0 update. Added space heat adjustment factor and electric resistance documentation requirement. |
| v9.0 | 10/2021 | TRM v9.0 update. No revision. |
| v10.0 | 10/2022 | TRM v10.0 update. No revision. |
| v11.0 | 10/2023 | TRM v11.0 update. Added electric resistance documentation adjustment factor. |

## 2.3.5 Floor Insulation Measure Overview

**TRM Measure ID:** R-BE-FI

**Market Sector:** Residential

**Measure Category:** Building envelope

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Building simulation modeling

## Measure Description

Floor insulation is installed on the underside of floor areas sitting below conditioned space. Typically, it is installed in ventilated crawlspaces. Savings are presented per square foot of treated floor area.

## Eligibility Criteria

Cooling savings in this measure apply to customers with central or mini-split electric refrigerated air conditioning in their homes, or to customers in TRM Climate Zones 1 and 5 who have evaporative cooling systems. Homes must be centrally heated with either an electric resistance furnace or a heat pump to claim heating savings. Customers who participate in hard-to-reach (HTR) or low-income (LI) programs are eligible to claim reduced heating savings for homes heated with electric resistance space heaters by applying an adjustment to deemed savings that is specified for that heat type. Customers participating in HTR or LI programs are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that is specified for homes with central refrigerated air.

Homes with gas heating are disqualified for adding floor insulation since this may result in an energy penalty due to floors not getting cooled from the ground during summer.

## Baseline Condition

The baseline is a house with pier and beam construction and no floor insulation against the floor of the conditioned area.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[229] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[230] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer/Winter Demand Savings Tables sections.

## High-Efficiency Condition

A floor insulation level of R-19 is recommended for site-built homes throughout Texas as prescribed by DOE and Texas Department of Housing and Community Affairs (TDHCA) programs. Batt insulation is recommended in most cases and must have the vapor barrier installed facing up and against the floor or conditioned area. Insulation should be attached or secured so that it can reasonably be expected to remain in place for at least 10 years.

Typical floor construction depth of manufactured homes usually does not allow R-19 batt to be installed within the floor joists, so R-15 loose-fill insulation is recommended by TDHCA.

A minimum of 24-inch clearance from the bottom of the insulation to the ground is required by the Occupational Safety and Health Association (OSHA).

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values.

Savings values for the deemed savings estimates for this measure were developed using demand and energy savings calculated using BEopt 2.6, running Energy Plus 8.1 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows: slab foundation was replaced with a crawlspace. A 5/8" thick wood floor is also specified.

The model runs calculated energy use for the prototypical home prior to the installation of the floor insulation measure. Next, change-case models were run to calculate energy use with the floor insulation measure in place.

229 Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

230 Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

**Table 176. Floor Insulation—Prototypical Home Characteristics**

| Shell characteristic | Value | Source |
|---|---|---|
| Foundation | Crawlspace | Skirting around the perimeter is assumed uninsulated and vented. The ground under the home is assumed to be bare, without any type of moisture barrier. |
| Base Floor Insulation | R-3.1 | BEopt default for floor assembly, assuming 5/8" thick hardwood floor without carpet or another type of covering. |
| Change Floor Insulation | R-19 (except for manufactured housing, R-15) | Efficiency measure - retrofit insulation level as required by DOE and Texas Department of Housing and Community Affairs programs in Texas. Due to the typical floor joists depths found in manufactured housing, TDHCA recommends R-15 loose-fill insulation for manufactured housing and other non-site-built homes. |

## Deemed Energy Savings Tables

Table 177 through Table 181 present energy savings on a kWh per square foot of insulation installed basis for all five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

For customers who participate in hard-to-reach (HTR) or low-income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying the appropriate cooling value in Table 177 through Table 181 by a factor of 0.6. Similarly for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 177 through Table 181 by a factor of 0.24.[231]

**Table 177. Floor Insulation—Climate Zone 1: Amarillo, Energy Savings (kWh/sq. ft.)**

| Home type | Cooling savings | | Heating savings | |
|---|---|---|---|---|
| | Refrigerated | Evaporative | Electric resistance | Heat pump |
| Site-built home | -0.13 | -0.07 | 1.72 | 0.68 |
| Manufactured home | -0.11 | -0.06 | 1.52 | 0.60 |

**Table 178. Floor Insulation—Climate Zone 2: Dallas, Energy Savings (kWh/sq. ft.)**

| Home type | Cooling savings | | Heating savings | |
|---|---|---|---|---|
| | Refrigerated | Evaporative | Electric resistance | Heat pump |
| Site-built home | -0.12 | - | 0.96 | 0.38 |
| Manufactured home | -0.10 | - | 0.85 | 0.33 |

231 This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

**Table 179. Floor Insulation—Climate Zone 3: Houston, Energy Savings (kWh/sq. ft.)**

| Home type | Cooling savings | | Heating savings | |
|---|---|---|---|---|
| | Refrigerated | Evaporative | Electric resistance | Heat pump |
| Site-built home | -0.12 | - | 0.63 | 0.24 |
| Manufactured home | -0.10 | - | 0.56 | 0.21 |

**Table 180. Floor Insulation—Climate Zone 4: Corpus Christi, Energy Savings (kWh/sq. ft.)**

| Home type | Cooling savings | | Heating savings | |
|---|---|---|---|---|
| | Refrigerated | Evaporative | Electric resistance | Heat pump |
| Site-built home | -0.07 | - | 0.40 | 0.15 |
| Manufactured home | -0.06 | - | 0.35 | 0.13 |

**Table 181. Floor Insulation—Climate Zone 5: El Paso, Energy Savings (kWh/sq. ft.)**

| Home type | Cooling savings | | Heating savings | |
|---|---|---|---|---|
| | Refrigerated | Evaporative | Electric resistance | Heat pump |
| Site-built home | -0.16 | -0.07 | 1.10 | 0.43 |
| Manufactured home | -0.13 | -0.06 | 0.97 | 0.38 |

## Deemed Summer Demand Savings Tables

Table 182 through Table 186 present the deemed summer demand savings (kW) for all five Texas climate zones.

For customers who participate in HTR/LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying the appropriate cooling value in Table 182 through Table 186 by a factor of 0.6.

**Table 182. Floor Insulation—Climate Zone 1: Amarillo, Summer Peak Demand Savings (kW/sq. ft.)**

| Home type | Refrigerated | Evaporative |
|---|---|---|
| Site-built home | 6.17E-06 | -1.52E-05 |
| Manufactured home | 5.48E-06 | -1.30E-05 |

**Table 183. Floor Insulation—Climate Zone 2: Dallas, Summer Peak Demand Savings (kW/sq. ft.)**

| Home type | Refrigerated | Evaporative |
|---|---|---|
| Site-built home | 3.10E-05 | – |
| Manufactured home | 2.75E-05 | – |

**Table 184. Floor Insulation—Climate Zone 3: Houston, Summer Peak Demand Savings (kW/sq. ft.)**

| Home type | Refrigerated | Evaporative |
|---|---|---|
| Site-built home | 3.36E-05 | – |
| Manufactured home | 2.77E-05 | – |

**Table 185. Floor Insulation—Climate Zone 4: Corpus Christi, Summer Peak Demand Savings (kW/sq. ft.)**

| Home type | Refrigerated | Evaporative |
|---|---|---|
| Site-built home | 3.58E-05 | – |
| Manufactured home | 3.07E-05 | – |

**Table 186. Floor Insulation—Climate Zone 5: El Paso, Summer Peak Demand Savings (kW/sq. ft.)**

| Home type | Refrigerated | Evaporative |
|---|---|---|
| Site-built home | 6.29E-06 | -1.34E-06 |
| Manufactured home | 8.30E-07 | 1.85E-07 |

## Deemed Winter Demand Savings Tables

Table 187 through Table 191 present the deemed winter demand savings for all five Texas climate zones.

For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 187 through Table 191 by a factor of 0.24.[232]

**Table 187. Floor Insulation—Climate Zone 1: Amarillo, Winter Peak Demand Savings (kW/sq. ft.)**

| Home type | Electric resistance | Heat pump |
|---|---|---|
| Site-built home | 5.23E-04 | 2.55E-04 |
| Manufactured home | 4.62E-04 | 2.25E-04 |

**Table 188. Floor Insulation—Climate Zone 2: Dallas, Winter Peak Demand Savings (kW/sq. ft.)**

| Home type | Electric resistance | Heat pump |
|---|---|---|
| Site-built home | 5.19E-04 | 2.88E-04 |
| Manufactured home | 4.56E-04 | 2.50E-04 |

232 This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

**Table 189. Floor Insulation—Climate Zone 3: Houston, Winter Peak Demand Savings (kW/sq. ft.)**

| Home type | Electric resistance | Heat pump |
|---|---|---|
| Site-built home | 4.22E-04 | 2.03E-04 |
| Manufactured home | 3.64E-04 | 1.74E-04 |

**Table 190. Floor Insulation—Climate Zone 4: Corpus Christi, Winter Peak Demand Savings (kW/sq. ft.)**

| Home type | Electric resistance | Heat pump |
|---|---|---|
| Site-built home | 3.51E-04 | 1.53E-04 |
| Manufactured home | 3.02E-04 | 1.31E-04 |

**Table 191. Floor Insulation—Climate Zone 5: El Paso, Winter Peak Demand Savings (kW/sq. ft.)**

| Home type | Electric resistance | Heat pump |
|---|---|---|
| Site-built home | 3.54E-04 | 1.44E-04 |
| Manufactured home | 3.19E-04 | 1.30E-04 |

## Example Deemed Savings Calculation

**Example 1.** A manufactured home in Climate Zone 5 with evaporative cooling and an electric resistance furnace insulates 500 square feet.

$$Energy\ Savings = (-0.06 + 0.97) \times 500 = 455.0\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 1.85 \times 10^{-7} \times 500 = 0.00\ kW$$

$$Winter\ Peak\ Demand\ Savings = 3.19 \times 10^{-4} \times 500 = 0.16\ kW$$

**Example 2.** A site-built home in Climate Zone 2 with an air-source heat pump insulates 825 square feet.

$$Energy\ Savings = (-0.12 + 0.38) \times 825 = 214.5\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 3.10 \times 10^{-5} \times 825 = 0.03\ kW$$

$$Winter\ Peak\ Demand\ Savings = 2.88 \times 10^{-4} \times 825 = 0.24\ kW$$

## 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

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007), the Estimated Useful Life is 25 years for floor insulation.

## 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 climate zone

- Climate zone or county
- Cooling type (evaporative cooling, central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
    - If documentation is not provided, an adjustment factor of 0.75 will be applied to the heating energy and winter demand savings
- Home type (site built or manufactured)
- Square footage of installed insulation

## References and Efficiency Standards

## Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Energy for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

## Relevant Standards and Reference Sources

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

## Document Revision History

**Table 192. Floor Insulation—Revision History**

| TRM version | Date | Description of Change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Added detail on methodology and model characteristics. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air. Climate Zone 2 savings values awarded for Climate Zone 5 homes with heat pumps. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Provided example savings calculations. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling. Disqualified homes with gas heating for adding floor insulation. |
| v5.0 | 10/2017 | TRM v5.0 update. Added an explicit reference to mini-split technology. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. No revision. |
| v8.0 | 10/2020 | TRM v8.0 update. Added space heat adjustment factor and electric resistance documentation requirement. |
| v9.0 | 10/2021 | TRM v9.0 update. No revision. |
| v10.0 | 10/2022 | TRM v10.0 update. No revision. |
| v11.0 | 10/2023 | TRM v11.0 update. Added electric resistance documentation adjustment factor. |

## 2.3.6 Duct Insulation Measure Overview

**TRM Measure ID:** R-BE-DI

**Market Sector:** Residential

**Measure Category:** Building envelope

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Building simulation modeling

### Measure Description

This measure consists of the installation of duct insulation with a minimum R value of 5.6 or 8.0 to uninsulated metal supply and return ductwork, located in unconditioned space that previously had no existing insulation. This measure applies to residential retrofit applications.

### Eligibility Criteria

Cooling savings in this measure apply to customers with central or mini-split electric refrigerated air conditioning in their homes. Homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Homes heated with gas or electric resistance space heating are not eligible to claim heating savings.

### Baseline Condition

The baseline for this measure is uninsulated sheet metal ducts or insulated metal ducts in which the insulation has failed. Failed insulation is insulation which has non-repairable tears to the vapor barrier or exhibits gaps with exposed metal between the insulation. Flex ducts and fiber board ducts are not eligible for this measure. The ducts must be located in unconditioned spaces, such as attics or crawl spaces. Old ductwork insulation must be removed prior to installation of new duct wrap insulation.

Unconditioned space is defined as a space which is neither directly nor indirectly conditioned and is isolated from conditioned space by partitions, such as walls and/or closeable doors and ceilings. The two specified locations available for claimed savings are attics and crawl spaces.

### High-Efficiency Condition

The high-efficiency condition for this measure requires that ducts must be insulated with duct wrap to an R-value of 5.6 or 8.0.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

This measure references deemed savings from the Arkansas Technical Reference Manual (TRM) v9.1 where calibrated simulation modeling was used to develop these deemed savings.[233] Specifically, these deemed savings estimates were developed using BEopt, running EnergyPlus as the underlying simulation engine. Since duct insulation savings are sensitive to weather, savings were modeled using typical meteorological year (TMY) 3 weather data.

Arkansas savings were mapped to Texas climate zones by comparing cooling and heating degree days developed using TMY data. Since TMY3 data is no longer accessible through the National Solar Radiation Database (NSRDB) Viewer, degree days were compared using TMY 2020 weather data.[234]

Degree day ratios were derived by dividing Texas cooling and heating degree days by the closest degree day match among Arkansas climate zones. These ratios were multiplied against corresponding Arkansas TRM deemed savings yielding savings values adjusted for Texas climate. The resulting ratios are specified in Table 193.

**Table 193. Duct Insulation—Cooling and Heating Adjustment Factors (AF)[235]**

| Climate zone | Cooling AF | Heating AF |
|---|---|---|
| Zone 1: Amarillo | 0.95 | 1.02 |
| Zone 2: Dallas | 1.06 | 0.88 |
| Zone 3: Houston | 1.12 | 0.56 |
| Zone 4: Corpus Christi | 1.44 | 0.27 |
| Zone 5: El Paso | 0.99 | 0.99 |

## Deemed Energy Savings Tables

Table 194 through Table 198 present the energy savings (kWh) in the five Texas climate zones per square foot of exposed metal duct area located in an unconditioned attic or crawl space. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

233 Arkansas Public Service Commission. Arkansas TRM v9.1
234 NSRDB Viewer: https://nsrdb.nrel.gov/.
235 These adjustment factors were multiplied against respective cooling and heating savings from the Arkansas TRM v9.1 Duct Insulation measure. The cooling factor for Amarillo was applied against Arkansas Climate Zone 8 (Fort Smith), and the heating factor for Amarillo was applied against Arkansas Climate Zone 9 (Fayetteville). Factors for all remaining Texas climate zones were applied against savings for Arkansas Climate Zone 6 (El Dorado).

**Table 194. Duct Insulation—Climate Zone 1: Amarillo, Energy Savings (kWh/sq. ft.)**

| Unconditioned duct location and added R-value | Refrigerated cooling savings | Heating savings | | |
|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump |
| Attic to R-8 | 0.093 | – | 0.354 | 0.347 |
| Attic to R-5.6 | 0.048 | – | 0.182 | 0.177 |
| Crawl space to R-8 | 0.064 | – | 0.352 | 0.338 |
| Crawl space to R-5.6 | 0.032 | – | 0.180 | 0.173 |

**Table 195. Duct Insulation—Climate Zone 2: Dallas, Energy Savings (kWh/sq. ft.)**

| Unconditioned duct location and added R-value | Refrigerated cooling savings | Heating savings | | |
|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump |
| Attic to R-8 | 0.132 | – | 0.224 | 0.198 |
| Attic to R-5.6 | 0.068 | – | 0.114 | 0.102 |
| Crawl space to R-8 | 0.086 | – | 0.252 | 0.209 |
| Crawl space to R-5.6 | 0.043 | – | 0.129 | 0.108 |

**Table 196. Duct Insulation—Climate Zone 3: Houston, Energy Savings (kWh/sq. ft.)**

| Unconditioned duct location and added R-value | Refrigerated cooling savings | Heating savings | | |
|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump |
| Attic to R-8 | 0.139 | – | 0.142 | 0.125 |
| Attic to R-5.6 | 0.071 | – | 0.072 | 0.064 |
| Crawl space to R-8 | 0.090 | – | 0.159 | 0.132 |
| Crawl space to R-5.6 | 0.046 | – | 0.082 | 0.068 |

**Table 197. Duct Insulation—Climate Zone 4: Corpus Christi, Energy (kWh/sq. ft.)**

| Unconditioned duct location and added R-value | Refrigerated cooling savings | Heating savings | | |
|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump |
| Attic to R-8 | 0.180 | – | 0.068 | 0.060 |
| Attic to R-5.6 | 0.092 | – | 0.035 | 0.031 |
| Crawl space to R-8 | 0.117 | – | 0.077 | 0.064 |
| Crawl space to R-5.6 | 0.059 | – | 0.039 | 0.033 |

**Table 198. Duct Insulation—Climate Zone 5: El Paso, Energy Savings (kWh/sq. ft.)**

| Unconditioned duct location and added R-value | Refrigerated cooling savings | Heating savings | | |
|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump |
| Attic to R-8 | 0.123 | – | 0.253 | 0.223 |
| Attic to R-5.6 | 0.063 | – | 0.129 | 0.115 |
| Crawl space to R-8 | 0.080 | – | 0.285 | 0.236 |
| Crawl space to R-5.6 | 0.040 | – | 0.146 | 0.122 |

## Deemed Summer Demand Savings Tables

Table 199 through Table 203 present the summer demand savings (kW) in the five Texas climate zones per square foot of exposed metal duct area located in an unconditioned attic or crawl space.

**Table 199. Duct Insulation—Climate Zone 1: Amarillo, Summer Peak Demand Savings (kW/sq. ft.)**

| Unconditioned duct location and added R-value | Demand savings (kW/sq. ft.) |
|---|---|
| Attic to R-8 | 0.00016 |
| Attic to R-5.6 | 0.00009 |
| Crawl space to R-8 | 0.00004 |
| Crawl space to R-5.6 | 0.00002 |

**Table 200. Duct Insulation—Climate Zone 2: Dallas, Summer Peak Demand Savings (kW/sq. ft.)**

| Unconditioned duct location and added R-value | Demand savings (kW/sq. ft.) |
|---|---|
| Attic to R-8 | 0.00020 |
| Attic to R-5.6 | 0.00011 |
| Crawl space to R-8 | 0.00007 |
| Crawl space to R-5.6 | 0.00003 |

**Table 201. Duct Insulation—Climate Zone 3: Houston, Summer Peak Demand Savings (kW/sq. ft.)**

| Unconditioned duct location and added R-value | Demand savings (kW/sq. ft.) |
|---|---|
| Attic to R-8 | 0.00021 |
| Attic to R-5.6 | 0.00011 |
| Crawl space to R-8 | 0.00008 |
| Crawl space to R-5.6 | 0.00003 |

**Table 202. Duct Insulation—Climate Zone 4: Corpus Christi, Summer Peak Demand Savings (kW/sq. ft.)**

| Unconditioned duct location and added R-value | Demand savings (kW/sq. ft.) |
|---|---|
| Attic to R-8 | 0.00027 |
| Attic to R-5.6 | 0.00014 |
| Crawl space to R-8 | 0.00010 |
| Crawl space to R-5.6 | 0.00004 |

**Table 203. Duct Insulation—Climate Zone 5: El Paso, Summer Peak Demand Savings (kW/sq. ft)**

| Unconditioned duct location and added R-value | Demand savings (kW/sq. ft.) |
|---|---|
| Attic to R-8 | 0.00019 |
| Attic to R-5.6 | 0.00010 |
| Crawl space to R-8 | 0.00007 |
| Crawl space to R-5.6 | 0.00003 |

## Deemed Winter Demand Savings Tables

Winter demand savings are not specified for this measure at this time. They will be added when savings are updated to reflect Texas consumption data.

## 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

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007),[236] the estimated useful life is 20 years for duct insulation.

## 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:

- Climate zone or county
- Uninsulated duct location
- R-value of installed insulation
- Square footage of treated duct area in unconditioned space
- Cooling type (evaporative cooling, central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
    - If documentation is not provided, an adjustment factor of 0.75 will be applied to the heating energy and winter demand savings

## 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 204. Duct Insulation—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v11.0 | 10/2023 | TRM v11.0 origin. |

236 GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007). http://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLightsandHVACGDS_1Jun2007.pdf.

## 2.3.7 Radiant Barriers Measure Overview

**TRM Measure ID:** R-BE-RB

**Market Sector:** Residential, low-Income, and hard-to-reach

**Measure Category:** Building envelope

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Building simulation modeling

### Measure Description

Radiant barriers are a highly reflective material designed to block radiant heat transfer between a roof and attic space insulation. They typically consist of a metallic foil material (usually aluminum) and are generally installed on the roof decking or beneath roof sheathing. Radiant barriers are most effective at reducing cooling consumption by reflecting heat away from a home.

### Eligibility Criteria

This measure is only applicable to retrofit applications. All radiant barriers should be installed according to the Reflective Insulation Manufacturers Association International (RIMA-I) Handbook, Section 7.4.[237] However, horizontal installation is not eligible due to the potential of moisture/dust accumulation and wear-and-tear damage to the radiant barrier that may negatively impact product performance.

A radiant barrier cannot be in contact with any other materials on its underside. Therefore, once a radiant barrier is installed on the roof decking, no additional roof deck insulation can be installed. However, additional insulation may still be added where it is not in contact (e.g., attic floor).

A study performed by RIMA-I found that none of the coating-type products currently on the market had an emittance of 0.10 or lower as required by the standards set by the American Society for Testing and Materials (ASTM) for a product to be considered a radiant barrier.[238] Therefore, interior radiation control coatings are ineligible to use this measure.

---

[237] RIMA-I Handbook. https://rimainternational.org/wp-content/uploads/2011/01/HandbookAll-2014-Final-1.pdf.

[238] "Radiant Barrier and STS Interior Coatings," RIMA International. https://rimainternational.org/technical/ircc/.

Cooling savings in this measure apply to customers with central or mini-split electric refrigerated air conditioning in their homes. Homes must be centrally heated with either a furnace (gas or electric resistance) or heat pump to claim heating savings. Customers who participate in hard-to-reach (HTR) or low-income (LI) programs are eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that are specified for homes with central refrigerated air. Customers participating in HTR or LI programs are also eligible to claim reduced heating savings for homes heated with electric resistance space heaters by applying an adjustment to deemed savings that are specified for that heat type.

## Baseline Condition

The baseline condition is defined as a residence with no existing radiant barrier installed on roof decking.

## High-Efficiency Condition

The high efficiency condition is defined as a radiant barrier installed on roof decking. The radiant barrier must be compliant with the standards set by RIMA-I, including proper attic ventilation. A list of verified products is available on the RIMA-I website.[239]

**Table 205. Radiant Barriers—RIMA-I Product Testing Requirements[240]**

| Physical property | Test method or standard | Requirement |
|---|---|---|
| Surface emittance | ASTM C 1371 | 0.1 or less |
| Water vapor transmission | ASTM E 96<br>Procedure A desiccant method | 0.02 for vapor retarder; 0.5 or greater for perforated products |
| **Surface burning** | | |
| Flame spread | ASTM E 84 | 25 or less |
| Smoke density | ASTM E 84 | 450 or less |
| Corrosivity | ASTM D 3310 | Corrosion on less than two percent of the affected surface |
| Tear resistance | ASTM D 2261 | N/A |
| **Adhesive performance** | | |
| Bleeding | Section 10.1 of ASTM C 1313 | Bleeding of delamination of less than two percent of the surface area |
| Pliability | Section 10.2 of ASTM C 1313 | No cracking or delamination |
| Mold and mildew | ASTM C 1338 | No growth when visually examined under 5x magnification |
| Tensile strength | ASTM D 2261 | Report tearing strength in machine direction and cross direction |

239 RIMA International verified products. https://rimainternational.org/verify/.
240 RIMA International Product Testing Requirements. https://rimainternational.org/technical/testing/.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

This measure references deemed savings from the Arkansas Technical Reference Manual (TRM) v9.0 where calibrated simulation modeling was used to develop these deemed savings.[241] Specifically, these deemed savings estimates were developed using BEopt, running EnergyPlus as the underlying simulation engine. Since radiant barrier savings are sensitive to weather, savings were modeled using typical meteorological year (TMY) 3 weather data.

Arkansas savings were mapped to Texas climate zones by comparing cooling and heating degree days developed using TMY data. Since TMY3 data is no longer accessible through the National Solar Radiation Database (NSRDB) Viewer, degree days were compared using TMY 2020 weather data.[242]

Degree day ratios were derived by dividing Texas cooling and heating degree days by the closest degree day match among Arkansas climate zones. These ratios were multiplied against corresponding Arkansas TRM deemed savings yielding savings values adjusted for Texas climate. The resulting ratios are specified in Table 206.

**Table 206. Radiant Barriers—Cooling and Heating Adjustment Factors (AF)[243]**

| Climate zone | Cooling AF | Heating AF |
|---|---|---|
| Zone 1: Amarillo | 0.95 | 1.02 |
| Zone 2: Dallas | 1.06 | 0.88 |
| Zone 3: Houston | 1.12 | 0.56 |
| Zone 4: Corpus Christi | 1.44 | 0.27 |
| Zone 5: El Paso | 0.99 | 0.99 |

## Deemed Energy Demand Savings Tables

Table 207 through Table 211 present the energy savings (kWh) in the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

[241] Arkansas Public Service Commission. AR TRM v9.0. http://www.apscservices.info/EEInfo/TRMV9.0.pdf.
[242] NSRDB Viewer: https://nsrdb.nrel.gov/.
[243] These adjustment factors were multiplied against respective cooling and heating savings from the Arkansas TRM v9.0 Radiant Barriers measure. The cooling factor for Amarillo was applied against Arkansas Climate Zone 8 (Fort Smith), and the heating factor for Amarillo was applied against Arkansas Climate Zone 9 (Fayetteville). Factors for all remaining TX climate zones were applied against savings for Arkansas Climate Zone 6 (El Dorado).

For customers who participate in HTR or LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying the appropriate cooling value in Table 207 through Table 211 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 207 through Table 211 by a factor of 0.24.[244]

Savings are specified per square foot of ceiling area over conditioned space directly below an unconditioned attic where the radiant barrier is installed. The square footage should not reflect the total area of installed radiant barrier.

**Table 207. Radiant Barriers—Climate Zone 1: Amarillo, Energy Savings (kWh/sq. ft.)**

| Radiant barrier with existing ceiling insulation base R-value | Cooling savings | Heating savings | | |
|---|---|---|---|---|
| | Refrigerated air | Gas | Electric resistance | Heat pump |
| ≤ R-19 | 0.2234 | 0.0072 | 0.2099 | 0.1106 |
| > R-19 | 0.1350 | 0.0031 | 0.0962 | 0.0573 |

**Table 208. Radiant Barriers—Climate Zone 2: Dallas, Energy Savings (kWh/sq. ft.)**

| Radiant barrier with existing ceiling insulation base R-value | Cooling savings | Heating savings | | |
|---|---|---|---|---|
| | Refrigerated air | Gas | Electric resistance | Heat pump |
| ≤ R-19 | 0.2887 | 0.0044 | 0.1449 | 0.0334 |
| > R-19 | 0.1777 | 0.0026 | 0.0676 | 0.0132 |

**Table 209. Radiant Barriers—Climate Zone 3: Houston, Energy Savings (kWh/sq. ft.)**

| Radiant barrier with existing ceiling insulation base R-value | Cooling savings | Heating savings | | |
|---|---|---|---|---|
| | Refrigerated air | Gas | Electric resistance | Heat pump |
| ≤ R-19 | 0.3046 | 0.0028 | 0.0916 | 0.0211 |
| > R-19 | 0.1874 | 0.0017 | 0.0427 | 0.0083 |

[244] This factor was derived based on expected capacity reduction assuming 1,200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42, 000 BTU for central electric furnaces and two 1,500 W portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 / 42,000 = 0.24.

Table 210. Radiant Barriers—Climate Zone 4: Corpus Christi, Energy Savings (kWh/sq. ft.)

| Radiant barrier with existing ceiling insulation base R-value | Cooling savings | Heating savings | | |
|---|---|---|---|---|
| | Refrigerated air | Gas | Electric resistance | Heat pump |
| ≤ R-19 | 0.3937 | 0.0013 | 0.0443 | 0.0102 |
| > R-19 | 0.2423 | 0.0008 | 0.0207 | 0.0040 |

Table 211. Radiant Barriers—Climate Zone 5: El Paso, Energy Savings (kWh/sq. ft.)

| Radiant barrier with existing ceiling insulation base R-value | Cooling savings | Heating savings | | |
|---|---|---|---|---|
| | Refrigerated | Gas | Electric resistance | Heat pump |
| ≤ R-19 | 0.2691 | 0.0050 | 0.1636 | 0.0377 |
| > R-19 | 0.1656 | 0.0030 | 0.0764 | 0.0149 |

## Deemed Summer Demand Savings Tables

Table 212 presents the summer demand savings (kW) in the five Texas climate zones per square foot of ceiling area over conditioned space directly below an unconditioned attic where the radiant barrier in installed.

For customers who participate in HTR or LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying the appropriate cooling value in Table 212 by a factor of 0.6.

Table 212. Radiant Barriers—Summer Peak Demand Savings for Residences with Refrigerated Air (kWh/sq. ft.)

| Radiant barrier with existing ceiling insulation base R-value | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| ≤ R-19 | 0.00014 | 0.00015 | 0.00016 | 0.00020 | 0.00014 |
| > R-19 | 0.00008 | 0.00010 | 0.00010 | 0.00013 | 0.00009 |

## Deemed Winter Demand Savings Tables

Winter demand savings are not specified for this measure at this time. They will be added when savings are updated to reflect Texas consumption data.

## 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

Radiant barriers and other reflective insulation systems have similar lifetime expectations to other attic insulation measures.[245] The estimated useful life (EUL) of radiant barriers is 25 years for radiant barriers based on the GDS Associates Measure Life Report value for ceiling insulation.

This value matches lifetime assumptions for radiant barriers from both Oak Ridge National Laboratory (ORNL)[246] and National Renewable Energy Laboratory (NREL).[247]

# 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
- Cooling type (central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
  - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
  - If documentation is not provided, an adjustment factor of 0.75 will be applied to the heating energy and winter demand savings
- Baseline R-value of existing ceiling insulation (≤ R-19, > R-19)
- Square footage of ceiling area over conditioned space directly below an unconditioned attic where the radiant barrier is installed
- Manufacturer and product name/model number

# References and Efficiency Standards

## Petitions and Rulings

Not applicable.

---

[245] US Department of Energy (DOE) Insulation Fact Sheet. https://web.ornl.gov/sci/buildings/docs/factSheets/Insulation-FactSheet-2008.pdf.

[246] "Radiant Barrier: Effect of Radiant Barriers on Heating and Cooling Bils", ORNL. https://web.ornl.gov/sci/buildings/tools/radiant/rb2/.

[247] National Residential Efficiency Measures Database, NREL. https://remdb.nrel.gov/measures.php?gId=13&ctId=51.

## Relevant Standards and Reference Sources

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

## Document Revision History

**Table 213. Radiant Barriers—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v10.0 | 10/2022 | TRM v10.0 origin. |
| v11.0 | 10/2023 | TRM v11.0 update. Clarified savings normalization by area. Added electric resistance documentation adjustment factor. |

## 2.3.8 Cool Roofs Measure Overview

**TRM Measure ID:** R-BE-CR

**Market Sector:** Residential

**Measure Category:** Building envelope

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Building simulation modeling

## Measure Description

Reflective roofing materials reduce the overall heat load on a home by reducing the total heat energy absorbed into the building system from incident solar radiation. This reduction in total load provides space cooling energy savings during the cooling season, but reduces free heat during the heating season, so the measure saves energy in the summer but uses more energy in winter. As such, cool roofs are most beneficial in warmer climates and may not be recommended for homes where the primary heat source is electric resistance. The measure is for retrofit of existing homes.

## Eligibility Criteria

Cooling savings in this measure apply to customers with central or mini-split electric refrigerated air conditioning in their homes, or to customers in TRM Climate Zones 1 and 5 who have evaporative cooling systems. Homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Customers who participate in hard-to-reach (HTR) or low-income (LI) programs are eligible to claim reduced heating savings for homes heated with gas or electric resistance space heaters by applying an adjustment to deemed savings that is specified for that heat type. Customers participating in HTR or LI programs are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that is specified for homes with central refrigerated air.

## Baseline Condition

The baseline condition is an existing home with a standard medium- or dark-colored roof.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[248] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[249] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer/Winter Demand Savings Tables sections.

## High-Efficiency Condition

The ENERGY STAR roofing products certification program was discontinued effective June 1, 2022.[250] Moving forward, installed roofing products will still be required to demonstrate compliance with the previous ENERGY STAR specification below.[251]

In lieu of the former ENERGY STAR list of qualified products, roofing products must now have a performance rating that is validated by the Cool Roof Rating Council (CRRC)[252,253] and be listed on the CRRC Rated Roof Products Directory.[254] This is consistent with the former ENERGY STAR test criteria, which allows for products already participating in the CRRC Product Rating Program to submit solar reflectance and thermal emittance product information derived from CRRC certification.

The ENERGY STAR program classifies roofs with a slope greater than 2/12 as having a steep slope and roofs with a slope less than or equal to 2/12 as low slope roofs. ENERGY STAR performance specifications for cool roof products for use on roofs with steep slopes and low slopes are provided in Table 214.

**Table 214. Cool Roofs—ENERGY STAR Specification[255]**

| Roof slope | Characteristic | Performance specification |
|---|---|---|
| Low slope<br>≤ 2/12 | Initial solar reflectance | ≥ 0.65 |
| | 3-year solar reflectance | ≥ 0.50 |
| High slope<br>> 2/12 | Initial solar reflectance | ≥ 0.25 |
| | 3-year solar reflectance | ≥ 0.15 |

248 Electric Resistance Heating. https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.
249 Portable Heaters. https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.
250 ENERGY STAR Roof Products Sunset Decision Memo. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Roof%20Products%20Sunset%20Decision%20Memo.pdf.
251 ENERGY STAR Program Requirements for Roof Products v2.1. https://www.energystar.gov/ia/partners/product_specs/program_reqs/roofs_prog_req.pdf.
252 CRRC guidance for roof rating alternative to discontinued ENERGY STAR® program. https://coolroofs.org/documents/CRRC-ENERGY-STAR-Sunset-Info-Sheet-2022-03-07.pdf.
253 CRRC Roof Rating Program. https://coolroofs.org/programs/roof-rating-program.
254 CRRC Rated Roof Products Directory. https://coolroofs.org/directory/roof.
255 ENERGY STAR Roof Products Specification. https://www.energystar.gov/products/building_products/roof_products/key_product_criteria.

If a cool roof is installed concurrently with changes to attic insulation levels, savings should be claimed for the reflective roof according to the post-retrofit (ceiling or roof deck) insulation levels. Savings for changes in insulation levels should be claimed separately according to the ceiling insulation or attic encapsulation measures, assuming the retrofit performed meets the requirements of those measures.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

Calibrated simulation modeling was used to develop these deemed savings values. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. To model this measure, the prototype home models for each climate zone were modified as follows. Roof slopes were modified to reflect representative levels for the low slope and steep slope roofs. A 1/12 slope was selected for modeling low slope roofs (defined as having slope <= 2/12), and a 4/12 slope was selected for modeling steep slope roofs (slope > 2/12). Based on the performance criteria and review of the rated 3-year reflectance of rated products listed in the CRRC database, four reflectance levels were selected for modeling: 0.2, 0.4, 0.6, and 0.8, representing 20 to 80 percent reflectance.

Because of the interplay between the performance of insulation and attic/roof deck temperatures, which are directly affected by the installation of a cool roof, savings were estimated for a range of different attic insulation scenarios: a range of ceiling insulation levels from no insulation (R-0) to R-30, and two roof deck insulation levels, R-19 and R-38, were modeled. Savings for a roof deck insulation level of R-30 are provided by interpolating between the R-19 and R-38 scenarios.

These modifications are shown in Table 215.

The model runs calculated energy use for the prototypical home prior to encapsulating the attic. Change-case models were run to calculate energy use with the floor insulation measure in place with either R-30 or R-38 insulation.

**Table 215. Cool Roofs—Prototypical Home Characteristics**

| Shell characteristic | Value | Source |
|---|---|---|
| Base case roof material | Medium asphalt shingle, reflectance = 0.15 | Prototype home default |
| Change case roof material | Medium asphalt shingle,<br>reflectance = 0.2<br>reflectance = 0.4<br>reflectance = 0.6<br>Reflectance = 0.8 | Lower reflectance levels only relevant for steep slope roofs. Modeled reflectance levels reflect midpoints of ranges:<br>0.15 ≤ R < 0.3<br>Reflectance 0.3 ≤ R < 0.5<br>Reflectance 0.5 ≤ R < 0.7<br>Reflectance > 0.7 |
| Roof slope: low-slope roof | 1/12 | Not modified between base and change cases |
| Roof slope: steep slope roof | 4/12 | Not modified between base and change cases |

| Shell characteristic | Value | Source |
|---|---|---|
| Ceiling (attic floor) insulation levels | < R-5<br>R-5 to R-8<br>R-9 to R-14<br>R-15 to R-22<br>R-30 | Not modified between base and change cases |
| Roof Deck (underside) Insulation Levels | R-19<br>R-38 | Not modified between base and change cases |

## Deemed Energy Savings Tables

Savings are presented first for homes with ceiling insulation and subsequently for those with roof deck insulation. For customers who participate in hard-to-reach (HTR) or low-income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate cooling values in Table 216 through Table 220 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 216 through Table 220 by a factor of 0.24.[256]

### *Homes with Ceiling Insulation*

Table 216 through Table 220 present the energy savings (kWh) for installation of a reflective roof on homes with varying levels of ceiling (attic floor) insulation for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types. Savings are per square foot of treated roof area.

**Table 216. Cool Roofs—Climate Zone 1: Amarillo, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| **Steep slope** | | | | | | |
| < R-5 | 0.15 – 0.29 | 0.03 | 0.01 | 0.00 | -0.05 | -0.02 |
| < R-5 | 0.3 – 0.49 | 0.15 | 0.06 | -0.02 | -0.26 | -0.09 |
| < R-5 | 0.5 – 0.69 | 0.27 | 0.10 | -0.03 | -0.47 | -0.18 |
| < R-5 | ≥ 0.7 | 0.40 | 0.15 | -0.06 | -0.71 | -0.26 |
| R-5 to R-8 | 0.15 – 0.29 | 0.02 | 0.01 | 0.00 | -0.04 | -0.01 |
| R-5 to R-8 | 0.3 – 0.49 | 0.12 | 0.04 | -0.02 | -0.20 | -0.07 |
| R-5 to R-8 | 0.5 – 0.69 | 0.21 | 0.08 | -0.03 | -0.36 | -0.14 |

256 This factor was derived based on expected capacity reduction assuming 1,200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500 W portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| R-5 to R-8 | ≥ 0.7 | 0.31 | 0.12 | -0.05 | -0.54 | -0.20 |
| R-9 to R-14 | 0.15 – 0.29 | 0.02 | 0.01 | 0.00 | -0.03 | -0.01 |
| R-9 to R-14 | 0.3 – 0.49 | 0.08 | 0.03 | -0.01 | -0.13 | -0.05 |
| R-9 to R-14 | 0.5 – 0.69 | 0.15 | 0.06 | -0.03 | -0.25 | -0.09 |
| R-9 to R-14 | ≥ 0.7 | 0.22 | 0.08 | -0.04 | -0.37 | -0.14 |
| R-15 to R-22 | 0.15 - 0.29 | 0.01 | 0.00 | 0.00 | -0.02 | -0.01 |
| R-15 to R-22 | 0.3 – 0.49 | 0.06 | 0.02 | -0.01 | -0.09 | -0.04 |
| R-15 to R-22 | 0.5 – 0.69 | 0.10 | 0.04 | -0.02 | -0.17 | -0.06 |
| R-15 to R-22 | ≥ 0.7 | 0.15 | 0.06 | -0.03 | -0.25 | -0.10 |
| R-30 | 0.15 – 0.29 | 0.01 | 0.00 | 0.00 | -0.01 | 0.00 |
| R-30 | 0.3 – 0.49 | 0.04 | 0.01 | -0.01 | -0.06 | -0.02 |
| R-30 | 0.5 – 0.69 | 0.07 | 0.02 | -0.02 | -0.11 | -0.04 |
| R-30 | ≥ 0.7 | 0.10 | 0.04 | -0.03 | -0.16 | -0.06 |
| **Low slope** | | | | | | |
| < R-5 | 0.5 – 0.69 | 0.30 | 0.11 | -0.04 | -0.52 | -0.20 |
| < R-5 | ≥ 0.7 | 0.43 | 0.16 | -0.06 | -0.77 | -0.29 |
| R-5 to R-8 | 0.5 – 0.69 | 0.23 | 0.09 | -0.03 | -0.40 | -0.15 |
| R-5 to R-8 | ≥ 0.7 | 0.34 | 0.13 | -0.05 | -0.59 | -0.22 |
| R-9 to R-14 | 0.5 – 0.69 | 0.16 | 0.06 | -0.03 | -0.27 | -0.10 |
| R-9 to R-14 | ≥ 0.7 | 0.23 | 0.09 | -0.04 | -0.41 | -0.15 |
| R-15 to R-22 | 0.5 – 0.69 | 0.11 | 0.04 | -0.02 | -0.19 | -0.07 |
| R-15 to R-22 | ≥ 0.7 | 0.17 | 0.07 | -0.03 | -0.28 | -0.11 |
| R-30 | 0.5 – 0.69 | 0.08 | 0.03 | -0.02 | -0.13 | -0.05 |
| R-30 | ≥ 0.7 | 0.12 | 0.05 | -0.03 | -0.19 | -0.07 |

**Table 217. Cool Roofs—Climate Zone 2: Dallas, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Cooling savings (refrigerated) | Heating savings | | |
|---|---|---|---|---|---|
| | | | Gas | Electric resistance | Heat pump |
| **Steep slope** | | | | | |
| < R-5 | 0.15 – 0.29 | 0.05 | 0.00 | -0.04 | -0.01 |
| < R-5 | 0.3 – 0.49 | 0.23 | -0.01 | -0.17 | -0.07 |
| < R-5 | 0.5 – 0.69 | 0.43 | -0.01 | -0.32 | -0.12 |

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Cooling savings (refrigerated) | Heating savings | | |
|---|---|---|---|---|---|
| | | | Gas | Electric resistance | Heat pump |
| < R-5 | ≥ 0.7 | 0.64 | -0.02 | -0.48 | -0.18 |
| R-5 to R-8 | 0.15 – 0.29 | 0.04 | 0.00 | -0.03 | -0.01 |
| R-5 to R-8 | 0.3 – 0.49 | 0.18 | -0.01 | -0.13 | -0.05 |
| R-5 to R-8 | 0.5 – 0.69 | 0.34 | -0.01 | -0.24 | -0.09 |
| R-5 to R-8 | ≥ 0.7 | 0.50 | -0.02 | -0.36 | -0.14 |
| R-9 to R-14 | 0.15 – 0.29 | 0.03 | 0.00 | -0.02 | -0.01 |
| R-9 to R-14 | 0.3 – 0.49 | 0.13 | -0.01 | -0.09 | -0.03 |
| R-9 to R-14 | 0.5 – 0.69 | 0.24 | -0.01 | -0.16 | -0.06 |
| R-9 to R-14 | ≥ 0.7 | 0.35 | -0.02 | -0.25 | -0.09 |
| R-15 to R-22 | 0.15 – 0.29 | 0.02 | 0.00 | -0.01 | 0.00 |
| R-15 to R-22 | 0.3 – 0.49 | 0.09 | 0.00 | -0.06 | -0.02 |
| R-15 to R-22 | 0.5 – 0.69 | 0.17 | -0.01 | -0.11 | -0.04 |
| R-15 to R-22 | ≥ 0.7 | 0.25 | -0.01 | -0.17 | -0.06 |
| R-30 | 0.15 – 0.29 | 0.01 | 0.00 | -0.01 | 0.00 |
| R-30 | 0.3 – 0.49 | 0.06 | 0.00 | -0.04 | -0.02 |
| R-30 | 0.5 – 0.69 | 0.12 | -0.01 | -0.07 | -0.03 |
| R-30 | ≥ 0.7 | 0.18 | -0.01 | -0.11 | -0.04 |
| **Low slope** | | | | | |
| < R-5 | 0.5 – 0.69 | 0.47 | -0.01 | -0.35 | -0.13 |
| < R-5 | ≥ 0.7 | 0.70 | -0.02 | -0.53 | -0.20 |
| R-5 to R-8 | 0.5 – 0.69 | 0.37 | -0.01 | -0.27 | -0.10 |
| R-5 to R-8 | ≥ 0.7 | 0.55 | -0.02 | -0.40 | -0.15 |
| R-9 to R-14 | 0.5 – 0.69 | 0.26 | -0.01 | -0.19 | -0.07 |
| R-9 to R-14 | ≥ 0.7 | 0.39 | -0.02 | -0.28 | -0.10 |
| R-15 to R-22 | 0.5 – 0.69 | 0.19 | -0.01 | -0.13 | -0.05 |
| R-15 to R-22 | ≥ 0.7 | 0.28 | -0.01 | -0.19 | -0.07 |
| R-30 | 0.5 – 0.69 | 0.14 | -0.01 | -0.08 | -0.03 |
| R-30 | ≥ 0.7 | 0.20 | -0.01 | -0.13 | -0.05 |

**Table 218. Cool Roofs—Climate Zone 3: Houston, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Cooling savings (refrigerated) | Heating savings | | |
|---|---|---|---|---|---|
| | | | Gas | Electric resistance | Heat pump |
| **Steep slope** | | | | | |
| < R-5 | 0.15 – 0.29 | 0.05 | 0.00 | -0.02 | -0.01 |
| < R-5 | 0.3 – 0.49 | 0.26 | 0.00 | -0.13 | -0.05 |
| < R-5 | 0.5 – 0.69 | 0.48 | -0.01 | -0.24 | -0.09 |
| < R-5 | ≥ 0.7 | 0.71 | -0.01 | -0.37 | -0.13 |
| R-5 to R-8 | 0.15 – 0.29 | 0.04 | 0.00 | -0.02 | -0.01 |
| R-5 to R-8 | 0.3 – 0.49 | 0.20 | 0.00 | -0.10 | -0.04 |
| R-5 to R-8 | 0.5 – 0.69 | 0.37 | -0.01 | -0.18 | -0.07 |
| R-5 to R-8 | ≥ 0.7 | 0.55 | -0.01 | -0.28 | -0.10 |
| R-9 to R-14 | 0.15 – 0.29 | 0.03 | 0.00 | -0.01 | -0.01 |
| R-9 to R-14 | 0.3 – 0.49 | 0.14 | 0.00 | -0.07 | -0.03 |
| R-9 to R-14 | 0.5 – 0.69 | 0.26 | -0.01 | -0.13 | -0.05 |
| R-9 to R-14 | ≥ 0.7 | 0.39 | -0.01 | -0.19 | -0.07 |
| R-15 to R-22 | 0.15 – 0.29 | 0.02 | 0.00 | -0.01 | 0.00 |
| R-15 to R-22 | 0.3 – 0.49 | 0.10 | 0.00 | -0.05 | -0.02 |
| R-15 to R-22 | 0.5 – 0.69 | 0.18 | -0.01 | -0.09 | -0.03 |
| R-15 to R-22 | ≥ 0.7 | 0.27 | -0.01 | -0.13 | -0.05 |
| R-30 | 0.15 – 0.29 | 0.01 | 0.00 | -0.01 | 0.00 |
| R-30 | 0.3 – 0.49 | 0.06 | 0.00 | -0.03 | -0.01 |
| R-30 | 0.5 – 0.69 | 0.12 | -0.01 | -0.06 | -0.02 |
| R-30 | ≥ 0.7 | 0.18 | -0.01 | -0.08 | -0.03 |
| **Low slope** | | | | | |
| < R-5 | 0.5 – 0.69 | 0.54 | -0.01 | -0.27 | -0.10 |
| < R-5 | ≥ 0.7 | 0.79 | -0.01 | -0.41 | -0.15 |
| R-5 to R-8 | 0.5 – 0.69 | 0.42 | -0.01 | -0.21 | -0.08 |
| R-5 to R-8 | ≥ 0.7 | 0.62 | -0.01 | -0.31 | -0.12 |
| R-9 to R-14 | 0.5 – 0.69 | 0.30 | -0.01 | -0.14 | -0.05 |
| R-9 to R-14 | ≥ 0.7 | 0.44 | -0.01 | -0.21 | -0.08 |

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Cooling savings (refrigerated) | Heating savings | | |
|---|---|---|---|---|---|
| | | | Gas | Electric resistance | Heat pump |
| R-15 to R-22 | 0.5 – 0.69 | 0.21 | -0.01 | -0.10 | -0.04 |
| R-15 to R-22 | > 0.7 | 0.31 | -0.01 | -0.15 | -0.06 |
| R-30 | 0.5 – 0.69 | 0.14 | -0.01 | -0.07 | -0.03 |
| R-30 | > 0.7 | 0.22 | -0.01 | -0.10 | -0.04 |

**Table 219. Cool Roofs—Climate Zone 4: Corpus Christi, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Cooling savings (refrigerated) | Heating Savings | | |
|---|---|---|---|---|---|
| | | | Gas | Electric resistance | Heat pump |
| **Steep slope** | | | | | |
| < R-5 | 0.15 – 0.29 | 0.04 | 0.00 | -0.01 | 0.00 |
| < R-5 | 0.3 – 0.49 | 0.19 | 0.00 | -0.08 | -0.03 |
| < R-5 | 0.5 – 0.69 | 0.34 | 0.00 | -0.15 | -0.06 |
| < R-5 | > 0.7 | 0.50 | -0.01 | -0.23 | -0.08 |
| R-5 to R-8 | 0.15 – 0.29 | 0.03 | 0.00 | -0.01 | 0.00 |
| R-5 to R-8 | 0.3 – 0.49 | 0.14 | 0.00 | -0.06 | -0.02 |
| R-5 to R-8 | 0.5 – 0.69 | 0.26 | 0.00 | -0.11 | -0.04 |
| R-5 to R-8 | > 0.7 | 0.38 | -0.01 | -0.17 | -0.06 |
| R-9 to R-14 | 0.15 – 0.29 | 0.02 | 0.00 | -0.01 | 0.00 |
| R-9 to R-14 | 0.3 – 0.49 | 0.10 | 0.00 | -0.04 | -0.02 |
| R-9 to R-14 | 0.5 – 0.69 | 0.17 | 0.00 | -0.08 | -0.03 |
| R-9 to R-14 | > 0.7 | 0.26 | 0.00 | -0.11 | -0.04 |
| R-15 to R-22 | 0.15 - 0.29 | 0.01 | 0.00 | -0.01 | 0.00 |
| R-15 to R-22 | 0.3 – 0.49 | 0.06 | 0.00 | -0.03 | -0.01 |
| R-15 to R-22 | 0.5 – 0.69 | 0.12 | 0.00 | -0.05 | -0.02 |
| R-15 to R-22 | > 0.7 | 0.17 | 0.00 | -0.08 | -0.03 |
| R-30 | 0.15 – 0.29 | 0.01 | 0.00 | 0.00 | 0.00 |
| R-30 | 0.3 – 0.49 | 0.04 | 0.00 | -0.02 | -0.01 |
| R-30 | 0.5 – 0.69 | 0.07 | 0.00 | -0.03 | -0.01 |
| R-30 | > 0.7 | 0.11 | 0.00 | -0.05 | -0.02 |

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Cooling savings (refrigerated) | Heating Savings | | |
|---|---|---|---|---|---|
| | | | Gas | Electric resistance | Heat pump |
| **Low slope** | | | | | |
| < R-5 | 0.5 – 0.69 | 0.37 | 0.00 | -0.17 | -0.07 |
| < R-5 | > 0.7 | 0.54 | -0.01 | -0.25 | -0.09 |
| R-5 to R-8 | 0.5 – 0.69 | 0.28 | 0.00 | -0.13 | -0.05 |
| R-5 to R-8 | > 0.7 | 0.41 | -0.01 | -0.19 | -0.07 |
| R-9 to R-14 | 0.5 – 0.69 | 0.19 | 0.00 | -0.09 | -0.03 |
| R-9 to R-14 | > 0.7 | 0.28 | 0.00 | -0.13 | -0.05 |
| R-15 to R-22 | 0.5 – 0.69 | 0.13 | 0.00 | -0.06 | -0.02 |
| R-15 to R-22 | > 0.7 | 0.19 | 0.00 | -0.08 | -0.03 |
| R-30 | 0.5 – 0.69 | 0.09 | 0.00 | -0.04 | -0.01 |
| R-30 | > 0.7 | 0.13 | 0.00 | -0.06 | -0.02 |

**Table 220. Cool Roofs—Climate Zone 5: El Paso,**
**Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| **Steep slope** | | | | | | |
| < R-5 | 0.15 – 0.29 | 0.05 | 0.02 | 0.00 | -0.05 | -0.02 |
| < R-5 | 0.3 – 0.49 | 0.27 | 0.10 | -0.01 | -0.26 | -0.09 |
| < R-5 | 0.5 – 0.69 | 0.50 | 0.19 | -0.02 | -0.49 | -0.19 |
| < R-5 | > 0.7 | 0.74 | 0.29 | -0.04 | -0.77 | -0.29 |
| R-5 to R-8 | 0.15 – 0.29 | 0.04 | 0.02 | 0.00 | -0.04 | -0.01 |
| R-5 to R-8 | 0.3 – 0.49 | 0.21 | 0.08 | -0.01 | -0.20 | -0.07 |
| R-5 to R-8 | 0.5 – 0.69 | 0.39 | 0.15 | -0.02 | -0.38 | -0.14 |
| R-5 to R-8 | > 0.7 | 0.58 | 0.23 | -0.03 | -0.59 | -0.22 |
| R-9 to R-14 | 0.15 – 0.29 | 0.03 | 0.01 | 0.00 | -0.03 | -0.01 |
| R-9 to R-14 | 0.3 – 0.49 | 0.15 | 0.06 | -0.01 | -0.14 | -0.05 |
| R-9 to R-14 | 0.5 – 0.69 | 0.27 | 0.11 | -0.01 | -0.27 | -0.10 |
| R-9 to R-14 | > 0.7 | 0.41 | 0.16 | -0.02 | -0.41 | -0.15 |
| R-15 to R-22 | 0.15 – 0.29 | 0.02 | 0.01 | 0.00 | -0.02 | -0.01 |
| R-15 to R-22 | 0.3 – 0.49 | 0.10 | 0.04 | -0.01 | -0.10 | -0.04 |
| R-15 to R-22 | 0.5 – 0.69 | 0.19 | 0.08 | -0.01 | -0.18 | -0.07 |

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| R-15 to R-22 | ≥ 0.7 | 0.29 | 0.12 | -0.02 | -0.28 | -0.10 |
| R-30 | 0.15 – 0.29 | 0.01 | 0.01 | 0.00 | -0.01 | -0.01 |
| R-30 | 0.3 – 0.49 | 0.07 | 0.03 | 0.00 | -0.06 | -0.02 |
| R-30 | 0.5 – 0.69 | 0.13 | 0.05 | -0.01 | -0.12 | -0.04 |
| R-30 | ≥ 0.7 | 0.20 | 0.08 | -0.01 | -0.18 | -0.07 |
| **Low slope** | | | | | | |
| < R-5 | 0.5 – 0.69 | 0.57 | 0.22 | -0.02 | -0.56 | -0.21 |
| < R-5 | ≥ 0.7 | 0.84 | 0.32 | -0.04 | -0.88 | -0.33 |
| R-5 to R-8 | 0.5 – 0.69 | 0.45 | 0.18 | -0.02 | -0.44 | -0.16 |
| R-5 to R-8 | ≥ 0.7 | 0.66 | 0.26 | -0.03 | -0.68 | -0.25 |
| R-9 to R-14 | 0.5 – 0.69 | 0.32 | 0.13 | -0.02 | -0.31 | -0.12 |
| R-9 to R-14 | ≥ 0.7 | 0.47 | 0.19 | -0.03 | -0.47 | -0.18 |
| R-15 to R-22 | 0.5 – 0.69 | 0.23 | 0.09 | -0.01 | -0.21 | -0.08 |
| R-15 to R-22 | ≥ 0.7 | 0.34 | 0.14 | -0.02 | -0.32 | -0.12 |
| R-30 | 0.5 – 0.69 | 0.17 | 0.07 | -0.01 | -0.14 | -0.06 |
| R-30 | ≥ 0.7 | 0.25 | 0.10 | -0.02 | -0.22 | -0.08 |

### *Homes with Roof Deck Insulation*

Table 221 through Table 225 present the energy savings (kWh) for the installation of a reflective roof on homes with varying levels of roof deck insulation for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types. Savings are per square foot of treated roof area.

**Table 221. Cool Roofs—Climate Zone 1: Amarillo, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| **Steep slope** | | | | | | |
| R-19 | 0.15 – 0.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| R-19 | 0.3 – 0.49 | 0.06 | 0.02 | -0.01 | -0.13 | -0.05 |
| R-19 | 0.5 – 0.69 | 0.13 | 0.04 | -0.01 | -0.28 | -0.11 |
| R-19 | ≥ 0.7 | 0.20 | 0.07 | -0.02 | -0.42 | -0.16 |
| R-30 | 0.15 – 0.29 | 0.01 | 0.00 | 0.00 | -0.01 | -0.01 |

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| R-30 | 0.3 – 0.49 | 0.05 | 0.02 | -0.01 | -0.12 | -0.04 |
| R-30 | 0.5 – 0.69 | 0.11 | 0.03 | -0.01 | -0.23 | -0.09 |
| R-30 | ≥ 0.7 | 0.16 | 0.05 | -0.02 | -0.35 | -0.14 |
| R-38 | 0.15 – 0.29 | 0.01 | 0.00 | 0.00 | -0.02 | -0.01 |
| R-38 | 0.3 – 0.49 | 0.05 | 0.02 | -0.01 | -0.11 | -0.04 |
| R-38 | 0.5 – 0.69 | 0.09 | 0.03 | -0.01 | -0.20 | -0.08 |
| R-38 | ≥ 0.7 | 0.13 | 0.04 | -0.02 | -0.30 | -0.12 |
| **Low slope** | | | | | | |
| R-19 | 0.5 – 0.69 | 0.13 | 0.04 | -0.01 | -0.27 | -0.11 |
| R-19 | ≥ 0.7 | 0.20 | 0.07 | -0.02 | -0.42 | -0.16 |
| R-30 | 0.5 – 0.69 | 0.11 | 0.03 | -0.01 | -0.23 | -0.09 |
| R-30 | ≥ 0.7 | 0.16 | 0.05 | -0.02 | -0.34 | -0.13 |
| R-38 | 0.5 – 0.69 | 0.09 | 0.03 | -0.01 | -0.20 | -0.08 |
| R-38 | ≥ 0.7 | 0.13 | 0.04 | -0.02 | -0.29 | -0.11 |

**Table 222. Cool Roofs—Climate Zone 2: Dallas, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Cooling savings (refrigerated) | Heating savings | | |
|---|---|---|---|---|---|
| | | | Gas | Electric resistance | Heat pump |
| **Steep slope** | | | | | |
| R-19 | 0.15 – 0.29 | 0.00 | 0.00 | 0.00 | 0.00 |
| R-19 | 0.3 – 0.49 | 0.10 | 0.00 | -0.09 | -0.03 |
| R-19 | 0.5 – 0.69 | 0.21 | -0.01 | -0.18 | -0.07 |
| R-19 | ≥ 0.7 | 0.32 | -0.01 | -0.28 | -0.11 |
| R-30 | 0.15 – 0.29 | 0.01 | 0.00 | -0.01 | -0.01 |
| R-30 | 0.3 – 0.49 | 0.09 | 0.00 | -0.08 | -0.03 |
| R-30 | 0.5 – 0.69 | 0.17 | -0.01 | -0.15 | -0.06 |
| R-30 | ≥ 0.7 | 0.26 | -0.01 | -0.23 | -0.09 |
| R-38 | 0.15 – 0.29 | 0.02 | 0.00 | -0.01 | -0.01 |
| R-38 | 0.3 – 0.49 | 0.08 | 0.00 | -0.07 | -0.03 |
| R-38 | 0.5 – 0.69 | 0.14 | -0.01 | -0.13 | -0.05 |
| R-38 | ≥ 0.7 | 0.21 | -0.01 | -0.19 | -0.07 |

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Cooling savings (refrigerated) | Heating savings | | |
|---|---|---|---|---|---|
| | | | Gas | Electric resistance | Heat pump |
| **Low slope** | | | | | |
| R-19 | 0.5 – 0.69 | 0.21 | -0.01 | -0.18 | -0.07 |
| R-19 | ≥ 0.7 | 0.32 | -0.01 | -0.28 | -0.11 |
| R-30 | 0.5 – 0.69 | 0.17 | -0.01 | -0.15 | -0.06 |
| R-30 | ≥ 0.7 | 0.26 | -0.01 | -0.23 | -0.09 |
| R-38 | 0.5 – 0.69 | 0.14 | -0.01 | -0.13 | -0.05 |
| R-38 | ≥ 0.7 | 0.21 | -0.01 | -0.19 | -0.07 |

**Table 223. Cool Roofs—Climate Zone 3: Houston, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Cooling savings (refrigerated) | Heating savings | | |
|---|---|---|---|---|---|
| | | | Gas | Electric resistance | Heat pump |
| **Steep slope** | | | | | |
| R-19 | 0.15 – 0.29 | 0.00 | 0.00 | 0.00 | 0.00 |
| R-19 | 0.3 – 0.49 | 0.11 | 0.00 | -0.07 | -0.03 |
| R-19 | 0.5 – 0.69 | 0.22 | -0.01 | -0.14 | -0.05 |
| R-19 | ≥ 0.7 | 0.34 | -0.01 | -0.22 | -0.08 |
| R-30 | 0.15 – 0.29 | 0.01 | 0.00 | -0.01 | 0.00 |
| R-30 | 0.3 – 0.49 | 0.09 | 0.00 | -0.06 | -0.02 |
| R-30 | 0.5 – 0.69 | 0.19 | 0.00 | -0.12 | -0.04 |
| R-30 | ≥ 0.7 | 0.28 | -0.01 | -0.18 | -0.07 |
| R-38 | 0.15 – 0.29 | 0.02 | 0.00 | -0.01 | 0.00 |
| R-38 | 0.3 – 0.49 | 0.08 | 0.00 | -0.06 | -0.02 |
| R-38 | 0.5 – 0.69 | 0.16 | 0.00 | -0.10 | -0.04 |
| R-38 | ≥ 0.7 | 0.23 | -0.01 | -0.15 | -0.06 |
| **Low slope** | | | | | |
| R-19 | 0.5 – 0.69 | 0.22 | -0.01 | -0.14 | -0.06 |
| R-19 | ≥ 0.7 | 0.35 | -0.01 | -0.22 | -0.08 |
| R-30 | 0.5 – 0.69 | 0.19 | 0.00 | -0.12 | -0.05 |
| R-30 | ≥ 0.7 | 0.28 | -0.01 | -0.18 | -0.07 |
| R-38 | 0.5 – 0.69 | 0.16 | 0.00 | -0.10 | -0.04 |
| R-38 | ≥ 0.7 | 0.23 | -0.01 | -0.15 | -0.06 |

**Table 224. Cool Roofs—Climate Zone 4: Corpus Christi, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Cooling savings (refrigerated) | Heating savings | | |
|---|---|---|---|---|---|
| | | | Gas | Electric resistance | Heat pump |
| **Steep slope** | | | | | |
| R-19 | 0.15 – 0.29 | 0.00 | 0.00 | 0.00 | 0.00 |
| R-19 | 0.3 – 0.49 | 0.09 | 0.00 | -0.04 | -0.02 |
| R-19 | 0.5 – 0.69 | 0.17 | 0.00 | -0.09 | -0.03 |
| R-19 | ≥ 0.7 | 0.26 | 0.00 | -0.13 | -0.05 |
| R-30 | 0.15 – 0.29 | 0.01 | 0.00 | -0.01 | 0.00 |
| R-30 | 0.3 – 0.49 | 0.08 | 0.00 | -0.03 | -0.01 |
| R-30 | 0.5 – 0.69 | 0.14 | 0.00 | -0.07 | -0.02 |
| R-30 | ≥ 0.7 | 0.21 | 0.00 | -0.11 | -0.04 |
| R-38 | 0.15 – 0.29 | 0.01 | 0.00 | -0.01 | 0.00 |
| R-38 | 0.3 – 0.49 | 0.07 | 0.00 | -0.03 | -0.01 |
| R-38 | 0.5 – 0.69 | 0.12 | 0.00 | -0.06 | -0.02 |
| R-38 | ≥ 0.7 | 0.18 | 0.00 | -0.09 | -0.03 |
| **Low slope** | | | | | |
| R-19 | 0.5 – 0.69 | 0.23 | -0.01 | -0.29 | -0.11 |
| R-19 | ≥ 0.7 | 0.36 | -0.02 | -0.46 | -0.18 |
| R-30 | 0.5 – 0.69 | 0.17 | 0.00 | -0.16 | -0.06 |
| R-30 | ≥ 0.7 | 0.26 | -0.01 | -0.25 | -0.09 |
| R-38 | 0.5 – 0.69 | 0.12 | 0.00 | -0.06 | -0.02 |
| R-38 | ≥ 0.7 | 0.18 | 0.00 | -0.09 | -0.03 |

**Table 225. Cool Roofs—Climate Zone 5: El Paso, Energy Savings for Residential Reflective Roof Installation (kWh/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| **Steep slope** | | | | | | |
| R-19 | 0.15 – 0.29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| R-19 | 0.3 – 0.49 | 0.11 | 0.04 | -0.01 | -0.14 | -0.05 |
| R-19 | 0.5 – 0.69 | 0.22 | 0.08 | -0.01 | -0.28 | -0.11 |
| R-19 | ≥ 0.7 | 0.35 | 0.12 | -0.02 | -0.45 | -0.17 |
| R-30 | 0.15 – 0.29 | 0.01 | 0.01 | 0.00 | -0.01 | -0.01 |

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| R-30 | 0.3 – 0.49 | 0.10 | 0.03 | 0.00 | -0.12 | -0.04 |
| R-30 | 0.5 – 0.69 | 0.19 | 0.06 | -0.01 | -0.23 | -0.09 |
| R-30 | ≥ 0.7 | 0.28 | 0.10 | -0.01 | -0.37 | -0.14 |
| R-38 | 0.15 – 0.29 | 0.02 | 0.01 | 0.00 | -0.02 | -0.01 |
| R-38 | 0.3 – 0.49 | 0.09 | 0.03 | 0.00 | -0.11 | -0.04 |
| R-38 | 0.5 – 0.69 | 0.16 | 0.05 | -0.01 | -0.20 | -0.08 |
| R-38 | ≥ 0.7 | 0.23 | 0.08 | -0.01 | -0.31 | -0.12 |
| **Low slope** | | | | | | |
| R-19 | 0.5 – 0.69 | 0.23 | 0.08 | -0.01 | -0.29 | -0.11 |
| R-19 | ≥ 0.7 | 0.36 | 0.12 | -0.02 | -0.46 | -0.18 |
| R-30 | 0.5 – 0.69 | 0.19 | 0.06 | -0.01 | -0.24 | -0.09 |
| R-30 | ≥ 0.7 | 0.29 | 0.10 | -0.01 | -0.38 | -0.15 |
| R-38 | 0.5 – 0.69 | 0.16 | 0.05 | -0.01 | -0.21 | -0.08 |
| R-38 | ≥ 0.7 | 0.24 | 0.08 | -0.01 | -0.32 | -0.12 |

## Deemed Summer Demand Savings Tables

Savings are presented first for homes with ceiling insulation, and subsequently for those with roof deck insulation. For customers who participate in HTR/LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate cooling values in Table 226 through Table 230 by a factor of 0.6.

### *Homes with Ceiling Insulation*

Table 226 through Table 230 present the summer demand savings (kW) associated with the installation of a reflective roof in homes with varying levels of ceiling insulation (attic floor) for the five Texas climate zones. Savings are per square foot of treated roof area.

**Table 226. Cool Roofs—Climate Zone 1: Amarillo, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | | Steep slope | |
|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Refrigerated | Evaporative |
| < R-5 | 0.15 – 0.29 | – | – | 2.34 x 10-5 | 1.06 x 10-5 |
| < R-5 | 0.3 – 0.49 | – | – | 1.21 x 10-4 | 6.05 x 10-5 |
| < R-5 | 0.5 – 0.69 | 2.50 x 10-4 | 1.18 x 10-4 | 2.35 x 10-4 | 1.06 x 10-4 |
| < R-5 | ≥ 0.7 | 3.97 x 10-4 | 1.94 x 10-4 | 3.94 x 10-4 | 1.85 x 10-4 |
| R-5 to R-8 | 0.15 – 0.29 | – | – | 1.48 x 10-5 | 6.69 x 10-6 |

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | | Steep slope | |
|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Refrigerated | Evaporative |
| R-5 to R-8 | 0.3 – 0.49 | – | – | 8.09 x 10-5 | 4.47 x 10-5 |
| R-5 to R-8 | 0.5 – 0.69 | 1.78 x 10-4 | 9.21 x 10-5 | 1.63 x 10-4 | 7.51 x 10-5 |
| R-5 to R-8 | ≥ 0.7 | 2.85 x 10-4 | 1.55 x 10-4 | 2.86 x 10-4 | 1.40 x 10-4 |
| R-9 to R-14 | 0.15 – 0.29 | – | – | 6.05 x 10-6 | 7.93 x 10-6 |
| R-9 to R-14 | 0.3 – 0.49 | – | – | 5.64 x 10-5 | 2.18 x 10-5 |
| R-9 to R-14 | 0.5 – 0.69 | 1.17 x 10-4 | 5.99 x 10-5 | 1.08 x 10-4 | 4.52 x 10-5 |
| R-9 to R-14 | ≥ 0.7 | 1.92 x 10-4 | 9.10 x 10-5 | 1.90 x 10-4 | 9.38 x 10-5 |
| R-15 to R-22 | 0.15 – 0.29 | – | – | 2.30 x 10-6 | -8.73 x 10-7 |
| R-15 to R-22 | 0.3 – 0.49 | – | – | 3.55 x 10-5 | 1.53 x 10-5 |
| R-15 to R-22 | 0.5 – 0.69 | 7.90 x 10-5 | 3.73 x 10-5 | 7.34 x 10-5 | 2.74 x 10-5 |
| R-15 to R-22 | ≥ 0.7 | 1.31 x 10-4 | 6.28 x 10-5 | 1.37 x 10-4 | 7.50 x 10-5 |
| R-30 | 0.15 – 0.29 | – | – | -8.06 x 10-7 | 3.42 x 10-6 |
| R-30 | 0.3 – 0.49 | – | – | 2.36 x 10-5 | 1.83 x 10-5 |
| R-30 | 0.5 – 0.69 | 5.39 x 10-5 | 1.76 x 10-5 | 4.99 x 10-5 | 2.70 x 10-5 |
| R-30 | ≥ 0.7 | 9.25 x 10-5 | 4.31 x 10-5 | 9.56 x 10-5 | 5.99 x 10-5 |

**Table 227. Cool Roofs—Climate Zone 2: Dallas, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | Steep slope |
|---|---|---|---|
| < R-5 | 0.15 – 0.29 | – | 3.46 x 10-5 |
| < R-5 | 0.3 – 0.49 | – | 1.79 x 10-4 |
| < R-5 | 0.5 – 0.69 | 3.63 x 10-4 | 3.41 x 10-4 |
| < R-5 | ≥ 0.7 | 5.36 x 10-4 | 5.15 x 10-4 |
| R-5 to R-8 | 0.15 – 0.29 | – | 2.63 x 10-5 |
| R-5 to R-8 | 0.3 – 0.49 | – | 1.36 x 10-4 |
| R-5 to R-8 | 0.5 – 0.69 | 2.83 x 10-4 | 2.64 x 10-4 |
| R-5 to R-8 | ≥ 0.7 | 4.10 x 10-4 | 4.06 x 10-4 |
| R-9 to R-14 | 0.15 – 0.29 | – | 1.78 x 10-5 |
| R-9 to R-14 | 0.3 – 0.49 | – | 1.02 x 10-4 |
| R-9 to R-14 | 0.5 – 0.69 | 1.99 x 10-4 | 1.73 x 10-4 |
| R-9 to R-14 | ≥ 0.7 | 2.85 x 10-4 | 2.85 x 10-4 |
| R-15 to R-22 | 0.15 – 0.29 | – | 9.26 x 10-6 |
| R-15 to R-22 | 0.3 – 0.49 | – | 7.69 x 10-5 |

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | Steep slope |
|---|---|---|---|
| R-15 to R-22 | 0.5 – 0.69 | 1.47 x 10-4 | 1.23 x 10-4 |
| R-15 to R-22 | ≥ 0.7 | 2.04 x 10-4 | 2.15 x 10-4 |
| R-30 | 0.15 – 0.29 | – | 1.34 x 10-5 |
| R-30 | 0.3 – 0.49 | – | 5.58 x 10-5 |
| R-30 | 0.5 – 0.69 | 1.01 x 10-4 | 8.64 x 10-5 |
| R-30 | ≥ 0.7 | 1.52 x 10-4 | 1.58 x 10-4 |

**Table 228. Cool Roofs—Climate Zone 3: Houston, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | Steep slope |
|---|---|---|---|
| < R-5 | 0.15 – 0.29 | – | 3.27 x 10-5 |
| < R-5 | 0.3 – 0.49 | – | 1.74 x 10-4 |
| < R-5 | 0.5 – 0.69 | 3.62 x 10-4 | 3.56 x 10-4 |
| < R-5 | ≥ 0.7 | 5.86 x 10-4 | 5.48 x 10-4 |
| R-5 to R-8 | 0.15 – 0.29 | – | 2.38 x 10-5 |
| R-5 to R-8 | 0.3 – 0.49 | – | 1.33 x 10-4 |
| R-5 to R-8 | 0.5 – 0.69 | 2.76 x 10-4 | 2.72 x 10-4 |
| R-5 to R-8 | ≥ 0.7 | 4.64 x 10-4 | 4.28 x 10-4 |
| R-9 to R-14 | 0.15 – 0.29 | – | 1.55 x 10-5 |
| R-9 to R-14 | 0.3 – 0.49 | – | 1.07 x 10-4 |
| R-9 to R-14 | 0.5 – 0.69 | 2.12 x 10-4 | 2.03 x 10-4 |
| R-9 to R-14 | ≥ 0.7 | 3.30 x 10-4 | 3.11 x 10-4 |
| R-15 to R-22 | 0.15 – 0.29 | – | 1.75 x 10-5 |
| R-15 to R-22 | 0.3 – 0.49 | – | 7.56 x 10-5 |
| R-15 to R-22 | 0.5 – 0.69 | 1.53 x 10-4 | 1.44 x 10-4 |
| R-15 to R-22 | ≥ 0.7 | 2.37 x 10-4 | 2.26 x 10-4 |
| R-30 | 0.15 – 0.29 | – | 9.44 x 10-6 |
| R-30 | 0.3 – 0.49 | – | 5.11 x 10-5 |
| R-30 | 0.5 – 0.69 | 1.09 x 10-4 | 9.65 x 10-5 |
| R-30 | ≥ 0.7 | 1.75 x 10-4 | 1.64 x 10-4 |

**Table 229. Cool Roofs—Climate Zone 4: Corpus Christi, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-Year reflectance | Low slope | Steep slope |
|---:|---:|---:|---:|
| < R-5 | 0.15 – 0.29 | – | 1.82 x 10-5 |
| < R-5 | 0.3 – 0.49 | – | 9.19 x 10-5 |
| < R-5 | 0.5 – 0.69 | 1.67 x 10-4 | 1.66 x 10-4 |
| < R-5 | $\geq$ 0.7 | 2.75 x 10-4 | 2.69 x 10-4 |
| R-5 to R-8 | 0.15 – 0.29 | – | 1.46 x 10-5 |
| R-5 to R-8 | 0.3 – 0.49 | – | 6.97 x 10-5 |
| R-5 to R-8 | 0.5 – 0.69 | 1.22 x 10-4 | 1.23 x 10-4 |
| R-5 to R-8 | $\geq$ 0.7 | 2.02 x 10-4 | 2.01 x 10-4 |
| R-9 to R-14 | 0.15 – 0.29 | – | 6.80 x 10-6 |
| R-9 to R-14 | 0.3 – 0.49 | – | 4.15 x 10-5 |
| R-9 to R-14 | 0.5 – 0.69 | 7.62 x 10-5 | 7.37 x 10-5 |
| R-9 to R-14 | $\geq$ 0.7 | 1.26 x 10-4 | 1.28 x 10-4 |
| R-15 to R-22 | 0.15 – 0.29 | – | 4.71 x 10-6 |
| R-15 to R-22 | 0.3 – 0.49 | – | 2.55 x 10-5 |
| R-15 to R-22 | 0.5 – 0.69 | 4.24 x 10-5 | 4.39 x 10-5 |
| R-15 to R-22 | $\geq$ 0.7 | 7.33 x 10-5 | 7.94 x 10-5 |
| R-30 | 0.15 – 0.29 | – | 2.50 x 10-6 |
| R-30 | 0.3 – 0.49 | – | 1.01 x 10-5 |
| R-30 | 0.5 – 0.69 | 2.41 x 10-5 | 2.04 x 10-5 |
| R-30 | $\geq$ 0.7 | 4.01 x 10-5 | 4.77 x 10-5 |

**Table 230. Cool Roofs—Climate Zone 5: El Paso, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | | Steep slope | |
|---:|---:|---:|---:|---:|---:|
| | | Refrigerated | Evaporative | Refrigerated | Evaporative |
| < R-5 | 0.15 – 0.29 | – | – | 3.58 x 10-5 | 1.28 x 10-5 |
| < R-5 | 0.3 – 0.49 | – | – | 1.72 x 10-4 | 7.49 x 10-5 |
| < R-5 | 0.5 – 0.69 | 3.95 x 10-4 | 1.54 x 10-4 | 3.44 x 10-4 | 1.65 x 10-4 |
| < R-5 | $\geq$ 0.7 | 6.15 x 10-4 | 2.42 x 10-4 | 5.19 x 10-4 | 2.20 x 10-4 |
| R-5 to R-8 | 0.15 – 0.29 | – | – | 2.72 x 10-5 | 8.96 x 10-6 |
| R-5 to R-8 | 0.3 – 0.49 | – | – | 1.27 x 10-4 | 6.00 x 10-5 |
| R-5 to R-8 | 0.5 – 0.69 | 3.06 x 10-4 | 1.34 x 10-4 | 2.59 x 10-4 | 1.38 x 10-4 |

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | | Steep slope | |
|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Refrigerated | Evaporative |
| R-5 to R-8 | ≥ 0.7 | 4.77 x 10-4 | 2.05 x 10-4 | 3.97 x 10-4 | 1.78 x 10-4 |
| R-9 to R-14 | 0.15 – 0.29 | – | – | 1.25 x 10-5 | 9.26 x 10-6 |
| R-9 to R-14 | 0.3 – 0.49 | – | – | 8.24 x 10-5 | 5.30 x 10-5 |
| R-9 to R-14 | 0.5 – 0.69 | 2.07 x 10-4 | 1.00 x 10-4 | 1.73 x 10-4 | 8.86 x 10-5 |
| R-9 to R-14 | ≥ 0.7 | 3.27 x 10-4 | 1.44 x 10-4 | 2.60 x 10-4 | 1.22 x 10-4 |
| R-15 to R-22 | 0.15 – 0.29 | – | – | 6.16 x 10-6 | 3.73 x 10-6 |
| R-15 to R-22 | 0.3 – 0.49 | – | – | 6.18 x 10-5 | 4.40 x 10-5 |
| R-15 to R-22 | 0.5 – 0.69 | 1.50 x 10-4 | 7.63 x 10-5 | 1.24 x 10-4 | 6.49 x 10-5 |
| R-15 to R-22 | ≥ 0.7 | 2.42 x 10-4 | 1.11 x 10-4 | 1.88 x 10-4 | 8.86 x 10-5 |
| R-30 | 0.15 – 0.29 | – | – | 6.64 x 10-6 | 5.65 x 10-7 |
| R-30 | 0.3 – 0.49 | – | – | 4.77 x 10-5 | 2.87 x 10-5 |
| R-30 | 0.5 – 0.69 | 1.01 x 10-4 | 5.91 x 10-5 | 8.81 x 10-5 | 5.07 x 10-5 |
| R-30 | ≥ 0.7 | 1.80 x 10-4 | 8.50 x 10-5 | 1.32 x 10-4 | 6.75 x 10-5 |

### *Homes with Roof Deck Insulation*

Table 231 through Table 235 present the summer demand savings (kW) associated with the installation of a reflective roof in homes with varying levels of roof deck for the five Texas climate zones. Savings are per square foot of treated roof area.

**Table 231. Cool Roofs—Climate Zone 1: Amarillo, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | | Steep slope | |
|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Refrigerated | Evaporative |
| R-19 | 0.15 – 0.29 | – | – | – | – |
| R-19 | 0.3 – 0.49 | – | – | 2.67 x 10-5 | 7.62 x 10-6 |
| R-19 | 0.5 – 0.69 | 5.56 x 10-5 | 1.84 x 10-5 | 5.35 x 10-5 | 1.55 x 10-5 |
| R-19 | ≥ 0.7 | 9.88 x 10-5 | 7.61 x 10-6 | 8.81 x 10-5 | 1.52 x 10-5 |
| R-30 | 0.15 – 0.29 | – | – | 3.37 x 10-6 | 3.42 x 10-6 |
| R-30 | 0.3 – 0.49 | – | – | 1.97 x 10-5 | 7.38 x 10-6 |
| R-30 | 0.5 – 0.69 | 3.21 x 10-5 | 9.13 x 10-6 | 3.06 x 10-5 | 1.25 x 10-5 |
| R-30 | ≥ 0.7 | 6.91 x 10-5 | 8.48 x 10-6 | 5.94 x 10-5 | 1.60 x 10-5 |
| R-38 | 0.15 – 0.29 | – | – | 5.82 x 10-6 | 5.90 x 10-6 |

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | | Steep slope | |
|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Refrigerated | Evaporative |
| R-38 | 0.3 – 0.49 | – | – | 1.46 x 10-5 | 7.20 x 10-6 |
| R-38 | 0.5 – 0.69 | 1.50 x 10-5 | 2.38 x 10-6 | 1.40 x 10-5 | 1.04 x 10-5 |
| R-38 | ≥ 0.7 | 4.75 x 10-5 | 9.12 x 10-6 | 3.85 x 10-5 | 1.66 x 10-5 |

**Table 232. Cool Roofs—Climate Zone 2: Dallas,**
**Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | Steep slope |
|---|---|---|---|
| | | Refrigerated | Refrigerated |
| R-19 | 0.15 – 0.29 | – | 5.45 x 10-5 |
| R-19 | 0.3 – 0.49 | – | 9.02 x 10-5 |
| R-19 | 0.5 – 0.69 | 7.41 x 10-5 | 1.21 x 10-4 |
| R-19 | ≥ 0.7 | 1.16 x 10-4 | 5.18 x 10-6 |
| R-30 | 0.15 – 0.29 | – | 2.22 x 10-5 |
| R-30 | 0.3 – 0.49 | – | 5.01 x 10-5 |
| R-30 | 0.5 – 0.69 | 4.37 x 10-5 | 7.67 x 10-5 |
| R-30 | ≥ 0.7 | 7.41 x 10-5 | 3.37 x 10-5 |
| R-38 | 0.15 – 0.29 | – | -1.31 x 10-6 |
| R-38 | 0.3 – 0.49 | – | 2.10 x 10-5 |
| R-38 | 0.5 – 0.69 | 2.16 x 10-5 | 4.44 x 10-5 |
| R-38 | ≥ 0.7 | 4.36 x 10-5 | 5.45 x 10-5 |

**Table 233. Cool Roofs—Climate Zone 3: Houston,**
**Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | Steep slope |
|---|---|---|---|
| | | Refrigerated | Refrigerated |
| R-19 | 0.15 – 0.29 | – | – |
| R-19 | 0.3 – 0.49 | – | – |
| R-19 | 0.5 – 0.69 | 9.43 x 10-5 | 9.42 x 10-5 |
| R-19 | ≥ 0.7 | 1.32 x 10-4 | 1.21 x 10-4 |
| R-30 | 0.15 – 0.29 | – | -1.46 x 10-6 |
| R-30 | 0.3 – 0.49 | – | 2.60 x 10-5 |
| R-30 | 0.5 – 0.69 | 7.13 x 10-5 | 6.50 x 10-5 |

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | Steep slope |
|---|---|---|---|
| | | Refrigerated | Refrigerated |
| R-30 | > 0.7 | 8.56 x 10-5 | 8.46 x 10-5 |
| R-38 | 0.15 – 0.29 | – | -2.53 x 10-6 |
| R-38 | 0.3 – 0.49 | – | 1.37 x 10-5 |
| R-38 | 0.5 – 0.69 | 5.46 x 10-5 | 4.37 x 10-5 |
| R-38 | > 0.7 | 5.19 x 10-5 | 5.82 x 10-5 |

**Table 234. Cool Roofs—Climate Zone 4: Corpus Christi, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | Steep slope |
|---|---|---|---|
| | | Refrigerated | Refrigerated |
| R-19 | 0.15 – 0.29 | – | – |
| R-19 | 0.3 – 0.49 | – | 3.38 x 10-5 |
| R-19 | 0.5 – 0.69 | 4.44 x 10-5 | 5.01 x 10-5 |
| R-19 | > 0.7 | 7.43 x 10-5 | 7.37 x 10-5 |
| R-30 | 0.15 – 0.29 | – | 3.36 x 10-6 |
| R-30 | 0.3 – 0.49 | – | 2.68 x 10-5 |
| R-30 | 0.5 – 0.69 | 2.09 x 10-5 | 3.56 x 10-5 |
| R-30 | > 0.7 | 5.33 x 10-5 | 5.29 x 10-5 |
| R-38 | 0.15 – 0.29 | – | 5.81 x 10-6 |
| R-38 | 0.3 – 0.49 | – | 2.17 x 10-5 |
| R-38 | 0.5 – 0.69 | 3.83 x 10-6 | 2.51 x 10-5 |
| R-38 | > 0.7 | 3.80 x 10-5 | 3.78 x 10-5 |

**Table 235. Cool Roofs—Climate Zone 5: El Paso, Summer Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | | Steep slope | |
|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Refrigerated | Evaporative |
| R-19 | 0.15 – 0.29 | – | – | – | – |
| R-19 | 0.3 – 0.49 | – | – | 3.64 x 10-5 | 2.24 x 10-5 |
| R-19 | 0.5 – 0.69 | 8.11 x 10-5 | 2.76 x 10-5 | 8.95 x 10-5 | 4.42 x 10-5 |
| R-19 | > 0.7 | 1.33 x 10-4 | 2.30 x 10-5 | 1.35 x 10-4 | 4.44 x 10-5 |
| R-30 | 0.15 – 0.29 | – | – | 6.66 x 10-6 | 1.11 x 10-6 |
| R-30 | 0.3 – 0.49 | – | – | 3.01 x 10-5 | 5.29 x 10-6 |
| R-30 | 0.5 – 0.69 | 5.61 x 10-5 | 1.09 x 10-5 | 6.63 x 10-5 | 1.83 x 10-5 |

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | | Steep slope | |
|---|---|---|---|---|---|
| | | Refrigerated | Evaporative | Refrigerated | Evaporative |
| R-30 | ≥ 0.7 | 1.13 x 10-4 | 1.29 x 10-5 | 1.05 x 10-4 | 2.23 x 10-5 |
| R-38 | 0.15 – 0.29 | – | – | 1.15 x 10-5 | 1.91 x 10-6 |
| R-38 | 0.3 – 0.49 | – | – | 2.55 x 10-5 | -7.15 x 10-6 |
| R-38 | 0.5 – 0.69 | 3.79 x 10-5 | -1.22 x 10-6 | 4.95 x 10-5 | -5.19 x 10-7 |
| R-38 | ≥ 0.7 | 9.92 x 10-5 | 5.60 x 10-6 | 8.40 x 10-5 | 6.29 x 10-6 |

## Deemed Winter Demand Savings Tables

Savings are presented first for homes with ceiling insulation, and subsequently for those with roof deck insulation. For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 236 through Table 240 by a factor of 0.24.[257]

### *Homes with Ceiling Insulation*

Table 236 through Table 240 present the winter demand savings (kW) associated with the installation of a reflective roof in homes with varying levels of ceiling insulation (attic floor) for the five Texas climate zones. Savings are per square foot of treated roof area.

**Table 236. Cool Roofs—Climate Zone 1: Amarillo,**
**Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| < R-5 | 0.15 – 0.29 | – | – | – | -5.60 x 10-7 | -1.18 x 10-5 | -5.68 x 10-6 |
| < R-5 | 0.3 – 0.49 | – | – | – | -3.08 x 10-6 | -5.83 x 10-5 | -2.67 x 10-5 |
| < R-5 | 0.5 – 0.69 | -3.03 x 10-6 | -1.14 x 10-4 | -5.47 x 10-5 | -6.38 x 10-6 | -1.06 x 10-4 | -4.91 x 10-5 |
| < R-5 | ≥ 0.7 | -1.46 x 10-5 | -1.66 x 10-4 | -8.19 x 10-5 | -2.21 x 10-5 | -1.54 x 10-4 | -7.28 x 10-5 |
| R-5 to R-8 | 0.15 – 0.29 | – | – | – | -1.01 x 10-6 | -9.53 x 10-6 | -4.74 x 10-6 |
| R-5 to R-8 | 0.3 – 0.49 | – | – | – | -4.25 x 10-6 | -4.66 x 10-5 | -2.12 x 10-5 |
| R-5 to R-8 | 0.5 – 0.69 | 1.52 x 10-6 | -9.25 x 10-5 | -4.52 x 10-5 | -5.04 x 10-6 | -8.62 x 10-5 | -4.15 x 10-5 |
| R-5 to R-8 | ≥ 0.7 | -9.01 x 10-6 | -1.34 x 10-4 | -6.68 x 10-5 | -2.13 x 10-5 | -1.24 x 10-4 | -5.82 x 10-5 |
| R-9 to R-14 | 0.15 – 0.29 | – | – | – | -8.59 x 10-7 | -7.63 x 10-6 | -3.69 x 10-6 |

[257] This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| R-9 to R-14 | 0.3 – 0.49 | – | – | – | -3.68 x 10-6 | -3.63 x 10-5 | -1.55 x 10-5 |
| R-9 to R-14 | 0.5 – 0.69 | -1.04 x 10-7 | -7.28 x 10-5 | -3.43 x 10-5 | -1.49 x 10-5 | -6.73 x 10-5 | -3.07 x 10-5 |
| R-9 to R-14 | > 0.7 | -6.86 x 10-6 | -1.05 x 10-4 | -4.98 x 10-5 | -2.11 x 10-5 | -9.83 x 10-5 | -4.57 x 10-5 |
| R-15 to R-22 | 0.15 – 0.29 | – | – | – | -8.96 x 10-7 | -5.40 x 10-6 | -2.51 x 10-6 |
| R-15 to R-22 | 0.3 – 0.49 | – | – | – | -3.85 x 10-6 | -2.60 x 10-5 | -1.08 x 10-5 |
| R-15 to R-22 | 0.5 – 0.69 | -1.72 x 10-6 | -5.26 x 10-5 | -2.47 x 10-5 | -1.19 x 10-5 | -4.80 x 10-5 | -2.15 x 10-5 |
| R-15 to R-22 | > 0.7 | -9.72 x 10-7 | -7.65 x 10-5 | -3.64 x 10-5 | -1.44 x 10-5 | -7.05 x 10-5 | -3.23 x 10-5 |
| R-30 | 0.15 – 0.29 | - | - | - | -8.09 x 10-7 | -3.58 x 10-6 | -1.64 x 10-6 |
| R-30 | 0.3 – 0.49 | - | - | - | -1.08 x 10-5 | -1.73 x 10-5 | -7.31 x 10-6 |
| R-30 | 0.5 – 0.69 | -5.10 x 10-6 | -3.52 x 10-5 | -1.58 x 10-5 | -1.54 x 10-5 | -3.12 x 10-5 | -1.36 x 10-5 |
| R-30 | > 0.7 | -3.71 x 10-6 | -5.35 x 10-5 | -2.58 x 10-5 | -2.10 x 10-5 | -4.64 x 10-5 | -2.11 x 10-5 |

**Table 237. Cool Roofs—Climate Zone 2: Dallas,**
**Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| < R-5 | 0.15 – 0.29 | – | – | – | 2.40 x 10-6 | -1.29 x 10-5 | -6.63 x 10-6 |
| < R-5 | 0.3 – 0.49 | – | – | – | -2.62 x 10-8 | -6.19 x 10-5 | -3.24 x 10-5 |
| < R-5 | 0.5 – 0.69 | -2.83 x 10-6 | -1.48 x 10-4 | -7.24 x 10-5 | -1.44 x 10-6 | -1.19 x 10-4 | -6.06 x 10-5 |
| < R-5 | > 0.7 | -6.02 x 10-6 | -2.17 x 10-4 | -1.07 x 10-4 | -4.75 x 10-6 | -1.81 x 10-4 | -9.06 x 10-5 |
| R-5 to R-8 | 0.15 – 0.29 | – | – | – | 4.57 x 10-6 | -1.03 x 10-5 | -5.30 x 10-6 |
| R-5 to R-8 | 0.3 – 0.49 | – | – | – | 1.59 x 10-6 | -4.70 x 10-5 | -2.68 x 10-5 |
| R-5 to R-8 | 0.5 – 0.69 | -3.36 x 10-6 | -1.19 x 10-4 | -5.69 x 10-5 | 1.19 x 10-6 | -9.33 x 10-5 | -4.88 x 10-5 |
| R-5 to R-8 | > 0.7 | -3.79 x 10-6 | -1.74 x 10-4 | -8.66 x 10-5 | -4.46 x 10-6 | -1.43 x 10-4 | -7.18 x 10-5 |
| R-9 to R-14 | 0.15 – 0.29 | – | – | – | -7.26 x 10-7 | -8.09 x 10-6 | -3.86 x 10-6 |
| R-9 to R-14 | 0.3 – 0.49 | – | – | – | -2.92 x 10-6 | -4.23 x 10-5 | -2.03 x 10-5 |
| R-9 to R-14 | 0.5 – 0.69 | -1.29 x 10-5 | -9.30 x 10-5 | -4.31 x 10-5 | -3.26 x 10-6 | -7.90 x 10-5 | -3.76 x 10-5 |
| R-9 to R-14 | > 0.7 | -1.27 x 10-5 | -1.41 x 10-4 | -6.53 x 10-5 | -7.53 x 10-6 | -1.19 x 10-4 | -5.52 x 10-5 |
| R-15 to R-22 | 0.15 – 0.29 | – | – | – | 3.23 x 10-7 | -5.84 x 10-6 | -2.76 x 10-6 |
| R-15 to R-22 | 0.3 – 0.49 | – | – | – | -1.95 x 10-6 | -3.04 x 10-5 | -1.43 x 10-5 |
| R-15 to R-22 | 0.5 – 0.69 | -1.48 x 10-5 | -6.81 x 10-5 | -3.23 x 10-5 | -2.74 x 10-6 | -5.69 x 10-5 | -2.66 x 10-5 |
| R-15 to R-22 | > 0.7 | -1.61 x 10-5 | -1.02 x 10-4 | -4.67 x 10-5 | -3.88 x 10-7 | -8.65 x 10-5 | -4.05 x 10-5 |

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| R-30 | 0.15 – 0.29 | – | – | – | -3.74 x 10-7 | 2.81 x 10-6 | 8.71 x 10-6 |
| R-30 | 0.3 – 0.49 | – | – | – | -1.78 x 10-6 | -1.39 x 10-5 | 9.39 x 10-7 |
| R-30 | 0.5 – 0.69 | -3.37 x 10-6 | -4.77 x 10-5 | -2.23 x 10-5 | -2.20 x 10-6 | -3.16 x 10-5 | -7.00 x 10-6 |
| R-30 | ≥ 0.7 | -1.67 x 10-5 | -7.04 x 10-5 | -3.03 x 10-5 | -4.41 x 10-6 | -5.14 x 10-5 | -1.57 x 10-5 |

**Table 238. Cool Roofs—Climate Zone 3: Houston, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| < R-5 | 0.15 - 0.29 | – | – | – | -7.91 x 10-7 | -1.54 x 10-5 | -7.77 x 10-6 |
| < R-5 | 0.3 – 0.49 | – | – | – | -3.12 x 10-6 | -7.71 x 10-5 | -3.90 x 10-5 |
| < R-5 | 0.5 – 0.69 | -3.28 x 10-6 | -1.56 x 10-4 | -7.95 x 10-5 | -6.08 x 10-6 | -1.40 x 10-4 | -7.09 x 10-5 |
| < R-5 | ≥ 0.7 | -4.78 x 10-6 | -2.23 x 10-4 | -1.11 x 10-4 | -7.97 x 10-6 | -2.04 x 10-4 | -1.05 x 10-4 |
| R-5 to R-8 | 0.15 - 0.29 | – | – | – | -7.39 x 10-7 | -1.25 x 10-5 | -6.46 x 10-6 |
| R-5 to R-8 | 0.3 – 0.49 | – | – | – | -2.67 x 10-6 | -6.28 x 10-5 | -3.05 x 10-5 |
| R-5 to R-8 | 0.5 – 0.69 | -4.26 x 10-6 | -1.28 x 10-4 | -6.54 x 10-5 | -5.79 x 10-6 | -1.14 x 10-4 | -5.59 x 10-5 |
| R-5 to R-8 | ≥ 0.7 | -4.68 x 10-6 | -1.84 x 10-4 | -9.11 x 10-5 | -9.38 x 10-6 | -1.68 x 10-4 | -8.50 x 10-5 |
| R-9 to R-14 | 0.15 - 0.29 | – | – | – | -6.93 x 10-7 | -9.35 x 10-6 | -4.68 x 10-6 |
| R-9 to R-14 | 0.3 – 0.49 | – | – | – | -3.38 x 10-6 | -4.69 x 10-5 | -2.31 x 10-5 |
| R-9 to R-14 | 0.5 – 0.69 | -5.14 x 10-6 | -9.71 x 10-5 | -4.78 x 10-5 | -6.46 x 10-6 | -8.68 x 10-5 | -4.28 x 10-5 |
| R-9 to R-14 | ≥ 0.7 | -4.83 x 10-6 | -1.41 x 10-4 | -6.90 x 10-5 | -1.00 x 10-5 | -1.27 x 10-4 | -6.19 x 10-5 |
| R-15 to R-22 | 0.15 - 0.29 | – | – | – | -7.06 x 10-7 | -6.48 x 10-6 | -3.22 x 10-6 |
| R-15 to R-22 | 0.3 – 0.49 | – | – | – | -3.70 x 10-6 | -3.32 x 10-5 | -1.62 x 10-5 |
| R-15 to R-22 | 0.5 – 0.69 | -5.52 x 10-6 | -6.85 x 10-5 | -3.34 x 10-5 | -6.80 x 10-6 | -6.15 x 10-5 | -3.00 x 10-5 |
| R-15 to R-22 | ≥ 0.7 | -8.06 x 10-6 | -1.00 x 10-4 | -4.89 x 10-5 | -9.55 x 10-6 | -9.10 x 10-5 | -4.44 x 10-5 |
| R-30 | 0.15 - 0.29 | – | – | – | -6.32 x 10-7 | -4.54 x 10-6 | -2.25 x 10-6 |
| R-30 | 0.3 – 0.49 | – | – | – | -3.32 x 10-6 | -2.23 x 10-5 | -1.07 x 10-5 |
| R-30 | 0.5 – 0.69 | -5.55 x 10-6 | -4.83 x 10-5 | -2.35 x 10-5 | -6.05 x 10-6 | -4.13 x 10-5 | -2.00 x 10-5 |
| R-30 | ≥ 0.7 | -6.77 x 10-6 | -7.30 x 10-5 | -3.95 x 10-5 | -8.39 x 10-6 | -6.06 x 10-5 | -2.93 x 10-5 |

**Table 239. Cool Roofs—Climate Zone 4: Corpus Christi, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| < R-5 | 0.15 - 0.29 | – | – | – | -4.72 x 10-7 | -1.47 x 10-5 | -6.94 x 10-6 |
| < R-5 | 0.3 – 0.49 | – | – | – | -2.45 x 10-6 | -7.36 x 10-5 | -3.49 x 10-5 |
| < R-5 | 0.5 – 0.69 | -5.41 x 10-6 | -1.51 x 10-4 | -7.33 x 10-5 | -4.77 x 10-6 | -1.34 x 10-4 | -6.20 x 10-5 |
| < R-5 | ≥ 0.7 | -7.53 x 10-6 | -2.19 x 10-4 | -1.02 x 10-4 | -7.11 x 10-6 | -1.99 x 10-4 | -9.32 x 10-5 |
| R-5 to R-8 | 0.15 - 0.29 | – | – | – | -4.02 x 10-7 | -1.19 x 10-5 | -5.71 x 10-6 |
| R-5 to R-8 | 0.3 – 0.49 | – | – | – | -2.13 x 10-6 | -5.99 x 10-5 | -2.89 x 10-5 |
| R-5 to R-8 | 0.5 – 0.69 | -3.72 x 10-6 | -1.20 x 10-4 | -5.60 x 10-5 | -3.17 x 10-6 | -1.08 x 10-4 | -5.08 x 10-5 |
| R-5 to R-8 | ≥ 0.7 | -7.11 x 10-6 | -1.79 x 10-4 | -8.65 x 10-5 | -4.84 x 10-6 | -1.61 x 10-4 | -7.59 x 10-5 |
| R-9 to R-14 | 0.15 - 0.29 | – | – | – | -6.35 x 10-7 | -8.94 x 10-6 | -4.36 x 10-6 |
| R-9 to R-14 | 0.3 – 0.49 | – | – | – | -1.95 x 10-6 | -4.53 x 10-5 | -2.21 x 10-5 |
| R-9 to R-14 | 0.5 – 0.69 | -3.55 x 10-6 | -9.21 x 10-5 | -4.40 x 10-5 | -2.94 x 10-6 | -8.27 x 10-5 | -3.89 x 10-5 |
| R-9 to R-14 | ≥ 0.7 | -4.77 x 10-6 | -1.35 x 10-4 | -6.41 x 10-5 | -3.95 x 10-6 | -1.23 x 10-4 | -5.95 x 10-5 |
| R-15 to R-22 | 0.15 - 0.29 | – | – | – | -1.73 x 10-6 | -6.16 x 10-6 | -2.94 x 10-6 |
| R-15 to R-22 | 0.3 – 0.49 | – | – | – | -2.67 x 10-6 | -3.25 x 10-5 | -1.62 x 10-5 |
| R-15 to R-22 | 0.5 – 0.69 | -3.83 x 10-6 | -6.74 x 10-5 | -3.45 x 10-5 | -3.08 x 10-6 | -5.91 x 10-5 | -2.83 x 10-5 |
| R-15 to R-22 | ≥ 0.7 | -4.47 x 10-6 | -9.81 x 10-5 | -4.84 x 10-5 | -4.19 x 10-6 | -8.82 x 10-5 | -4.34 x 10-5 |
| R-30 | 0.15 - 0.29 | – | – | – | -1.34 x 10-7 | -4.03 x 10-6 | -1.87 x 10-6 |
| R-30 | 0.3 – 0.49 | – | – | – | -9.58 x 10-7 | -2.14 x 10-5 | -1.03 x 10-5 |
| R-30 | 0.5 – 0.69 | -3.13 x 10-6 | -4.69 x 10-5 | -2.41 x 10-5 | -2.42 x 10-6 | -4.01 x 10-5 | -2.00 x 10-5 |
| R-30 | ≥ 0.7 | -3.46 x 10-6 | -6.78 x 10-5 | -3.32 x 10-5 | -2.98 x 10-6 | -5.89 x 10-5 | -2.88 x 10-5 |

**Table 240. Cool Roofs—Climate Zone 5: El Paso, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| < R-5 | 0.15 - 0.29 | – | – | – | -6.68 x 10-7 | -2.51 x 10-5 | -1.01 x 10-5 |
| < R-5 | 0.3 – 0.49 | – | – | – | -7.29 x 10-6 | -1.33 x 10-4 | -5.50 x 10-5 |
| < R-5 | 0.5 – 0.69 | -1.53 x 10-5 | -2.93 x 10-4 | -1.17 x 10-4 | -1.34 x 10-5 | -2.50 x 10-4 | -1.02 x 10-4 |
| < R-5 | ≥ 0.7 | -1.73 x 10-5 | -4.44 x 10-4 | -1.79 x 10-4 | -1.93 x 10-5 | -3.82 x 10-4 | -1.57 x 10-4 |
| R-5 to R-8 | 0.15 - 0.29 | – | – | – | -2.41 x 10-7 | -1.98 x 10-5 | -7.98 x 10-6 |

| Ceiling insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| R-5 to R-8 | 0.3 – 0.49 | – | – | – | -4.83 x 10-6 | -1.03 x 10-4 | -4.14 x 10-5 |
| R-5 to R-8 | 0.5 – 0.69 | -1.33 x 10-5 | -2.36 x 10-4 | -9.44 x 10-5 | -1.22 x 10-5 | -1.99 x 10-4 | -7.97 x 10-5 |
| R-5 to R-8 | ≥ 0.7 | -1.47 x 10-5 | -3.64 x 10-4 | -1.48 x 10-4 | -1.73 x 10-5 | -3.11 x 10-4 | -1.28 x 10-4 |
| R-9 to R-14 | 0.15 - 0.29 | – | – | – | -5.77 x 10-7 | -1.35 x 10-5 | -5.48 x 10-6 |
| R-9 to R-14 | 0.3 – 0.49 | – | – | – | -4.07 x 10-6 | -7.56 x 10-5 | -3.15 x 10-5 |
| R-9 to R-14 | 0.5 – 0.69 | -9.52 x 10-6 | -1.70 x 10-4 | -6.83 x 10-5 | -9.66 x 10-6 | -1.44 x 10-4 | -5.76 x 10-5 |
| R-9 to R-14 | ≥ 0.7 | -1.06 x 10-5 | -2.73 x 10-4 | -1.12 x 10-4 | -1.38 x 10-5 | -2.33 x 10-4 | -9.66 x 10-5 |
| R-15 to R-22 | 0.15 - 0.29 | – | – | – | -4.29 x 10-7 | -9.41 x 10-6 | -4.20 x 10-6 |
| R-15 to R-22 | 0.3 – 0.49 | – | – | – | -3.14 x 10-6 | -4.91 x 10-5 | -2.00 x 10-5 |
| R-15 to R-22 | 0.5 – 0.69 | -7.55 x 10-6 | -1.14 x 10-4 | -4.66 x 10-5 | -7.70 x 10-6 | -9.71 x 10-5 | -4.02 x 10-5 |
| R-15 to R-22 | ≥ 0.7 | -8.94 x 10-6 | -1.85 x 10-4 | -7.43 x 10-5 | -1.05 x 10-5 | -1.55 x 10-4 | -6.29 x 10-5 |
| R-30 | 0.15 - 0.29 | – | – | – | -2.85 x 10-7 | -6.26 x 10-6 | -2.54 x 10-6 |
| R-30 | 0.3 – 0.49 | – | – | – | -2.32 x 10-6 | -3.11 x 10-5 | -1.25 x 10-5 |
| R-30 | 0.5 – 0.69 | -5.52 x 10-6 | -7.44 x 10-5 | -2.95 x 10-5 | -6.01 x 10-6 | -5.97 x 10-5 | -2.46 x 10-5 |
| R-30 | ≥ 0.7 | -7.73 x 10-6 | -1.20 x 10-4 | -4.89 x 10-5 | -7.78 x 10-6 | -9.69 x 10-5 | -3.98 x 10-5 |

### *Homes with Roof Deck Insulation*

Table 241 through Table 245 present the winter demand savings (kW) associated with the installation of a reflective roof in homes with varying levels of roof deck for the five Texas climate zones. Savings are per square foot of treated roof area.

**Table 241. Cool Roofs—Climate Zone 1: Amarillo, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| R-19 | 0.15 - 0.29 | – | – | – | – | – | – |
| R-19 | 0.3 – 0.49 | – | – | – | 6.62 x 10-7 | -3.75 x 10-5 | -1.86 x 10-5 |
| R-19 | 0.5 – 0.69 | 1.68 x 10-6 | -6.28 x 10-5 | -2.35 x 10-5 | 5.59 x 10-6 | -7.49 x 10-5 | -3.71 x 10-5 |
| R-19 | ≥ 0.7 | -1.78 x 10-6 | -9.77 x 10-5 | -4.08 x 10-5 | 7.13 x 10-6 | -1.12 x 10-4 | -5.19 x 10-5 |
| R-30 | 0.15 - 0.29 | – | – | – | -1.08 x 10-7 | -3.00 x 10-6 | -1.52 x 10-6 |
| R-30 | 0.3 – 0.49 | – | – | – | 2.49 x 10-6 | -3.23 x 10-5 | -1.75 x 10-5 |
| R-30 | 0.5 – 0.69 | -5.08 x 10-7 | -5.14 x 10-5 | -2.26 x 10-5 | 3.99 x 10-6 | -6.01 x 10-5 | -3.15 x 10-5 |

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| R-30 | ≥ 0.7 | -1.76 x 10-6 | -7.76 x 10-5 | -3.59 x 10-5 | 4.24 x 10-6 | -8.76 x 10-5 | -4.38 x 10-5 |
| R-38 | 0.15 - 0.29 | – | – | – | -1.87 x 10-7 | -5.19 x 10-6 | -2.62 x 10-6 |
| R-38 | 0.3 – 0.49 | – | – | – | 3.82 x 10-6 | -2.85 x 10-5 | -1.67 x 10-5 |
| R-38 | 0.5 – 0.69 | -2.10 x 10-6 | -4.31 x 10-5 | -2.20 x 10-5 | 2.82 x 10-6 | -4.93 x 10-5 | -2.74 x 10-5 |
| R-38 | ≥ 0.7 | -1.74 x 10-6 | -6.29 x 10-5 | -3.23 x 10-5 | 2.13 x 10-6 | -6.99 x 10-5 | -3.79 x 10-5 |

**Table 242. Cool Roofs—Climate Zone 2: Dallas, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| R-19 | 0.15 - 0.29 | – | – | – | – | – | – |
| R-19 | 0.3 – 0.49 | – | – | – | -1.68 x 10-6 | -4.21 x 10-5 | -2.13 x 10-5 |
| R-19 | 0.5 – 0.69 | 3.73 x 10-6 | -8.26 x 10-5 | -3.29 x 10-5 | 3.93 x 10-6 | -8.72 x 10-5 | -4.49 x 10-5 |
| R-19 | ≥ 0.7 | 2.09 x 10-6 | -1.33 x 10-4 | -5.96 x 10-5 | 2.27 x 10-6 | -1.30 x 10-4 | -5.31 x 10-5 |
| R-30 | 0.15 - 0.29 | – | – | – | -7.35 x 10-8 | -3.36 x 10-6 | -1.70 x 10-6 |
| R-30 | 0.3 – 0.49 | – | – | – | -1.19 x 10-6 | -3.52 x 10-5 | -1.73 x 10-5 |
| R-30 | 0.5 – 0.69 | 6.09 x 10-7 | -6.66 x 10-5 | -3.33 x 10-5 | 8.00 x 10-8 | -6.99 x 10-5 | -3.56 x 10-5 |
| R-30 | ≥ 0.7 | -1.22 x 10-6 | -1.03 x 10-4 | -5.11 x 10-5 | -1.19 x 10-6 | -1.03 x 10-4 | -4.63 x 10-5 |
| R-38 | 0.15 - 0.29 | – | – | – | -1.27 x 10-7 | -5.81 x 10-6 | -2.93 x 10-6 |
| R-38 | 0.3 – 0.49 | – | – | – | -8.41 x 10-7 | -3.02 x 10-5 | -1.44 x 10-5 |
| R-38 | 0.5 – 0.69 | -1.66 x 10-6 | -5.49 x 10-5 | -3.36 x 10-5 | -2.72 x 10-6 | -5.73 x 10-5 | -2.88 x 10-5 |
| R-38 | ≥ 0.7 | -3.63 x 10-6 | -8.17 x 10-5 | -4.49 x 10-5 | -3.70 x 10-6 | -8.42 x 10-5 | -4.14 x 10-5 |

**Table 243. Cool Roofs—Climate Zone 3: Houston, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| R-19 | 0.15 - 0.29 | – | – | – | – | – | – |
| R-19 | 0.3 – 0.49 | – | – | – | 5.21 x 10-8 | -4.60 x 10-5 | -2.10 x 10-5 |
| R-19 | 0.5 – 0.69 | -4.82 x 10-7 | -9.84 x 10-5 | -5.19 x 10-5 | -1.73 x 10-7 | -9.69 x 10-5 | -4.88 x 10-5 |
| R-19 | ≥ 0.7 | 1.47 x 10-6 | -1.47 x 10-4 | -7.52 x 10-5 | 2.13 x 10-6 | -1.52 x 10-4 | -8.03 x 10-5 |
| R-30 | 0.15 - 0.29 | – | – | – | 2.41 x 10-8 | -3.94 x 10-6 | -2.10 x 10-6 |

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| R-30 | 0.3 – 0.49 | – | – | – | 1.86 x 10-7 | -4.00 x 10-5 | -1.93 x 10-5 |
| R-30 | 0.5 – 0.69 | -1.49 x 10-6 | -8.32 x 10-5 | -4.30 x 10-5 | -4.20 x 10-7 | -7.79 x 10-5 | -4.01 x 10-5 |
| R-30 | ≥ 0.7 | -1.30 x 10-6 | -1.17 x 10-4 | -6.28 x 10-5 | -7.36 x 10-7 | -1.19 x 10-4 | -6.33 x 10-5 |
| R-38 | 0.15 - 0.29 | – | – | – | 4.96 x 10-8 | -6.80 x 10-6 | -3.63 x 10-6 |
| R-38 | 0.3 – 0.49 | – | – | – | 4.75 x 10-7 | -3.56 x 10-5 | -1.81 x 10-5 |
| R-38 | 0.5 – 0.69 | -2.23 x 10-6 | -7.22 x 10-5 | -3.66 x 10-5 | -5.99 x 10-7 | -6.41 x 10-5 | -3.37 x 10-5 |
| R-38 | ≥ 0.7 | -3.32 x 10-6 | -9.52 x 10-5 | -5.37 x 10-5 | -2.82 x 10-6 | -9.58 x 10-5 | -5.09 x 10-5 |

**Table 244. Cool Roofs—Climate Zone 4: Corpus Christi, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| R-19 | 0.15 - 0.29 | – | – | – | – | – | – |
| R-19 | 0.3 – 0.49 | – | – | – | -1.53 x 10-6 | -4.45 x 10-5 | -2.26 x 10-5 |
| R-19 | 0.5 – 0.69 | -2.27 x 10-6 | -9.14 x 10-5 | -3.90 x 10-5 | -2.29 x 10-6 | -9.18 x 10-5 | -4.65 x 10-5 |
| R-19 | ≥ 0.7 | -2.65 x 10-6 | -1.39 x 10-4 | -6.06 x 10-5 | -4.16 x 10-6 | -1.37 x 10-4 | -6.18 x 10-5 |
| R-30 | 0.15 - 0.29 | – | – | – | -1.08 x 10-7 | -3.76 x 10-6 | -1.77 x 10-6 |
| R-30 | 0.3 – 0.49 | – | – | – | -1.19 x 10-6 | -3.68 x 10-5 | -1.74 x 10-5 |
| R-30 | 0.5 – 0.69 | -2.72 x 10-6 | -7.35 x 10-5 | -3.29 x 10-5 | -2.34 x 10-6 | -7.31 x 10-5 | -3.62 x 10-5 |
| R-30 | ≥ 0.7 | -3.34 x 10-6 | -1.09 x 10-4 | -4.88 x 10-5 | -3.60 x 10-6 | -1.09 x 10-4 | -5.07 x 10-5 |
| R-38 | 0.15 - 0.29 | – | – | – | -1.87 x 10-7 | -6.50 x 10-6 | -3.06 x 10-6 |
| R-38 | 0.3 – 0.49 | – | – | – | -9.37 x 10-7 | -3.12 x 10-5 | -1.36 x 10-5 |
| R-38 | 0.5 – 0.69 | -3.05 x 10-6 | -6.05 x 10-5 | -2.85 x 10-5 | -2.37 x 10-6 | -5.95 x 10-5 | -2.87 x 10-5 |
| R-38 | ≥ 0.7 | -3.85 x 10-6 | -8.74 x 10-5 | -4.03 x 10-5 | -3.19 x 10-6 | -8.78 x 10-5 | -4.27 x 10-5 |

**Table 245. Cool Roofs—Climate Zone 5: El Paso, Winter Peak Demand Savings for Residential Reflective Roof Installation (kW/sq. ft.)**

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| R-19 | 0.15 - 0.29 | – | – | – | – | – | – |
| R-19 | 0.3 – 0.49 | – | – | – | 2.07 x 10-6 | -5.87 x 10-5 | -2.38 x 10-5 |
| R-19 | 0.5 – 0.69 | 7.97 x 10-7 | -1.30 x 10-4 | -5.39 x 10-5 | 1.10 x 10-6 | -1.31 x 10-4 | -5.30 x 10-5 |

| Roof deck insulation R-value | Installed roof material 3-year reflectance | Low slope | | | Steep slope | | |
|---|---|---|---|---|---|---|---|
| | | Gas | Electric resistance | Heat pump | Gas | Electric resistance | Heat pump |
| R-19 | > 0.7 | -1.19 x 10-6 | -2.13 x 10-4 | -8.83 x 10-5 | -8.95 x 10-7 | -2.10 x 10-4 | -8.53 x 10-5 |
| R-30 | 0.15 - 0.29 | – | – | – | -1.04 x 10-7 | -4.45 x 10-6 | -1.81 x 10-6 |
| R-30 | 0.3 – 0.49 | – | – | – | 4.81 x 10-7 | -4.81 x 10-5 | -1.95 x 10-5 |
| R-30 | 0.5 – 0.69 | 3.74 x 10-8 | -1.01 x 10-4 | -4.16 x 10-5 | -7.12 x 10-7 | -1.01 x 10-4 | -4.15 x 10-5 |
| R-30 | > 0.7 | -1.64 x 10-6 | -1.61 x 10-4 | -6.73 x 10-5 | -2.51 x 10-6 | -1.60 x 10-4 | -6.58 x 10-5 |
| R-38 | 0.15 - 0.29 | – | – | – | -1.79 x 10-7 | -7.68 x 10-6 | -3.13 x 10-6 |
| R-38 | 0.3 – 0.49 | – | – | – | -6.75 x 10-7 | -4.04 x 10-5 | -1.63 x 10-5 |
| R-38 | 0.5 – 0.69 | -5.15 x 10-7 | -7.93 x 10-5 | -3.26 x 10-5 | -2.03 x 10-6 | -7.94 x 10-5 | -3.31 x 10-5 |
| R-38 | > 0.7 | -1.97 x 10-6 | -1.24 x 10-4 | -5.20 x 10-5 | -3.68 x 10-6 | -1.24 x 10-4 | -5.16 x 10-5 |

## Example Deemed Savings Calculation

**Example 1.** A contractor installs 1500 square feet of white asphalt shingle roofing with a 3-year rated reflectance of 0.55 on a home in Climate Zone 3 with a roof slope of 4/12, refrigerated air, and a gas furnace, which has existing ceiling insulation estimated at R-12.

$$Energy\ Savings = (0.26 - 0.01) \times 1500 = 375\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 2.03x10^{-4} \times 1500 = 0.30\ kW$$

$$Winter\ Peak\ Demand\ Savings = -6.46x10^{-6} \times 1500 = -0.01\ kW$$

**Example 2.** A contractor applies a reflective coating to a 1200 square foot home with a heat pump and a low-slope roof in Climate Zone 2, with R-19 roof deck insulation. The coating has a 3-year rated reflectance of 0.75.

$$Energy\ Savings = (0.32 - 0.11) \times 1200 = 252\ kWh$$

$$Summer\ Peak\ Demand\ Savings = N/A$$

$$Winter\ Peak\ Demand\ Savings = -5.96x10^{-5} \times 1200 = -0.07\ kW$$

## 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) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID BS-LtRoof.[258]

## 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:

- Climate zone or county
- Insulation R-value (as is, post measure installation of ceiling/roof insulation)
- Only for homes with a reported baseline R-value that is less than R-5:
    - Two pictures: (1) a picture showing the entire attic floor, and (2) a close-up picture of a ruler that shows the measurement of the depth of the insulation.

      Note: The second photo type is required for each area of insulation where there are varying R-values less than R-5. Additionally, both photo types are required for all separate attic/ceiling areas, even when the installed R-value is the same.
- Cooling type (evaporative cooling, central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
    - Because heating savings are negative, no adjustment factor will be applied to projects with missing documentation
- Square footage of reflective roofing material installed
- Slope of the roof (low or high slope)
- Three-year solar reflectance as rated by Cool Roof Rating Certification of the reflective material installed
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

[258] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

## References and Efficiency Standards

### Petitions and Rulings

- Docket No. 47755-1. Petition of AEP Texas Inc., CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company. Petition To Approve Revisions To Residential And Nonresidential Deemed Savings Incorporated In Texas Technical Reference Manual Version 5.0 Program Year 2018 And Deemed Savings Derived For A New Measure. Public Utility Commission of Texas.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 246. Cool Roofs—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v6.0 | 11/2018 | TRM v6.0 origin. |
| v7.0 | 11/2019 | TRM v7.0 update. Added savings for R-30 insulation. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated savings tables. Added space heat adjustment factor and electric resistance documentation requirement. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated savings tables for < R-5 baseline category. Updated EUL reference. |
| v10.0 | 10/2022 | TRM v10.0 update. Addressed sunsetting of ENERGY STAR Roof program. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision. |

## 2.3.9 Solar Screens Measure Overview

**TRM Measure ID:** R-BE-SS

**Market Sector:** Residential

**Measure Category:** Building envelope

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Building simulation modeling

## Measure Description

Savings are presented for the installation of solar screens on west- and/or south-facing windows or glass doors. Deemed savings are calculated per square foot of treated window or door opening.

## Eligibility Criteria

Cooling savings in this measure apply to customers with central or mini-split electric refrigerated air conditioning in their homes, or to customers in TRM Climate Zones 1 and 5 who have evaporative cooling systems. The heating savings penalty applies to homes that are centrally heated with either a furnace (gas or electric resistance) or a heat pump. Customers who participate in hard-to-reach (HTR) or low-income (LI) programs are eligible to claim reduced heating savings for homes heated with gas or electric resistance space heaters by applying an adjustment to deemed savings that is specified for that heat type. Customers participating in HTR or LI programs are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that is specified for homes with central refrigerated air.

Solar screens must be installed on windows or glass doors that face west or south and receive significant direct sun exposure. Solar screens must block at least 65 percent of the solar heat gain to qualify for deemed savings.

## Baseline Condition

The baseline is a single pane, clear glass, unshaded, west-, or south-facing window with a solar heat gain coefficient of 0.68. The baseline window area is assumed to be 7.5 percent of the total wall area.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[259] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[260] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer/Winter Demand Savings Tables sections.

## High-Efficiency Condition

Solar screen material installed on south- or west-facing windows must reduce solar heat gain by at least 65 percent. Solar screens are not recommended for homes with electric resistance heat.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Deemed savings values have been estimated using calibrated simulation models. Specifically, these deemed savings estimates were developed using BEopt 2.6, running EnergyPlus 8.4 as the underlying simulation engine. A single modification was made to the prototype models for the various climate zone-HVAC type combinations to create the base case models for estimating savings for the solar screens measure. Windows facing all directions are assumed to be single-pane windows with U-values of 1.16 BTU/h-sq. ft.-R and solar heat gain coefficients (SHGC) of 0.76.

For the change case models, an 80 percent reduction was applied to the solar heat gain coefficient for the south- and west-facing windows.

Summer and winter peak demand savings are estimated by taking the difference in demand for the 20 hours identified from the TMY3 datasets in which the summer and winter peaks are most likely to occur, as described in TRM Volume 1 Section 4 - Peak Demand Definitions.

The model assumes the average solar screen installed blocks 80 percent of the solar heat gain attributed to the south and west-facing windows based on performance data from solar screens analyzed at sun angles of 30, 45, and 75 degrees to the window. [261]

While it is recommended that solar screens be removed during winter to allow the advantage of free heat from the sun, they are often not removed seasonally. This may be due to solar screens serving as an insect screen in addition to blocking the sun or simply that they're installed in difficult-to-reach areas such as second-floor windows. The savings estimates presented herein assume that the installed solar screens remain in place year-round.

[259] Electric Resistance Heating: https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[260] Portable Heaters: https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

[261] Performance data from Matrix, Inc., Mesa, Arizona testing facility for Phifer Wire Products' SunTex screen, blocks 80 percent of solar heat gain.

### *Thermal Performance Improvement*

Manual J and other studies researched indicate a thermal improvement to a window with a solar screen due to reduced air infiltration. The National Certified Testing Laboratories provided a report stating a 15 percent reduction in the thermal transmittance of a single pane, ¼" clear glass window with a solar screen added to the exterior.

Another study that was conducted for NFRC indicated between a 22 percent and 4 percent improvement to the U-value of a window with a solar screen. A single pane, clear window has a 22 percent improvement with the addition of a solar screen, whereas a double pane, spectrally selective low-E window may only have a 4 percent improvement. The deemed savings models assume an average 10 percent improvement in thermal performance with the addition of a solar screen.

### *Window Frame*

The window frame accounts for 10-30 percent[262] of the window area, and since it is opaque and blocks sunlight from entering the home, it is factored into the model. An average of 15 percent frame area was incorporated into the performance of the window.

### *Example Calculation*

**Example 1.** A home in Climate Zone 4 with a central air conditioning unit and an electric resistance furnace installs 75 square feet of solar screens.

$$Energy\ Savings = \left(6.09 + (-3.21)\right) \times 75 = 216\ kWh$$

$$Summer\ Peak\ Demand\ Savings = 3.17 \times 10^{-3} \times 75 = 0.24\ kW$$

$$Winter\ Peak\ Demand\ Savings = -2.32 \times 10^{-3} \times 75 = -0.17\ kW$$

## Deemed Energy Savings Tables

Table 247 presents the deemed energy savings value per square foot of solar screen installed. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

For customers who participate in hard-to-reach (HTR) or low-income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate cooling value in Table 247 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 247 by a factor of 0.24.[263]

[262] Residential Windows – A Guide to New Technologies and Energy Performance, 2000.
[263] This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

**Table 247. Solar Screens—Energy Savings (kWh) per Square Foot of Solar Screen**

| Climate zone | Cooling savings (kWh/sq. ft.) | | Heating savings (kWh/sq. ft.) | | |
|---|---|---|---|---|---|
| | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | 3.67 | 1.34 | -0.62 | -12.81 | -4.54 |
| Zone 2: Dallas | 5.38 | - | -0.29 | -7.14 | -2.56 |
| Zone 3: Houston | 5.33 | - | -0.16 | -4.69 | -1.69 |
| Zone 4: Corpus Christi | 6.09 | - | -0.09 | -3.21 | -1.16 |
| Zone 5: El Paso | 5.62 | 1.99 | -0.44 | -10.48 | -3.81 |

## Deemed Summer Demand Savings Tables

Table 248 presents the deemed summer peak demand savings value per square foot of solar screen installed.

For customers who participate in HTR/LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate cooling value in Table 248 by a factor of 0.6.

**Table 248. Solar Screens—Summer Peak Demand Savings (kW) per Square Foot of Solar Screen**

| Climate zone | Refrigerated | Evaporative |
|---|---|---|
| Zone 1: Amarillo | 2.89E-03 | 1.35E-03 |
| Zone 2: Dallas | 3.42E-03 | - |
| Zone 3: Houston | 3.29E-03 | - |
| Zone 4: Corpus Christi | 3.17E-03 | - |
| Zone 5: El Paso | 3.12E-03 | 1.07E-03 |

## Deemed Winter Demand Savings Tables

Table 249 presents the deemed winter peak demand savings value per square foot of solar screen installed.

For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate heating values in Table 249 by a factor of 0.24.[264]

[264] This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

**Table 249. Solar Screens—Winter Peak Demand Savings (kW) per Square Foot of Solar Screen**

| Climate zone | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| Zone 1: Amarillo | -1.16E-04 | -1.73E-03 | -9.45E-04 |
| Zone 2: Dallas | -5.20E-05 | -1.32E-03 | -7.96E-04 |
| Zone 3: Houston | -1.07E-04 | -2.65E-03 | -1.71E-03 |
| Zone 4: Corpus Christi | -7.68E-05 | -2.32E-03 | -1.08E-03 |
| Zone 5: El Paso | -1.45E-04 | -3.34E-03 | -1.30E-03 |

### 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) is 10 years as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID BS-WinFilm.[265]

## 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
- Cooling type (evaporative cooling, central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
    - Because heating savings are negative, no adjustment factor will be applied to projects with missing documentation
- Square footage of windows or door openings treated
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification

[265] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

## References and Efficiency Standards

### Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Energy for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 41070. Petition of El Paso Electric Company to Approve Revisions to Residential and Commercial Deemed Savings Based on Climate Data Specific to El Paso, Texas. Public Utility Commission of Texas.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 250. Solar Screens—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Added detail on methodology and model characteristics. Savings awarded for south-facing windows, in addition to east- and west-facing windows. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air. Climate Zone 2 savings values awarded for Climate Zone 5 homes with heat pumps. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Provided example savings calculations. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling. |
| v5.0 | 10/2017 | TRM v5.0 update. Added explicit reference to mini-split technology. Added provision for low-income and hard-to-reach customers cooled by room air conditioners to claim savings. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. Updated documentation requirements. |
| v8.0 | 10/2020 | TRM v8.0 update. Added space heat adjustment factor and electric resistance documentation requirement. |
| 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. No revision. |

## 2.3.10 ENERGY STAR® Windows Measure Overview

**TRM Measure ID:** R-BE-EW

**Market Sector:** Residential

**Applicable Building Types:** Single-family, multifamily, manufactured

**Measure Category:** Building envelope

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Building simulation modeling

## Measure Description

Replacing existing single- or double-pane windows with ENERGY STAR-compliant windows can help reduce heat transfer through window glazing, minimize air infiltration around window frames, reduce sun ultraviolet damage to household furniture, and lower household energy bills by an average of 12 percent nationwide.[266]

Window savings are calculated on a per-square-foot-of-window basis, inclusive of frame and sash.

## Eligibility Criteria

Cooling savings in this measure apply to customers with central or mini-split electric refrigerated air conditioning in their homes, or to customers in TRM Climate Zones 1 and 5 who have evaporative cooling systems. Homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Customers who participate in hard-to-reach (HTR) or low-income (LI) programs are eligible to claim reduced heating savings for homes heated with gas or electric resistance space heaters by applying an adjustment to deemed savings that is specified for that heat type. Customers participating in HTR or LI programs are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that is specified for homes with central refrigerated air.

## Baseline Condition

There are two base cases: single-pane and double-pane windows. In both cases, a metal frame is specified. Estimated U-Values and SHGCs for baseline windows are presented in Table 251. A weighted single- and double-pane baseline is also provided, assuming a standard distribution

[266] ENERGY STAR Windows, Doors, & Skylights. https://www.energystar.gov/products/res_windows_doors_skylights.

of 46 percent single-pane and 54 percent double-pane based on 2020 RECS survey data.[267] This baseline may be used exclusively if applied consistently for all projects.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[268] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[269] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer/Winter Demand Savings Tables sections.

**Table 251. Windows—Baseline Window Specification**

| Number of panes | U-factor Btu/(h·sq. ft.·°F) | Solar heat gain coefficient (SHGC) |
|---|---|---|
| 1 | 1.16 | 0.76 |
| 2 | 0.76 | 0.67 |

## High-Efficiency Condition

Performance criteria are based on ratings certified by the National Fenestration Rating Council (NFRC) and vary by location.

The table below displays the ENERGY STAR Final Version 7.0 Requirements for eligible windows, doors, and skylights effective October 23, 2023.[270] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

**Table 252. Windows—ENERGY STAR Requirements[271]**

| US region, ENERGY STAR | U-factor Btu/(h·sq. ft.·°F) | Solar heat gain coefficient (SHGC) |
|---|---|---|
| North-Central | ≤ 0.25 | ≤ 0.40 |
| South-Central | ≤ 0.28 | ≤ 0.23 |
| Southern | ≤ 0.32 | ≤ 0.23 |

[267] 2020 Residential Energy Consumption Survey (RECS). Structural and geographic characteristics in the South and West regions (HC2.8). Analysis based on West South-Central census region. https://www.eia.gov/consumption/residential/data/2020/.

[268] Electric Resistance Heating. https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[269] Portable Heaters. https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

[270] ENERGY STAR Residential Windows, Doors, and Skylights Final Version 6.0 Program Requirements. https://www.energystar.gov/sites/default/files/ES_Residential_WDS_V7_Final%20Specification%202022.pdf.

[271] ENERGY STAR Windows, Doors, and Skylights Climate Zone Finder. Note that these zones differ from the TRM climate zones. https://www.energystar.gov/products/building_products/residential_windows_doors_and_skylights/climate_zone/search.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

Deemed savings values have been estimated using calibrated simulation models. Base case homes were fitted with single-pane and double-pane windows. Efficiency case homes were equipped with windows meeting the appropriate ENERGY STAR window specification for the location in which the window was to be installed. The climate zones in the ENERGY STAR windows specification were mapped to the Texas TRM climate zones as shown in Table 253.

**Table 253. Windows—TRM and ENERGY STAR Climate Zones**

| Climate zone | US region, ENERGY STAR |
|---|---|
| Zone 1: Amarillo | North-Central |
| Zone 2: Dallas | South-Central |
| Zone 3: Houston | Southern |
| Zone 4: Corpus Christi | Southern |
| Zone 5: El Paso | South-Central |

### Deemed Energy Savings Tables

Table 254 through Table 256 present the energy savings (kWh) for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

For customers who participate in hard-to-reach (HTR) or low-income (LI) programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate cooling values in Table 254 and Table 256 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate deemed heating values by a factor of 0.24.[272]

[272] This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

**Table 254. Windows—Energy Savings (kWh/sq. ft.), Single-Pane Baseline**

| Climate zone | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|
| | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | 2.83 | 0.98 | 0.29 | 6.70 | 3.16 |
| Zone 2: Dallas | 5.42 | – | 0.10 | 3.09 | 1.45 |
| Zone 3: Houston | 5.32 | – | 0.02 | 0.77 | 0.41 |
| Zone 4: Corpus Christi | 5.97 | – | 0.02 | 0.82 | 0.34 |
| Zone 5: El Paso | 5.67 | 1.90 | 0.00 | 0.99 | 0.69 |

**Table 255. Windows—Energy Savings (kWh/sq. ft.), Double-Pane Baseline**

| Climate zone | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|
| | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | 2.03 | 0.72 | 0.18 | 4.15 | 2.00 |
| Zone 2: Dallas | 4.11 | – | 0.04 | 1.47 | 0.76 |
| Zone 3: Houston | 3.96 | – | -0.01 | -0.21 | 0.01 |
| Zone 4: Corpus Christi | 4.45 | – | 0.00 | -0.01 | 0.02 |
| Zone 5: El Paso | 4.24 | 1.46 | -0.03 | -0.18 | 0.16 |

**Table 256. Windows—Energy Savings (kWh/sq. ft.), Weighted-Pane Baseline**

| Climate zone | Cooling savings | | Heating savings | | |
|---|---|---|---|---|---|
| | Refrigerated | Evaporative | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | 2.40 | 0.84 | 0.23 | 5.33 | 2.54 |
| Zone 2: Dallas | 4.71 | – | 0.07 | 2.22 | 1.08 |
| Zone 3: Houston | 4.59 | – | – | 0.24 | 0.19 |
| Zone 4: Corpus Christi | 5.15 | – | 0.01 | 0.37 | 0.17 |
| Zone 5: El Paso | 4.90 | 1.66 | -0.02 | 0.36 | 0.40 |

## Deemed Summer Demand Savings Tables

Table 257 through Table 259 presents the summer demand savings (kW) for the five Texas climate zones.

For customers who participate in HTR/LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate deemed cooling values by a factor of 0.6.

**Table 257. Windows—Summer Peak Demand Savings (kW/sq. ft.), Single-Pane Baseline**

| Climate zone | Refrigerated | Evaporative |
|---|---|---|
| Zone 1: Amarillo | 3.09E-03 | 1.16E-03 |
| Zone 2: Dallas | 3.89E-03 | – |
| Zone 3: Houston | 3.51E-03 | – |
| Zone 4: Corpus Christi | 2.99E-03 | – |
| Zone 5: El Paso | 3.86E-03 | 1.05E-03 |

**Table 258. Windows—Summer Peak Demand Savings (kW/sq. ft.), Double-Pane Baseline**

| Climate zone | Refrigerated | Evaporative |
|---|---|---|
| Zone 1: Amarillo | 2.08E-03 | 8.36E-04 |
| Zone 2: Dallas | 2.80E-03 | – |
| Zone 3: Houston | 2.40E-03 | – |
| Zone 4: Corpus Christi | 2.15E-03 | – |
| Zone 5: El Paso | 2.76E-03 | 8.09E-04 |

**Table 259. Windows—Summer Peak Demand Savings (kW/sq. ft.), Weighted-Pane Baseline**

| Climate zone | Refrigerated | Evaporative |
|---|---|---|
| Zone 1: Amarillo | 2.55E-03 | 9.86E-04 |
| Zone 2: Dallas | 3.30E-03 | – |
| Zone 3: Houston | 2.91E-03 | – |
| Zone 4: Corpus Christi | 2.54E-03 | – |
| Zone 5: El Paso | 3.27E-03 | 9.20E-04 |

Deemed Winter Demand Savings Table 260 through Table 262 presents the winter demand savings (kW) for the five Texas climate zones.

For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate deemed heating values by a factor of 0.24.[273]

[273] This factor was derived based on expected capacity reduction assuming 1200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

**Table 260. Windows—Winter Peak Demand Savings (kW/sq. ft.), Single-Pane Baseline**

| Climate zone | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| Zone 1: Amarillo | 2.01E-04 | 4.98E-03 | 2.43E-03 |
| Zone 2: Dallas | 1.77E-04 | 4.73E-03 | 2.74E-03 |
| Zone 3: Houston | 6.89E-05 | 1.78E-03 | 3.11E-04 |
| Zone 4: Corpus Christi | 4.78E-05 | 1.65E-03 | 6.68E-04 |
| Zone 5: El Paso | 2.83E-05 | 1.10E-03 | 5.00E-04 |

**Table 261. Windows—Winter Peak Demand Savings (kW/sq. ft.), Double-Pane Baseline**

| Climate zone | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| Zone 1: Amarillo | 1.32E-04 | 3.30E-03 | 1.64E-03 |
| Zone 2: Dallas | 1.12E-04 | 3.16E-03 | 1.89E-03 |
| Zone 3: Houston | 2.33E-05 | 6.68E-04 | 3.58E-06 |
| Zone 4: Corpus Christi | 1.53E-05 | 5.62E-04 | 2.34E-04 |
| Zone 5: El Paso | 1.31E-05 | 5.84E-04 | 2.76E-04 |

**Table 262. Windows—Winter Peak Demand Savings (kW/sq. ft.), Weighted-Pane Baseline**

| Climate zone | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| Zone 1: Amarillo | 1.64E-04 | 4.08E-03 | 2.00E-03 |
| Zone 2: Dallas | 4.42E-04 | 3.88E-03 | 2.28E-03 |
| Zone 3: Houston | 4.44E-05 | 1.18E-03 | 1.46E-04 |
| Zone 4: Corpus Christi | 3.03E-05 | 1.06E-03 | 4.34E-04 |
| Zone 5: El Paso | 2.01E-05 | 8.22E-04 | 3.79E-04 |

## Example Deemed Savings Calculation

**Example 1.** A home in Climate Zone 1 with evaporative cooling and an electric resistance furnace replaces 125 square feet of single-pane windows with ENERGY STAR windows.

$$Energy\ Savings = (0.98\ +\ 6.70)\ \times\ 125 = \mathit{960\ kWh}$$

$$Summer\ Peak\ Demand\ Savings = 1.16x10^{-3}\ \times\ 125 = 0.15\ kW$$

$$Winter\ Peak\ Demand\ Savings = 4.98x10^{-3}\ \times\ 125 = 0.62\ kW$$

**Example 2.** A home in Climate Zone 5 with a central air conditioning unit and a gas furnace replaces 250 square feet of windows with unknown number of panes with ENERGY STAR windows.

$$Energy\ Demand\ Savings = \left(4.90 + \ (-0.02)\right)\ \times\ 250 = \mathit{1{,}220\ kWh}$$

$$Summer\ Peak\ Demand\ Savings = 3.27\ \times\ 10^{-3}\ \times\ 250 = 0.82\ kW$$

$$Winter\ Peak\ Demand\ Savings = 2.01\ \times\ 10^{-5}\ \times\ 250 = 0.01\ kW$$

## 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

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007), the Estimated Useful Life is 25 years for ENERGY STAR windows[274].

## 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:

- Climate zone or county
- Cooling type (evaporative cooling, central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
  - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
  - If documentation is not provided, an adjustment factor of 0.75 will be applied to the heating energy and winter demand savings
- Baseline window number of panes (single, double, weighted)
  - The weighted baseline may be used if applied universally for all projects in a given program during the entire program year.
- U-factor and SHGC of each new window
- Area of new ENERGY STAR windows
- Proof of purchase – with date of purchase and quantity
  - Alternative: photo of unit installed or another pre-approved method of installation verification.

[274] "Measure Life Report: Residential and Commercial Industrial Lighting and HVAC Measures," The New England State Program Working Group (SPWG). June 2007. https://library.cee1.org/sites/default/files/library/8842/CEE_Eval_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf.

## References and Efficiency Standards

### Petitions and Rulings

- Docket No. 22241, Item 48. Petition by Frontier Energy for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 27903. Order Adopting New §25.184 as Approved at the August 21, 2003, Open Meeting and Submitted to the Secretary of State. Public Utility Commission of Texas.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 263. Windows—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Minor edits to language. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. Multiplier provided to adjust cooling side savings for homes with evaporative cooling due to lower energy usage and demand associated with evaporative coolers relative to refrigerated air. Climate Zone 2 savings values awarded for Climate Zone 5 homes. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Provided example savings calculations. Consolidated table formats. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Updated energy and demand savings per new prototype energy simulation models. Added separate savings for homes with evaporative cooling. |
| v5.0 | 10/2017 | TRM v5.0 update. Added explicit reference to mini-split technology |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. Updated documentation requirements. |
| v8.0 | 10/2020 | TRM v8.0 update. Added space heat adjustment factor and electric resistance documentation requirement. |
| v9.0 | 10/2021 | TRM v9.0 update. No revision. |
| v10.0 | 10/2022 | TRM v10.0 update. Added option for a weighted single-pane and double-pane baseline. |
| v11.0 | 10/2023 | TRM v11.0 update. Updated ENERGY STAR specification. Added electric resistance documentation adjustment factor. |

## 2.3.11 ENERGY STAR® Low-E Storm Windows Measure Overview

**TRM Measure ID:** R-BE-SW

**Market Sector:** Residential

**Applicable Building Types:** Single-family, multifamily, manufactured

**Measure Category:** Building envelope

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Building simulation modeling and third-party field testing

## Measure Description

ENERGY STAR low-e storm windows are a glazing attachment added to single- or double-pane windows. Storm windows are an affordable option for homes where full window replacement may be difficult. Low-emissivity (low-e) metal oxide coating decreases the summer heat gain and winter heat loss of an existing window by reducing thermal transmission. Thermal transmission is reduced as follows:

- The low-e coating acts as a selective heat mirror that reflects infrared light back outside during the summer and back onto the home during the winter.
- The marine-quality glazing and caulked or compression-sealed interface reduces air leakage and infiltration.
- The dead air space, or air barrier, created between the existing window and new storm window frame further reduces thermal transmission during both summer and winter.

The low-e coating is extremely durable and has negligible impact on visible light transmission.

## Eligibility Criteria

A low-e storm window may be installed on the interior or exterior of the existing window assembly. Installation is a simple process that is often completed by residential homeowners without the assistance of professional contractors. Due to the simple installation process, low-e storm windows are sometimes installed seasonally. However, savings estimates assume windows are installed for the entire year. Therefore, windows should be permanently mounted and operable.

Cooling savings in this measure apply to customers with central or mini-split electric refrigerated air conditioning in their homes. Homes must be centrally heated with either a furnace (gas or electric resistance) or a heat pump to claim heating savings. Customers who participate in hard-to-reach (HTR) or low-income (LI) programs are eligible to claim reduced heating savings for homes heated with gas or electric resistance space heaters by applying an adjustment to deemed savings that is specified for that heat type. Customers participating in HTR or LI programs are also eligible to claim reduced cooling savings for homes cooled by one or more room air conditioners by applying an adjustment to deemed savings that is specified for homes with central refrigerated air.

## Baseline Condition

The baseline condition is an existing single- or double-pane window assembly according to manufacturer specifications. A weighted single- and double-pane baseline is also provided, assuming a standard distribution of 46 percent single-pane and 54 percent double-pane based on 2020 RECS survey data.[275] This baseline may be used exclusively if applied consistently for all projects.

Electric resistance heating baselines may refer to residences heated by a centralized forced-air furnace or by individual space heaters.[276] Space heating primarily refers to electric baseboard zonal heaters controlled by thermostats or to portable plug-load heaters.[277] Electric resistance heat controlled by a wall thermostat is eligible to claim the deemed savings presented in this measure. Homes with portable space heaters may be eligible for reduced savings as described in the Deemed Energy and Summer/Winter Demand Savings Tables sections.

## High-Efficiency Condition

Performance criteria are based on ratings certified by the National Fenestration Rating Council (NFRC) and vary by location.

The table below displays the ENERGY STAR Final Version 1.0 Requirements for eligible exterior and interior storm windows effective September 5, 2018.[278] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

[275] 2020 Residential Energy Consumption Survey (RECS). Structural and geographic characteristics in the South and West regions (HC2.8). Analysis based on West South-Central census region. https://www.eia.gov/consumption/residential/data/2020/.

[276] Electric Resistance Heating. https://www.energy.gov/energysaver/home-heating-systems/electric-resistance-heating.

[277] Portable Heaters. https://www.energy.gov/energysaver/home-heating-systems/portable-heaters.

[278] ENERGY STAR Program Requirements Product Specification for Exterior and Interior Storm Windows, v1.0. https://www.energystar.gov/sites/default/files/Storm%20Window%20Product%20Specification_Final_0.pdf.

**Table 264. Low-E Storm Windows—ENERGY STAR Requirements**

| US region, ENERGY STAR | Emissivity | Solar transmission |
|---|---|---|
| North-Central | ≤ 0.22 | Any |
| South-Central | ≤ 0.22 | ≤ 0.55 |
| Southern | ≤ 0.22 | ≤ 0.55 |

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Deemed savings values have been estimated using Lawrence Berkeley National Laboratory's RESFEN building simulation models for residential fenestration.[279] The properties of low-e storm windows used in the RESFEN building models are presented in Table 265. This measure assumes equal weighting between the three low-e storm window glass options.

**Table 265. Low-E Storm Windows—Window Assembly Properties[280]**

| Window type | Glass options | U-factor | SHGC | Air leakage |
|---|---|---|---|---|
| Storm window over existing single-pane | Low-e | 0.35 | 0.47 | 1.25 |
| | Low-e with solar control | 0.35 | 0.32 | 1.25 |
| Storm window over existing double-pane | Low-e | 0.26 | 0.43 | 1.25 |
| | Low-e with solar control | 0.27 | 0.29 | 1.25 |

Assumed building characteristics are based on a 1,700 square-foot single-story and 2,800 square-foot two-story residence. The modeled residence has a 15 percent window-to-floor-area ratio. Assumed building characteristics are presented in Table 266.

**Table 266. Low-E Storm Windows—Modeled Building Characteristics**

| Characteristic | Model assumption |
|---|---|
| Area | Single-story: 1,700 sq. ft.<br>Two-story: 2,800 sq. ft. |
| Existing window performance[281,282] | Single pane: 0.88 U-factor, 0.61 SHGC, 2 cfm/sq. ft. air infiltration<br>Double pane: 0.51 U-factor, 0.57 SHGC, 2 cfm/sq. ft. air infiltration |
| Existing window area | 15 percent of floor area |

279 RESFEN window tool. LBNL. https://windows.lbl.gov/software/resfen.

280 Averaged values from the selected products in Attachments Energy Rating Council (AERC). https://aercenergyrating.org/product-search/residential-product-search/.

281 Culp, TD and KA Cort. "Database of Low-e Storm Window Energy Performance across US Climate Zones." US DOE, September 2014. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22864rev2.pdf.

282 Air infiltration assumption from: "AERC 1.2: Physical Test Methods for Measuring Energy Performance Properties of Fenestration Attachments." AERC, 2018. www.aercnet.org.

| Characteristic | Model assumption |
|---|---|
| Existing window frame | Wood double-hung |
| Foundation | Slab on-grade |
| Insulation | Newer construction: IECC 2006 based on climate zone<br>Older construction: See RESFEN 6 documentation |
| HVAC efficiency | Newer construction: 13 SEER, 7.7 HSPF, 0.8 AFUE for IECC Climate Zones 1-3 and 0.9 AFUE for IECC Climate Zones 4-8<br>Older construction: 10 SEER, 6.8 HSPF, 0.78 AFUE |

## Deemed Energy Savings Tables

Table 267 through Table 269 present the energy savings (kWh) for the five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

For customers who participate in HTR or LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate cooling values in Table 267 and Table 269 by a factor of 0.6. Similarly, for HTR/LI customers, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate deemed heating values by a factor of 0.24.[283]

Savings are an average of newer and older construction baselines for retrofit applications.

**Table 267. Low-E Storm Windows—Energy Savings (kWh/sq. ft.), Single-Pane Baseline**

| | Cooling savings | Heating savings | | |
|---|---|---|---|---|
| Climate zone | Refrigerated | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | 1.49 | – | 15.66 | 5.34 |
| Zone 2: Dallas | 2.52 | – | 6.65 | 2.09 |
| Zone 3: Houston | 2.49 | – | 4.55 | 1.48 |
| Zone 4: Corpus Christi | 3.22 | – | 2.82 | 0.80 |
| Zone 5: El Paso | 2.35 | – | 6.00 | 2.06 |

**Table 268. Low-E Storm Windows—Energy Savings (kWh/sq. ft.), Double-Pane Baseline**

| | Cooling savings | Heating savings | | |
|---|---|---|---|---|
| Climate zone | Refrigerated | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | 1.56 | – | 6.23 | 2.35 |
| Zone 2: Dallas | 2.50 | – | 2.46 | 0.88 |
| Zone 3: Houston | 2.62 | – | 1.84 | 0.67 |

283 This factor was derived based on expected capacity reduction assuming 1,200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

| Climate zone | Cooling savings | Heating savings | | |
| --- | --- | --- | --- | --- |
| | Refrigerated | Gas | Electric resistance | Heat pump |
| Zone 4: Corpus Christi | 3.21 | – | 1.05 | 0.32 |
| Zone 5: El Paso | 2.37 | – | 1.90 | 0.79 |

**Table 269. Low-E Storm Windows—Energy Savings (kWh/sq. ft.), Weighted-Pane Baseline**

| Climate zone | Cooling savings | Heating savings | | |
| --- | --- | --- | --- | --- |
| | Refrigerated | Gas | Electric resistance | Heat pump |
| Zone 1: Amarillo | 1.53 | – | 10.58 | 3.73 |
| Zone 2: Dallas | 2.51 | – | 4.39 | 1.44 |
| Zone 3: Houston | 2.56 | – | 3.09 | 1.04 |
| Zone 4: Corpus Christi | 3.21 | – | 1.87 | 0.54 |
| Zone 5: El Paso | 2.36 | – | 3.79 | 1.38 |

## Deemed Summer Demand Savings Tables

Table 270 through Table 272 present the summer demand savings (kW) for the five Texas climate zones.

For customers who participate in HTR/LI programs, cooling savings may be claimed for homes cooled by one or more room air conditioners by multiplying appropriate deemed cooling values by a factor of 0.6.

**Table 270. Low-E Storm Windows—Summer Peak Demand Savings (kW/sq. ft.), Single-Pane Baseline**

| Climate zone | Refrigerated air |
| --- | --- |
| Zone 1: Amarillo | 0.0016 |
| Zone 2: Dallas | 0.0018 |
| Zone 3: Houston | 0.0016 |
| Zone 4: Corpus Christi | 0.0016 |
| Zone 5: El Paso | 0.0016 |

**Table 271. Low-E Storm Windows—Summer Peak Demand Savings (kW/sq. ft.), Double-Pane Baseline**

| Climate zone | Refrigerated air |
| --- | --- |
| Zone 1: Amarillo | 0.0016 |
| Zone 2: Dallas | 0.0017 |
| Zone 3: Houston | 0.0016 |
| Zone 4: Corpus Christi | 0.0016 |
| Zone 5: El Paso | 0.0015 |

**Table 272. Low-E Storm Window—Summer Peak Demand Savings (kW/sq. ft.), Weighted-Pane Baseline**

| Climate zone | Refrigerated air |
|---|---|
| Zone 1: Amarillo | 0.0016 |
| Zone 2: Dallas | 0.0017 |
| Zone 3: Houston | 0.0016 |
| Zone 4: Corpus Christi | 0.0016 |
| Zone 5: El Paso | 0.0015 |

## Deemed Winter Demand Savings Tables

Table 273 through Table 275 present the winter demand savings (kW) for the five Texas climate zones.

For customers who participate in HTR/LI programs, heating savings may be claimed for homes with electric resistance space heaters serving as the primary heating source by multiplying appropriate deemed heating values by a factor of 0.24.[284]

**Table 273. Low-E Storm Windows—Winter Peak Demand Savings (kW/sq. ft.), Single-Pane Baseline**

| Climate zone | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| Zone 1: Amarillo | – | 0.0116 | 0.0041 |
| Zone 2: Dallas | – | 0.0102 | 0.0039 |
| Zone 3: Houston | – | 0.0105 | 0.0011 |
| Zone 4: Corpus Christi | – | 0.0057 | 0.0016 |
| Zone 5: El Paso | – | 0.0067 | 0.0015 |

**Table 274. Low-E Storm Windows—Peak Demand Savings (kW/sq. ft.), Double-Pane Baseline**

| Climate zone | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| Zone 1: Amarillo | – | 0.0050 | 0.0019 |
| Zone 2: Dallas | – | 0.0053 | 0.0022 |
| Zone 3: Houston | – | 0.0039 | 0.0002 |
| Zone 4: Corpus Christi | – | 0.0019 | 0.0037 |
| Zone 5: El Paso | – | 0.0035 | 0.0014 |

284 This factor was derived based on expected capacity reduction assuming 1,200 sq. ft. (historical analysis of HTR participants) x 0.35 BTU/sq. ft. = 42,000 BTU for central electric furnaces and two 1,500-watt portable heaters per home rated at 5,100 BTU/heater. Taking the ratio of portable to furnace capacity yields 10,200 ÷ 42,000 = 0.24.

**Table 275. Low-E Storm Windows—Winter Peak Demand Savings (kW/sq. ft.), Weighted-Pane Baseline**

| Climate zone | Gas | Electric resistance | Heat pump |
|---|---|---|---|
| Zone 1: Amarillo | – | 0.0080 | 0.0029 |
| Zone 2: Dallas | – | 0.0076 | 0.0030 |
| Zone 3: Houston | – | 0.0069 | 0.0006 |
| Zone 4: Corpus Christi | – | 0.0037 | 0.0027 |
| Zone 5: El Paso | – | 0.0050 | 0.0014 |

## Claimed Peak Demand Savings

No load shape could be extracted from the building simulation for this measure. Due to the equivalent load shape with the existing ENERGY STAR Windows measure, demand savings were estimated by applying the ratio of energy to demand savings from the windows measure to the modeled storm windows energy 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 low-e storm windows is 20 years according to the US Department of Energy.[285]

## 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:

- Climate zone or county
- Cooling type (central refrigerated cooling, room air conditioner, none)
- Heating type (central gas, portable gas, central electric resistance, portable electric resistance, heat pump, none)
    - Additional documentation is required to validate electric resistance heat (e.g., nameplate photo, utility inspection, or other evaluator-approved approach); sampling is allowed for multifamily complexes
    - If documentation is not provided, an adjustment factor of 0.75 will be applied to the heating energy and winter demand savings

[285] Culp, TD and KA Cort. "Database of Low-e Storm Window Energy Performance across US Climate Zones." US DOE, September 2014. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22864rev2.pdf.

- Baseline window number of panes (single, double, weighted)
  - The weighted baseline may be used if applied universally for all projects in a given program during the entire program year.
- Emissivity and solar transmission of each new window
- Area of new ENERGY STAR storm windows
- Proof of purchase – with date of purchase and quantity
  - Alternative: photo of unit installed or another pre-approved method of installation verification.

## 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 276. Low-E Storm Windows—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v9.0 | 10/2021 | TRM v9.0 origin. |
| v10.0 | 10/2022 | TRM v10.0 update. Added option for a weighted single-pane and double-pane baseline. |
| v11.0 | 10/2023 | TRM v11.0 update. Added electric resistance documentation adjustment factor. |

## 2.4 RESIDENTIAL: WATER HEATING

### 2.4.1 Water Heater Installations—Electric Tankless and Fuel Substitution Measure Overview

**TRM Measure ID:** R-WH-WH

**Market Sector:** Residential

**Measure Category:** Water heating

**Applicable Building Types:** Single-family, multifamily manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This measure involves installing a new electric tankless[286] or gas-fueled water heater (storage or tankless) in place of an electric storage water heater.

## Eligibility Criteria

This measure involves installing a gas storage, gas (instantaneous tankless), or electric tankless water heater in place of an electric storage water heater that meets all the additional requirements described below. Currently, there are no conventional, electrically fueled storage units that sufficiently exceed the new federal standard to merit inclusion as an efficient condition in these deemed savings.

Savings may be awarded for installations in newly constructed homes where customer and utility representatives provide written indication that an electric storage water heater would otherwise have been installed, along with relevant design documentation showing an electric storage water heater.

[286] Currently, most electric tankless water heaters are rated at or near the federal standard and may yield negative or no energy savings using the current baseline. However, this measure maintains eligibility for any electric tankless water heaters that may be rated above current minimum efficiency requirements.

## Baseline Condition

The baseline condition is an electric storage water heater with baseline efficiency Uniform Energy Factor (UEF) determined by tank size and first hour rating (FHR), a proxy for draw pattern. This baseline is specified according to the current federal energy efficiency standards for residential water heaters with tank sizes from 20 to 120 gallons, effective April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register (see Table 277).[287]

This baseline applies to replace-on-burnout and new construction applications. No additional savings are awarded for early retirement. Early retirement projects should calculate savings using an assumed replace-on-burnout baseline.

**Table 277. DHW Replacements—Federal Standard for Residential Electric Storage Water Heaters**

| Rated storage volume | Draw pattern | First hour rating (FHR)[288,289] | Uniform energy factor (UEF)[290] |
|---|---|---|---|
| ≥ 20 gal and ≤ 55 gal | Very small usage | $0 \leq FHR < 18$ | $0.8808 - (0.0008 \times V_r)$ |
| | Low usage | $18 \leq FHR < 51$ | $0.9254 - (0.0003 \times V_r)$ |
| | Medium usage | $51 \leq FHR < 75$ | $0.9307 - (0.0002 \times V_r)$ |
| | High usage | $75 \leq FHR$ | $0.9349 - (0.0001 \times V_r)$ |
| > 55 gal and ≤ 120 gal | Very small usage | $0 \leq FHR < 18$ | $1.9236 - (0.0011 \times V_r)$ |
| | Low usage | $18 \leq FHR < 51$ | $2.0440 - (0.0011 \times V_r)$ |
| | Medium usage | $51 \leq FHR < 75$ | $2.1171 - (0.0011 \times V_r)$ |
| | High usage | $75 \leq FHR$ | $2.2418 - (0.0011 \times V_r)$ |

## High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v5.0 specification effective April 18, 2023, with qualified products meeting the minimum requirements from

Table 278[291]. However, the ENERGY STAR v5.0 specification does not cover electric tankless water heaters or gas storage products with an FHR less than 51. In these cases, the high efficiency condition corresponds to the respective federal standards for residential water heaters.[292]

---

[287] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32.

[288] "The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs" presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf.

[289] Assume FHR equal to that of installed water heater.

[290] Vr is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.17.

[291] https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Water%20Heaters%20Version%205.0%20Specification%20and%20Partner%20Commitments_0.pdf.

[292] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32.

Table 278 has consolidated both sources in one location for ease of reference.

For water heater replacement and fuel substitution, the new unit must meet the following federal minimum energy factor shown in

Table 278. Water heaters must be installed in accordance with local code requirements.

FHR does not apply to tankless water heaters, which are rated in terms of max gallons per minute (GPM). For gas storage water heaters, reported draw pattern should be consistent with the ENERGY STAR certificate.[293]

**Table 278. DHW Replacements—Efficiency Standards[294]**

| DHW type | Rated storage volume | Draw pattern | FHR | UEF[295] |
|---|---|---|---|---|
| Electric tankless[296] | < 2 gal | Very small usage | N/A | 0.91 |
| | | Low usage | | 0.91 |
| | | Medium usage | | 0.91 |
| | | High usage | | 0.92 |
| Gas tankless | < 2 gal and > 50,000 Btuh | Very small usage | N/A | 0.95 |
| | | Low usage | | |
| | | Medium usage | | |
| | | High usage | | |
| Gas storage | ≥ 20 gal and ≤ 55 gal | Very small usage | 0 ≤ FHR < 18 | 0.3456 – (0.0020 x $V_r$) |
| | | Low usage | 18 ≤ FHR < 51 | 0.5982 – (0.0019 x $V_r$) |
| | | Medium usage | 51 ≤ FHR < 75 | 0.81 |
| | | High usage | 75 ≤ FHR | 0.86 |
| | > 55 gal and ≤ 100 gal | Very small usage | 0 ≤ FHR < 18 | 0.86 |
| | | Low usage | 18 ≤ FHR < 51 | |
| | | Medium usage | 51 ≤ FHR < 75 | |
| | | High usage | 75 ≤ FHR | |

[293] As of August 2023, all gas tankless products on the ENERGY STAR qualified product listing were rated as high usage. https://www.energystar.gov/productfinder/product/certified-water-heaters/results.
[294] 10 CFR Part 430.32 Energy and water conservation standards. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32.
[295] Vr is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.17.
[296] There is no ENERGY STAR tankless water heater category because all products perform at or near the federal standard. These units are still eligible to claim savings against the *electric storage water heater* baseline if draw pattern and UEF can be verified using manufacturer specification sheets or other documentation.

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

All deemed savings values are calculated using the following standard algorithms for water heating. These algorithms assume a replace-on-burnout or new construction scenario but may be used to award savings for early retirement projects.

### *Electric Tankless Water Heater*

**Energy Savings Algorithm**

$$Energy\ Savings\ [\Delta kWh] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,avg}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{3{,}412}$$

**Equation 67**

*Where:*

$\rho$ = *Water density [lbs/gal] = 8.33*

$C_p$ = *Specific heat of water [Btu/lb·°F] = 1*

*GPY* = *Estimated annual hot water use in gallons/year, specified by number of bedrooms in the home (see Table 279). For midstream/upstream applications, the number of bedrooms is assumed to be 3.*[297]

**Table 279. DHW Replacements—Water Heater Consumption (Gal/Year)**[298]

| Climate zone | Number of bedrooms | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Zone 1: Amarillo | 15,476 | 20,171 | 24,866 | 29,561 |
| Zone 2: Dallas | 14,778 | 19,244 | 23,710 | 28,177 |
| Zone 3: Houston | 14,492 | 18,864 | 23,236 | 27,608 |
| Zone 4: Corpus Christi | 14,213 | 18,494 | 22,775 | 27,056 |
| Zone 5: El Paso | 14,905 | 19,412 | 23,920 | 28,427 |

[297] Weighted average of number of bedrooms in West South-Central Region. 2020 RECS Survey Data – Table HC2.8 Structural and geographic characteristics of homes in the South and West regions, 2020. https://www.eia.gov/consumption/residential/data/2020/.

[298] Building America Research Benchmark Definition. December 2009, p 13. Available online: http://www.nrel.gov/docs/fy10osti/47246.pdf.

$T_{setpoint}$ = *Water heater setpoint temperature [°F]*[299] *= 120*

$T_{supply,avg}$ = *Average annual supply water temperature [°F] (see Table 280)*

$UEF_{pre}$ = *Baseline uniform energy factor (see Table 278)*[300]

$UEF_{post}$ = *Uniform energy factor of new water heater (see Table 278)*

*3,412* = *Constant to convert from Btu to kWh*

**Table 280. DHW Replacements—Water Mains Temperature (°F)**[301]

| Climate zone | $T_{supply,avg}$ | $T_{supply,seasonal}$ | |
|---|---|---|---|
| | | Summer | Winter |
| Zone 1: Amarillo | 62.9 | 73.8 | 53.7 |
| Zone 2: Dallas | 71.8 | 84.0 | 60.6 |
| Zone 3: Houston | 74.7 | 84.5 | 65.5 |
| Zone 4: Corpus Christi | 77.2 | 86.1 | 68.5 |
| Zone 5: El Paso | 70.4 | 81.5 | 60.4 |

## Demand Savings Algorithm

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,seasonal}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{365 \times 3{,}412} \times CF_{S/W}$$

**Equation 68**

*Where:*

$CF_{S/W}$ = *Summer/winter peak coincidence factor (see Table 281)*

$T_{supply,seasonal}$ = *Seasonal supply water temperature [°F] (see Table 280)*

299 120°F represents the assumed water heater setpoint. The New York Department of Public Service recommends using the water heater setpoint as a default value, see “New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs.” Page 99. October 2010. The data collection discussed in Appendix D of the EM&V team’s Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) also supports a default value of 120°F.

300 Note that for efficient water heater installations in newly-constructed homes, the baseline energy factor is the efficiency of the electric storage water heater that would otherwise have been installed, according to appropriate design documentation.

301 Based on typical meteorological year (TMY) 3 dataset for TMY3, available through the National Solar Radiation Database (NSRDB) Data Viewer. https://nsrdb.nrel.gov/data-viewer. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

**Table 281. DHW Replacements—Coincidence Factors[302]**

| Climate zone | Summer | Winter |
|---|---|---|
| Zone 1: Amarillo | 0.042 | 0.067 |
| Zone 2: Dallas | 0.039 | 0.068 |
| Zone 3: Houston | 0.041 | 0.070 |
| Zone 4: Corpus Christi | 0.041 | 0.065 |
| Zone 5: El Paso | 0.036 | 0.067 |

## *Gas Storage or Tankless Water Heater (Fuel Substitution)*

Energy and demand savings awarded for replacing an electric water heater with a gas storage or gas tankless water heater are equal to the consumption of the unit replaced.

### Energy Savings Algorithm for Units Less than 55 Gallons

$$Energy\ Savings\ [\Delta kWh] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{UEF_{pre}}\right)}{3{,}412}$$

**Equation 69**

### Demand Savings Algorithm for Units Less than 55 Gallons

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = CF_S \times \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,summer}) \times \left(\frac{1}{UEF_{pre}}\right)}{365 \times 3{,}412}$$

**Equation 70**

$$Winter\ Peak\ Demand\ Savings\ [\Delta kW] = CF_W \times \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,winter}) \times \left(\frac{1}{UEF_{pre}}\right)}{365 \times 3{,}412}$$

**Equation 71**

302 Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from Building America Performance Analysis Procedures for Existing Homes, page 18, Figure 4: Combined Domestic Hot Water Use Profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

## Example Deemed Savings Calculation

**Example 1.** An existing 40-gallon electric water heater in a two-bedroom home in Dallas is replaced with a new, electric tankless water heater with a high usage draw pattern and a uniform energy factor of 0.92. Important: note that energy savings can be negative if the UEF rating does not exceed the equivalent electric storage water heater baseline.

$$\Delta kWh = \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 71.8) \times \left(\frac{1}{0.9309} - \frac{1}{0.92}\right)\right]}{3{,}412} = -29\ kWh$$

$$\Delta kW_S = 0.042 \times \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 84) \times \left(\frac{1}{0.930} - \frac{1}{0.92}\right)\right]}{365 \times 3{,}412} = -0.002\ kW$$

$$\Delta kW_W = 0.068 \times \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 60.6) \times \left(\frac{1}{0.9227} - \frac{1}{0.99}\right)\right]}{365 \times 3{,}412} = -0.007\ kW$$

**Example 2.** An old 30-gallon electric water heater in a one-bedroom house in El Paso is replaced with a new gas storage water heater with a first-hour rating of 51 gal/hr and a uniform energy factor of 0.81.

$$\Delta kWh = \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 70.4) \times \left(\frac{1}{0.9247}\right)\right]}{3{,}412} = 1{,}952\ kWh$$

$$\Delta kW_S = 0.036 \times \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 81.5) \times \left(\frac{1}{0.9247}\right)\right]}{365 \times 3{,}412} = 0.15\ kW$$

$$\Delta kW_W = 0.067 \times \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 60.4) \times \left(\frac{1}{0.9247}\right)\right]}{365 \times 3{,}412} = 0.43\ kW$$

## 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) is 20 years for a tankless water heater (gas or electric), as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-Instant-Res.[303]

The EUL is 11 years for a high-efficiency gas water heater, as specified for EUL ID WtrHt-Res-Gas.

## 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
- Number of bedrooms (not required for upstream/midstream program delivery)
- Water heater quantity
- Manufacturer and model number of new water heater
- ENERGY STAR certificate matching model number (if applicable)
- Baseline volume (gallons), FHR, and UEF
- New water heater volume (gallons, zero if tankless), FHR, and UEF
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

## 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.

[303] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

## Document Revision History

**Table 282. DHW Replacements—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. Updated measure to require electric tankless rather than electric storage water heater installation for non-fuel-switching option. Updated by Frontier Energy, March 2014, based on new federal standards. |
| v2.1 | 01/30/2015 | TRM v2.1 update. Updated to reflect that new construction permitted to claim savings subject to documentation requirements and that gas-fueled tankless water heaters are eligible for installation. |
| v3.0 | 04/10/2015 | TRM v3.0 update. Amended fuel substitution savings to reflect the full consumption of the electric unit being replaced. Revised demand savings for installing an electric tankless unit to reflect daily usage patterns. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Clarified the baseline for water heaters greater than 55 gallons. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Updated HPWH baseline usage for gas storage water heaters larger than 55 gallons. |
| v5.0 | 10/2017 | TRM v5.0 update. No revision. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 11/2019 | TRM v7.0 update. Implemented new baseline and high-efficiency standards. |
| v8.0 | 10/2020 | TRM v8.0 update. Clarified HPWH baseline for tanks sizes over 55 gal. Updated algorithms to refer to UEF. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated EUL reference. |
| v10.0 | 10/2022 | TRM v10.0 update. Verified compliance with ENERGY STAR specification v4.0. Updated documentation requirements. |
| v11.0 | 10/2023 | TRM v11.0 update. Removed requirement to install HPWH for DHW > 55 gallons. Incorporated updated ENERGY STAR specification v5.0. Updated documentation requirements. |

## 2.4.2 ENERGY STAR® Heat Pump Water Heaters Measure Overview

**TRM Measure ID:** R-WH-HW

**Market Sector:** Residential

**Measure Category:** Water heating

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity and gas

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This measure involves the installation of an ENERGY STAR-compliant heat pump water heater (HPWH). Note that this measure does not account for the interactive air conditioning energy savings and heating penalty associated with the HPWH when installed inside conditioned space.

## Eligibility Criteria

This measure applies to residential, electric, and storage-type heat pump water heaters. Heat pump add-ons to existing storage water heaters are ineligible. The measure does not apply to the replacement of gas water heaters.

First hour rating (FHR) is a proxy for draw pattern. There are no certified ENERGY STAR water heaters in the very small usage category, and that draw pattern is not covered in the current ENERGY STAR specification. Approximately 94 percent of certified units are in the medium and high usage categories. However, HPWHs with low usage draw patterns are eligible as long as they comply with minimum ENERGY STAR FHR requirements.

## Baseline Condition

The baseline condition is an electric storage water heater (EWH) with baseline efficiency uniform energy factor (UEF) determined by tank size and FHR. This baseline is specified according to the current federal energy efficiency standards for residential water heaters with tank sizes 20 to 120 gallons, effective April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register.[304]

[304] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. www.ecfr.gov/cgi-bin/text-idx?SID=80dfa785ea350ebeee184bb0ae03e7f0&mc=true&node=se10.3.430_132&rgn=div8.

This baseline applies to replace-on-burnout and new construction applications. No additional savings are awarded for early retirement at this time. Early retirement projects should calculate savings using an assumed replace-on-burnout baseline. However, the Department of Energy (DOE) issued a notice of proposed rulemaking for consumer water heaters on July 27, 2023.[305] The TRM will add an early retirement baseline after the effective date for the new standard.

**Table 283. HPWHs—Federal Standard for Residential Water Heaters**

| Rated storage volume | Draw pattern | FHR [306] [307] | UEF [308] |
|---|---|---|---|
| ≥ 20 gal and ≤ 55 gal | Very small usage | $0 \le FHR < 18$ | $0.8808 - (0.0008 \times V_r)$ |
| | Low usage | $18 \le FHR < 51$ | $0.9254 - (0.0003 \times V_r)$ |
| | Medium usage | $51 \le FHR < 75$ | $0.9307 - (0.0002 \times V_r)$ |
| | High usage | $75 \le FHR$ | $0.9349 - (0.0001 \times V_r)$ |
| > 55 gal and ≤ 120 gal | Very small usage | $0 \le FHR < 18$ | $1.9236 - (0.0011 \times V_r)$ |
| | Low usage | $18 \le FHR < 51$ | $2.0440 - (0.0011 \times V_r)$ |
| | Medium usage | $51 \le FHR < 75$ | $2.1171 - (0.0011 \times V_r)$ |
| | High usage | $75 \le FHR$ | $2.2418 - (0.0011 \times V_r)$ |

## High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v5.0 specification, effective April 18, 2023. Qualified products must meet the minimum requirements from Table 284.[309]

**Table 284. HPWHs—ENERGY STAR Specification**

| Criteria | | ENERGY STAR Requirements |
|---|---|---|
| UEFr | Integrated HPWH | UEF ≥ 3.30 |
| | Integrated HPWH, 120 volt/15 amp circuit | UEF ≥ 2.20 |
| | Split-system HPWH | UEF ≥ 2.20 |

305 Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters. https://www.regulations.gov/document/EERE-2017-BT-STD-0019-0063.

306 "The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs" presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf.

307 Assume FHR equal to that of installed water heater.

308 Vr is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.17.

309 ENERGY STAR HPWH Key Product Criteria. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Water%20Heaters%20Version%205.0%20Specification%20and%20Partner%20Commitments_0.pdf.[310] ENERGY STAR-certified water heaters qualified product listing. https://www.energystar.gov/productfinder/product/certified-water-heaters/?formId=96913462-da32-4dc2-ad53-f31203352209&scrollTo=546&search_text=&type_filter=Hybrid%2FElectric+Heat+Pump&fuel_filter=Electric&brand_name_isopen=0&input_rate_thousand_btu_per_hour_isopen=0&markets_filter=United+

| Criteria | ENERGY STAR Requirements |
|---|---|
| First-hour rating | FHR ≥ 45 gallons per hour |
| Warranty | Warranty ≥ 6 years on sealed system |
| Safety | UL 174 and UL 1995 or UL 60335-2-40 |
| Lower compressor cut-off temperature (reporting requirement only) | Report ambient temperature below which the compressor cuts off and electric-resistance-only operation begins |

A complete list of certified ENERGY STAR HPWHs can be accessed via the ENERGY STAR program website.[310]

HPWHs depend on adequate ventilation to properly function, including adequate space for both inlet and outlet airflow, and should be installed in spaces in where temperature does not drop below a certain level. The Department of Energy recommends installation in locations that remain above 40°F year-round and provide a minimum of 1,000 cubic feet of air space around the water heater.[311] Modern HPWHs operate with little to no change in performance with considerably less air volume. Updated recommendations reduce the air volume requirement to 700 cubic feet.[312] These conditions are not enforced as an eligibility requirement but should be considered when installing an HPWH.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

HPWH savings are calculated on a per-unit basis. Deemed savings are calculated utilizing the standard algorithms outlined below for water heating. Consumption in gallons per year us estimated using data from Building America Performance Analysis Procedures for Existing Homes.[313] Temperature data are based on TMY3 dataset.[314]

States&zip_code_filter=&product_types=Select+a+Product+Category&sort_by=brand_name&sort_direction=asc&page_number=0&lastpage=0.

310 ENERGY STAR-certified water heaters qualified product listing. https://www.energystar.gov/productfinder/product/certified-water-heaters/?formId=96913462-da32-4dc2-ad53-f31203352209&scrollTo=546&search_text=&type_filter=Hybrid%2FElectric+Heat+Pump&fuel_filter=Electric&brand_name_isopen=0&input_rate_thousand_btu_per_hour_isopen=0&markets_filter=United+States&zip_code_filter=&product_types=Select+a+Product+Category&sort_by=brand_name&sort_direction=asc&page_number=0&lastpage=0.

311 Heat Pump Water Heaters. Department of Energy, May 2012. http://energy.gov/energysaver/articles/heat-pump-water-heaters

312 Heat Pump Water Heaters – Code Compliance Brief, U.S. Department of Energy Building Technologies Office. https://basc.pnnl.gov/code-compliance/heat-pump-water-heaters-code-compliance-brief.

313 Building America Performance Analysis Procedures for Existing Homes, page 18, figure 4: combined domestic hot water use profile. https://www.nrel.gov/docs/fy06osti/38238.pdf..

314 TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, https://maps.nrel.gov/nsrdb-viewer/. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

For upstream/midstream program delivery, a default of three bedrooms may be used to calculate the annual hot water use in gallons per year (GPY). The default number of bedrooms was estimated by taking the weighted average calculated from 2020 RECS Survey Data.

## Energy Savings Algorithm

$$Energy\ Savings\ [\Delta kWh] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{3{,}412}$$

**Equation 72**

*Where:*

$\rho$ = *Water density [lbs/gal] = 8.33*

$C_p$ = *Specific heat of water [Btu/lb·°F] = 1*

$GPY$ = *Estimated annual hot water use in gallons/year, specified by number of bedrooms in the home (see Table 285). For midstream/upstream applications, the number of bedrooms is assumed to be 3.*[315]

**Table 285. HPWHs—Water Heater Consumption (Gal/Year)** [316]

| Climate zone | Number of bedrooms | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Zone 1: Amarillo | 15,476 | 20,171 | 24,866 | 29,561 |
| Zone 2: Dallas | 14,778 | 19,244 | 23,710 | 28,177 |
| Zone 3: Houston | 14,492 | 18,864 | 23,236 | 27,608 |
| Zone 4: Corpus Christi | 14,213 | 18,494 | 22,775 | 27,056 |
| Zone 5: El Paso | 14,905 | 19,412 | 23,920 | 28,427 |

$T_{setpoint}$ = *Water heater setpoint temperature [°F]*[317] *= 120*

$T_{supply,annual}$ = *Average annual supply water temperature [°F] (see Table 286)*

[315] Weighted average of number of bedrooms in West South-Central Region. 2020 RECS Survey Data – Table HC2.8 Structural and geographic characteristics of homes in the South and West regions, 2020. https://www.eia.gov/consumption/residential/data/2020/.

[316] Building America Research Benchmark Definition. December 2009, p 13. Available online: http://www.nrel.gov/docs/fy10osti/47246.pdf.

[317] 120°F represents the assumed water heater setpoint. The New York Department of Public Service recommends using the water heater setpoint as a default value, see “New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs.” Page 99. October 2010. The data collection discussed in Appendix D of the EM&V team’s Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) also supports a default value of 120°F.

| | | |
|---|---|---|
| $UEF_{pre}$ | = | *Baseline uniform energy factor (calculate per Table 283)*[318] |
| $UEF_{post}$ | = | *Uniform energy factor of new water heater* |
| *3,412* | = | *Constant to convert from Btu to kWh* |

**Table 286. HPWHs—Water Mains Temperature (°F)[319]**

| Climate zone | $T_{supply,annual}$ | $T_{supply,seasonal}$ | |
|---|---|---|---|
| | | Summer | Winter |
| Zone 1: Amarillo | 62.9 | 73.8 | 53.7 |
| Zone 2: Dallas | 71.8 | 84.0 | 60.6 |
| Zone 3: Houston | 74.7 | 84.5 | 65.5 |
| Zone 4: Corpus Christi | 77.2 | 86.1 | 68.5 |
| Zone 5: El Paso | 70.4 | 81.5 | 60.4 |

## Demand Savings Algorithm

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,seasonal}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{UEF_{post}}\right)}{365 \times 3{,}412} \times CF_{S/W}$$

**Equation 73**

*Where:*

| | | |
|---|---|---|
| $T_{supply,seasonal}$ | = | *Seasonal supply water temperature [°F] (see Table 286)* |
| $CF_{S/W}$ | = | *Summer/winter peak coincidence factor (see Table 287)* |

**Table 287. HPWHs—Coincidence Factors[320]**

| Climate zone | Summer | Winter |
|---|---|---|
| Zone 1: Amarillo | 0.042 | 0.067 |
| Zone 2: Dallas | 0.039 | 0.068 |
| Zone 3: Houston | 0.041 | 0.070 |
| Zone 4: Corpus Christi | 0.041 | 0.065 |

318 Note that for efficient water heater installations in new construction homes, the baseline uniform energy factor is the efficiency of the electric storage water heater that would otherwise have been installed, according to appropriate design documentation.

319 Based on TMY3 dataset. TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, https://maps.nrel.gov/nsrdb-viewer/. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

320 Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from Building America Performance Analysis Procedures for Existing Homes, page 18, Figure 4: Combined Domestic Hot Water Use Profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

| | | |
|---|---|---|
| Zone 5: El Paso | 0.036 | 0.067 |

### 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 this measure is 13 years.[321]

## 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
- Number of bedrooms (not required for upstream/midstream program delivery)
- Manufacturer and model number of new HPWH
- ENERGY STAR certificate matching model number (if applicable)
- HPWH quantity
- HPWH type (integrated HPWH, integrated HPWH 120v/15A circuit, split-system HPWH)
- Baseline volume (gallons), FHR, and UEF

[321] 2010 ACEEE Summer Study on Energy Efficiency in Buildings, LBNL, "Heat Pump Water Heaters and American Homes: A Good Fit?" p 9-74. https://www.aceee.org/files/proceedings/2010/data/papers/2205.pdf.

- New HPWH volume (gallons), FHR, and UEF
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

## 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 288. HPWHs—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. Updated by Frontier Energy, March 2014, based on new federal standards. |
| v2.1 | 01/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 04/10/2015 | TRM v3.0 update. No revision. |
| v3.1 | 11/05/2015 | TRM v3.1 update. No revision. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Consolidated table formats. |
| v5.0 | 10/2017 | TRM v5.0 update. No revision. |
| v6.0 | 11/2018 | TRM v6.0 update. Implementation of new baseline and update to the efficiency of qualifying HPWHs. |
| v7.0 | 10/2019 | TRM v7.0 update. No revision. |
| v8.0 | 10/2020 | TRM v8.0 update. Added new construction eligibility |
| v9.0 | 10/2021 | TRM v9.0 update. Clarified baseline condition. Confirmed ENERGY STAR-qualified product listing still does not contain a significant number of products with low or very small usage patterns. |
| v10.0 | 10/2022 | TRM v10.0 update. Verified compliance with ENERGY STAR Version 4.0 Requirements. Updated savings methodology to algorithm approach. Updated documentation requirements. |
| v11.0 | 10/2023 | TRM v11.0 update. Incorporated updated ENERGY STAR specification v5.0. Updated documentation requirements. |

## 2.4.3 ENERGY STAR® Solar Water Heaters Measure Overview

**TRM Measure ID:** R-WH-SW

**Market Sector:** Residential

**Measure Category:** Water heating

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This measure involves installing a new solar water heater in place of an electric storage water heater. Solar water heating deemed savings values are calculated based on the Solar Rating and Certification Corporation's (SRCC) test for solar water heaters (test OG-300).

## Eligibility Criteria

These deemed savings are for solar water heaters installed as a replace-on-burnout measure or as an early retirement measure in existing homes and in new construction homes. However, savings are calculated under the assumption of replace-on-burnout.

## Baseline Condition

The baseline condition is an electric storage water heater with baseline efficiency uniform energy factor (UEF) determined by tank size and first hour rating (FHR), a proxy for draw pattern. This baseline is specified according to the current federal energy efficiency standards for residential water heaters with tank sizes from 20 to 120 gallons, effective April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register (see Table 279).[322]

This baseline applies to replace-on-burnout, and new construction applications. No additional savings are awarded for early retirement. Early retirement projects should calculate savings using an assumed replace-on-burnout baseline. However, the Department of Energy (DOE) issued a notice of proposed rulemaking for consumer water heaters on July 27, 2023.[323] The TRM will add an early retirement baseline after the effective date for the new standard.

[322] 10 CFR Part 430.32 Energy and water conservation standards and their effective dates. Available online: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=32.

[323] Energy Conservation Program: Energy Conservation Standards for Consumer Water Heaters. https://www.regulations.gov/document/EERE-2017-BT-STD-0019-0063.

**Table 289. Solar DHW—Federal Standard for Residential Electric Storage Water Heaters**

| Rated storage volume | Draw pattern | FHR[324,325] | UEF[326] |
|---|---|---|---|
| ≥ 20 gal and ≤ 55 gal | Very small usage | 0 ≤ FHR < 18 | 0.8808 − (0.0008 × $V_r$) |
| | Low usage | 18 ≤ FHR < 51 | 0.9254 − (0.0003 × $V_r$) |
| | Medium usage | 51 ≤ FHR < 75 | 0.9307 − (0.0002 × $V_r$) |
| | High usage | 75 ≤ FHR | 0.9349 − (0.0001 × $V_r$) |
| > 55 gal and ≤ 120 gal | Very small usage | 0 ≤ FHR < 18 | 1.9236 − (0.0011 × $V_r$) |
| | Low usage | 18 ≤ FHR < 51 | 2.0440 − (0.0011 × $V_r$) |
| | Medium usage | 51 ≤ FHR < 75 | 2.1171 − (0.0011 × $V_r$) |
| | High usage | 75 ≤ FHR | 2.2418 − (0.0011 × $V_r$) |

## High-Efficiency Condition

Eligible equipment must be compliant with the current ENERGY STAR v5.0 specification, effective April 18, 2023. Qualified products must have a solar uniform energy factor (SUEF) greater than or equal to 3.0, and warranties of ≥ 10 years on collectors, ≥ 6 years on sealed systems, ≥ 2 years on controls, and ≥ 1 year on piping and parts.[327] A complete list of certified ENERGY STAR solar water heaters can be accessed via the ENERGY STAR program website.[328]

Solar water heaters must be certified according to the current SRCC OG-300 standard based on tank size and final SUEF.[329]

324 "The Revised Method of Test for Residential Water Heating and Its Impact on Incentive Programs" presentation, Glanville, Paul. ACEEE Hot Water Forum. February 24, 2015. https://aceee.org/sites/default/files/pdf/conferences/hwf/2015/6B-Glanville.pdf.

325 Assume FHR equal to that of installed water heater.

326 Vr is the rated storage volume (in gallons), as determined pursuant to 10 CFR 429.17.

327 ENERGY STAR Requirements (effective January 5th, 2022, released March 29, 2022). https://www.energystar.gov/products/water_heaters/residential_water_heaters_key_product_criteria.

328 ENERGY STAR-certified water heaters qualified product listing. https://www.energystar.gov/productfinder/product/certified-water-heaters/?formId=bb099b76-3da7-49bf-a746-fbde4d076d0d&scrollTo=422&search_text=&type_filter=Solar+with+Electric+Backup&fuel_filter=&brand_name_isopen=0&input_rate_thousand_btu_per_hour_isopen=0&markets_filter=United+States&zip_code_filter=&product_types=Select+a+Product+Category&sort_by=brand_name&sort_direction=asc&currentZipCode=78701&page_number=0&lastpage=0. 0

329 ENERGY STAR certification for residential water heaters. https://solar-rating.org/programs/estar/.

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Solar water heating savings values are on a per-unit basis. Variables used to compute deemed savings include tank volume and installed unit SUEF as rated in the SRCC "Summary of SRCC Certified Solar Collector and Water Heating System Ratings." The SUEF is determined under SRCC's Operating Guideline 300, "Operating Guidelines and Minimum Standards for Certifying Solar Water Heating Systems" and was developed as a means to compare solar water heating systems with conventional water heating systems rated with an UEF and listed in the Gas Appliance Manufacturers Association Directory of Certified Water Heating Products.

Both UEF and SUEF are based on the same environmental and hot water use conditions used in the DOE Test Procedures for Water Heaters. The only significant difference is that the DOE test does not specify solar radiation. So SRCC uses a 1500 Btu/sq. ft./day solar radiation profile—a value typical of Sunbelt states (note - the annual average solar radiation for Dallas is 1533 Btu/sq. ft./day. Information on the SRCC can be found at http://www.solar-rating.org/.

All deemed savings values are calculated using the following standard algorithms for water heating. These algorithms assume a replace-on-burnout or new construction scenario but may be used to award savings for early retirement projects.

### *Energy Savings Algorithm*

$$Energy\ Savings\ [\Delta kWh] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,annual}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{SUEF_{post}}\right)}{3{,}412}$$

**Equation 74**

*Where:*

| | | |
|---|---|---|
| $\rho$ | = | *Water density [lbs/gal] = 8.33* |
| $C_p$ | = | *Specific heat of water [Btu/lb·°F] = 1* |
| $GPY$ | = | *Estimated annual hot water use in gallons/year, specified by number of bedrooms in the home (see Table 290). For midstream/upstream applications, the number of bedrooms is assumed to be 3.*[330] |
| $T_{setpoint}$ | = | *Water heater setpoint temperature [°F]*[331] *= 120* |

[330] Weighted average of number of bedrooms in West South-Central Region. 2020 RECS Survey Data – Table HC2.8 Structural and geographic characteristics of homes in the South and West regions, 2020. https://www.eia.gov/consumption/residential/data/2020/.

[331] 120°F represents the assumed water heater setpoint. The New York Department of Public Service recommends using the water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs." Page 99. October 2010. The data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) also supports a default value of 120°F.

| | | |
|---|---|---|
| $T_{supply,annual}$ | = | *Average annual supply water temperature [°F] (see Table 291)* |
| $UEF_{pre}$ | = | *Baseline uniform energy factor (calculate per Table 289)*[332] |
| $SUEF_{post}$ | = | *Solar uniform energy factor of new water heater* |
| *3,412* | = | *Constant to convert from Btu to kWh* |

**Table 290. Solar DHW—Water Heater Consumption (Gal/Year)** [333]

| Climate zone | Number of bedrooms | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Zone 1: Amarillo | 15,476 | 20,171 | 24,866 | 29,561 |
| Zone 2: Dallas | 14,778 | 19,244 | 23,710 | 28,177 |
| Zone 3: Houston | 14,492 | 18,864 | 23,236 | 27,608 |
| Zone 4: Corpus Christi | 14,213 | 18,494 | 22,775 | 27,056 |
| Zone 5: El Paso | 14,905 | 19,412 | 23,920 | 28,427 |

**Table 291. Solar DHW—Water Mains Temperature (°F)**[334]

| Climate zone | $T_{supply,annual}$ | $T_{supply,seasonal}$ | |
|---|---|---|---|
| | | Summer | Winter |
| Zone 1: Amarillo | 62.9 | 73.8 | 53.7 |
| Zone 2: Dallas | 71.8 | 84.0 | 60.6 |
| Zone 3: Houston | 74.7 | 84.5 | 65.5 |
| Zone 4: Corpus Christi | 77.2 | 86.1 | 68.5 |
| Zone 5: El Paso | 70.4 | 81.5 | 60.4 |

## *Demand Savings Algorithm*

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\rho \times C_p \times GPY \times (T_{setpoint} - T_{supply,seasonal}) \times \left(\frac{1}{UEF_{pre}} - \frac{1}{SUEF_{post}}\right)}{365 \times 3{,}412} \times CF_{S/W}$$

**Equation 75**

332 Note that for efficient water heater installations in new construction homes, the baseline uniform energy factor is the efficiency of the electric storage water heater that would otherwise have been installed, according to appropriate design documentation.

333 Building America Research Benchmark Definition. December 2009, p 13. Available online: http://www.nrel.gov/docs/fy10osti/47246.pdf.

334 Based on TMY3 dataset. TMY data is available through the National Solar Radiation Database (NSRDB) Data Viewer, https://maps.nrel.gov/nsrdb-viewer/. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

*Where:*

| | | |
|---|---|---|
| $T_{supply,seasonal}$ | = | *Seasonal supply water temperature [°F] (see Table 291)* |
| $CF_{S/W}$ | = | *Summer/winter peak coincidence factor (see Table 292)* |

**Table 292. Solar DHW—Coincidence Factors[335]**

| Climate zone | Summer | Winter |
|---|---|---|
| Zone 1: Amarillo | 0.042 | 0.067 |
| Zone 2: Dallas | 0.039 | 0.068 |
| Zone 3: Houston | 0.041 | 0.070 |
| Zone 4: Corpus Christi | 0.041 | 0.065 |
| Zone 5: El Paso | 0.036 | 0.067 |

## 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) is 15 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-SWH.[336]

335 Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from Building America Performance Analysis Procedures for Existing Homes, page 18, Figure 4: Combined Domestic Hot Water Use Profile. https://www.nrel.gov/docs/fy06osti/38238.pdf.

336 DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

## 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
- Number of bedrooms (not required for upstream/midstream program delivery)
- Solar DHW quantity
- Manufacturer and model number of new solar water heater
- Baseline volume (gallons), FHR, and UEF
- New solar water heater volume (gallons), FHR, and SUEF
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

## References and Efficiency Standards

### Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Energy for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 27903. Order Adopting New §25.184 as Approved at the August 21, 2003, Open Meeting and Submitted to the Secretary of State. Public Utility Commission of Texas.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 293. Solar DHW—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Minor edits to language. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. No revision. |
| v3.1 | 11/05/2015 | TRM v3.1 update. No revision. |
| v4.0 | 10/10/2016 | TRM v4.0 update. No revision |
| v5.0 | 10/2017 | TRM v5.0 update. No revision. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |

| TRM version | Date | Description of change |
|---|---|---|
| v7.0 | 10/2019 | TRM v7.0 update. No revision. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated algorithms and coincidence factors. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated EUL reference. |
| v10.0 | 10/2022 | TRM v10.0 update. Verified compliance with ENERGY STAR Version 4.0 Requirements. Updated documentation requirements. |
| v11.0 | 10/2023 | TRM v11.0 update. Incorporated updated ENERGY STAR specification v5.0. Updated documentation requirements. |

## 2.4.4 Water Heater Tank Insulation Measure Overview

**TRM Measure ID:** R-WH-TI

**Market Sector:** Residential

**Measure Category:** Water heating

**Applicable Building Types:** Single-family, multifamily, manufactured

**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 requires the installation of tank wrap insulation on an uninsulated water heater tank.

## Eligibility Criteria

Water heater tank insulation is a residential retrofit measure. New construction and water heater replacements are not eligible for this measure because they must meet current code requirements. Tank insulation must be installed on an uninsulated electric resistance water heater.

To be eligible for this measure, water heaters must have been installed prior to April 16, 2015. Water heaters manufactured after this date are compliant with the current federal standard[337] and are built with a thicker tank with a higher baseline R-value. Modern water heaters are expected to be rated at a minimum of R-24.[338,339]

---

337 "Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters". Effective 6/15/2010 with compliance starting 5/16/2015. https://www.federalregister.gov/documents/2010/04/16/2010-7611/energy-conservation-program-energy-conservation-standards-for-residential-water-heaters-direct.

338 "Do-It-Yourself Savings Project: Insulate Water Heater Tank," U.S. Department of Energy. https://www.energy.gov/energysaver/do-it-yourself-savings-project-insulate-water-heater-tank.

339 "Water Heating Products," Air-Conditioning, Heating, and Refrigeration Institute (AHRI). https://www.ahrinet.org/scholarships-education/education/homeowners/save-energy/water-heating-products.

## Baseline Condition

The baseline is assumed to be a typical electric water heater with no insulation. The baseline tank is assumed to be one to two inches thick with an assumed R-value of approximately R-8 per inch.[340]

## High-Efficiency Condition

The high-efficiency condition is a water heater tank wrap or insulated blanket with an R-value of at least 8.

The manufacturer's instructions on the water heater jacket and the water heater itself should be followed. Thermostat and heating element access panels must be left uncovered.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Energy Savings Algorithms*

Hot water tank insulation energy savings are calculated using the following formula:

$$Energy\ Savings\ [\Delta kWh] = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{tank} - T_{ambient,annual}\right) \times \left(\frac{1}{RE}\right) \times \frac{hours}{3{,}412}$$

**Equation 76**

*Where:*

| | | |
|---|---|---|
| $R_{pre}$ | = | *Uninsulated tank R-value = 12 [sq. ft. °F hr/Btu]*[341] |
| $R_{post}$ | = | *Tank insulation R-value = 12 + 8 = 20 = [sq. ft. °F hr/Btu]* |
| $U_{pre}$ | = | *1 / $R_{pre}$ = 1 / 12 = 0.083 [Btu/hr sq. ft. °F]* |
| $U_{post}$ | = | *1 / $R_{post}$ = 1 / 20 = 0.05 [Btu/hr sq. ft. °F]* |
| *A* | = | *Tank surface area insulated in square feet* ($\pi DL$) *with L (length) and D (tank diameter) in feet; if the tank area is not known, use Table 294* |

[340] "Energy Conservation Program for Consumer Products: Energy Conservation Standards for Water Heaters", Section V. Analytical Results and Conclusion, subsection C. Lessening of Utility or Performance of Products. Effective 1/20/2004. https://www.federalregister.gov/documents/2001/01/17/01-1081/energy-conservation-program-for-consumer-products-energy-conservation-standards-for-water-heaters.

[341] Baseline storage tank assembly is assumed to have thermal performance of R12, assuming an average tank thickness of 1-2 inches (average 1.5) and an approximate R-value of R-8 per inch.

**Table 294. DHW Tank Insulation—Estimated Tank Area**[342]

| Volume (gal) | A (sq. ft.) |
|---:|---:|
| 30 | 17.45 |
| 40 | 21.81 |
| 50 | 22.63 |
| 60 | 26.94 |
| 80 | 30.36 |
| 120 | 38.73 |

$T_{tank}$ = *Average tank water temperature [°F]; default = 120°F* [343]

$T_{ambient,annual}$ = *Average annual ambient temperature [°F] (see Table 295)*

*RE* = *Recovery efficiency; default = 0.98 for electric resistance water heaters*[344]

*hours* = *8,760 hours per year*

*3,412* = *Constant to convert from Btu to kWh*

## Demand Savings Algorithms

$$Peak\ Demand\ Savings\ [\Delta kW] = \left(U_{pre} - U_{post}\right) \times A \times (T_{tank} - T_{ambient,seasonal}) \times \frac{1}{RE} \times \frac{CF_{S/W}}{3{,}412}$$

**Equation 77**

*Where:*

$T_{ambient,seasonal}$ = *Seasonal ambient temperature [°F] (see Table 295)*

$CF_{S/W}$ = *Seasonal peak coincidence factor*[345] *= 1*

[342] Tank area was obtained from a survey of electric water heater manufacturer data from A.O. Smith and Whirlpool conducted in 2013. Dimensions for each tank size were collected and averaged to determine typical square footage of each size water heater.

[343] 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs" October 2010, page 99.
Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), supports a default value of 120°F.

[344] Default based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://www.ahrinet.org.

[345] Coincidence factor of 1 assumes that a constant tank temperature is maintained across all hours of the year.

Table 295. DHW Tank Insulation—Ambient Temperature (°F)

| Climate zone | Water heater location: unconditioned space[346] | | | Water heater location: conditioned space[347] | | |
|---|---|---|---|---|---|---|
| | Annual | Peak seasonal | | Annual | Peak seasonal | |
| | | Summer | Winter | | Summer | Winter |
| Zone 1: Amarillo | 65.5 | 106.0 | 32.0 | 71.8 | 73.9 | 69.6 |
| Zone 2: Dallas | 73.1 | 108.1 | 42.0 | | | |
| Zone 3: Houston | 76.3 | 108.2 | 46.0 | | | |
| Zone 4: Corpus Christi | 78.4 | 103.0 | 55.0 | | | |
| Zone 5: El Paso | 71.8 | 108.0 | 41.1 | | | |

## Deemed Energy Savings Tables

Table 296. DHW Tank Insulation—Energy Savings

| Tank volume | Unconditioned | | | | | Conditioned |
|---|---|---|---|---|---|---|
| | Amarillo | Dallas | Houston | Corpus Christi | El Paso | All zones |
| 30 | 83 | 71 | 67 | 63 | 73 | 73 |
| 40 | 104 | 89 | 83 | 79 | 92 | 92 |
| 50 | 108 | 93 | 86 | 82 | 95 | 95 |
| 60 | 128 | 110 | 103 | 98 | 113 | 113 |
| 80 | 144 | 124 | 116 | 110 | 128 | 128 |
| 120 | 184 | 159 | 148 | 141 | 163 | 163 |

[346] Average ambient temperatures for unconditioned space were taken from TMY3 data, with a 7°F increase in winter and an 11°F increase in summer based on ASHRAE 152 Heating System and Cooling System Location Temperatures (Garage).

[347] Average ambient temperatures for conditioned space were taken from the US Energy Information Administration Residential Energy Consumption Survey (RECS), tables hc7.9 and hc6.8. Summer and winter indoor temperature averages are weighted by the number of homes. Annual temperature is the average of summer and winter weighted by number of days.

## Deemed Summer Demand Savings Tables

**Table 297. DHW Tank Insulation—Energy Savings**

| Tank volume | Unconditioned | | | | | Conditioned |
|---|---|---|---|---|---|---|
| | Amarillo | Dallas | Houston | Corpus Christi | El Paso | All zones |
| 30 | 0.0024 | 0.0021 | 0.0021 | 0.0030 | 0.0021 | 0.0080 |
| 40 | 0.0030 | 0.0026 | 0.0026 | 0.0037 | 0.0026 | 0.0100 |
| 50 | 0.0032 | 0.0027 | 0.0027 | 0.0038 | 0.0027 | 0.0104 |
| 60 | 0.0038 | 0.0032 | 0.0032 | 0.0046 | 0.0032 | 0.0124 |
| 80 | 0.0042 | 0.0036 | 0.0036 | 0.0051 | 0.0036 | 0.0140 |
| 120 | 0.0054 | 0.0046 | 0.0046 | 0.0066 | 0.0046 | 0.0178 |

## Deemed Winter Demand Savings Tables

**Table 298. DHW Tank Insulation—Energy Savings**

| Tank volume | Unconditioned | | | | | Conditioned |
|---|---|---|---|---|---|---|
| | Amarillo | Dallas | Houston | Corpus Christi | El Paso | All zones |
| 30 | 0.0153 | 0.0136 | 0.0129 | 0.0113 | 0.0137 | 0.0088 |
| 40 | 0.0191 | 0.0170 | 0.0161 | 0.0141 | 0.0172 | 0.0110 |
| 50 | 0.0199 | 0.0176 | 0.0167 | 0.0147 | 0.0178 | 0.0114 |
| 60 | 0.0236 | 0.0209 | 0.0199 | 0.0175 | 0.0212 | 0.0135 |
| 80 | 0.0266 | 0.0236 | 0.0224 | 0.0197 | 0.0239 | 0.0153 |
| 120 | 0.0340 | 0.0301 | 0.0286 | 0.0251 | 0.0305 | 0.0195 |

## Claimed Peak Demand Savings

Refer to Volume 1, Section 4.

## Additional Calculators and Tools

Not applicable.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 7 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-TankIns-Elec.[348]

[348] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

## 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
- Water heater location (conditioned, unconditioned)
- Tank volume (30, 40, 50, 60, 80, 120)
- The R-value of the installed tank insulation
- Water heater model number and manufacture date

## References and Efficiency Standards

### Petitions and Rulings

- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 299. DHW Tank Insulation—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Minor edits to language. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. No revision. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Supplemented reference for water heater setpoint temperature. |
| v4.0 | 10/10/2016 | TRM v4.0 update. No revision. |
| v5.0 | 10/2017 | TRM v5.0 update. No revision. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 11/2019 | TRM v7.0 update. No revision. |

| TRM version | Date | Description of change |
|---|---|---|
| v8.0 | 10/2020 | TRM v8.0 update. Updated ambient temperatures. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated EUL reference. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated documentation requirements. |
| v11.0 | 10/2023 | TRM v11.0 update. Clarified baseline and added deemed savings. Updated documentation requirements. |

## 2.4.5 Water Heater Pipe Insulation Measure Overview

**TRM Measure ID:** R-WH-PI

**Market Sector:** Residential

**Measure Category:** Water heating

**Applicable Building Types:** Single-family, multifamily, manufactured

**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 requires the installation of pipe insulation on uninsulated water heater pipes that are served by an electric water heater.

### Eligibility Criteria

Water heaters plumbed with heat traps are not eligible to receive incentives for this measure. It is recommended that the installer (or contractor) checks to see if the water heater heat trap works properly before declaring the water heater ineligible.

Water heater pipe insulation is a residential retrofit measure. New construction and retrofits involving the installation of new water heaters are not eligible for this measure, because they must meet current code requirements. To use these deemed savings, the fuel type of the water heater must be electricity.

### Baseline Condition

The baseline is assumed to be a typical electric water heater with no heat traps and no insulation on water heater pipes.

### High-Efficiency Condition

The efficiency standard requires an insulation thickness R-3. The International Residential Code (IRC) 2018 section N1103.4: Mechanical system piping insulation requires R-3 insulation.

All visible hot water piping must be insulated. Savings are based on a maximum allowable insulation length of 6 feet of piping.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Energy Savings Algorithms*

Hot water pipe insulation energy savings are calculated using the following formula:

$$Energy\ Savings\ [\Delta kWh] = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{pipe} - T_{ambient,avg}\right) \times \left(\frac{1}{RE}\right) \times \frac{hours}{3{,}412}$$

**Equation 78**

*Where:*

$U_{pre}$ = $\frac{1}{2.03} = 0.49\ {}^{Btu}/_{hr \cdot sq.ft.\cdot\ °F}$[349]

$U_{post}$ = $\frac{1}{2.03 + R_{Insulation}}\ {}^{Btu}/_{hr \cdot sq.ft.\cdot\ °F}$

$R_{Insulation}$ = *R-value of installed insulation*

*A* = *Pipe surface area insulated in square feet* ($\pi DL$) *with L (length) and D (pipe diameter) in feet. The maximum length allowable for insulation is 6 feet; if the pipe area is unknown, use the following table.*

**Table 300. DHW Pipe Insulation—Estimated Pipe Surface Area**

| Pipe diameter (inches) | Pipe surface area (square feet)[350] |
|---|---|
| 0.5 | 0.16 x required input “Pipe Length insulated (feet)” |
| 0.75 | 0.23 x required input “Pipe Length insulated (feet)” |
| 1.0 | 0.29 x required input “Pipe Length insulated (feet)” |

349 2.03 is the R-value representing the film coefficients between water and the inside of the pipe, and between the surface and air. Mark’s Standard Handbook for Mechanical Engineers, 8th edition.

350 Factors used in the calculation for pipe area were determined by using the outside diameter of the pipe in inches, converting it to feet, and multiplying by π as shown below.

| Nominal diameter (inches) | Outside diameter (inches) | Factor to calculate pipe area |
|---|---|---|
| 0.5 | 0.625 | 0.16 |
| 0.75 | 0.875 | 0.23 |
| 1.0 | 1.125 | 0.29 |

| | | |
|---|---|---|
| $T_{pipe}$ | = | *Average pipe water temperature [°F]; default[351] = 120* |
| $T_{ambient,avg}$ | = | *Average annual ambient temperature [°F] (see Table 301)* |
| $RE$ | = | *Recovery efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.[352]* |
| *hours* | = | *8,760 hours per year* |

## Demand Savings Algorithms

$$Peak\ Demand\ Savings\ [\Delta kW] = \left(U_{pre} - U_{post}\right) \times A \times \left(T_{Pipe} - T_{ambient,seasonal}\right) \times \left(\frac{1}{RE}\right) \times \frac{CF_{S/W}}{3{,}412}$$

**Equation 79**

*Where:*

| | | |
|---|---|---|
| $T_{ambient,seasonal}$ | = | *Seasonal ambient temperature [°F] (see Table 301)* |
| $CF_{S/W}$ | = | *Seasonal peak coincidence factor[353] = 1* |

**Table 301. DHW Pipe Insulation—Ambient Temperature (°F)**

| Climate zone | Water heater location: unconditioned space[354] | | | Water heater location: conditioned space[355] | | |
|---|---|---|---|---|---|---|
| | Annual | Peak seasonal | | Annual | Peak seasonal | |
| | | Summer | Winter | | Summer | Winter |
| Zone 1: Amarillo | 65.5 | 106.0 | 32.0 | 71.8 | 73.9 | 69.6 |
| Zone 2: Dallas | 73.1 | 108.1 | 42.0 | | | |
| Zone 3: Houston | 76.3 | 108.2 | 46.0 | | | |

351 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs" October 2010, page 102.
Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

352 Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://www.ahrinet.org.

353 Coincidence factor of 1 assumes that a constant tank and near tank piping temperature is maintained across all hours of the year.

354 Average ambient temperatures for unconditioned space were taken from TMY3 data, with a 7°F increase in winter and an 11°F increase in summer based on ASHRAE 152 Heating System and Cooling System Location Temperatures (Garage).

355 Average ambient temperatures for conditioned space were taken from the US Energy Information Administration Residential Energy Consumption Survey (RECS), tables hc7.9 and hc6.8. Summer and winter indoor temperature averages are weighted by the number of homes. Annual temperature is the average of summer and winter weighted by number of days.

| Climate zone | Water heater location: unconditioned space[354] | | | Water heater location: conditioned space[355] | | |
|---|---|---|---|---|---|---|
| | | Peak seasonal | | | Peak seasonal | |
| | Annual | Summer | Winter | Annual | Summer | Winter |
| Zone 4: Corpus Christi | 78.4 | 103 | 55.0 | 71.8 | 73.9 | 69.6 |
| Zone 5: El Paso | 71.8 | 108 | 41.1 | | | |

### 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) is 13 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-PipeIns-Elec.[356]

## 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
- Water heater location (conditioned, unconditioned)
- The R-value of the installed insulation

[356] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- Recovery efficiency (RE) or COP, if available
- Pipe length insulated (feet)
- The pipe surface area insulated in square feet (at least the pipe diameter in inches)

## References and Efficiency Standards

### Petitions and Rulings

- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 302. DHW Pipe Insulation—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Minor edits to language. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. No revision. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Supplemented reference for water heater setpoint temperature. |
| v4.0 | 10/10/2016 | TRM v4.0 update. No revision. |
| v5.0 | 10/2017 | TRM v5.0 update. No revision. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 11/2019 | TRM v7.0 update. No revision. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated ambient temperatures. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated EUL reference. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated documentation requirements. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision. |

## 2.4.6 Faucet Aerators Measure Overview

**TRM Measure ID:** R-WH-FA

**Market Sector:** Residential

**Measure Category:** Water heating

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This measure involves installing aerators on kitchen and bathroom water faucets as a retrofit measure.

## Eligibility Criteria

The savings values are per faucet aerator installed. It is not a requirement that all faucets in a home be treated for the deemed savings to be applicable.

These deemed savings are for residential, retrofit or new construction, and installations of kitchen and bathroom faucet aerators. To be awarded these deemed savings, the fuel type of the water heater must be electricity.

## Baseline Condition

The 2.2 gallon per minute (GPM) baseline faucet flow rate is based on the Department of Energy (DOE) maximum flow rate standard.[357] The deemed savings assume that the existing faucet aerators have a minimum flow rate of 2.2 GPM. The US EPA WaterSense specification for faucet aerators is 1.5 GPM.[358]

## High-Efficiency Condition

Aerators that have been defaced to make the flow rating illegible are not eligible for replacement. For direct install programs, all aerators removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

[357] DOE maximum flow rate for faucet aerators. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=40.

[358] https://www.epa.gov/watersense/bathroom-faucets.

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Energy Savings Algorithms*

The deemed savings, for any faucet aerator change case using aerators with flow rates of 1.5 GPM or lower, are calculated as follows:

$$Energy\ Savings\ per\ aerator\ [\Delta kWh] = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times 365 \times \left(T_{faucet,avg} - T_{supply,avg}\right)}{FPH \times RE \times 3{,}412}$$

**Equation 80**

*Where:*

| | | |
|---|---|---|
| $\rho$ | = | *Water density [lbs/gal] = 8.33* |
| $C_p$ | = | *Specific heat of water [Btu/lb°F] = 1* |
| $GPM_{Base}$ | = | *Average baseline flow rate of aerator = 2.2 gallons per minute* |
| $GPM_{Low}$ | = | *Post-installation flow rate of aerator, typically 1.5, 1.0, or 0.5 gallons per minute; if unknown, assume 1.5 gallons per minute* |
| $N$ | = | *Average number of persons per household = 2.83 persons*[359] |
| $t$ | = | *Average time in minutes of hot water usage per person per day; default = 2.34 min/person/day*[360] |
| $T_{faucet,avg}$ | = | *Average faucet temperature [°F]*[361] *= 88* |
| $T_{supply,avg}$ | = | *Average annual supply water temperature [°F] (see Table 303)* |
| $FPH$ | = | *Average number of faucets per household = 3.87 faucets*[362] |

359 Occupants per home for Texas from US Census Bureau, "Persons Per Household, 2016-2020". https://www.census.gov/quickfacts/fact/table/TX,US/PST045221.

360 Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study." Prepared for Michigan Evaluation Working Group. Derived by taking weighted average of average minutes per person per day specified for kitchens (4.5) and bathrooms (1.6) assuming 1 kitchen aerator and 2.93 bathrooms.

361 Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study." Prepared for Michigan Evaluation Working Group. Derived by taking weighted average of average temperature for kitchens (93°F) and bathrooms (86°F) assuming 1 kitchen aerator and 2.93 bathrooms.
Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

362 Faucets per home assumed to be equal to one per kitchen and each half-bath plus 1.5 per each full bathroom per home. Bathroom counts extracted from the 2015 Residential Energy Consumption Survey (RECS), Table HC2.8 Structural and Geographic Characteristics of Homes in West South-Central Region.

| | | |
|---|---|---|
| *RE* | = | *Recovery Efficiency (or in the case of heat pump water heaters, COP). If unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters.*[363] |
| *3,412* | = | *Constant to convert from Btu to kWh* |

### Demand Savings Algorithms

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a coincidence factor equivalent to the daily fraction hot water use during the weighted peak hour for each climate zone (see Volume 1, Section 4), and dividing by 365 days/year, with 365 canceling from the savings algorithm numerator and denominator.

$$Peak\ Demand\ Savings\ per\ aerator\ [\Delta kW] = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times \left(T_{faucet,avg} - T_{supply,seasonal}\right)}{FPH \times RE \times 3{,}412} \times CF_{S/W}$$

**Equation 81**

*Where:*

| | | |
|---|---|---|
| $T_{supply,seasonal}$ | = | *Seasonal supply water temperature [°F] (Table 303)* |
| $CF_{S/W}$ | = | *Seasonal peak coincidence factor (Table 304)* |

**Table 303. Faucet Aerators—Water Mains Temperature (°F)[364]**

| Climate zone | $T_{supply,avg}$ | $T_{supply,seasonal}$ | |
|---|---|---|---|
| | | Summer | Winter |
| Zone 1: Amarillo | 62.9 | 73.8 | 53.7 |
| Zone 2: Dallas | 71.8 | 84.0 | 60.6 |
| Zone 3: Houston | 74.7 | 84.5 | 65.5 |
| Zone 4: Corpus Christi | 77.2 | 86.1 | 68.5 |
| Zone 5: El Paso | 70.4 | 81.5 | 60.4 |

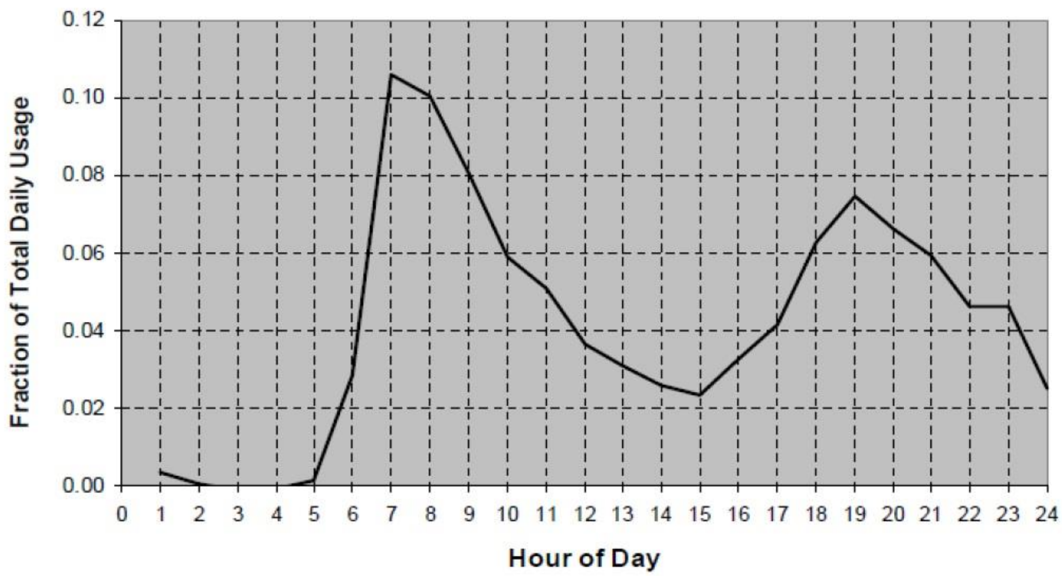
363 Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, https://www.ahridirectory.org/.

364 Based on typical meteorological year (TMY) dataset for TMY3, available through the National Solar Radiation Database (NSRDB) Data Viewer. https://nsrdb.nrel.gov/data-viewer. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

**Table 304. Faucet Aerators—Coincidence Factors**

| Climate zone | Summer | Winter |
|---|---|---|
| Zone 1: Amarillo | 0.039 | 0.073 |
| Zone 2: Dallas | 0.035 | 0.075 |
| Zone 3: Houston | 0.038 | 0.080 |
| Zone 4: Corpus Christi | 0.038 | 0.068 |
| Zone 5: El Paso | 0.028 | 0.069 |

**Figure 4. Faucet Aerators—Shower, Bath, and Sink Hot Water Use Profile**[365]




## 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.

[365] Building America performance analysis procedures for existing homes.

## 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) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Aertr.[366]

# 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
- Recovery Efficiency (RE) or COP, if available
- Flow rate in gallons per minute (GPM) of faucet installed
- Water heater type (e.g., heat pump, electric resistance)

# References and Efficiency Standards

## Petitions and Rulings

- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

## Relevant Standards and Reference Sources

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

[366] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

## Document Revision History

**Table 305. Faucet Aerators—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Minor edits to language. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. No revision. |
| v3.1 | 10/30/2015 | TRM v3.1 update. Supplemented reference for water heater setpoint temperature. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Updated methodology to calculate energy and demand savings. |
| v5.0 | 10/2017 | TRM v5.0 update. No revision. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 11/2019 | TRM v7.0 update. No revision. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated coincidence factors. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated EUL reference. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated number of occupants per home. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision. |

## 2.4.7 Low-Flow Showerheads Measure Overview

**TRM Measure ID:** R-WH-SH

**Market Sector:** Residential

**Measure Category:** Water heating

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This measure consists of removing existing showerheads and installing low-flow showerheads in residences.

### Eligibility Criteria

The incentive is for replacement of an existing showerhead with a new showerhead rated at or below 2.0gallons per minute (GPM). The only showerheads eligible for installation are those that are not easily modified to increase the flow rate.

These deemed savings are for showerheads installed as a retrofit or new construction measure. To be awarded these deemed savings, the fuel type of the water heater must be electricity.

### Baseline Condition

Federal standards set a maximum flow rate of 2.5 GPM,[367] while the US Environmental Protection Agency (EPA) WaterSense Program has implemented efficiency standards for showerheads requiring a maximum flow rate of 2.0 GPM.[368]

### High-Efficiency Condition

In addition to meeting the baseline requirements above, existing showerheads that have been defaced to make the flow rating illegible are not eligible for replacement. All showerheads removed shall be collected by the contractor and held for possible inspection by the utility until all inspections for invoiced installations have been completed.

---

367 http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/37.
368 http://www.epa.gov/watersense/products/showerheads.html.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Energy Savings Algorithms*

Energy savings for this measure are calculated as follows:

$$Energy\ Savings\ per\ showerhead\ [\Delta kWh] = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times 365 \times (T_{shower,avg} - T_{supply,avg})}{SPH \times RE \times 3{,}412}$$

**Equation 82**

*Where:*

| | | |
|---|---|---|
| $\rho$ | = | *Water density [lbs/gal] = 8.33* |
| $C_p$ | = | *Specific heat of water [Btu/lb°F] = 1* |
| $GPM_{Base}$ | = | *Average baseline flow rate of aerator = 2.5 gallons per minute* |
| $GPM_{Low}$ | = | *Post-installation flow rate of aerator; if unknown, assume 2.0 gallons per minute* |
| $N$ | = | *Average number of persons per household = 2.83 persons*[369] |
| $t$ | = | *Average time in minutes of hot water usage per person per day; default = 7.8 min/person/day*[370] |
| $T_{shower,avg}$ | = | *Average shower temperature [°F]*[371] *= 101* |
| $T_{supply,avg}$ | = | *Average annual supply water temperature [°F] (see Table 306)* |
| $SPH$ | = | *Average number of showerheads per household = 1.74 showerheads*[372] |

369 Occupants per home for Texas from US Census Bureau, "Persons per household, 2016-2020". https://www.census.gov/quickfacts/fact/table/TX,US/PST045221.

370 Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study." Prepared for Michigan Evaluation Working Group.

371 Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study." Prepared for Michigan Evaluation Working Group

372 Showerheads per home assumed to be equal to the number of full bathrooms per home as specified in the 2009 Residential Energy Consumption Survey (RECS), Table HC2.10.

| | | |
|---|---|---|
| *RE* | = | *Recovery Efficiency (or in the case of heat pump water heaters, COP); if unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters*[373] |
| *3,412* | = | *Constant to convert from Btu to kWh* |

## *Demand Savings Algorithms*

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a coincidence factor equivalent to the daily fraction hot water use during the weighted peak hour for each climate zone (see Volume 1, Section 4), and dividing by 365 days/year, with 365 canceling from the savings algorithm numerator and denominator.

$$Demand\ Savings\ per\ showerhead\ [\Delta kWh] = \frac{\rho \times C_P \times (GPM_{Base} - GPM_{Low}) \times N \times t \times (T_{shower,avg} - T_{supply,seasonal})}{SPH \times RE \times 3{,}412} \times CF_{S/W}$$

**Equation 83**

*Where:*

| | | |
|---|---|---|
| $T_{supply,seasonal}$ | = | *Seasonal supply water temperature [°F] (see Table 306)* |
| $CF_{S/W}$ | = | *Seasonal peak coincidence factor (see Table 307)* |

**Table 306. Low-Flow Showerheads—Water Mains Temperature (°F)[374]**

| Climate zone | $T_{SupplyAverage}$ | $T_{SupplySeasonal}$ | |
|---|---|---|---|
| | | Summer | Winter |
| Zone 1: Amarillo | 62.9 | 73.8 | 53.7 |
| Zone 2: Dallas | 71.8 | 84.0 | 60.6 |
| Zone 3: Houston | 74.7 | 84.5 | 65.5 |
| Zone 4: Corpus Christi | 77.2 | 86.1 | 68.5 |
| Zone 5: El Paso | 70.4 | 81.5 | 60.4 |

[373] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://cafs.ahrinet.org/gama_cafs/sdpsearch/search.jsp?table=CWH .

[374] Based on typical meteorological year (TMY) dataset for TMY3, available through the National Solar Radiation Database (NSRDB) Data Viewer. https://nsrdb.nrel.gov/data-viewer. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

**Table 307. Low-Flow Showerheads—Coincidence Factors**

| Climate zone | Summer | Winter |
|---|---|---|
| Zone 1: Amarillo | 0.039 | 0.073 |
| Zone 2: Dallas | 0.035 | 0.075 |
| Zone 3: Houston | 0.038 | 0.080 |
| Zone 4: Corpus Christi | 0.038 | 0.068 |
| Zone 5: El Paso | 0.028 | 0.069 |

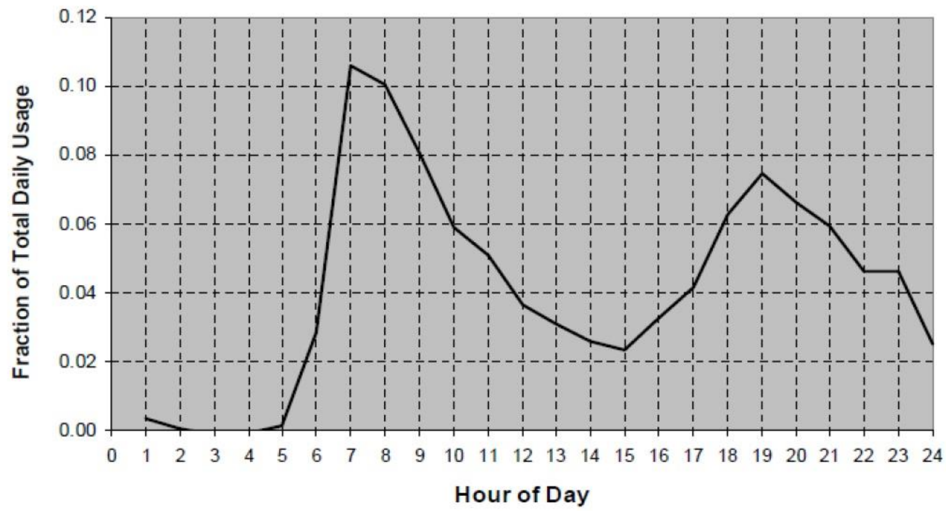



**Figure 5. Low-Flow Showerheads—Shower, Bath, and Sink Hot Water Use Profile[375]**

Source: Building America Performance Analysis Procedures for Existing Homes.

## 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.

[375] Building America performance analysis procedures for existing homes.

## 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) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.[376]

# 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
- Recovery efficiency (RE) or COP, if available
- Flow rate in gallons per minute (GPM) of showerhead installed
- Water heater type (e.g., heat pump, electric resistance)

# References and Efficiency Standards

## Petitions and Rulings

- Docket No. 41722. Petition of AEP Texas Central Company, AEP Texas North Company, CenterPoint Energy Houston Electric, LLC, El Paso Electric Company, Entergy Texas, Inc., Oncor Electric Delivery Company LLC, Sharyland Utilities, L.P., Southwestern Electric Power Company, Southwestern Public Service Company, and Texas-New Mexico Power Company to Approve Revisions to Residential Deemed Savings to Incorporate Winter Peak Demand Impacts and Update Certain Existing Deemed Savings Values. Public Utility Commission of Texas.

## Relevant Standards and Reference Sources

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

[376] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

## Document Revision History

**Table 308. Low-Flow Showerheads—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Minor edits to language. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. No revision. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Provided clarification that savings are to be awarded per showerhead. Supplemented reference for water heater setpoint temperature. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Updated methodology to calculate energy and demand savings. |
| v5.0 | 10/2017 | TRM v5.0 update. No revision. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 11/2019 | TRM v7.0 update. No revision. |
| v8.0 | 10/2020 | TRM v8.0 update. Added new savings category and updated coincidence factors. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated EUL reference. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated number of occupants per home. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision. |

### 2.4.8 Showerhead Temperature Sensitive Restrictor Valves Measure Overview

**TRM Measure ID:** R-WH-SV

**Market Sector:** Residential

**Measure Category:** Water heating

**Applicable Building Types:** Single-family, multifamily; manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This measure consists of installing a temperature sensitive restrictor valve (TSRV)[377] between the existing shower arm and showerhead. The valve restricts hot water flow through the showerhead once the water reaches a set temperature (generally 95˚F) to prevent water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste.

## Eligibility Criteria

These deemed savings are for temperature sensitive restrictor valves installed in new construction or as a retrofit measure in residential applications. Buildings must have electrically-fueled hot water to be eligible for this measure.

## Baseline Condition

The baseline condition is the residential shower arm and standard (2.5 GPM) showerhead without a temperature sensitive restrictor valve installed.

## High-Efficiency Condition

The high-efficiency condition is a temperature sensitive restrictor valve installed on a residential shower arm and showerhead with either a standard (2.5 GPM) or low-flow (2.0, 1.75, or 1.5 GPM) showerhead. If this measure is installed in conjunction with a low-flow showerhead, refer to the Low-flow Showerheads measure and claim additional savings as outlined in that measure.

[377] A temperature sensitive restrictor valve is any device that uses water temperature to regulate water flow in showers.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Estimated Hot Water Usage Reduction*

To determine gallons of behavioral waste (defined as hot water that goes down the drain before the user enters the shower) per year, the following formula was used:

$$Annual\ Showerhead\ Behavioral\ Waste = SHFR \times BW \times n_S \times 365 \times \frac{n_O}{n_{SH}}$$

**Equation 84**

*Where:*

| | | |
|---|---|---|
| *SHFR* | = | *Showerhead flow rate, gallons per minute [gpm] (see Table 309)* |
| *BW* | = | *Behavioral waste, minutes per shower (see Table 309)* |
| $n_S$ | = | *Number of showers per person per day (see Table 309)* |
| *365* | = | *Constant to convert days to years (see Table 309)* |
| $n_O$ | = | *Number of occupants per home (see Table 309)* |
| $n_{SH}$ | = | *Number of showerheads per home (see Table 309)* |

Applying the formula to the values from Table 309 returns the following values for baseline behavioral waste in gallons per showerhead per year:

$$Showerhead\ (2.5\ GPM): 2.5 \times\ 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72} = 713\ gal$$

$$Showerhead\ (2.0\ GPM): 2.0 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72} = 570\ gal$$

$$Showerhead\ (1.75\ GPM): 1.75 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72} = 499\ gal$$

$$Showerhead\ (1.5\ GPM): 1.5 \times 0.783 \times 0.6 \times 365 \times \frac{2.86}{1.72} = 428\ gal$$

Gallons of hot water saved per year can be found by multiplying the baseline behavioral waste gallons per year by the percent of hot water from Table 309.

$$Gallons\ of\ hot\ water\ saved\ per\ year = Annual\ Behavioral\ Waste \times HW\%$$

**Equation 85**

*Where:*

*HW%* = *Hot water percentage (see Table 309)*

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (2.5\ GPM): 713 \times\ 0.825 = 588\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (2.0\ GPM): 570 \times\ 0.825 = 470\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (1.75\ GPM): 499 \times\ 0.825 = 412\ gal$$

$$Gallons\ of\ hot\ water\ saved\ per\ year\ (1.5\ GPM): 428 \times\ 0.825 = 353\ gal$$

**Table 309. Showerhead TSRVs—Hot Water Usage Reduction**

| Description | 2.5 GPM | 2.0 GPM | 1.75 GPM | 1.5 GPM |
|---|---|---|---|---|
| Average behavioral waste (minutes per shower)[378] | | | | 0.783 |
| Showers/person/day[379] | | | | 0.6 |
| Occupants per home[380] | | | | 2.83 |
| Showerheads/home[381] | | | | 1.72 |
| Behavioral waste/showerhead/year (gal) | 713 | 570 | 499 | 428 |
| Percent hot water[382] | | | | 80-85%, or 82.5% average |
| Hot water saved/year (gal) | 588 | 470 | 412 | 353 |

## Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$Energy\ Savings\ per\ TSRV\ [\Delta kWh] = \frac{\rho \times C_P \times V \times (T_{setpoint} - T_{supply,avg})}{RE \times 3{,}412}$$

**Equation 86**

[378] "Disaggregating Residential Shower Warm-Up Waste", Sherman, Troy. August 2014. Derived by dividing average behavioral waste time (47 seconds) by 60 seconds.

[379] Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study". Prepared for Michigan Evaluation Working Group. June 2013.

[380] Occupants per home for Texas from US Census Bureau, "Persons per household, 2016-2020". https://www.census.gov/quickfacts/fact/table/TX,US/PST045221.

[381] Showerheads per home assumed to be equal to the number of full bathrooms per home. Bathroom counts extracted from the 2015 Residential Energy Consumption Survey (RECS) Table HC2.8 Structural and geographic characteristics of homes in the West South-Central region. https://www.eia.gov/consumption/residential/data/2015/#structural.

[382] "Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV", Sherman, Troy. Evolve Technologies. December 15, 2015.

*Where:*

| | | |
|---|---|---|
| *$\rho$* | = | *Water density [lbs/gal] = 8.33* |
| *$C_p$* | = | *Specific heat of water [Btu/lb°F] = 1* |
| *V* | = | *Gallons of hot water saved per year per showerhead (see Table 309)* |
| *$T_{setpoint}$* | = | *Water heater setpoint temperature [°F][383] = 120* |
| *$T_{supply,avg}$* | = | *Average annual supply water temperature [°F] (see Table 310)* |
| *RE* | = | *Recovery Efficiency (or in the case of heat pump water heaters, COP); if unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters* |
| *3,412* | = | *Constant to convert from Btu to kWh* |

**Demand Savings Algorithms**

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a coincidence factor equivalent to the daily fraction hot water use during the weighted peak hour for each climate zone (see Volume 1, Section 4), and dividing by 365 days/year.

$$Peak\ Demand\ Savings\ per\ TSRV\ [\Delta kW] = \frac{\rho \times C_P \times V \times (T_{setpoint} - T_{supply,seasonal})}{RE \times 3{,}412 \times 365} \times CF_{S/W}$$

**Equation 87**

*Where:*

| | | |
|---|---|---|
| *$T_{supply,seasonal}$* | = | *Seasonal supply water temperature [°F] (see Table 310)* |
| *$CF_{S/W}$* | = | *Seasonal peak coincidence factor (see Table 311)* |

383 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see “New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs” October 2010, page 99.
Data collection discussed in Appendix D of the EM&V team’s Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

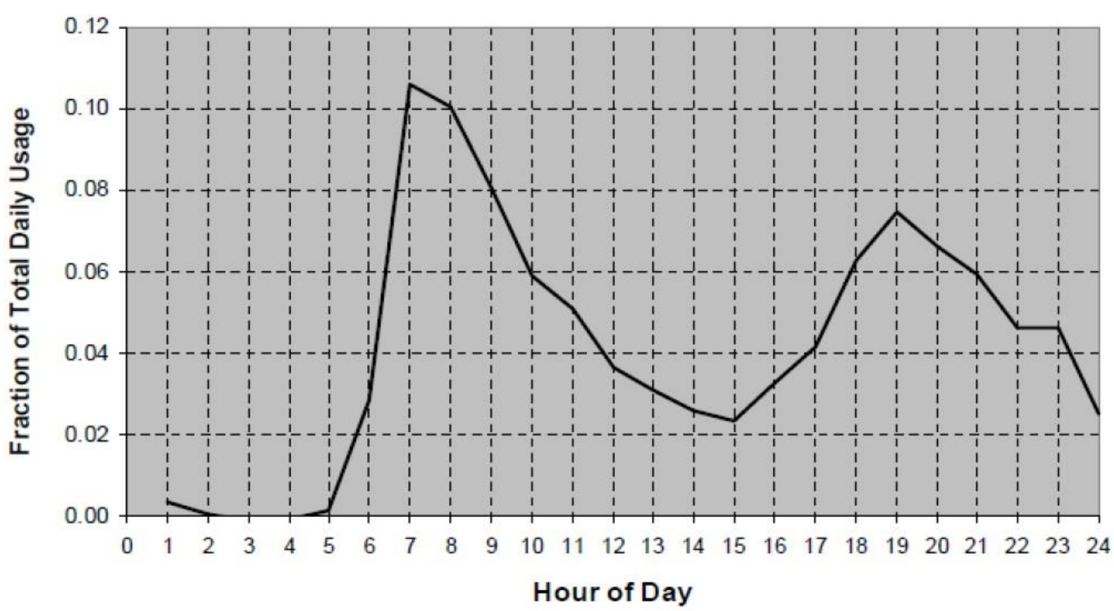
**Table 310. Showerhead TSRVs—Water Mains Temperature (°F)**[384]

| Climate zone | $T_{SupplyAverage}$ | $T_{SupplySeasonal}$ Summer | $T_{SupplySeasonal}$ Winter |
|---|---|---|---|
| Zone 1: Amarillo | 62.9 | 73.8 | 53.7 |
| Zone 2: Dallas | 71.8 | 84.0 | 60.6 |
| Zone 3: Houston | 74.7 | 84.5 | 65.5 |
| Zone 4: Corpus Christi | 77.2 | 86.1 | 68.5 |
| Zone 5: El Paso | 70.4 | 81.5 | 60.4 |

**Table 311. Showerhead TSRVs—Coincidence Factors**

| Climate zone | Summer | Winter |
|---|---|---|
| Zone 1: Amarillo | 0.039 | 0.073 |
| Zone 2: Dallas | 0.035 | 0.075 |
| Zone 3: Houston | 0.038 | 0.080 |
| Zone 4: Corpus Christi | 0.038 | 0.068 |
| Zone 5: El Paso | 0.028 | 0.069 |

**Figure 6. Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile**[385]




Source: Building America Performance Analysis Procedures for Existing Homes.

[384] Based on typical meteorological year (TMY) dataset for TMY3 available through the National Solar Radiation Database (NSRDB) Data Viewer. https://nsrdb.nrel.gov/data-viewer. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

[385] Building America performance analysis procedures for existing homes.

## 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) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.[386]

# 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
- DHW recovery efficiency (RE) or COP, if available
- Flow rate in gallons per minute (GPM) of showerhead installed
- Water heater type (heat pump, electric resistance)

# References and Efficiency Standards

## Petitions and Rulings

Not applicable.

[386] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

## Relevant Standards and Reference Sources

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

## Document Revision History

**Table 312. Showerhead TSRVs—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v5.0 | 10/2017 | TRM v5.0 origin. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. No revision. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated coincidence factors. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated EUL reference and restricted measure to electric DHW. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated number of occupants per home. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision. |

## 2.4.9 Tub Spout and Showerhead Temperature Sensitive Restrictor Valves Measure Overview

**TRM Measure ID:** R-WH-TV

**Market Sector:** Residential

**Measure Category:** Water heating

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This measure consists of replacing existing tub spouts and showerheads with an automatically diverting tub spout and showerhead system with a temperature sensitive restrictor valve (TSRV) [387] between the existing shower arm and showerhead. The tub spout will contain temperature sensitive restrictor technology that will cause the tub spout to automatically engage the anti-leak diverter once the water reaches a set temperature (generally 95˚F). The water will divert to a showerhead with a normally closed valve that will prevent the hot water from going down the drain prior to the user entering the shower, thereby eliminating behavioral waste and tub spout leakage waste.

### Eligibility Criteria

These deemed savings are for tub spout and showerhead systems with temperature sensitive restrictor technology installed in new construction or as a retrofit measure in existing homes. Buildings must have electrically fueled hot water to be eligible for this measure.

### Baseline Condition

The baseline condition is the residential tub spout with a standard diverter and a standard (2.5 gpm) showerhead.

[387] A temperature sensitive restrictor valve is any device that uses water temperature to regulate water flow in showers.

## High-Efficiency Condition

The high-efficiency condition is an anti-leak, automatically diverting tub spout system with temperature sensitive restrictor technology installed on a residential shower arm and showerhead with a standard (2.5 GPM) or low-flow (2.0, 1.75, or 1.5 GPM) showerhead. If this measure is installed in conjunction with a low-flow showerhead, refer to the Low-flow Showerheads measure and claim additional savings as outlined in that measure.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Estimated Hot Water Usage Reduction*

This system provides savings in two parts: elimination of behavioral waste (hot water that goes down the drain prior to the user entering the shower) and elimination of tub spout diverter leakage.

**Part 1:** To determine baseline gallons of behavioral waste per year, the following formula was used:

$$Annual\ Showerhead\ Behavioral\ Waste = \%WUE_{SH} \times SHFR \times BW \times n_S \times 365 \times \frac{n_O}{n_{SH}}$$

**Equation 88**

$$Annual\ Tub\ Spout\ Behavioral\ Waste = \%WUE_{TS} \times TSFR \times BW \times n_S \times 365 \times \frac{n_O}{n_{SH}}$$

**Equation 89**

*Where:*

$\%WUE_{SH}$ = *Showerhead percentage of warm-up events (see Table 313)*

$\%WUE_{TS}$ = *Tub spout percentage of warm-up events (see Table 313)*

*SHFR* = *Showerhead flow rate, gallons per minute [gpm] (see Table 313)*

*TSFR* = *Tub spout flow rate, gallons per minute [gpm] (see Table 313)*

*BW* = *Behavioral waste, minutes per shower (see Table 313)*

$n_S$ = *Number of showers per person per day (see Table 313)*

*365* = *Constant to convert days to years (see Table 313)*

$n_O$ = *Number of occupants per home (see Table 313)*

$n_{SH}$ = *Number of showerheads per home (see Table 313)*

Applying the formula to the values from Table 313 returns the following values:

$$Showerhead\ (1.5\ GPM): 0.6 \times \left(1.5 \times 0.783 \times 0.60 \times 365 \times \frac{2.86}{1.72}\right) = 257$$

$$Showerhead\ (1.75\ GPM): 0.6 \times \left(1.75 \times 0.783 \times 0.60 \times 365 \times \frac{2.86}{1.72}\right) = 299$$

$$Showerhead\ (2.0\ GPM): 0.6 \times \left(2.0 \times 0.783 \times 0.60 \times 365 \times \frac{2.86}{1.72}\right) = 342$$

$$Showerhead\ (2.5\ GPM): 0.6 \times \left(2.5 \times 0.783 \times 0.60 \times 365 \times \frac{2.86}{1.72}\right) = 428$$

$$Tub\ Spout\ (5.0\ GPM): 0.4 \times \left(5.0 \times 0.783 \times 0.60 \times 365 \times \frac{2.86}{1.72}\right) = 570$$

**Part 2:** To determine baseline gallons of diverter leakage per year, the following formula was used:

$$Annual\ Diverter\ Waste = DLR \times t_S \times n_S \times 365\ \frac{days}{year} \times \frac{n_O}{n_{SH}}$$

**Equation 90**

*Where:*

| | | |
|---|---|---|
| *DLR* | = | *Diverter leakage rate [gpm] (see Table 313)* |
| $t_S$ | = | *Shower time (min/shower) (see Table 313)* |

Applying the formula to the values from Table 313 returns the following values:

$$Diverter\ (0.8\ GPM): 0.8 \times 7.8 \times 0.60 \times 365 \times \frac{2.86}{1.72} = 2{,}272$$

**Part 3:** To determine gallons of water saved per year can be found by multiplying the total waste by the percent of hot water from Table 313.

$$Gallons\ of\ hot\ water\ saved = (SHBW + TSBW) \times HW\%_{SH,TS} + DW \times HW\%_D$$

**Equation 91**

*Where:*

| | | |
|---|---|---|
| *SHBW* | = | *Showerhead behavioral waste [gal]* |
| *TSBW* | = | *Tub spout behavioral waste [gal]* |
| *DW* | = | *Diverter waste [gal]* |
| $HW\%_{SH,TS}$ | = | *Showerheads and tub spout hot water percentage (see Table 313)* |
| $HW\%_D$ | = | *Diverter hot water percentage (see Table 313)* |

Applying the formula to the values from Table 313 returns the following values:

$$Total\ Annual\ Waste\ (1.5\ gpm): (257 + 570) \times 0.825 + 2{,}272 \times 0.737 = 2{,}357$$

$$Total\ Annual\ Waste\ (1.75\ gpm): (299 + 570) \times 0.825 + 2{,}272 \times 0.737 = 2{,}392$$

$$Total\ Annual\ Waste\ (2.0\ gpm): (342 + 570) \times 0.825 + 2{,}272 \times 0.737 = 2{,}427$$

$$Total\ Annual\ Waste\ (2.5\ gpm): (428 + 570) \times 0.825 + 2{,}272 \times 0.737 = 2{,}498$$

**Table 313. Tub Spout/Showerhead TSRVs—Hot Water Usage Reduction**

| Description | Part 1—Behavioral waste | | Part 2—Diverter leakage | Part 3—Total |
|---|---|---|---|---|
| | SH Warm-up | TS Warm-up | | |
| Baseline showerhead flow rate (GPM) | 1.5, 1.75, 2.0, or 2.5 | | | – |
| Tub spout flow rate (GPM)[388] | – | 5.0 | | – |
| Percent of warm-up events[389] | 60% | 40% | | – |
| Average behavioral waste (minutes per shower)[390] | | 0.783 | | – |
| Average diverter leakage rate (GPM)[391] | | – | 0.80 | – |
| Average shower time (minutes per shower)[392] | | – | 7.8 | – |
| Showers/person/day[393] | | | | 0.60 |
| Occupants/home[394] | | | | 2.83 |
| Showerheads/home[395] | | | | 1.72 |
| Gallons behavioral waste. per tub spout/showerhead per year (1.5 GPM) | 257 | 570 | 2,272 | 3,099 |
| Gallons behavioral waste per tub spout/showerhead per year (1.75 GPM) | 299 | | | 3,142 |
| Gallons behavioral waste per tub spout/showerhead per year (2.0 GPM) | 342 | | | 3,185 |

388 Assumption from (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

389 Percent of warm-up events from (Sherman 2014) Disaggregating Residential Shower Warm-Up Waste (Appendix B, Question 8).

390 Average behavioral waste from Lutz (2004) Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems and Sherman (2014) Disaggregating Residential Shower Warm-Up Waste. Derived by dividing 47 seconds by 60 seconds.

391 Average diverter leak rate from (Taitem 2011) Taitem Tech Tip – Leaking Shower Diverters.

392 Cadmus and Opinion Dynamics Evaluation Team, "Memorandum: Showerhead and Faucet Aerator Meter Study". Prepared for Michigan Evaluation Working Group.

393 Derivation of value for showers per person per day defined in the Low Flow Showerhead measure.

394 Occupants per home for Texas from US Census Bureau, Texas, "Persons per household, 2016-2020." https://www.census.gov/quickfacts/fact/table/TX,US/PST045221.

395 Showerheads per home assumed to be equal to the number of full bathrooms per home, taken from 2015 RECS, Table HC2.8. https://www.eia.gov/consumption/residential/data/2015/#structural.

| Description | Part 1—Behavioral waste | | Part 2—Diverter leakage | Part 3—Total |
|---|---|---|---|---|
| | SH Warm-up | TS Warm-up | | |
| Gallons behavioral waste per tub spout/showerhead per year (2.5 GPM) | 428 | | | 3,270 |
| Percentage hot water[396] | 80-85%, or 82.5% average | | 73.7% | – |
| Gallons hot water saved per year (1.5 GPM) | | | – | 2,357 |
| Gallons hot water saved per year (1.75 GPM) | | | – | 2,392 |
| Gallons hot water saved per year (2.0 GPM) | | | – | 2,427 |
| Gallons hot water saved per year (2.5 GPM) | | | – | 2,498 |

### *Energy Savings Algorithms*

Energy savings for this measure are calculated as follows:

$$Energy\ Savings\ per\ TSRV\ [\Delta kWh] = \frac{\rho \times C_P \times V \times (T_{setpoint} - T_{supply,avg})}{RE \times 3{,}412}$$

**Equation 92**

*Where:*

$\rho$ = *Water density [lbs/gal] = 8.33*

$C_p$ = *Specific heat of water [Btu/lb°F] = 1*

$V$ = *Gallons of hot water saved per year per showerhead (see Table 313)*

$T_{setpoint}$ = *Water heater setpoint temperature*[397] *[°F] = 120*

$T_{supply,avg}$ = *Average annual supply water temperature [°F] (see Table 314)*

$RE$ = *Recovery Efficiency (or in the case of heat pump water heaters, COP); if unknown, use 0.98 as a default for electric resistance water heaters or 2.2 for heat pump water heaters*

*3,412* = *Constant to convert from Btu to kWh*

396 Average percentage hot water for warm up events from (Lutz 2004) Feasibility Study and Roadmap to Improve Residential Hot Water Distribution Systems and (Sherman 2015) Calculating Savings For: Auto-Diverting Tub Spout System with ShowerStart TSV.

397 120°F represents the assumed water heater setpoint. New York Department of Public Service recommends using water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs" October 2010, page 99. Data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015), also supports a default value of 120°F.

### *Demand Savings Algorithms*

Demand savings are calculated by substituting the average supply temperature for the average seasonal temperature, multiplying by a coincidence factor equivalent to the daily fraction hot water use during the weighted peak hour for each climate zone (see Volume 1, Section 4), and dividing by 365 days/year.

$$Peak\ Demand\ Savings\ per\ TSRV\ [\Delta kW] = \frac{\rho \times C_P \times V \times (T_{setpoint} - T_{supply,seasonal})}{RE \times 3{,}412 \times 365} \times CF_{S/W}$$

**Equation 93**

*Where:*

$T_{supply,seasonal}$ = *Seasonal supply water temperature [°F] (see Table 314)*

$CF_{S/W}$ = *Peak coincidence factor (see Table 315)*

**Table 314. Tub Spout/Showerhead TSRVs—Water Mains Temperature (°F)[398]**

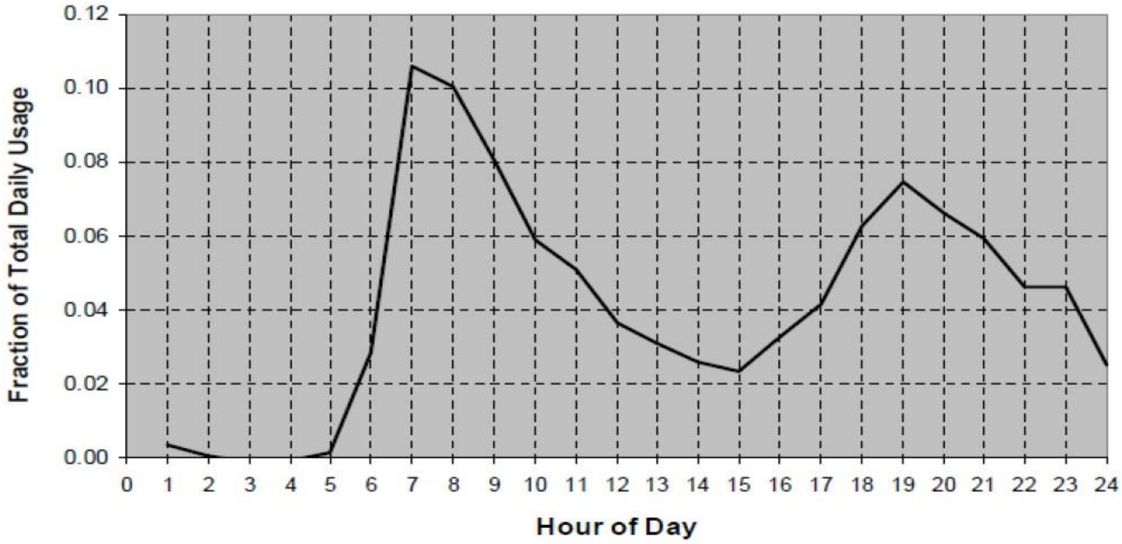
| Climate zone | $T_{SupplyAverage}$ | $T_{SupplySeasonal}$ | |
|---|---|---|---|
| | | Summer | Winter |
| Zone 1: Amarillo | 62.9 | 73.8 | 53.7 |
| Zone 2: Dallas | 71.8 | 84.0 | 60.6 |
| Zone 3: Houston | 74.7 | 84.5 | 65.5 |
| Zone 4: Corpus Christi | 77.2 | 86.1 | 68.5 |
| Zone 5: El Paso | 70.4 | 81.5 | 60.4 |

**Table 315. Tub Spout/Showerhead TSRVs—Coincidence Factors**

| Climate zone | Summer | Winter |
|---|---|---|
| Zone 1: Amarillo | 0.039 | 0.073 |
| Zone 2: Dallas | 0.035 | 0.075 |
| Zone 3: Houston | 0.038 | 0.080 |
| Zone 4: Corpus Christi | 0.038 | 0.068 |
| Zone 5: El Paso | 0.028 | 0.069 |

398 Based on typical meteorological year (TMY) dataset for TMY3, available through the National Solar Radiation Database (NSRDB) Data Viewer. https://nsrdb.nrel.gov/data-viewer. Data for Texas climate zones can also be accessed directly here: https://texasefficiency.com/index.php/regulatory-filings/deemed-savings.

**Figure 7. Tub Spout/Showerhead TSRVs—Shower, Bath, and Sink Hot Water Use Profile**[399]




Source: Building America Performance Analysis Procedures for Existing Homes.

## 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.

[399] Building America performance analysis procedures for existing homes.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID WtrHt-WH-Shrhd.[400]

## 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
- Flow rate in gallons per minute (GPM) of showerhead installed
- Water heater type (heat pump, electric resistance)
- DHW recovery efficiency (RE) or COP, if available

## 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 316. Tub Spout/Showerhead TSRVs—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v5.0 | 10/2017 | TRM v5.0 origin. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. No revision. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated coincidence factors. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated EUL reference and restricted measure to electric DHW. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated number of occupants per home. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision. |

400 DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

## 2.4.10 Water Heater Temperature Setback Measure Overview

**TRM Measure ID:** R-WH-TS

**Market Sector:** Residential

**Measure Category:** Water heating

**Applicable Building Types:** Single-family, multifamily, manufactured

**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 outlines the demand and energy savings yielded from reprogramming residential water heater thermostats with default settings of greater than 120°F to 120°F.

### Eligibility Criteria

Electric storage water heaters with default temperature setpoints in excess of 120°F are eligible to claim savings from this measure.

### Baseline Condition

The baseline condition is an electric storage water heater with a thermostat setting that is higher than 120°F.

### High-Efficiency Condition

The efficient condition is an electric storage water heater with a thermostat setting reduced to 120°F.

## Energy and Demand Savings Methodology

### Savings Algorithms and Input Variables

Water heater temperature setback savings are calculated on a per-unit basis. Deemed savings variables include the tank surface area, the heat transfer coefficient for the tank, and hot water setpoint prior to adjustment.

## *Energy Savings Algorithm*

$$Energy\ Savings\ [\Delta kWh] = \frac{A \times U \times (T_{pre} - T_{post}) \times 8{,}760}{RE \times 3{,}412}$$

**Equation 94**

*Where:*

| | | |
|---|---|---|
| $A$ | = | *Tank surface area insulated in square feet (πDL) with L (length) and D (tank diameter) in feet; if the tank area is not known, use Table 317* |

**Table 317. DHW Temperature Setback—Estimated Tank Area**[401]

| Volume (gal) | A (sq. ft.) |
|---|---|
| 30 | 17.45 |
| 40 | 21.81 |
| 50 | 22.63 |
| 60 | 26.94 |
| 80 | 30.36 |
| 120 | 38.73 |

| | | |
|---|---|---|
| $U$ | = | *Overall heat transfer coefficient for the tank*[402] *(Btu/Hr·°F·ft$^2$)* |
| $T_{pre}$ | = | *Hot water setpoint prior to adjustment [°F]* |
| $T_{post}$ | = | *Water heater setpoint [°F]*[403] *= 120* |
| *8,760* | = | *Total hours per year* |
| *RE* | = | *Recovery efficiency of electric hot water heater = 0.98*[404] |
| *3,412* | = | *Constant to convert from Btu to kWh* |

401 Texas TRM Vol 2, 2.4.4 Water Heater Tank Insulation, Table 317.
402 If unknown, assume R-5 (U = 1/5).
403 120°F represents the assumed water heater setpoint. The New York Department of Public Service recommends using the water heater setpoint as a default value, see "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs." Page 99. October 2010. The data collection discussed in Appendix D of the EM&V team's Annual Statewide Portfolio Report for Program Year 2014-Volume 1, Project Number 40891 (August 2015) also supports a default value of 120°F.
404 Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://www.ahrinet.org.

### *Demand Savings Algorithm*

$$Summer\ Peak\ Demand\ Savings\ [\Delta kW] = \frac{kWh_{savings}}{8{,}760} \times CF_S$$

**Equation 95**

*Where:*

$CF_S$ = *Summer peak coincidence factor = 1.0*

## 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) is 2 years[405].

[405] 2022 Illinois Statewide Technical Reference Manual Version 10.0, Volume 3 – 5.4.6 Water Heater Temperature Setback. September 24, 2021.

## 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
- R-value or overall heat transfer coefficient of tank (1 / R-value)
- Tank surface area insulated in square feet ($\pi DL$) with L (length) and D (tank diameter) in feet; if unable to determine tank area, tank volume must be recorded
- Hot water setpoint prior to adjustment
- Photo of reprogrammed temperature setpoint or another pre-approved method of verification
- Water heater manufacture date

## 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 318. DHW Temperature Setback—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. |

## 2.5 RESIDENTIAL: APPLIANCES

### 2.5.1 ENERGY STAR® Ceiling Fans Measure Overview

**TRM Measure ID:** R-AP-CF

**Market Sector:** Residential

**Measure Category:** Appliances

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

#### Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR ceiling fan and light kit. Savings are awarded at a flat per-unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

#### Eligibility Criteria

Savings values in this measure are based on indoor usage patterns and are not applicable to outdoor applications.

#### Baseline Condition

The baseline is a conventional non-ENERGY STAR labeled ceiling fan and light kit.

#### High-Efficiency Condition

The table below displays the ENERGY STAR Version 4.0 Requirements for eligible ceiling fans effective June 15, 2018.[406] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

406 ENERGY STAR Ceiling Fan and Light Kits, Final Version 4.0 Program Requirements. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Ceiling%20Fans%20and%20Ceiling%20Fan%20Light%20Kits%20Version%204.0_Program%20Requirements_0_0.pdf.

**Table 319. Ceiling Fans—Fan Definitions**

| Fan type | Description |
|---|---|
| Ceiling fan | A non-portable device designed for home use that is suspended from the ceiling for circulating air via the rotation of fan blades; for which the lowest point on fan blades is greater than 10 inches from the ceiling. |
| Hugger ceiling fan | A ceiling fan for which the lowest point on the fan blades is less than or equal to 10 inches from the ceiling. Hugger ceiling fans can be safely installed on low ceilings, and some are sold with ceiling fan light kits. |

**Table 320. Ceiling Fans—Efficiency Requirements**

| Type | Diameter (inches) | Minimum efficiency (cfm/W) | Minimum high speed airflow (cfm) |
|---|---|---|---|
| Ceiling fan | $D \leq 36$ | $\geq 0.72 \times D + 41.93$ | $\geq$ 1,767 |
| | $36 < D < 78$ | $\geq 2.63 \times D - 26.83$ | $\geq 250 \times \pi \times (D/24)^2$ |
| | $D \geq 78$ | | $\geq$ 8,296 |
| Hugger ceiling fan | $D \leq 36$ | $\geq 0.31 \times D + 36.84$ | $\geq$ 1,414 |
| | $36 < D < 78$ | $\geq 1.75 \times D - 15$ | $\geq 200 \times \pi \times (D/24)^2$ |
| | $D \geq 78$ | | $\geq$ 6,637 |

**Table 321. Ceiling Fans—Light Kit Efficacy Requirements**

| Type | Minimum efficacy (lumens/W) | Minimum light output (lumens) |
|---|---|---|
| Shipped with ENERGY STAR certified light bulbs | 65.0 | – |
| Separable light source | 65.0 | 800 |
| Integrated light source | 70.0 | |

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Energy Savings Algorithms*

Energy savings were calculated using the ENERGY STAR Ceiling Fan Savings Calculator found on the ENERGY STAR website.[407] Default values were taken directly from the ENERGY STAR Ceiling Fan Savings Calculator, unless otherwise specified.

[407] ENERGY STAR Ceiling Fan Savings Calculator (updated September 2013). https://www.energystar.gov/sites/default/files/asset/document/light_fixture_ceiling_fan_calculator.xlsx.

$$Energy\ Savings\ [\Delta kWh] = (kWh_{baseline} - kWh_{ES})_{fan} + (kWh_{baseline} - kWh_{ES})_{lgt} \times IEF_E$$

**Equation 96**

$$kWh_{baseline,Fan} = \frac{W_{Fan,baseline} \times AOH_{Fan}}{1{,}000}$$

**Equation 97**

$$kWh_{ES,Fan} = \frac{W_{Fan,ES} \times AOH_{Fan}}{1{,}000}$$

**Equation 98**

$$W_{Fan} = (W_{LS} \times OP_{LS}) + (W_{MS} \times OP_{MS}) + (W_{HS} \times OP_{HS})$$

**Equation 99**

$$kWh_{baseline,Lgt} = \frac{W_{Lgt,baseline} \times AOH_{Lgt}}{1{,}000}$$

**Equation 100**

$$kWh_{ES,Lgt} = \frac{W_{Lgt,ES} \times AOH_{Lgt}}{1{,}000}$$

**Equation 101**

*Where:*

| | | |
|---|---|---|
| $kWh_{baseline}$ | = | *Non-ENERGY STAR baseline energy usage* |
| $kWh_{ES}$ | = | *ENERGY STAR average energy usage* |
| $IEF_E$ | = | *Energy interactive effects factor from Table 322 assuming heating/cooling unknown* [408] |
| $W_{Lgt,baseline}$ | = | *Conventional lighting total wattage = 58 W (160 W default value from ENERGY STAR calculator reduced to comply with EISA 2007 45 lumens/watt backstop)*[409] |
| $W_{Lgt,ES}$ | = | *Actual wattage of installed ENERGY STAR lighting; assume one high-efficiency 32 W lamp* |
| $W_{Fan,baseline}$ | = | *Conventional fan motor wattage* |
| $W_{Fan,ES}$ | = | *ENERGY STAR fan motor wattage* |
| $W_{LS/MS/HS}$ | = | *Fan motor wattage at low, medium, and high speed; see Table 323* |

408 The assumed energy interactive effects factors are taken from the residential lighting measure.

409 Assumes a mix of general service incandescent lamps. EISA 2007 45 lumens/watt backstop is approximately 36 percent of standard incandescent wattages for the 40, 60, 75, and 100 equivalent wattage categories. 160 W x 0.36 = 58 W.

| | | |
|---|---|---|
| $OP_{LS/MS/HS}$ | = | *Fan operating percentage at low, medium, and high speed; see Table 324* |
| $AOH_{Lgt}$ | = | *Annual lighting operating hours = 803 hours/year (assuming 2.2 hours/day and 365 days/year operation)*[410] |
| $AOH_{Fan}$ | = | *Annual fan operating hours = 1,095 hours/year (assuming 3.0 hours/day and 365 days/year operation)*[411] |
| *1,000* | = | *Constant to convert from W to kW* |

**Table 322. Ceiling Fans—Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties**[412]

| $IEF_E$ | | | | | |
|---|---|---|---|---|---|
| Heating/cooling type | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
| Heating/cooling unknown[413] | 0.88 | 0.98 | 1.04 | 1.07 | 0.95 |

**Table 323. Ceiling Fans— Motor Wattages**

| Fan type | Fan speed | Fan motor wattage (W) |
|---|---|---|
| Conventional | Low | 15 |
| | Medium | 34 |
| | High | 67 |
| ENERGY STAR | Low | 6 |
| | Medium | 23 |
| | High | 56 |

[410] The assumed annual operating hours are taken from the residential lighting measure.

[411] The assumed annual operating hours are taken from the previously cited ENERGY STAR Light Fixture and Ceiling Fan Calculator.

[412] Extracted from BEopt energy models used to estimate savings for envelope measures. Referencing the EISA baseline table, the typical lumen output was determined by taking the midpoint for the 60-watt equivalent lamp (900 lm), which was assumed to be the most typical installation. The resulting lumens were divided by the default wattage for incandescents (43 W), CFLs (13 W), and LEDs (10 W) resulting in an assumed efficacy for incandescents (21 lm/W), CFLs (70 lm/W), and LEDs (90 lm/W). IEF values were calculated using the following formula: $1 + HVAC_{savings}/Lighting_{savings}$.

[413] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16 percent outdoor lighting except for upstream defaults. Cadmus report: Cadmus. Entergy Energy-Efficiency Portfolio Evaluation Report 2013 Program Year. Prepared for Entergy Arkansas, Inc. March 14, 2014. Docket No. 07-082-TF.

**Table 324. Ceiling Fans—Operating Percentages**

| Fan speed | Operating percentage (OP) |
|---|---|
| Low | 40% |
| Medium | 40% |
| High | 20% |

## *Demand Savings Algorithms*

Peak demand savings were calculated using separate coincidence factors for the lighting and the fan motor portion of the ceiling fan savings. For lighting the coincidence factor varies based on climate zone. For the fan motor a coincidence factor of 0.446 was applied (derived from the EnergyGauge software ceiling fan profiles).

$$Peak\ Demand\ Savings\ [\Delta kW] = kW_{Fan} + kW_{Lgt}$$

**Equation 102**

$$kW_{Fan} = \frac{W_{Fan,baseline} - W_{Fan,ES}}{1{,}000} \times CF_{Fan}$$

**Equation 103**

$$kW_{Lgt} = \frac{W_{Lgt,baseline} - W_{Lgt,ES}}{1{,}000} \times CF_{Lgt,S/W} \times IEF_{D,S/W}$$

**Equation 104**

*Where:*

$kW_{Fan}$ = *Fan demand savings*

$CF_{Fan}$ = *Fan motor peak coincidence factor = 0.446*

$kW_{Lgt}$ = *Lighting demand savings*

$CF_{Lgt,S/W}$ = *Lighting seasonal peak coincidence factor (Table 325)*

$IEF_{D,S/W}$ = *Demand interactive effects factor from Table 326 assuming heating/cooling unknown*[414]

[414] The assumed demand interactive effects factors are taken from the residential lighting measure.

Table 325. Ceiling Fans—Lighting Coincidence Factors[415]

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 0.060 | 0.053 | 0.063 | 0.059 | 0.032 |
| Winter | 0.275 | 0.232 | 0.199 | 0.263 | 0.358 |

Table 326. Ceiling Fans—Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[416]

| $IEF_{D,S}$ | | | | | |
|---|---|---|---|---|---|
| Heating/cooling type | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
| Heating/cooling unknown[417] | 1.39 | 1.28 | 1.58 | 1.20 | 1.38 |
| $IEF_{D,W}$ | | | | | |
| Heating/cooling type | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
| Heating/cooling unknown[418] | 0.76 | 0.72 | 0.73 | 0.75 | 0.80 |

## Deemed Energy Savings Tables

Table 327. Ceiling Fans—Energy Savings (kWh)

| Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|
| 29.5 | 31.6 | 32.9 | 33.5 | 31.0 |

## Deemed Summer Demand Savings Tables

Table 328. Ceiling Fans—Summer Peak Demand Savings (kW)

| Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|
| 0.007 | 0.006 | 0.007 | 0.006 | 0.006 |

415 See Volume 1, Section 4.
416 See Table 322.
417 Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16 percent outdoor lighting except for upstream defaults. Cadmus report: Cadmus. Entergy Energy-Efficiency Portfolio Evaluation Report 2013 Program Year. Prepared for Entergy Arkansas, Inc. March 14, 2014. Docket No. 07-082-TF.
418 Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16 percent outdoor lighting except for upstream defaults. Cadmus report: Cadmus. Entergy Energy-Efficiency Portfolio Evaluation Report 2013 Program Year. Prepared for Entergy Arkansas, Inc. March 14, 2014. Docket No. 07-082-TF.

## Deemed Winter Demand Savings Tables

**Table 329. Ceiling Fans—Winter Peak Demand Savings (kW)**

| Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|
| 0.010 | 0.009 | 0.008 | 0.010 | 0.012 |

## 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) is established at 10 years according to the ENERGY STAR Ceiling Fan Savings Calculator.

This EUL is consistent with Docket No. 38025 approved in 2010.[419]

## 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
- Quantity of installed ENERGY STAR ceiling fan and light kits
- Manufacturer and model number
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

## References and Efficiency Standards

## Petitions and Rulings

- Docket No. 38025. Petition of Electric Utility Marketing Managers of Texas to Amend Deemed Savings for ENERGY STAR Appliance Measures. Public Utility Commission of Texas.

[419] Docket No. 38025. Petition of Electric Utility Marketing Managers of Texas to Amend Deemed Savings for ENERGY STAR Appliance Measures. Public Utility Commission of Texas.

## Relevant Standards and Reference Sources

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

## Document Revision History

**Table 330. Ceiling Fans—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Minor edits to language and updates to the ENERGY STAR specification table. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2014 | TRM v3.0 update. Explanation of methodology and alignment with ENERGY STAR calculator. Introduction of interactive effects factors and in-service rates. New peak savings calculated according to revised peak definition. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Revision of interactive effects factors to reflect indoor-specific values for additional heating and cooling equipment types. |
| v3.1 | 3/28/2016 | TRM v3.1 March revision. Updated summer and winter coincidence factors. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Updated interactive effect values using building energy simulation. |
| v5.0 | 10/2017 | TRM v5.0 update. Updated footnote reference to ENERGY STAR calculator. |
| v6.0 | 11/2018 | TRM v6.0 update. Updated interactive effect values. |
| v7.0 | 11/2019 | TRM v7.0 update. Established deemed savings approach. |
| v8.0 | 10/2020 | TRM v8.0 update. No revision. |
| v9.0 | 10/2021 | TRM v9.0 update. No revision. |
| v10.0 | 10/2022 | TRM v10.0 update. Reduced baseline lighting wattage and resulting deemed energy savings for compliance with reinstated EISA 2007 45 lumens/watt baseline. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision. |

## 2.5.2 ENERGY STAR® Clothes Washers Measure Overview

**TRM Measure ID:** R-AP-CW

**Market Sector:** Residential

**Measure Category:** Appliances

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR clothes washer. Savings are awarded at a flat per unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

These deemed savings are calculated using the federal standards effective January 1, 2018.

## Eligibility Criteria

Not applicable.

## Baseline Condition

Effective January 1, 2018, the baseline is the Department of Energy (DOE) minimum efficiency standard[420] for top-loading clothes washers. While the DOE provides criteria for both top- and front-loading washers, only the standards for top-loading washers are listed below, as a top-loading unit is assumed to be the baseline equipment. This approach is based on customers having the option to install a top-loading clothes washer. Therefore, savings are calculated using the lower top-loading baseline condition.

[420] DOE minimum efficiency standard for residential clothes washers. https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39.

**Table 331. Clothes Washers—Federal Standard**

| Product type | Current criteria as of January 1, 2018 |
|---|---|
| Top-loading, standard (1.6 $ft^3$ or greater capacity) | IMEF ≥ 1.57<br>IWF≤ 6.5 |
| Top-loading, compact (less than 1.6 $ft^3$ capacity) | IMEF ≥ 1.15<br>IWF≤ 12.0 |

## High-Efficiency Condition

The table below displays the ENERGY STAR Final Version 8.1 Requirements for eligible clothes washers effective February 5, 2018.[421] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

**Table 332. Clothes Washers—ENERGY STAR Requirements**

| Product type | Current criteria as of February 5, 2018 |
|---|---|
| ENERGY STAR residential front-loading (> 2.5 $ft^3$) | IMEF ≥ 2.76<br>IWF ≤ 3.2 |
| ENERGY STAR residential top-loading (> 2.5 $ft^3$) | IMEF ≥ 2.06<br>IWF ≤ 4.3 |
| ENERGY STAR residential small or compact (< 2.5 $ft^3$) | IMEF ≥ 2.07<br>IWF ≤ 4.2 |

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Energy Savings Algorithms*

Energy savings for this measure were derived using the ENERGY STAR Appliance Savings Calculator found on the ENERGY STAR website.[422] This document will be updated regularly to apply the values provided in the latest available ENERGY STAR Appliance Savings Calculator. The most recent TRM version should be referenced to determine the savings for this measure.

$$Energy\ Savings\ [\Delta kWh] = kWh_{baseline} - kWh_{ES}$$

**Equation 105**

[421] ENERGY STAR Clothes Washer Final Version 8.1 Program Requirements. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%208.0%20Clothes%20Washer%20Partner%20Commitments%20and%20Eligibility%20Criteria.pdf.

[422] ENERGY STAR Appliance Savings Calculator (updated October 2016). The previously cited URL is no longer available, but a copy of the calculator can be provided upon request.

## Baseline Unit

$$kWh_{baseline} = kWh_{conv,machine} + kWh_{conv,WH} + kWh_{conv,dryer} + kWh_{conv,LPM}$$

**Equation 106**

$$kWh_{conv,machine} = MCF \times RUEC_{conv} \times \frac{LPY}{RLPY}$$

**Equation 107**

$$kWh_{conv,WH} = WHCF \times RUEC_{conv} \times \frac{LPY}{RLPY}$$

**Equation 108**

$$kWh_{conv,LPM} = kW_{conv,LPM} \times (8{,}760 - LPY)$$

**Equation 109**

$$kWh_{conv,dryer} = \left[\left(\frac{Cap_{conv}}{IMEF_{FS}} \times LPY\right) - \left(RUEC_{conv} \times \frac{LPY}{RLPY}\right) - kWh_{conv,LPM}\right] \times \frac{DU}{DUF}$$

**Equation 110**

*Where:*

| | | |
|---|---|---|
| $kWh_{baseline}$ | = | *Federal standard baseline energy usage* |
| $kWh_{conv,machine}$ | = | *Conventional machine energy* |
| $kWh_{conv,WH}$ | = | *Conventional water heater energy* |
| $kWh_{conv,dryer}$ | = | *Conventional dryer energy* |
| $kWh_{conv,LPM}$ | = | *Conventional combined low-power mode energy* |
| $RUEC_{conv}$ | = | *Conventional rated unit electricity consumption = 381 kWh/year (top-loading, standard)*[423]*, 163 kWh/year top-loading, compact)* |
| $LPY$ | = | *Loads per year = 295* |
| $RLPY$ | = | *Reference loads per year = 392* |
| $kW_{conv,LPM}$ | = | *Combined low-power mode wattage of conventional unit = 0.00115 kW (top-loading, standard), 0.00144 kW (top-loading, compact)* |
| $Cap_{conv}$ | = | *Average machine capacity = 4.5 ft$^3$ (top-loading, standard), 2.1 ft$^3$ (top-loading, compact)* |
| $IMEF_{FS}$ | = | *Federal standard integrated modified energy factor (Table 331)* |

[423] This value is taken from the ENERGY STAR appliance calculator and corresponds with the federal standard after March 7, 2015.

| | | |
|---|---|---|
| *MCF* | = | *Machine consumption factor = 20 percent* |
| *WHCF* | = | *Water heater consumption factor = 80 percent* |
| *DU* | = | *Dryer usage in households with both a washer and a dryer = 95 percent* |
| *DUF* | = | *Dryer use factor (percentage of washer loads dried in machine) = 91 percent* |

**ENERGY STAR Unit**

$$kWh_{ES} = kWh_{ES,machine} + kWh_{ES,WH} + kWh_{ES,dryer} + kWh_{ES,LPM}$$

**Equation 111**

$$kWh_{ES,machine} = MCF \times RUEC_{ES} \times \frac{LPY}{RLPY}$$

**Equation 112**

$$kWh_{ES,WH} = WHCF \times RUEC_{ES} \times \frac{LPY}{RLPY}$$

**Equation 113**

$$kWh_{ES,LPM} = kW_{ES,LPM} \times (8{,}760 - LPY)$$

**Equation 114**

$$kWh_{ES,dryer} = \left[\left(\frac{Cap_{ES}}{IMEF_{ES}} \times LPY\right) - \left(RUEC_{ES} \times \frac{LPY}{RLPY}\right) - kWh_{ES,LPM}\right] \times \frac{DU}{DUF}$$

**Equation 115**

*Where:*

| | | |
|---|---|---|
| $kWh_{ES}$ | = | *ENERGY STAR average energy usage* |
| $kWh_{ES,machine}$ | = | *ENERGY STAR machine energy* |
| $kWh_{ES,WH}$ | = | *ENERGY STAR water heater energy* |
| $kWh_{ES,dryer}$ | = | *ENERGY STAR dryer energy* |
| $kWh_{ES,LPM}$ | = | *ENERGY STAR combined low-power mode energy* |
| $RUEC_{ES}$ | = | *ENERGY STAR rated unit electricity consumption (see Table 333)* |
| $kW_{ES,LPM}$ | = | *Combined low-power mode wattage of ENERGY STAR unit (see Table 333)* |
| $IMEF_{ES}$ | = | *ENERGY STAR integrated modified energy factor (see Table 332)* |
| $Cap_{ES}$ | = | *Average machine capacity (see Table 333)* |

**Table 333. Clothes Washers—ENERGY STAR Characteristics**[424]

| Product type | ENERGY STAR rated unit electricity consumption (kWh) | Average capacity (ft³) | Combined low-power mode wattage (kW) |
|---|---|---|---|
| Residential front-loading (> 2.5 ft³) | 127 | 4.0 | 0.00160 |
| Residential top-loading (> 2.5 ft³) | 230 | 4.5 | 0.00115 |
| Residential small or compact (< 2.5 ft³) | 108 | 2.1 | 0.00144 |

## Demand Savings Algorithms

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh}{AOH} \times CF_{S/W}$$

**Equation 116**

$$AOH = LPY \times d$$

**Equation 117**

*Where:*

| | | |
|---|---|---|
| *AOH* | = | *Annual operating hours* |
| $CF_{S/W}$ | = | *Seasonal peak coincidence factor (Table 334)* |
| *LPY* | = | *Loads per year = 295* |
| *d* | = | *Average wash cycle duration = 1 hour* [425,426] |

**Table 334. Clothes Washers—Coincidence Factors**[427]

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 0.040 | 0.040 | 0.040 | 0.041 | 0.041 |
| Winter | 0.043 | 0.043 | 0.043 | 0.044 | 0.039 |

424 This value is taken from the ENERGY STAR appliance calculator and corresponds with the ENERGY STAR specification after March 7, 2015.

425 Weighted average of Consumer Reports Cycle Times for Top and Front-Loading Clothes Washers.

426 Consumer Reports. “Top-loading washers remain more popular with Americans”. April 13, 2010. Weighted average of 75 percent Top-Loading Clothes Washers and 25 percent Front-Loading Clothes Washers.

427 See Volume 1, Section 4.

## Deemed Energy Savings Tables

**Table 335. Clothes Washers—Energy Savings (kWh)**

| Type | Water heater fuel type | Dryer fuel type | kWh/unit |
|---|---|---|---|
| Front-loading > 2.5 ft³ | Electric | Electric | 428 |
| | | Gas | 187 |
| | Gas | Electric | 275 |
| | | Gas | 34 |
| Top-loading > 2.5 ft³ | Electric | Electric | 205 |
| | | Gas | 114 |
| | Gas | Electric | 114 |
| | | Gas | 23 |
| All ≤ 2.5 ft³ | Electric | Electric | 248 |
| | | Gas | 41 |
| | Gas | Electric | 215 |
| | | Gas | 8 |

## Deemed Summer Demand Savings Tables

**Table 336. Clothes Washers—Summer Peak Demand Savings (kW)**

| Washer type | Fuel Type | | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|---|
| | Water heater | Dryer | | | | | |
| Front-loading > 2.5 ft³ | Electric | Electric | 0.058 | 0.058 | 0.058 | 0.060 | 0.060 |
| | | Gas | 0.025 | 0.025 | 0.025 | 0.026 | 0.026 |
| | Gas | Electric | 0.037 | 0.037 | 0.037 | 0.038 | 0.038 |
| | | Gas | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| Top-loading > 2.5 ft³ | Electric | Electric | 0.028 | 0.028 | 0.028 | 0.028 | 0.028 |
| | | Gas | 0.015 | 0.015 | 0.015 | 0.016 | 0.016 |
| | Gas | Electric | 0.015 | 0.015 | 0.015 | 0.016 | 0.016 |
| | | Gas | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| All ≤ 2.5 ft³ | Electric | Electric | 0.034 | 0.034 | 0.034 | 0.034 | 0.034 |
| | | Gas | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 |
| | Gas | Electric | 0.029 | 0.029 | 0.029 | 0.030 | 0.030 |
| | | Gas | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

## Deemed Winter Demand Savings Tables

**Table 337. Clothes Washers—Winter Peak Demand Savings (kW)**

| Washer type | Fuel type: Water heater | Fuel type: Dryer | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|---|
| Front-loading > 2.5 $ft^3$ | Electric | Electric | 0.062 | 0.062 | 0.062 | 0.064 | 0.057 |
| | | Gas | 0.027 | 0.027 | 0.027 | 0.028 | 0.025 |
| | Gas | Electric | 0.040 | 0.040 | 0.040 | 0.041 | 0.036 |
| | | Gas | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| Top-loading > 2.5 $ft^3$ | Electric | Electric | 0.030 | 0.030 | 0.030 | 0.031 | 0.027 |
| | | Gas | 0.017 | 0.017 | 0.017 | 0.017 | 0.015 |
| | Gas | Electric | 0.017 | 0.017 | 0.017 | 0.017 | 0.015 |
| | | Gas | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| All ≤ 2.5 $ft^3$ | Electric | Electric | 0.036 | 0.036 | 0.036 | 0.037 | 0.033 |
| | | Gas | 0.006 | 0.006 | 0.006 | 0.006 | 0.005 |
| | Gas | Electric | 0.031 | 0.031 | 0.031 | 0.032 | 0.028 |
| | | Gas | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

## 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) of an ENERGY STAR clothes washer is established at 11 years based on the Technical Support Document for the current DOE Final Rule standards for residential clothes washers.[428]

[428] The median lifetime was calculated using the survival function outlined in the DOE Technical Support Document. Final Rule: Standards, Federal Register, 77 FR 32308 (May 31, 2012) and associated Technical Support Document. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=68&action=viewlive. Download TSD at: https://www.regulations.gov/document/EERE-2008-BT-STD-0019-0047.

## 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
- Unit quantity
- Manufacturer and model number
- Type of unit (top-loading, front-loading, or compact)
- DHW fuel type (gas or electric)
- Dryer fuel type (gas or electric)
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

## 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 338. Clothes Washers—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Updated by Frontier Energy, March 2014, based on new federal standards. |
| v2.1 | 1/30/2015 | TRM v2.1 update. New ENERGY STAR standards incorporated. |
| v3.0 | 4/10/2015 | TRM v3.0 update. Updated EUL to align with median lifetime. New peak savings calculated according to revised peak definition. |
| v3.1 | 11/05/2015 | TRM v3.1 update. New ENERGY STAR algorithms and default assumptions incorporated. |
| v3.1 | 3/28/2016 | TRM v3.1 March revision. Updated winter coincidence factors and winter and summer demand savings tables. |
| v4.0 | 10/10/2016 | TRM v4.0 update. No revision. |

| TRM version | Date | Description of change |
|---|---|---|
| v5.0 | 10/2017 | TRM v5.0 update. Updated baseline IMEF to reflect changes in Federal Standard. Updated Front Load Washer IMEF to reflect changes in ENERGY STAR Specification. Added baseline for compact units to reflect Federal Standard for compact washers. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 11/2019 | TRM v7.0 update. Updated links and dates. |
| v8.0 | 10/2020 | TRM v8.0 update. No revision. |
| v9.0 | 10/2021 | TRM v9.0 update. General reference checks and text edits. Updated deemed savings tables to match savings algorithms and ENERGY STAR calculator. |
| v10.0 | 10/2022 | TRM v10.0 update. No revision. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision. |

## 2.5.3 ENERGY STAR® Clothes Dryers Measure Overview

**TRM Measure ID:** R-AP-CD

**Market Sector:** Residential

**Measure Category:** Appliances

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR electric clothes dryer. Savings are awarded at a flat per-unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

## Eligibility Criteria

Gas dryers are ineligible to claim savings under this measure. Savings may be claimed for the replacement of gas dryers if the decision to switch fuels predates the decision to install efficient equipment.

## Baseline Condition

Effective January 1, 2015, the baseline is the Department of Energy (DOE) minimum federal efficiency standard[429], adjusted to reflect recent combined energy factor (CEF) definition updates for vented and ventless clothes dryers. These adjusted baselines consider calculated differences between CEF values under original clothes dryer testing procedures of 10 CFR 430, Subpart B, Appendix D1, and those amended procedures outlined in Appendix D2; a change indicated in detail in the September 5, 2013, ENERGY STAR stakeholder webinar. These values are consistent with the current ENERGY STAR Appliance Savings Calculator.

[429] DOE minimum efficiency standard for residential clothes dryers. https://www.regulations.gov/document?D=EERE-2007-BT-STD-0010-0050.

**Table 339. Clothes Dryers—Federal Standard**

| Product type | Average capacity ($ft^3$) | Amended minimum CEF: calculations | Minimum CEF levels (lbs/kWh) |
|---|---|---|---|
| Vented electric, standard | ≥ 4.4 | 3.73 – (3.73 x 0.166) | 3.11 |
| Vented electric, compact (120 V) | < 4.4 | 3.61 – (3.61 x 0.166) | 3.01 |
| Vented electric, compact (240 V) | < 4.4 | 3.27 – (3.27 x 0.166) | 2.73 |
| Ventless electric, compact (240 V) | < 4.4 | 2.55 – (2.55 x 0.166) | 2.13 |

## High-Efficiency Condition

The table below displays the ENERGY STAR Final Version 1.1 Requirements for eligible clothes dryers effective January 1, 2015.[430] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

**Table 340. Clothes Dryers—ENERGY STAR Requirements**

| Product type | Average Capacity ($ft^3$) | Minimum CEF levels (lbs/kWh) |
|---|---|---|
| ENERGY STAR ventless or vented electric, standard | ≥ 4.4 | 3.93 |
| ENERGY STAR ventless or vented electric, compact (120 V) | < 4.4 | 3.80 |
| ENERGY STAR vented electric, compact (240 V) | < 4.4 | 3.45 |
| ENERGY STAR ventless electric, compact (240 V) | < 4.4 | 2.68 |

# <u>Energy and Demand Savings Methodology</u>

## Savings Algorithms and Input Variables

### *Energy Savings Algorithms*

Energy savings for this measure were derived using the ENERGY STAR Appliance Savings Calculator found on the ENERGY STAR website.[431] This document will be updated regularly to apply the values provided in the latest available ENERGY STAR appliance calculator. The most recent TRM version should be referenced to determine the savings for this measure.

[430] ENERGY STAR Clothes Dryers Final Version 1.1 Program Requirements. https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Final%20Version%201.1%20Clothes%20Dryers%20Specification%20-%20Program%20Commitment%20Criteria%20and%20Eligibility%20Criteria.pdf.

[431] ENERGY STAR Appliance Savings Calculator (updated October 2016). The previously cited URL is no longer available, but a copy of the calculator can be provided upon request.

**Table 341. Clothes Dryers—Default Average Load**

| Product type | Average load (lbs) |
|---|---|
| Vented electric, standard | 8.45 |
| Vented electric, compact (120 V) | 3.00 |
| Vented electric, compact (240 V) | 3.00 |
| Ventless electric, compact (240 V) | 3.00 |

$$Energy\ Savings\ [\Delta kWh] = kWh_{baseline} - kWh_{ES}$$

**Equation 118**

## Baseline Unit

$$kWh_{baseline} = \frac{AvgLoad \times LPY}{CEF_{baseline}}$$

**Equation 119**

*Where:*

$kWh_{baseline}$ = *Federal standard baseline energy usage*

$AvgLoad$ = *Average load in lbs (Table 341)*

$LPY$ = *Loads per year = 283*

$CEF_{baseline}$ = *Baseline combined energy factor (see Table 339)*

## ENERGY STAR Unit

$$kWh_{ES} = \frac{AvgLoad \times LPY}{CEF_{ES}}$$

**Equation 120**

*Where:*

$kWh_{ES}$ = *ENERGY STAR average energy usage*

$CEF_{ES}$ = *ENERGY STAR minimum combined energy factor (see Table 340)*

## *Demand Savings Algorithms*

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh}{AOH} \times CF_{S/W}$$

**Equation 121**

*Where:*

*AOH* = *Annual operating hours = (8,760 – 8,463) = 297 hours*[432]

$CF_{S/W}$ = *Seasonal peak coincidence factor (Table 342)*

**Table 342. Clothes Dryers—Coincidence Factors**[433]

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 0.041 | 0.041 | 0.041 | 0.041 | 0.042 |
| Winter | 0.045 | 0.045 | 0.041 | 0.048 | 0.047 |

## Deemed Energy Savings Tables

**Table 343. Clothes Dryers—Energy Savings (kWh)**

| Product type | Average capacity ($ft^3$) | Energy savings (kWh) |
|---|---|---|
| Ventless or vented electric, standard | ≥ 4.4 | 160 |
| Ventless or vented electric, compact (120 V) | < 4.4 | 59 |
| Vented electric, compact (240 V) | < 4.4 | 65 |
| Ventless electric, compact (240 V) | < 4.4 | 82 |

## Deemed Summer Demand Savings Tables

**Table 344. Clothes Dryers—Summer Peak Demand Savings (kW)**

| Product type | Average capacity ($ft^3$) | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|
| Ventless or vented electric, standard | ≥ 4.4 | 0.022 | 0.022 | 0.022 | 0.022 | 0.023 |
| Ventless or vented electric, compact (120 V) | < 4.4 | 0.008 | 0.008 | 0.008 | 0.008 | 0.008 |
| Vented electric, compact (240 V) | < 4.4 | 0.009 | 0.009 | 0.009 | 0.009 | 0.009 |
| Ventless electric, compact (240 V) | < 4.4 | 0.011 | 0.011 | 0.011 | 0.011 | 0.012 |

432 Concerning annual operating hours: Minute-by-minute field data shows "96.6% ± 0.5% idle time, or about 8463 hours." Hannas, Benjamin and Gilman, Lucinda. Dryer Field Study, 39. https://neea.org/img/uploads/neea-clothes-dryer-field-study.pdf.

433 See Volume 1, Section 4.

## Deemed Winter Demand Savings Tables

**Table 345. Clothes Dryers—Winter Peak Demand Savings (kW)**

| Product type | Average capacity ($ft^3$) | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|
| Ventless or vented electric, standard | ≥ 4.4 | 0.024 | 0.024 | 0.022 | 0.026 | 0.025 |
| Ventless or vented electric, compact (120 V) | < 4.4 | 0.009 | 0.009 | 0.008 | 0.009 | 0.009 |
| Vented electric, compact (240 V) | < 4.4 | 0.010 | 0.010 | 0.009 | 0.011 | 0.010 |
| Ventless electric, compact (240 V) | < 4.4 | 0.012 | 0.013 | 0.011 | 0.013 | 0.013 |

## 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) of an ENERGY STAR clothes dryer is established at 16 years based on the current DOE Final Rule standards for clothes dryers.[434]

## 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
- Unit quantity
- Manufacturer and model number
- Type of unit (vented or ventless)
- Capacity (≥ 4.4 $ft^3$/standard or < 4.4 $ft^3$/compact)
- Proof of purchase – including date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

[434] Technical Support Document (April 2011). See "Appendix 8C.Lifetime Distributions": https://www.regulations.gov/document?D=EERE-2007-BT-STD-0010-0053

# 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 346. Clothes Dryers—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v7.0 | 10/2019 | TRM v7.0 origin. |
| v8.0 | 10/2020 | TRM v8.0 update. No revision. |
| v9.0 | 10/2021 | TRM v9.0 update. No revision. |
| v10.0 | 10/2022 | TRM v10.0 update. No revision. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision. |

## 2.5.4 ENERGY STAR® Dishwashers Measure Overview

**TRM Measure ID:** R-AP-DW

**Market Sector:** Residential

**Measure Category:** Appliances

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR dishwasher. Savings are awarded at a flat per-unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

## Eligibility Criteria

This measure applies to both standard and compact dishwasher types.

## Baseline Condition

Effective May 30, 2013, the baseline is the Department of Energy (DOE) minimum efficiency standard[435] for dishwashers.

**Table 347. Dishwashers—Federal Standard**

| Product type | Annual energy use (kWh/year) | Water consumption (gallons/cycle) |
|---|---|---|
| Standard (≥ 8 place settings) | ≤ 307 | ≤ 5.0 |
| Compact (< 8 place settings) | ≤ 222 | ≤ 3.5 |

[435] DOE minimum efficiency standard for residential dishwashers. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=38&action=viewlive.

## High-Efficiency Condition

The following table displays the ENERGY STAR Final Version 6.0 Requirements for eligible dishwashers effective January 29, 2016.[436] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

**Table 348. Dishwashers—ENERGY STAR Requirements**

| Product type | Annual energy use (kWh/year) | Water consumption (gallons/cycle) |
|---|---|---|
| Standard (≥ 8 place settings + 6 serving pieces) | ≤ 270 | ≤ 3.5 |
| Compact (< 8 place settings + 6 serving pieces) | ≤ 203 | ≤ 3.1 |

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Energy Savings Algorithms*

Energy savings for this measure were derived using the ENERGY STAR Appliance Savings Calculator found on the ENERGY STAR website and the revised ENERGY STAR specification in Table 348.[437] Default values were taken directly from the ENERGY STAR Appliance Savings Calculator. This document will be updated regularly to apply the values provided in the latest available ENERGY STAR specification and appliance calculator. The most recent TRM version should be referenced to determine measure savings for this measure.

$$Energy\ Savings\ [\Delta kWh] = kWh_{baseline} - kWh_{ES}$$

**Equation 122**

$$kWh_{baseline} = kWh_{conv,machine} + kWh_{conv,WH}$$

**Equation 123**

$$kWh_{conv,machine} = RUEC_{conv} \times MCF$$

**Equation 124**

$$kWh_{conv,WH} = RUEC_{conv} \times WHCF$$

**Equation 125**

$$kWh_{ES} = kWh_{ES,machine} + kWh_{ES,WH}$$

**Equation 126**

[436] ENERGY STAR Dishwashers Final Version 6.0 Program Requirements. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Dishwasher%20Version%206.0%20Final%20Program%20Requirements.pdf.

[437] ENERGY STAR Appliance Savings Calculator (updated October 2016). The previously cited URL is no longer available, but a copy of the calculator can be provided upon request.

$$kWh_{ES,machine} = RUEC_{ES} \times MCF$$

**Equation 127**

$$kWh_{ES,WH} = RUEC_{ES} \times WHCF$$

**Equation 128**

*Where:*

| | | |
|---|---|---|
| $kWh_{baseline}$ | = | *Federal standard baseline energy usage* |
| $kWh_{ES}$ | = | *ENERGY STAR average energy usage* |
| $kWh_{conv,machine}$ | = | *Conventional machine energy* |
| $kWh_{conv,WH}$ | = | *Conventional water heater energy* |
| $kWh_{ES,machine}$ | = | *ENERGY STAR machine energy* |
| $kWh_{ES,WH}$ | = | *ENERGY STAR water heater energy* |
| $RUEC_{conv}$ | = | *Conventional rated use electricity consumption = 307 kWh/year for standard and 222 kWh/year for compact (Table 347)* |
| $RUEC_{ES}$ | = | *ENERGY STAR rated use electricity consumption = 270 kWh/year for standard and 203 kWh/year for compact (Table 348)* |
| *MCF* | = | *Machine consumption factor = 44 percent* |
| *WHCF* | = | *Water heater consumption factor = 56 percent* |

## *Demand Savings Algorithms*

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh}{AOH} \times CF_{S/W}$$

**Equation 129**

$$AOH = CPY \times d$$

**Equation 130**

*Where:*

| | | |
|---|---|---|
| *AOH* | = | *Annual operating hours* |
| $CF_{S/W}$ | = | *Seasonal peak coincidence factor = (Table 349)* |
| *CPY* | = | *Cycles per year = 215* |
| *d* | = | *Average wash cycle duration = 2.1 hours*[438] |

[438] Average of consumer reports cycle times for dishwashers.

**Table 349. Dishwashers—Coincidence Factors[439]**

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 0.042 | 0.041 | 0.042 | 0.041 | 0.042 |
| Winter | 0.106 | 0.104 | 0.090 | 0.112 | 0.129 |

## Deemed Energy Savings Tables

**Table 350. Dishwashers—Energy Savings (kWh)**

| Product type | Electric DHW | Gas DHW |
|---|---|---|
| Standard | 37 | 16 |
| Compact | 19 | 8 |

## Deemed Summer Demand Savings Tables

**Table 351. Dishwashers—Summer Peak Demand Savings (kW)**

| Dishwasher type | DHW fuel | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|
| Standard | Electric | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| | Gas | 0.002 | 0.001 | 0.002 | 0.001 | 0.002 |
| Compact | Electric | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| | Gas | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

## Deemed Winter Demand Savings Tables

**Table 352. Dishwashers—Winter Peak Demand Savings (kW)**

| Dishwasher type | DHW fuel | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|
| Standard | Electric | 0.009 | 0.009 | 0.007 | 0.009 | 0.011 |
| | Gas | 0.004 | 0.004 | 0.003 | 0.004 | 0.005 |
| Compact | Electric | 0.004 | 0.004 | 0.004 | 0.005 | 0.005 |
| | Gas | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |

439 See Volume 1, Section 4.

## 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) is established at 15 years based on the Technical Support Document for the current DOE Final Rule standards for residential dishwashers.[440]

# 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
- Unit quantity
- Manufacturer and model number
- Type of dishwasher (standard or compact)
- Fuel type of water heater (gas or electric)
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

# 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.

[440] The median lifetime was calculated using the survival function outlined in the DOE Technical Support Document. Final Rule: Standards, Federal Register, 77 FR 31918 (May 30, 2012) and associated Technical Support Document. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=38&action=viewlive.

## Document Revision History

**Table 353. Dishwashers—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin. |
| v2.0 | 4/18/2014 | TRM v2.0 update. Updated by Frontier Energy, March 2014, based on new federal standards. |
| v2.1 | 1/30/2015 | TRM v2.1 update. No revision. |
| v3.0 | 4/10/2015 | TRM v3.0 update. New ENERGY STAR specification incorporated into the measure. New peak savings calculated according to revised peak definition. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Final ENERGY STAR specification incorporated into the measure. Consolidated table formats. |
| v3.1 | 3/28/2016 | TRM 3.1 March revision. Updated summer and winter coincidence factors and demand savings tables. |
| v4.0 | 10/10/2016 | TRM v4.0 update. No revision. |
| v5.0 | 10/2017 | TRM v5.0 update. Updated footnote reference to ENERGY STAR calculator. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. Updated links and dates. |
| v8.0 | 10/2020 | TRM v8.0 update. No revision. |
| v9.0 | 10/2021 | TRM v9.0 update. No revision. |
| v10.0 | 10/2022 | TRM v10.0 update. No revision. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision. |

## 2.5.5 ENERGY STAR® Refrigerators Measure Overview

**TRM Measure ID:** R-AP-RF

**Market Sector:** Residential

**Measure Category:** Appliances

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Replace-on-burnout, early retirement, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This measure applies to all ENERGY STAR refrigerators that meet the criteria for the ENERGY STAR label specified below.

### Eligibility Criteria

To qualify for early retirement, the ENERGY STAR unit must replace an existing, full-size unit with a maximum age of 20 years. To determine the remaining useful life of an existing unit, see Table 357. All retired refrigerators must be dismantled in an environmentally safe manner in accordance with applicable federal, state, and local regulations. The installer will provide documentation of proper disposal of refrigerators. To receive early retirement savings, the unit to be replaced must be functioning at the time of removal.

Newly installed refrigerators must meet current ENERGY STAR efficiency levels.

### Baseline Condition

For new construction or replace-on-burnout, the baseline is the Department of Energy (DOE) minimum efficiency standard[441] for refrigerators, effective September 15, 2014.

[441] DOE minimum efficiency standard for residential refrigerators and freezers. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

For early retirement, the baseline for refrigerators is the annual unit energy consumption of an assumed refrigerator's adjusted energy usage rating based on an average of values reported by the Midwest Energy Performance Analytics (MwEPA) Refrigerator and Freezer Energy Rating Database.[442] Since the federal standard effective date occurred in late 2014, existing units manufactured as of 2015 are not eligible for early retirement.

## High-Efficiency Condition

The table below displays the ENERGY STAR Final Version 5.1 Requirements for eligible consumer refrigeration products effective September 15, 2014.[443] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

**Table 354. Refrigerators—ENERGY STAR Requirements**

| ENERGY STAR refrigerator | | |
|---|---|---|
| **Product type** | **Volume** | **Criteria as of September 15, 2014** |
| Full-size refrigerators and refrigerator-freezers | 7.75 cubic feet or greater | Approximately 10 percent more energy efficient than the minimum federal standard (see Table 355) |

442 Refrigerator and Freezer Energy Rating Database. Midwest Energy Performance Analytics, Inc. in combination with the State of Wisconsin and US Department of Energy's Weatherization Assistance Program. https://www.energy.gov/eere/wap/articles/refrigerator-and-freezer-energy-rating-database-search-tool.

443 ENERGY STAR Consumer Refrigeration Products Final Version 5.1 Program Requirements. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%205.1%20Consumer%20Refrigeration%20Products%20Final%20Specification_0.pdf.

**Table 355. Refrigerators—Formulas to Calculate the Energy Usage by Product Class[444]**

| Product number | Product class | Baseline energy usage federal standard as of September 15, 2014 (kWh/year)[445] | Average ENERGY STAR energy usage (kWh/year)[446] | Adjusted volume[447] (cubic feet) | Baseline energy usage (kWh/year) | ENERGY STAR energy usage (kWh/year) |
|---|---|---|---|---|---|---|
| 3 | Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker | 8.07 × AV + 233.7 | 7.26 × AV + 210.3 | 16.9 | 370.1 | 333.0 |
| 5 | Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker | 8.85 × AV + 317.0 | 7.97 × AV + 285.3 | 18.6 | 481.5 | 433.5 |
| 5A | Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service | 9.25 × AV + 475.4 | 8.33 × AV + 436.3 | 32.1 | 772.1 | 703.5 |
| 7 | Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service | 8.54 × AV + 432.8 | 7.69 × AV + 397.9 | 30.4 | 692.1 | 631.4 |

[444] Federal standard for refrigerators and freezers. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=37&action=viewlive. Select product classes excluded.
[445] http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.
[446] Approximately ten percent more efficient than baseline, as specified in the ENERGY STAR Appliance Savings Calculator (updated September 2015). The previously cited URL is no longer available, but a copy of the calculator can be provided upon request.
[447] AV is calculated as a simple average across all refrigerators in the corresponding Product Class utilizing data provided by https://www.energystar.gov/productfinder/product/certified-residential-refrigerators/results.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *New Construction or Replace-on-Burnout*

#### Energy Savings Algorithms

$$Energy\ Savings\ [\Delta kWh] = kWh_{baseline} - kWh_{ES}$$

**Equation 131**

*Where:*

*kWh*$_{baseline}$ = *Federal standard baseline energy usage (see Table 355)*

*kWh*$_{ES}$ = *ENERGY STAR average energy usage (see Table 355)*

#### Demand Savings Algorithms

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh}{8{,}760\ hrs} \times CF_{S/W}$$

**Equation 132**

*Where:*

*C*$_{S/W}$ = *Seasonal coincidence factor (see Table 356)*

**Table 356. Refrigerators—Coincidence Factors[448]**

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 1.112 | 1.099 | 1.108 | 1.100 | 1.081 |
| Winter | 0.929 | 0.966 | 0.924 | 0.941 | 0.966 |

### *Early Retirement*

Annual energy (kWh) and peak demand (kW) savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period (EUL – RUL)

[448] See Volume 1, Section 4.

Annual energy and peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in the Volume 3 appendices.

*Where:*

| | | |
|---|---|---|
| *RUL* | = | *Remaining useful life (see Table 357); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 5.0 years* |
| *EUL* | = | *Estimated useful life = 16 years*[449] |

**Table 357. Refrigerators—RUL of Replaced Unit**[450]

| Age of replaced refrigerator (years) | RUL (years) | Age of replaced refrigerator (years) | RUL (years) |
|---|---|---|---|
| 1 | 15.2 | 12 | 7.0 |
| 2 | 14.2 | 13 | 6.6 |
| 3 | 13.2 | 14 | 6.3 |
| 4 | 12.2 | 15 | 6.0 |
| 5 | 11.2 | 16 | 5.0 |
| 6 | 10.3 | 17 | 4.0 |
| 7 | 9.6 | 18 | 3.0 |
| 8 | 8.9 | 19 | 2.0 |
| 9 | 8.3 | 20 | 1.0 |
| 10 | 7.8 | 21[451,452] | 0.0 |
| 11 | 7.4 | | |

449 Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43. Download TSD at: https://www.regulations.gov/document/EERE-2008-BT-STD-0012-0128.

450 Current federal standard effective date is 9/15/2014. Since the federal standard effective date occurred in late 2014, existing units manufactured as of 2015 are not eligible to use the early retirement baseline and should use the ROB baseline instead.

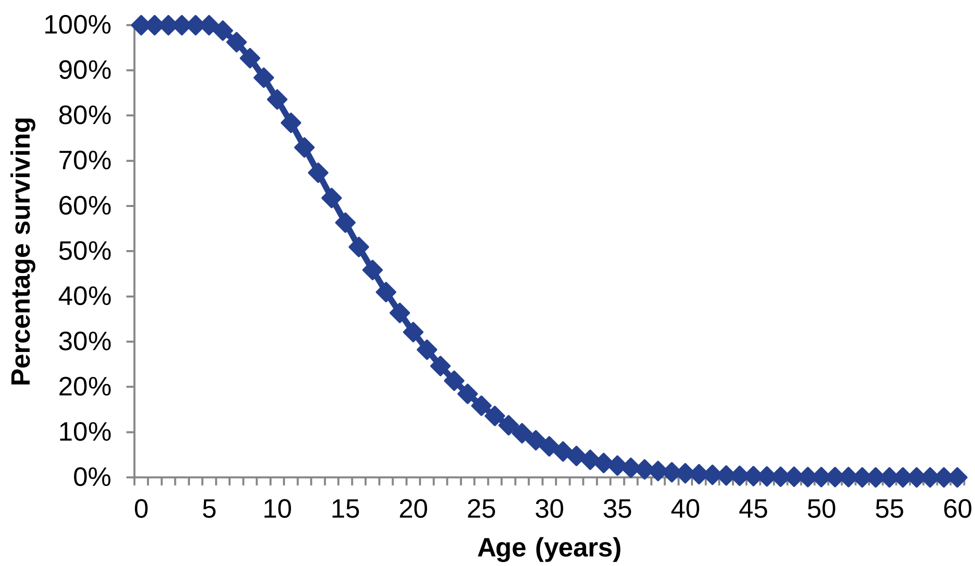
451 RULs are capped at the 75th percentile of equipment age as determined based on DOE survival curves (see Figure 8). Systems older than this age should use the ROB baseline. See the January 2015 memo, “Considerations for early replacement of residential equipment,” for further detail.

452 Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. “Considerations for early replacement of residential equipment.” Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to all Texas investor-owned utilities through the EM&V team’s SharePoint.

### *Derivation of RULs*

ENERGY STAR refrigerators have an estimated useful life of 16 years. This estimate is consistent with the age at which approximately 50 percent of the refrigerators installed in a given year will no longer be in service, as described by the survival function in Figure 8.

**Figure 8. Refrigerators—Survival Function[453]**




The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 8. The age of the refrigerator being replaced is found on the horizontal axis, and the corresponding percentage of surviving refrigerators is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For example, assume a refrigerator being replaced is 15 years old. The corresponding percent surviving value is 56 percent. Half of 56 percent is 28 percent. The age corresponding to 28 percent on the chart is 21 years. Therefore, the RUL of the refrigerator being replaced is (21 – 15) = 6 years.

[453] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

## Energy Savings Algorithms

For the RUL time period:

$$kWh_{savings,ER} = kWh_{manf} - kWh_{ES}$$

**Equation 133**

For the remaining time in the EUL period., calculate annual savings as you would for a replace-on-burnout project:

$$kWh_{savings,ROB} = kWh_{baseline} - kWh_{ES}$$

**Equation 134**

*Where:*

$kWh_{manf}$ = *968 kWh/Year*[454]

## Demand Savings Algorithms

To calculate demand savings for the early retirement of a refrigerator, a similar methodology is used as for replace-on-burnout installations, with separate savings calculated for the remaining useful life of the unit, and the remainder of the EUL as outlined in the section above.

For the RUL time period:

$$kW_{savings,ER} = \frac{kWh_{avings,ER}}{8{,}760\ hrs} \times CF_{S/W}$$

**Equation 135**

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

$$kW_{savings,ROB} = \frac{kWh_{savings,ROB}}{8{,}760\ hrs} \times CF_{S/W}$$

**Equation 136**

Annual deemed summer peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in the Volume 3 appendices.

[454] This is the weighted average of Adjusted annual unit energy consumption, derived from the MwEPA Refrigerator and Freezer Energy Rating Database (or from metering). Weights are calculated from the millions-of-households measurements obtained from the Residential Energy Consumption Survey, or RECS, (https://www.eia.gov/consumption/residential/data/2015/hc/php/hc3.6.php) corresponding to the year range classifications of refrigerators greater than 15 years old (specifically, 15-to-19-years-old and 20-or-more-years-old). Data in which refrigerators' model years were older than 1975 were excluded.

## Deemed Energy Savings Tables

**Table 358. Refrigerators—Energy Savings (kWh)**

| Through-the-door ice? | Door type | Product class | ROB savings (kWh/year) | ER savings (kWh/year) |
|---|---|---|---|---|
| No | Top freezer | 3: Refrigerator freezers—automatic defrost with a top-mounted freezer without an automatic icemaker | 37 | 224 |
| | Bottom freezer | 5: Refrigerator-freezers—automatic defrost with a bottom-mounted freezer without an automatic icemaker | 48 | 200 |
| Yes | Bottom freezer | 5A: Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service | 69 | 147 |
| | Side-by-side | 7: Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service | 61 | 130 |
| Unknown or average refrigerator[455] | | | 44 | 205 |

[455] An "Unknown or Average" refrigerator's savings are calculated as the difference between the weighted average of baseline energy usage ratings and the weighted average of ENERGY STAR energy usage ratings for the four selected refrigerator categories, with weights ascertained from averages of refrigerators in 10–14-year-old, 5–9-year-old, and 2–4-year-old age groups. The data used to calculate weights is hosted by Natural Resources Canada (NRCAN) at the following link which contains a table of the distribution of refrigerator types in households by year: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/showTable.cfm?type=CM&sector=aaa&juris=ca&rn=3&page=1. Weights were similarly calculated utilizing data from RECS (data, which is summarized, i.e., not yearly, and located here: https://www.eia.gov/consumption/residential/data/2015/hc/php/hc3.6.php). While the reported distribution of refrigerator types between the two sets of data varies, we prefer the year-level granularity of the data from NRCAN considering that the differences between both sets of weighted average baseline energy usage and weighted average ENERGY STAR energy usage were nearly identical. Hence, we elect to utilize the more detailed weightings derived from the data hosted by NRCAN.

## Deemed Summer Demand Savings Tables

**Table 359. Refrigerators—Replace-on-Burnout – Summer Peak Demand Savings (kW)**

| Through-the-door ice? | Door type | Product class | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|---|
| No | Top freezer | 3: Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker | 0.0047 | 0.0047 | 0.0047 | 0.0047 | 0.0046 |
| | Bottom freezer | 5: Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker | 0.0061 | 0.0060 | 0.0061 | 0.0060 | 0.0059 |
| Yes | Bottom freezer | 5A: Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service | 0.0087 | 0.0086 | 0.0087 | 0.0086 | 0.0085 |
| | Side-by-side | 7: Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service | 0.0077 | 0.0076 | 0.0077 | 0.0076 | 0.0075 |
| Unknown or average refrigerator | | | 0.0056 | 0.0056 | 0.0056 | 0.0056 | 0.0055 |

**Table 360. Refrigerators—Early Retirement—Summer Peak Demand Savings (kW)**

| Through-the-door ice? | Door type | Product class | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|---|
| No | Top freezer | 3: Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker | 0.028 | 0.028 | 0.028 | 0.028 | 0.028 |
| | Bottom freezer | 5: Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 |
| Yes | Bottom freezer | 5A: Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service | 0.016 | 0.016 | 0.016 | 0.016 | 0.016 |
| | Side-by-side | 7: Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service | 0.019 | 0.018 | 0.019 | 0.018 | 0.018 |
| Unknown or average refrigerator | | | 0.026 | 0.026 | 0.026 | 0.026 | 0.025 |

## Deemed Winter Demand Savings Tables

**Table 361. Refrigerators—Replace-on-Burnout—Winter Peak Demand Savings (kW)**

| Through-the-door ice? | Door type | Product class | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|---|
| No | Top freezer | 3: Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker | 0.0039 | 0.0041 | 0.0039 | 0.0040 | 0.0041 |
| | Bottom freezer | 5: Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker | 0.0051 | 0.0053 | 0.0051 | 0.0052 | 0.0053 |
| Yes | Bottom freezer | 5A: Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service | 0.0073 | 0.0076 | 0.0072 | 0.0074 | 0.0076 |
| | Side-by-side | 7: Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service | 0.0064 | 0.0067 | 0.0064 | 0.0065 | 0.0067 |
| Unknown or average refrigerator | | | 0.0047 | 0.0049 | 0.0047 | 0.0048 | 0.0049 |

**Table 362. Refrigerators—Early Retirement—Winter Peak Demand Savings (kW)**

| Through-the-door ice? | Door type | Product class | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|---|
| No | Top freezer | 3: Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker | 0.024 | 0.025 | 0.024 | 0.024 | 0.025 |
| | Bottom freezer | 5: Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker | 0.021 | 0.022 | 0.021 | 0.021 | 0.022 |
| Yes | Bottom freezer | 5A: Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service | 0.014 | 0.014 | 0.014 | 0.014 | 0.014 |
| | Side-by-side | 7: Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service | 0.016 | 0.016 | 0.015 | 0.016 | 0.016 |
| Unknown or average refrigerator | | | 0.022 | 0.023 | 0.022 | 0.022 | 0.023 |

## 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) is established at 16 years based on the current DOE Final Rule standards for residential refrigerators.[456]

## 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
- Unit quantity
- Baseline type (new construction, replace-on-burnout, or early retirement)
- Manufacturer and model number
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)
- Document proper disposal of the existing refrigerator (early retirement only)
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

## References and Efficiency Standards

## Petitions and Rulings

Not applicable.

[456] Final Rule: Standards, Federal Register, 76 FR 57516 (Sept. 15, 2011) and associated Technical Support Document. http://www1.eere.energy.gov/buildings/appliance_sta https://www.regulations.gov/document/EERE-2008-BT-STD-0012-0128 ndards/product.aspx/productid/43. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

## Relevant Standards and Reference Sources

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

## Document Revision History

**Table 363. Refrigerators—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v1.0 | 11/25/2013 | TRM v1.0 origin |
| v2.0 | 4/18/2014 | TRM v2.0 update. Low-income and hard-to-reach Market Transformation section merged with the main measure as “early retirement” option. Updated by Frontier Energy, March 2014, based on new federal standards. |
| v2.1 | 1/30/2015 | TRM v2.1 update. New ENERGY STAR standards incorporated. |
| v3.0 | 4/10/2015 | TRM v3.0 update. early retirement savings may be claimed through any appropriately designed program in accordance with the EM&V team’s memo, “Considerations for early replacement of residential equipment.” Remaining useful lifetimes updated. CF updated to align with new peak demand methodology. |
| v3.1 | 11/05/2015 | TRM v3.1 update. Correction to legacy CF. Revision to align with ENERGY STAR calculator and specification. |
| v3.1 | 3/28/2016 | TRM v3.1 March revision. Updated summer and winter coincidence factors. |
| v4.0 | 10/10/2016 | TRM v4.0 update. Updated RUL value for units with the age of seven years and added RUL values for units with an age of one to five years. Added a default RUL value for when the age of the unit is unknown. Eliminated the eligibility requirement of the existing unit to have an age of minimum of five years. |
| v5.0 | 10/2017 | TRM v5.0 update. No revision. |
| v6.0 | 11/2018 | TRM v6.0 update. Updated database reference. |
| v7.0 | 10/2019 | TRM v7.0 update. Established deemed savings approach. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated early retirement age eligibility. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated early retirement age eligibility. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated early retirement age eligibility. |
| v11.0 | 10/2023 | TRM v11.0 update. Updated early retirement age eligibility. |

## 2.5.6 ENERGY STAR® Freezers Measure Overview

**TRM Measure ID:** R-AP-FZ

**Market Sector:** Residential

**Measure Category:** Appliances

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Replace-on-burnout, early retirement, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This measure applies to all ENERGY STAR freezers that meet the criteria for the ENERGY STAR label specified below.

## Eligibility Criteria

To qualify for early retirement, the ENERGY STAR unit must replace an existing, full-size unit with a maximum age of 27 years. To determine the remaining useful life of an existing unit, see Table 367. All retired freezers must be dismantled in an environmentally safe manner in accordance with applicable federal, state, and local regulations. The installer will provide documentation of proper disposal of freezers. In order to receive early retirement savings, the unit to be replaced must be functioning at the time of removal.

Newly-installed freezers must meet current ENERGY STAR efficiency levels.

## Baseline Condition

For new construction or replace-on-burnout, the baseline is the Department of Energy (DOE) minimum efficiency standard[457] for freezers, effective September 15, 2014.

For early retirement, the baseline for freezers is the annual unit energy consumption of a freezer's adjusted energy usage rating based on an average of values reported by the Midwest Energy Performance Analytics (MwEPA) Refrigerator and Freezer Energy Rating Database.[458]

[457] DOE minimum efficiency standard for residential refrigerators and freezers. https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8.

[458] Refrigerator and Freezer Energy Rating Database. Midwest Energy Performance Analytics, Inc. in combination with the State of Wisconsin and US Department of Energy's Weatherization Assistance Program. https://www.energy.gov/eere/wap/articles/refrigerator-and-freezer-energy-rating-database-search-tool.

Since the federal standard effective date occurred in late 2014, existing units manufactured as of 2015 are not eligible for early retirement.

Alternatively, the baseline annual energy usage of the freezer being replaced may be estimated by metering for a period of at least two hours using the measurement protocol specified in the DOE report, "Incorporating Refrigerator Replacement into the Weatherization Assistance Program."[459]

To determine annual kWh of the freezer being replaced, use the following formula:

$$Annual\ kWh\ Usage = \frac{WH \times 8{,}760}{h \times 1{,}000}$$

**Equation 137**

*Where:*

| | | |
|---|---|---|
| *WH* | = | *Watt-hours metered during a time period* |
| *h* | = | *Measurement time period (hours)* |
| *8,760* | = | *Total hours per year* |
| *1,000* | = | *Constant to convert from W to kW* |

## High-Efficiency Condition

The table below displays the ENERGY STAR Final Version 5.1 Requirements for eligible consumer refrigeration products effective September 15, 2014.[460] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

**Table 364. Freezers—ENERGY STAR Requirements[461]**

| ENERGY STAR freezer | | |
|---|---|---|
| **Product type** | **Volume** | **Criteria as of September 15, 2014** |
| Freezers | 7.75 cubic feet or greater | Approximately ten percent more energy efficient than the minimum federal standard (see Table 355) |
| Compact freezers | Less than 7.75 cubic feet | Approximately ten percent more energy efficient than the minimum federal standard (see Table 355) |

[459] Alex Moore, DandR International, Ltd. "Incorporating Refrigerator Replacement into the Weatherization Assistance Program" Information Tool Kit." Department of Energy. November 19, 2001. https://aceee.org/files/proceedings/2002/data/papers/SS02_Panel2_Paper16.pdf.

[460] ENERGY STAR Consumer Refrigeration Products Final Version 5.1 Program Requirements. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%205.1%20Consumer%20Refrigeration%20Products%20Final%20Specification_0.pdf.

[461] https://www.energystar.gov/products/appliances/refrigerators/key_product_criteria.

Table 365. Freezers—Formulas to Calculate the Energy Usage by Product Class[462]

| Product number | Full product name[463] | Product class | Baseline energy usage federal standard (kWh/year)[464] | Average ENERGY STAR energy usage (kWh/year)[465] | Adjusted volume[466] (cubic feet) | Baseline energy usage (kWh/year) | ENERGY STAR energy usage (kWh/year) |
|---|---|---|---|---|---|---|---|
| 8 | Upright freezers with manual defrost | Upright (manual defrost) | 5.57 × AV + 193.7 | 5.01 × AV + 174.3 | 16.12 | 283.5 | 255.1 |
| 9 | Upright freezers with automatic defrost without an automatic icemaker | Upright (auto defrost) | 8.62 × AV + 228.3 | 7.76 × AV + 205.5 | 29.96 | 486.6 | 438.0 |
| 10 | Chest freezers and all other freezers except compact freezers | Chest | 7.29 × AV + 107.8 | 6.56 × AV + 97 | 25.25 | 291.8 | 262.6 |
| 16 | Compact upright freezers with manual defrost | Compact upright (manual defrost) | 8.65 × AV + 225.7 | 7.79 × AV + 203.1 | 5.34 | 271.9 | 244.7 |
| 17 | Compact upright freezers with automatic defrost | Compact upright (auto defrost) | 10.17 × AV + 351.9 | 9.15 × AV + 316.7 | 7.95 | 432.7 | 389.4 |
| 18 | Compact chest freezers | Compact chest | 9.25 × AV + 136.8 | 8.33 × AV + 123.1 | 9.06 | 220.6 | 198.6 |

[462] Federal standard for refrigerators and freezers. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=37&action=viewlive. Select product classes excluded.

[463] Note that when calculating deemed savings for upright freezers, we calculated a weighted average of adjusted energy usage of manual versus automatic defrost upright freezers, with weights based on the number of millions-of-households which contain these types of freezers, obtained from the Residential Energy Consumption Survey, or RECS, (https://www.eia.gov/consumption/residential/data/2015/hc/php/hc3.6.php), thus eliminating this input from consideration.

[464] https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8.

[465] Approximately 10 percent more efficient than baseline, as specified in the ENERGY STAR Appliance Savings Calculator (updated September 2015). The previously cited URL is no longer available, but a copy of the calculator can be provided upon request.

[466] AV is calculated as a simple average per selected freezer product type in the corresponding Product Class utilizing data provided by https://www.energystar.gov/productfinder/product/certified-residential-freezers/results.

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *New Construction or Replace-on-Burnout*

#### Energy Savings Algorithms

$$Energy\ Savings\ [\Delta kWh] = kWh_{baseline} - kWh_{ES}$$

**Equation 138**

*Where:*

| | | |
|---|---|---|
| $kWh_{baseline}$ | = | *Federal standard baseline energy usage (see Table 365)* |
| $kWh_{ES}$ | = | *ENERGY STAR average energy usage (see Table 365)* |

#### Demand Savings Algorithms

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh}{8{,}760\ hrs} \times CF_{S/W}$$

**Equation 139**

*Where:*

| | | |
|---|---|---|
| $CF_{S/W}$ | = | *Seasonal coincidence factor (see Table 366)* |

**Table 366. Freezers—Coincidence Factors**[467]

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 1.112 | 1.099 | 1.108 | 1.100 | 1.081 |
| Winter | 0.929 | 0.966 | 0.924 | 0.941 | 0.966 |

### *Early Retirement*

Annual energy (kWh) and peak demand (kW) savings must be calculated separately for two time periods:

1. The estimated remaining life of the equipment that is being removed, designated the remaining useful life (RUL), and
2. The remaining time in the EUL period (EUL – RUL)

[467] See Volume 1, Section 4.

Annual energy and peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in the Volume 3 appendices.

*Where:*

| | | |
|---|---|---|
| *RUL* | = | *Remaining useful life (see Table 367); if unknown, assume the age of the replaced unit is equal to the EUL resulting in a default RUL of 5.0 years* |
| *EUL* | = | *Estimated useful life = 22 years*[468] |

**Table 367. Freezers—RUL of Replaced Unit** [469]

| Age of replaced freezer (years) | RUL (years) | Age of replaced freezer (years) | RUL (years) | Age of replaced freezer (years) | RUL (years) |
|---|---|---|---|---|---|
| 1 | 20.7 | 10 | 12.1 | 19 | 6.6 |
| 2 | 19.7 | 11 | 11.3 | 20 | 6.2 |
| 3 | 18.7 | 12 | 10.6 | 21 | 5.9 |
| 4 | 17.7 | 13 | 9.9 | 22 | 5.0 |
| 5 | 16.7 | 14 | 9.2 | 23 | 4.0 |
| 6 | 15.7 | 15 | 8.6 | 24 | 3.0 |
| 7 | 14.8 | 16 | 8.1 | 25 | 2.0 |
| 8 | 13.8 | 17 | 7.5 | 26 | 1.0 |
| 9 | 13.0 | 18 | 7.1 | 27[470,471] | 0.0 |

[468] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. Download TSD at: https://www.regulations.gov/document/EERE-2008-BT-STD-0012-0128.

[469] Current federal standard effective date is 9/15/2014. Since the federal standard effective date occurred in late 2014, existing units manufactured as of 2015 are not eligible to use the early retirement baseline and should use the ROB baseline instead.

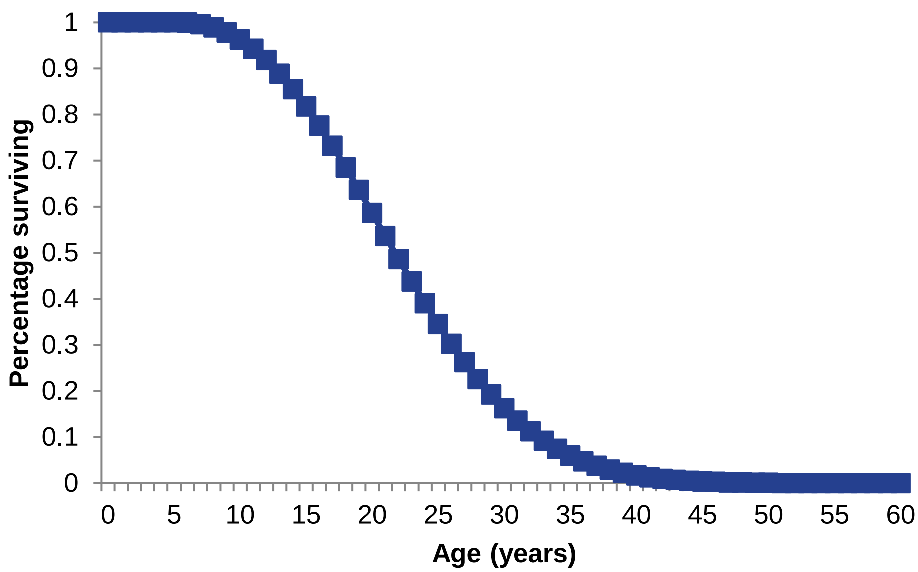
[470] RULs are capped at the 75th percentile of equipment age as determined based on DOE survival curves (see Figure 8). Systems older than this age should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

[471] Ward, B., Bodington, N., Farah, H., Reeves, S., and Lee, L. "Considerations for early replacement of residential equipment." Prepared by the Evaluation, Measurement, and Verification (EM&V) team for the Electric Utility Marketing Managers of Texas (EUMMOT). January 2015. This document has been made available to all Texas investor-owned utilities through the EM&V team's SharePoint.

## *Derivation of RULs*

ENERGY STAR freezers have an estimated useful life of 22 years. This estimate is consistent with the age at which approximately 50 percent of the freezers installed in a given year will no longer be in service, as described by the survival function in Figure 9.

**Figure 9. Freezers—Survival Function**[472]




The method for estimating the RUL of a replaced system uses the age of the existing system to re-estimate the projected unit lifetime based on the survival function shown in Figure 9. The age of the freezer being replaced is found on the horizontal axis, and the corresponding percentage of surviving freezers is determined from the chart. The surviving percentage value is then divided in half, creating a new estimated useful lifetime applicable to the current unit age. Then, the age (year) that corresponds to this new percentage is read from the chart. RUL is estimated as the difference between that age and the current age of the system being replaced.

For example, assume a freezer being replaced is 22 years old (the estimated useful life). The corresponding percent surviving value is approximately 50 percent. Half of 50 percent is 25 percent. The age corresponding to 25 percent on the chart is approximately 27 years. Therefore, the RUL of the freezer being replaced is 27 – 22 = 5 years.

[472] Department of Energy, Federal Register, 76 Final Rule 57516, Technical Support Document: 8.2.3.1 Estimated Survival Function. September 15, 2011. http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf.

## Energy Savings Algorithms

For the RUL time period:

$$kWh_{savings,ER} = kWh_{manf} - kWh_{ES}$$

**Equation 140**

For the remaining time in the EUL period., calculate annual savings as you would for a replace-on-burnout project:

$$kWh_{savings,ROB} = \ kWh_{baseline} - kWh_{ES}$$

**Equation 141**

*Where:*

$kWh_{manf}$ = *841 kWh/Year*[473]

## Demand Savings Algorithms

To calculate demand savings for the early retirement of a freezer, a similar methodology is used as for replace-on-burnout installations, with separate savings calculated for the remaining useful life of the unit, and the remainder of the EUL as outlined in the section above.

For the RUL time period:

$$kW_{savings,ER} = \frac{kWh_{savings,ER}}{8{,}760\ hrs} \times CF_{S/W}$$

**Equation 142**

For the remaining time in the EUL period, calculate annual savings as you would for a replace-on-burnout project:

$$kW_{savings,ROB} = \frac{kWh_{savings,ROB}}{8{,}760\ hrs} \times CF_{S/W}$$

**Equation 143**

Annual deemed summer peak demand savings are calculated by weighting the early retirement and replace-on-burnout savings by the RUL of the unit and the remainder of the EUL period, as outlined in the Volume 3 appendices.

[473] This is the weighted average of adjusted annual unit energy consumption, a metric obtained from the MwEPA Refrigerator and Freezer Energy Rating Database (if from metering, substitute recorded value in lieu of this weighted average). Weights are calculated from the millions-of-households measurements obtained from RECS, (https://www.eia.gov/consumption/residential/data/2015/hc/php/hc3.6.php) corresponding to the year range classifications of freezers greater than 15 years old (specifically, 15-to-19-years-old and 20-or-more-years-old). The oldest freezers for which we had data were from 1979.

## Deemed Energy Savings Tables

**Table 368. Freezers—Savings (kWh)**

| Freezer type | Size | ROB savings (kWh) | ER savings (kWh) |
|---|---|---|---|
| Chest | Standard (≥ 7.75 $ft^3$) | 29 | 154 |
| | Compact (< 7.75 $ft^3$) | 22 | 163 |
| Upright | Standard (≥ 7.75 $ft^3$) | 48 | 130 |
| | Compact (< 7.75 $ft^3$) | 32 | 151 |

## Deemed Summer Demand Savings Tables

**Table 369. Freezers—Replace-on-Burnout—Summer Peak Demand Savings (kW)**

| Freezer type | Product class | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|
| Chest | Standard (≥ 7.75 $ft^3$) | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 |
| | Compact (< 7.75 $ft^3$) | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| Upright | Standard (≥ 7.75 $ft^3$) | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 |
| | Compact (< 7.75 $ft^3$) | 0.004 | 0.004 | 0.004 | 0.004 | 0.004 |

**Table 370. Freezers—Early Retirement—Summer Peak Demand Savings (kW)**

| Freezer type | Product class | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|
| Chest | Standard (≥ 7.75 $ft^3$) | 0.020 | 0.019 | 0.019 | 0.019 | 0.019 |
| | Compact (< 7.75 $ft^3$) | 0.021 | 0.020 | 0.021 | 0.020 | 0.020 |
| Upright | Standard (≥ 7.75 $ft^3$) | 0.017 | 0.016 | 0.016 | 0.016 | 0.016 |
| | Compact (< 7.75 $ft^3$) | 0.019 | 0.019 | 0.019 | 0.019 | 0.019 |

## Deemed Winter Demand Savings Tables

**Table 371. Freezers—Replace-on-Burnout—Winter Peak Demand Savings (kW)**

| Freezer type | Product class | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|
| Chest | Standard (≥ 7.75 $ft^3$) | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| | Compact (< 7.75 $ft^3$) | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| Upright | Standard (≥ 7.75 $ft^3$) | 0.005 | 0.005 | 0.005 | 0.005 | 0.005 |
| | Compact (< 7.75 $ft^3$) | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |

**Table 372. Freezers—Early Retirement—Winter Peak Demand Savings (kW)**

| Freezer type | Product class | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|---|
| Chest | Standard (≥ 7.75 $ft^3$) | 0.016 | 0.017 | 0.016 | 0.017 | 0.017 |
| | Compact (< 7.75 $ft^3$) | 0.017 | 0.018 | 0.017 | 0.018 | 0.018 |
| Upright | Standard (≥ 7.75 $ft^3$) | 0.014 | 0.014 | 0.014 | 0.014 | 0.014 |
| | Compact (< 7.75 $ft^3$) | 0.016 | 0.017 | 0.016 | 0.016 | 0.017 |

## 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) is established at 22 years based on the current DOE Final Rule standards for residential freezers.[474]

## 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
- Unit quantity
- Baseline type (new construction, replace-on-burnout, or early retirement)
- Manufacturer and model number
- Freezer type (upright or chest)
- Freezer size (standard, i.e., ≥ 7.75 $ft^3$, or compact, i.e., < 7.75 $ft^3$)
- Photograph demonstrating functionality of existing equipment and/or customer responses to survey questionnaire documenting the condition of the replaced unit and their motivation for measure replacement for early retirement eligibility determination (early retirement only)
- The installer will provide documentation of proper disposal of freezers in accordance with applicable federal, state, and local regulations (early retirement only)
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

[474] Final Rule: Standards, Federal Register, 76 FR 57516 (Sept. 15, 2011) and associated Technical Support Document. https://www.ecfr.gov/cgi-bin/text-idx?SID=48f64e166fe3561666f871e521996e13&mc=true&node=se10.3.430_132&rgn=div8. Download TSD at: https://www.regulations.gov/document/EERE-2008-BT-STD-0012-0128.

# 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 373. Freezers—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v7.0 | 10/2019 | TRM v7.0 origin. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated early retirement age eligibility. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated early retirement age eligibility. |
| v10.0 | 10/2022 | TRM v10.0 update. Updated early retirement age eligibility. |
| v11.0 | 10/2023 | TRM v10.0 update. Updated early retirement age eligibility. |

## 2.5.7 Refrigerator/Freezer Recycling Measure Overview

**TRM Measure ID:** R-AP-RR

**Market Sector:** Residential

**Measure Category:** Appliance Recycling

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Early retirement

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings calculation

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This measure involves early retirement and recycling of an existing, full-size (7.75 $ft^3$ or greater) refrigerator or combined refrigerator/freezer in a residential application. Savings represent the entire estimated energy consumption of the existing unit and are applicable over the estimated remaining life of the existing unit.

## Eligibility Criteria

This measure applies to operable primary and secondary retired refrigerators/freezers. Recycling savings for this measure are limited to the removal of a working refrigerator/freezer from the electrical grid and differ from the savings specified in the ENERGY STAR Refrigerator replacement measure. The latter, which pertain to the direct replacement of a refrigerator and reflect the difference in energy consumption between new ENERGY STAR qualifying and standard efficiency models, may be claimed for the recycling of primary refrigerators/freezers that have been replaced if savings for that replacement were not already claimed in another energy efficiency program. To qualify, the customer must release the existing unit to the utility or utility representative to ensure proper disposal in accordance with applicable federal, state, and local regulations.

## Baseline Condition

Without program intervention, the recycled refrigerator or refrigerator/freezer would have remained operable on the electrical grid. As a result, the baseline condition for early retirement programs is continued operation of the existing refrigerator.

## High-Efficiency Condition

There is no efficiency standard for a recycling measure because the energy efficient action is the removal of an operable appliance, not—as with most demand-side management programs—the installation of a higher efficiency model.

# Energy and Demand Savings Methodology

The basis for estimating energy savings is the annual energy consumption of the refrigerator or refrigerator/freezer being retired.

## Savings Algorithms and Input Variables

### *Energy Savings Algorithms*

Energy savings are calculated as follows:

$$Energ\ Savings\ [\Delta kWh] = kWh_{existig} \times ISAF \times PUF$$

**Equation 144**

*Where:*

| | | |
|---|---|---|
| $kWh_{existing}$ | = | *Average annual energy consumption*[475] *(see Table 374)* |
| *ISAF* | = | *In situ adjustment factor*[476] *= 0.942* |
| *PUF* | = | *Part use factor*[477] *= 0.915* |

**Table 374. Refrigerator/Freezer Recycling—Average Annual Energy Consumption**

| Total capacity ($ft^3$) | Year manufactured | $kWh_{existing}$ by freezer configuration | | | | |
|---|---|---|---|---|---|---|
| | | Top | Bottom | Side | Upright | Chest |
| < 16.5 | ≤ 2000 | 861 | 962 | 1,139 | 937 | 532 |
| | 2001-2010 | 556 | 724 | 747 | 713 | 435 |
| | ≥ 2011 | 374 | 483 | 592 | 449 | 292 |

475 ENERGY STAR Flip Your Fridge Calculator. https://www.energystar.gov/index.cfm?fuseaction=refrig.calculator.

476 The Cadmus Group, Inc. "Residential Retrofit High Impact Measure Evaluation Report". Prepared for California Public Utilities Commission Energy Division. February 8, 2010. Factor to account for variation between site conditions and controlled DOE testing conditions (90 °F test chamber, empty refrigerator and freezer cabinets, and no door openings). Appliances in warmer climate zones use more energy than those in cooler climate zones; utilized SCE data (highest percentage of warm climate projects) to best approximate Texas climate, p. 139-140.

477 Ibid. Factor to account for the number of refrigerators that were running, running part time, or not running at the time of recycling, p. 142-143 (weighted by representative utility survey participation, p. 117).

| Total capacity (ft³) | Year manufactured | kWh$_{existing}$ by freezer configuration | | | | |
|---|---|---|---|---|---|---|
| | | Top | Bottom | Side | Upright | Chest |
| 16.5-18.9 | $\leq$ 2000 | 962 | 1,051 | 1,266 | 1,058 | 621 |
| | 2001-2010 | 613 | 747 | 818 | 805 | 508 |
| | $\geq$ 2011 | 412 | 517 | 640 | 507 | 341 |
| 19.0-21.4 | $\leq$ 2000 | 1,031 | 1,110 | 1,329 | 1,138 | 680 |
| | 2001-2010 | 651 | 762 | 854 | 866 | 557 |
| | $\geq$ 2011 | 438 | 539 | 664 | 545 | 373 |
| 21.5-24.4 | $\leq$ 2000 | 1,090 | 1,172 | 1,368 | 1,194 | 721 |
| | 2001-2010 | 683 | 777 | 876 | 909 | 591 |
| | $\geq$ 2011 | 459 | 562 | 679 | 572 | 396 |
| $\geq$ 24.5 | $\leq$ 2000 | 1,223 | 1,347 | 1,528 | 1,355 | 840 |
| | 2001-2010 | 758 | 822 | 966 | 1,031 | 688 |
| | $\geq$ 2011 | 508 | 627 | 740 | 648 | 461 |

### *Demand Savings Algorithms*

Summer peak demand savings are calculated as follows:

$$Peak\ Demand\ Svings\ [\Delta \mathrm{kW}] = \frac{\Delta kWh}{AOH} \times CF_{S/W}$$

**Equation 145**

*Where:*

$AOH$ = *Annual operating hours = 8,760 hours*

$CF_{S/W}$ = *Seasonal coincidence factor (see Table 375)*

**Table 375. Refrigerator/Freezer Recycling—Coincidence Factors[478]**

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 1.112 | 1.099 | 1.108 | 1.100 | 1.081 |
| Winter | 0.929 | 0.966 | 0.924 | 0.941 | 0.966 |

478 See Volume 1, Appendix B.

## 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

Based on the KEMA Residential Refrigerator Recycling Ninth Year Retention Study,[479] the Estimated Useful Life of Refrigerator Recycling is 8 years, representing the assumed remaining useful life of the retired unit.

# 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
- Number of refrigerators/freezers removed
- Year removed unit manufactured
- Total capacity (in cubic feet)
- Freezer configuration (top, bottom, side-by-side, upright, or chest)

[479] KEMA, Inc. “Residential Refrigerator Recycling Ninth Year Retention Study.” Prepared for Southern California Edison Company. July 22, 2004.

## References and Efficiency Standards

### Petitions and Rulings

- Docket No. 42212. Petition of El Paso Electric Company to Approve Revisions to the Deemed Savings for the Appliance Recycling Market Transformation program. Public Utility Commission of Texas.

### Relevant Standards and Reference Sources

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

### Document Revision History

**Table 376. Refrigerator/Freezer Recycling—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v2.1 | 1/30/2015 | TRM v2.1 origin. |
| v3.0 | 4/10/2015 | TRM v3.0 update. CF updated to align with new peak demand methodology. |
| v3.1 | 11/05/2015 | TRM v3.1 update. No revision. |
| v3.1 | 3/28/2016 | TRM v3.1 March revision. Updated summer and winter CFs. |
| v4.0 | 10/10/2016 | TRM v4.0 update. No revision. |
| v5.0 | 10/2017 | TRM v5.0 update. No revision. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. No revision. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated baseline energy consumption. |
| v9.0 | 10/2021 | TRM v9.0 update. Correct deemed ranges for refrigerator volume. |
| v10.0 | 10/2022 | TRM v10.0 update. No revision. |
| v11.0 | 10/2023 | TRM v11.0 update. No revision. |

## 2.5.8 ENERGY STAR® Air Purifiers Measure Overview

**TRM Measure ID:** R-AP-AP

**Market Sector:** Residential

**Measure Category:** Appliances

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Replace-on-burnout, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This document presents the accepted deemed savings awarded for the installation of an ENERGY STAR air purifier. Savings are awarded at a flat per-unit rate, both for energy and demand savings. This measure will apply to existing homes and new construction.

## Eligibility Criteria

This measure applies to floor, tabletop, and wall-mounted air purifiers/room air cleaners.

## Baseline Condition

The baseline condition is the current federal standard Tier 1 requirements, effective August 9, 2023, with compliance enforced as of December 31, 2023. The standard will increase to Tier 2 requirements on December 31, 2025.[480]

**Table 377. Air Purifiers—Federal Standard**

| Smoke CADR | Tier 1 CADR/W | Tier 2 CADR/W |
|---|---|---|
| 10–99 | 1.7 | 1.9 |
| 100–149 | 1.9 | 2.4 |
| 150+ | 2.0 | 2.9 |

[480] DOE minimum efficiency standard for residential air cleaners. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=77. https://www.energy.gov/sites/default/files/2023-03/air-cleaners-ecs-dfr.pdf.

## High-Efficiency Condition

The table below displays the ENERGY STAR Final Version 2.0 Requirements for eligible room air cleaners effective October 17, 2020, and revised May 2022.[481] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

**Table 378. Air Purifiers—ENERGY STAR Requirements**

| Smoke CADR | Minimum CADR/W |
|---|---:|
| 10–99 | 1.9 |
| 100–149 | 2.4 |
| 150+ | 2.9 |

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Energy Savings Algorithms*

Energy savings for this measure were derived using the ENERGY STAR Appliance Savings Calculator and the revised ENERGY STAR specification in Table 348.[482] Default baseline standby power and clean air delivery rate (CADR) efficiency (CADR/W) values were taken from the ENERGY STAR calculator. ENERGY STAR standby power, CADR, and CADR/W are averages from the ENERGY STAR qualified product listing. Baseline CADR is assumed to be equivalent to ENERGY STAR CADR.

This measure will be updated to comply with the latest available ENERGY STAR specification and appliance calculator. It will also periodically be updated to comply with the latest updates to the ENERGY STAR qualified product listing.

$$Energy\ Savings\ [\Delta kWh] = (kWh_{baseline,OP} + kWh_{baseline,SB}) - (kWh_{ES,OP} + kWh_{ES,SB})$$

**Equation 146**

$$kWh_{baseline,OP} = \left(\frac{CADR_{baseline}}{\eta_{baseline}}\right)/1{,}000 \times hours \times days$$

**Equation 147**

$$kWh_{baseline,SB} = (8{,}760 - hours \times days) \times \frac{W_{baseline,SB}}{1{,}000}$$

**Equation 148**

[481] ENERGY STAR Room Air Cleaners Final Version 2.0 Program Requirements. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%202.0%20Room%20Air%20Cleaners%20Specification%20%28Rev.%20May%202022%29_0.pdf.

[482] ENERGY STAR Appliance Savings Calculator (updated October 2016). The previously cited URL is no longer available, but a copy of the calculator can be provided upon request.

$$kWh_{ES,OP} = \left(\frac{CADR_{ES}}{\eta_{ES}}\right)/1{,}000 \times hours \times days$$

**Equation 149**

$$kWh_{ES,SB} = (8{,}760 - hours \times days) \times \frac{W_{ES,SB}}{1{,}000}$$

**Equation 150**

*Where:*

| | | |
|---|---|---|
| $kWh_{baseline,OP}$ | = | *Baseline/conventional operating energy usage* |
| $kWh_{baseline,SB}$ | = | *Baseline/conventional standby energy usage* |
| $kWh_{ES,OP}$ | = | *ENERGY STAR average operating energy usage* |
| $kWh_{ES,SB}$ | = | *ENERGY STAR average standby energy usage* |
| $CADR_{baseline}$ | = | *Baseline unit clean air delivery rate (cu ft/min), assume equivalent to* $CADR_{ES}$ |
| $CADR_{ES}$ | = | *ENERGY STAR unit clean air delivery rate (cu ft/min) (see Table 380)* |
| $\eta_{baseline}$ | = | *Baseline clean air delivery efficiency = 1.0 cfm/W* |
| $\eta_{ES}$ | = | *ENERGY STAR air delivery efficiency (cfm/W) (see Table 380)* |
| *hours* | = | *Average hours of operation per day = 16* |
| *days* | = | *Average days of operation per year = 365* |
| $W_{baseline,SB}$ | = | *Conventional model standby power = 1.0 W* |
| $W_{ES,SB}$ | = | *ENERGY STAR model standby power = 0.6 W* |
| *1,000* | = | *Constant to convert from W to kW* |
| *8,760* | = | *Total hours per year* |

## *Demand Savings Algorithms*

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh}{hours \times days} \times CF_{S/W}$$

**Equation 151**

*Where:*

| | | |
|---|---|---|
| $CF_{S/W}$ | = | *Seasonal peak coincidence factor (see Table 379)* |

**Table 379. Air Purifiers—Coincidence Factors[483]**

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 0.636 | 0.617 | 0.631 | 0.620 | 0.564 |
| Winter | 0.882 | 0.907 | 0.829 | 0.876 | 0.926 |

## Deemed Energy Savings Tables

**Table 380. Air Purifiers—Energy Savings (kWh)**

| Smoke CADR range (cu ft/min) | ENERGY STAR QPL Average Smoke CADR | ENERGY STAR QPL Average Smoke CADR/W | kWh savings |
|---|---|---|---|
| 10–99 | 75 | 3.0 | 115 |
| 100–149 | 129 | 4.3 | 222 |
| 150–199 | 171 | 4.6 | 284 |
| 200–249 | 225 | 4.4 | 363 |
| 250–299 | 275 | 5.7 | 522 |
| 300+ | 375 | 5.5 | 699 |

## Deemed Summer Demand Savings Tables

**Table 381. Air Purifiers—Summer Peak Demand Savings (kW)**

| Smoke CADR range (cu ft/min) | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| 10–99 | 0.012 | 0.012 | 0.012 | 0.012 | 0.011 |
| 100–149 | 0.024 | 0.023 | 0.024 | 0.024 | 0.021 |
| 150–199 | 0.031 | 0.030 | 0.031 | 0.030 | 0.027 |
| 200–249 | 0.040 | 0.038 | 0.039 | 0.039 | 0.035 |
| 250–299 | 0.057 | 0.055 | 0.056 | 0.055 | 0.051 |
| 300+ | 0.076 | 0.074 | 0.076 | 0.074 | 0.068 |

483 See Volume 1, Section 4.

## Deemed Winter Demand Savings Tables

**Table 382. Air Purifiers—Winter Peak Demand Savings (kW)**

| Smoke CADR range (cu ft/min) | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| 10–99 | 0.017 | 0.018 | 0.016 | 0.017 | 0.018 |
| 100–149 | 0.034 | 0.034 | 0.032 | 0.033 | 0.035 |
| 150–199 | 0.043 | 0.044 | 0.040 | 0.043 | 0.045 |
| 200–249 | 0.055 | 0.056 | 0.052 | 0.054 | 0.058 |
| 250–299 | 0.079 | 0.081 | 0.074 | 0.078 | 0.083 |
| 300+ | 0.106 | 0.109 | 0.099 | 0.105 | 0.111 |

## 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) is 9 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID RES-AirCleaner.[484]

## 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
- Unit quantity
- Manufacturer and model number
- ENERGY STAR certificate matching model number
- Smoke clean air delivery rate (CADR) in cu ft/min (cfm)
- Proof of purchase – including date of purchase and quantity
  - Alternative: photo of unit installed or another pre-approved method of installation verification.

[484] DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

## 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 383. Air Purifiers—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v7.0 | 10/2019 | TRM v7.0 origin. |
| v8.0 | 10/2020 | TRM v8.0 update. No revision. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated EUL reference. |
| v10.0 | 10/2022 | TRM v10.0 update. Verified compliance with ENERGY STAR Final Version 2.0 Requirements. Updated dust CADR references to refer to smoke CADR. Updated deemed savings ranges and values. |
| v11.0 | 10/2023 | TRM v11.0 update. Updated baseline to Tier 1 federal standard. |

## 2.5.9 ENERGY STAR® Pool Pumps Measure Overview

**TRM Measure ID:** R-AP-PP

**Market Sector:** Residential

**Measure Category:** Appliances

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This measure involves the replacement of a single-speed pool pump with an ENERGY STAR-certified variable-speed or multi-speed pool pump.

## Eligibility Criteria

This measure applies to all residential applications of in-ground pools or above-ground pools. Pools that serve multiple tenants in a common area are not eligible for this measure. Ineligible pump products include waterfall, integral cartridge filter, integral sand filter, storable electric spa, and rigid electric spa.[485]

Multi-speed pool pumps are an alternative to variable speed pumps. The multi-speed pump uses an induction motor that functions as two motors in one, with full-speed and half-speed options. Multi-speed pumps may enable significant energy savings. However, if the half-speed motor is unable to complete the required water circulation task, the larger motor will operate exclusively. Having only two speed-choices limits the ability of the pump motor to fine-tune the flow rates required for maximum energy savings.[486] Therefore, multi-speed pumps must have a high-speed override capability to revert back to low speed after a period not to exceed 24 hours.

---

[485] These product types are excluded by the ENERGY STAR specification. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.1%20Pool%20Pumps%20Final%20Specification_0.pdf.

[486] Hunt, A. and Easley, S., 2012, "Measure Guideline: Replacing Single-Speed Pool Pumps with Variable Speed Pumps for Energy Savings." Building America Retrofit Alliance (BARA), US DOE. May 2012. http://www.nrel.gov/docs/fy12osti/54242.pdf.

## Baseline Condition

The baseline is assumed to be a new pool pump that is compliant with the current federal standard, effective July 19, 2021.[487] Weighted energy factor (WEF) requirements are based on rated hydraulic horsepower (hhp).

**Table 384. Baseline Condition—Federal Standard Effective July 19, 2021**

| Pump subtype | Size class | WEF |
|---|---|---|
| Self-priming (inground) pool umps | Extra small (hhp ≤ 0.13) | WEF = 5.55 |
| | Small (hhp > 0.13 to < 0.711) | WEF = -1.30 x ln(hhp) + 2.90 |
| | Standard (hhp ≥ 0.711) | WEF = -2.30 x ln(hhp) + 6.59 |
| Non-self priming (above ground) pool pumps | Extra small (hhp ≤ 0.13) | WEF = 4.60 |
| | Standard size (hhp > 0.13) | WEF = -0.85 x ln(hhp) + 2.87 |

## High-Efficiency Condition

The high-efficiency condition is a 1 to 5 hp variable speed pump (VSP) or multi-speed pool pump that is compliant with the ENERGY STAR Final Version 3.1 Requirements for pool pumps effective July 19, 2021.[488] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

Additional optional efficiency standards are available, aligning with recommendations from the Consortium for Energy Efficiency (CEE) residential swimming pool pump specification, effective October 21, 2020.[489] For all in-ground pumps, CEE Tier 1 matches the current federal standard, and CEE Tier 2 matches the current ENERGY STAR specification for in-ground standard size pumps. Additional savings are only specified for CEE tiers where there is an incremental efficiency improvement above the ENERGY STAR specification.

Compliance only needs to be verified against the CEE specification when claiming CEE savings that exceed the corresponding ENERGY STAR savings values. ENERGY STAR savings should be claimed for all pumps where CEE compliance is not verified and where there are no CEE savings specified.

---

487 Federal standard for dedicated-purpose pool pumps. https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=67.

488 ENERGY STAR Pool Pumps Final Version 3.1 Program Requirements. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%203.1%20Pool%20Pumps%20Final%20Specification_0.pdf.

489 CEE Residential Swimming Pool Pump Specification. https://library.cee1.org/system/files/library/14404/CEE_ResSwimmingPoolPump_Specification_21Oct2020.pdf.

**Table 385. ENERGY STAR Pool Pumps – Energy Efficiency Level**

| Pump Subtype | Size class | ENERGY STAR | CEE Tier 1 | CEE Tier 2 |
|---|---|---|---|---|
| Self-priming (inground) pool pumps | Extra small (hhp ≤ 0.13) | WEF ≥ 13.40 | – | – |
| | Small (hhp > 0.13 to < 0.711) | WEF ≥ -2.45 x ln(hhp) + 8.40 | WEF ≥ -1.30 x ln(hhp) + 4.95 | WEF ≥ -2.83 x ln(hhp) + 8.84 |
| | Standard (hhp ≥ 0.711) | | WEF ≥ -2.30 x ln(hhp) + 6.59 | WEF ≥ -2.45 x ln(hhp) + 8.40 |
| Non-self priming (above ground) pool pumps | Extra small (hhp ≤ 0.13) | WEF ≥ 4.92 | – | – |
| | Standard size (hhp > 0.13) | WEF ≥ -1.00 x ln(hhp) + 3.85 | WEF ≥ -1.60 x ln(hhp) + 9.10 | – |

## Energy and Demand Savings Methodology

Savings for this measure are based on methods and input assumptions from the ENERGY STAR Pool Pump Savings Calculator.

## Savings Algorithms and Input Variables

### *Energy Savings Algorithms*

Energy savings for this measure were derived using the ENERGY STAR Pool Pump Savings Calculator with Texas selected as the applicable location, so Texas-specific assumptions were used.[490]

$$Energy\ Savings\ [\Delta kWh] = kWh_{base} - kWh_{ES}$$

**Equation 152**

*Where:*

| | | |
|---|---|---|
| $kWh_{base}$ | = | *Baseline pool pump energy (kWh)* |
| $kWh_{ES}$ | = | *ENERGY STAR variable speed pool pump energy (kWh)* |

Algorithms to calculate the above parameters are defined as:

$$kWh_{base} = \frac{PFR_{base} \times 60 \times hours \times days}{WEF_{base} \times 1{,}000}$$

**Equation 153**

$$kWh_{ES} = \frac{V \times TO \times days}{WEF_{ES} \times 1{,}000}$$

**Equation 154**

*Where:*

| | | |
|---|---|---|
| $PFR_{base}$ | = | *Baseline pump flow rate [gal/min] (Table 386)* |
| $_{W}EF_{base}$ | = | *Baseline pump energy factor [gal/W x hr] (Table 386)* |
| $WEF_{ES}$ | = | *ENERGY STAR pump energy factor [gal/W x hr] (Table 387)* |
| *hours* | = | *Pump daily operating hours (Table 386)* |
| *days* | = | *Operating days per year = 365 days (default)* |

[490] The ENERGY STAR Pool Pump Savings Calculator, updated February 2013, can be found on the ENERGY STAR website at: https://www.energystar.gov/productfinder/product/certified-pool-pumps/results.

| | | |
|---|---|---|
| *V* | = | *Pool volume [gal] (Table 386)* |
| *TO* | = | *Turnovers per day, number of times the volume of the pool is run through the pump per day (Table 387)* |
| *60* | = | *Constant to convert between minutes and hours* |
| *1,000* | = | *Constant to convert from W to kW* |

**Table 386. Pool Pumps—Baseline Assumptions[491]**

| New pump HP | Reference HP | Reference HHP[492] | Hours[493] | $PFR_{base}$ (gal/min) |
|---|---|---|---|---|
| ≤ 1.25 | 1.0 | 0.533 | 4.9 | 75.5000 |
| 1.25 < hp ≤ 1.75 | 1.5 | 0.800 | 4.7 | 78.1429 |
| 1.75 < hp ≤ 2.25 | 2.0 | 1.066 | 4.1 | 88.6667 |
| 2.25 < hp ≤ 2.75 | 2.5 | 1.333 | 4.0 | 93.0910 |
| 2.75 < hp ≤ 5 | 3.0 | 1.599 | 4.0 | 101.6667 |

**Table 387. Pool Pumps—ENERGY STAR Assumptions[494]**

| New pump HP | V (gal) | Turnovers/day |
|---|---|---|
| ≤ 1.25 | 22,000 | 1.0 |
| 1.25 < hp ≤ 1.75 | | |
| 1.75 < hp ≤ 2.25 | | |
| 2.25 < hp ≤ 2.75 | | |
| 2.75 < hp ≤ 5 | | |

## Demand Savings Algorithms

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{kWh_{base} - kWh_{ES}}{hours} \times \frac{CF_{S/W}}{days}$$

**Equation 155**

[491] Conventional pump PFR and EF values are taken from pump curves found in the ENERGY STAR Pool Pump Savings Calculator. Note: input assumptions will be updated once calculator has been updated for compliance with the current specification.

[492] Hhp not available in ENERGY STAR calculator. Assumed hhp calculated as follows: Ref. horsepower x AF. AF = 0.533 based on ratio of hhp to hp from ENERGY STAR qualified product listing. Accessed 8/11/2023.

[493] The daily average operating hours for conventional single-speed pumps, based on 2014 residential pool pump program survey results from CenterPoint Energy.

[494] ENERGY STAR values are taken from default inputs and pump curves found in the ENERGY STAR Pool Pump Savings Calculator. Note: input assumptions will be updated once calculator has been updated for compliance with the current specification.

*Where:*

$CF_{S/W}$ = *Seasonal peak coincidence factor (Table 388)*

**Table 388. Pool Pumps—Coincidence Factors[495]**

| Climate zone | Summer CF | Winter CF |
|---|---|---|
| Zone 1: Amarillo | 0.258 | -0.002 |
| Zone 2: Dallas | 0.329 | 0.025 |
| Zone 3: Houston | 0.276 | 0.108 |
| Zone 4: Corpus Christi | 0.266 | 0.036 |
| Zone 5: El Paso | 0.497 | -0.143 |

## Deemed Energy Savings Tables

**Table 389. Pool Pumps—Energy Savings (kWh)[496]**

| New pump hp | Inground | Above ground |
|---|---|---|
| **ENERGY STAR** | | |
| ≤ 1.25 | 1,371 | 587 |
| 1.25 < hp ≤ 1.75 | 235 | 657 |
| 1.75 < hp ≤ 2.25 | 262 | 707 |
| 2.25 < hp ≤ 2.75 | 332 | 852 |
| 2.75 < hp ≤ 5 | 509 | 1,229 |
| **CEE Tier 1** | | |
| ≤ 1.25 | – | 1,585 |
| 1.25 < hp ≤ 1.75 | – | 1,779 |
| 1.75 < hp ≤ 2.25 | – | 1,935 |
| 2.25 < hp ≤ 2.75 | – | 2,176 |
| 2.75 < hp ≤ 5 | – | 2,642 |
| **CEE Tier 2** | | |
| ≤ 1.25 | 1,423 | – |
| 1.25 < hp ≤ 5 | – | – |

[495] Coincidence factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from the US Department of Energy's Building America B10 Benchmark load profiles for pool pumps. The profile used to determine coincidence factors is calculated as the difference of single speed and variable speed profiles. Summer profiles include April through September and winter profiles include October through March.

[496] The results in this table may vary slightly from results produced by the ENERGY STAR calculator because of rounding of default savings coefficients throughout the measure and pool volume.

## Deemed Summer Demand Savings Tables[497]

**Table 390. Pool Pumps—Summer Peak Demand Savings (kW) for Inground Pools**

| New pump HP | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| **ENERGY STAR** | | | | | |
| ≤ 1.25 | 0.198 | 0.252 | 0.212 | 0.204 | 0.381 |
| 1.25 < hp ≤ 1.75 | 0.035 | 0.045 | 0.038 | 0.036 | 0.068 |
| 1.75 < hp ≤ 2.25 | 0.045 | 0.057 | 0.048 | 0.046 | 0.087 |
| 2.25 < hp ≤ 2.75 | 0.059 | 0.075 | 0.063 | 0.060 | 0.113 |
| 2.75 < hp ≤ 5 | 0.090 | 0.115 | 0.096 | 0.093 | 0.173 |
| **CEE Tier 1** | | | | | |
| All sizes | – | – | – | – | – |
| **CEE Tier 2** | | | | | |
| ≤ 1.25 | 0.206 | 0.262 | 0.220 | 0.212 | 0.396 |
| 1.25 < hp ≤ 5 | – | – | – | – | – |

**Table 391. Pool Pumps—Summer Peak Demand Savings (kW) for Above Ground Pools**

| New pump HP | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| **ENERGY STAR** | | | | | |
| ≤ 1.25 | 0.085 | 0.108 | 0.091 | 0.087 | 0.163 |
| 1.25 < hp ≤ 1.75 | 0.099 | 0.126 | 0.106 | 0.102 | 0.190 |
| 1.75 < hp ≤ 2.25 | 0.122 | 0.155 | 0.130 | 0.126 | 0.235 |
| 2.25 < hp ≤ 2.75 | 0.151 | 0.192 | 0.161 | 0.155 | 0.290 |
| 2.75 < hp ≤ 5 | 0.218 | 0.277 | 0.233 | 0.224 | 0.418 |
| **CEE Tier 1** | | | | | |
| ≤ 1.25 | 0.229 | 0.291 | 0.245 | 0.236 | 0.441 |
| 1.25 < hp ≤ 1.75 | 0.268 | 0.341 | 0.287 | 0.276 | 0.516 |
| 1.75 < hp ≤ 2.25 | 0.334 | 0.425 | 0.357 | 0.344 | 0.643 |
| 2.25 < hp ≤ 2.75 | 0.385 | 0.490 | 0.412 | 0.396 | 0.741 |
| 2.75 < hp ≤ 5 | 0.468 | 0.595 | 0.500 | 0.481 | 0.900 |

[497] Ibid.

| New pump HP | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| CEE Tier 2 | | | | | |
| All sizes | – | – | – | – | – |

## Deemed Winter Demand Savings Tables

**Table 392. Pool Pumps—Winter Peak Demand Savings (kW) for Inground Pools**

| New pump HP | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| ENERGY STAR | | | | | |
| ≤ 1.25 | -0.001 | 0.019 | 0.083 | 0.027 | -0.110 |
| 1.25 < hp ≤ 1.75 | 0.000 | 0.003 | 0.015 | 0.005 | -0.020 |
| 1.75 < hp ≤ 2.25 | 0.000 | 0.004 | 0.019 | 0.006 | -0.025 |
| 2.25 < hp ≤ 2.75 | 0.000 | 0.006 | 0.025 | 0.008 | -0.032 |
| 2.75 < hp ≤ 5 | -0.001 | 0.009 | 0.038 | 0.012 | -0.050 |
| CEE Tier 1 | | | | | |
| All sizes | – | – | – | – | – |
| CEE Tier 2 | | | | | |
| ≤ 1.25 | -0.001 | 0.020 | 0.086 | 0.029 | -0.114 |
| 1.25 < hp ≤ 5 | – | – | – | – | – |

**Table 393. Pool Pumps—Peak Demand Savings (kW) for Above Ground Pools**

| New pump HP | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| ENERGY STAR | | | | | |
| ≤ 1.25 | -0.001 | 0.008 | 0.036 | 0.012 | -0.047 |
| 1.25 < hp ≤ 1.75 | -0.001 | 0.010 | 0.042 | 0.014 | -0.055 |
| 1.75 < hp ≤ 2.25 | -0.001 | 0.012 | 0.051 | 0.017 | -0.067 |
| 2.25 < hp ≤ 2.75 | -0.001 | 0.014 | 0.063 | 0.021 | -0.083 |
| 2.75 < hp ≤ 5 | -0.001 | 0.021 | 0.091 | 0.030 | -0.120 |

| New pump HP | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| **CEE Tier 1** | | | | | |
| ≤ 1.25 | -0.001 | 0.022 | 0.096 | 0.032 | -0.127 |
| 1.25 < hp ≤ 1.75 | -0.002 | 0.026 | 0.112 | 0.037 | -0.148 |
| 1.75 < hp ≤ 2.25 | -0.002 | 0.032 | 0.140 | 0.046 | -0.185 |
| 2.25 < hp ≤ 2.75 | -0.002 | 0.037 | 0.162 | 0.053 | -0.213 |
| 2.75 < hp ≤ 5 | -0.003 | 0.045 | 0.196 | 0.065 | -0.259 |
| **CEE Tier 2** | | | | | |
| All sizes | – | – | – | – | – |

### Claimed Peak Demand Savings

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

### Additional Calculators and Tools

ENERGY STAR Pool Pump Savings Calculator, updated May 2020, can be found on the ENERGY STAR website at https://www.energystar.gov/productfinder/product/certified-pool-pumps/results.

### Measure Life and Lifetime Savings

The estimated useful life (EUL) is 10 years, as specified in the California Database of Energy Efficiency Resources (DEER) READI tool for EUL ID OutD-PoolPump.[498]

## 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 include the below.

For all projects collect:

- Climate zone or county
- Unit quantity
- Manufacturer and model number of new pool pump
- ENERGY STAR certificate matching model number
- Weighted energy factor of new pool pump
- Rated hydraulic horsepower of new pool pump

498 DEER READI (Remote Ex-Ante Database Interface). http://www.deeresources.com/index.php/readi.

- Rated horsepower of new pool pump
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or other pre-approved method of installation verification

For a significant sample of projects where attainable (e.g., those projects that are selected for inspection, not midstream or retail programs):

- Items listed for all projects above
- Decision/action type: early retirement, replace-on-burnout, or new construction
- Rated horsepower of existing pool pump
- Existing and new pool pump operating hours

## 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 394. Pool Pumps—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v5.0 | 10/2017 | TRM v5.0 origin. |
| v6.0 | 11/2018 | TRM v6.0 update. No revision. |
| v7.0 | 10/2019 | TRM v7.0 update. Updated eligibility to include above ground pool pumps now eligible for ENERGY STAR certification. Acknowledged the forthcoming ENERGY STAR v2.0. |
| v8.0 | 10/2020 | TRM v8.0 update. Incorporated ENERGY STAR v2.0 updated deemed savings. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated EUL reference and documentation requirements. |
| v10.0 | 10/2022 | TRM v10.0 update. Verified compliance with ENERGY STAR Final Version 3.1 Requirements. Updated savings coefficient definitions. |
| v11.0 | 10/2023 | TRM v11.0 update. Updated baseline to current federal standard. Added new savings tiers. Updated documentation requirements. |

## 2.5.10 Advanced Power Strips Measure Overview

**TRM Measure ID:** R-AP-PS

**Market Sector:** Residential

**Measure Category:** Appliances

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Deemed savings values

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

This measure involves the installation of a multi-plug advanced power strip (APS) with the ability to automatically disconnect specific loads depending on the power draw of a specified, or "master," load.

For a Tier 1 APS, a load sensor in the strip disconnects power from the control outlets when the master power draw is below a certain threshold. This feature allows for a reduction of power draw from peripheral consumer electronics, which usually maintain some load even when in the off or standby position. Therefore, when the master device (e.g., television) is turned off, the power supply is cut to other related equipment (e.g., set-top boxes, speakers, video game consoles).

A Tier 2 APS uses an external sensor paired with a configurable countdown timer to manage both active and standby power loads for controlled devices in a complete system. A Tier 2 APS may operate either with or without a master control socket. Those without a master control socket sense power of all devices connected to the controlled sockets, while those with a master control socket sense power for the device connected to the master control socket. The external sensor of a Tier 2 APS may use an infrared-only sensor, or it may use a "multi-sensor," which detects both infrared (IR) remote control signals and motion to determine device inactivity and deliver additional savings as compared to a Tier 1 APS. Both versions of external sensors use IR filtering to prevent inappropriate switching events that may have otherwise resulted from natural interference, such as sunlight or CFL light bulbs.

## Eligibility Criteria

This measure applies to all residential applications. For Tier 2 applications, the APS must control at least two audiovisual devices.

## Baseline Condition

The baseline condition is assumed to be uncontrolled peripheral loads, each plugged into a traditional surge protector or wall outlet.

## High-Efficiency Condition

The high-efficiency condition is peripheral loads controlled by a Tier 1 or Tier 2 APS.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Savings were developed based on reported plug load electricity consumption and hourly use data. A set of home entertainment and home office peripheral equipment and related performance data are presented in the following table. “Daily Standby Hours” and “Daily Off Hours” represent the average number of hours the device is left in standby or off mode. For each device, a weighted watt per hour value is calculated based on projected watts consumed in either mode.

There are three savings paths available for Tier 1. Savings can be estimated by:

1. Complete system type (home entertainment or home office)
2. Per APS for an average complete system if the type is unknown
3. Per individual peripheral device

Tier 2 savings are determined using the average component uses for a complete system and an energy reduction percentage.

Table 395. APS—Peripheral Watt Consumption Breakdown[499]

| System type | Peripheral device | Daily standby hours | Daily off hours | Standby power (W) | Off power (W) | Weighted W/hr | Annual APS hours |
|---|---|---|---|---|---|---|---|
| Home entertainment | Audio equipment: AV receiver | 0.0 | 18.0 | 19.2 | 3.1 | 3.1 | 6,570 |
| | Audio equipment: Speakers | 0.0 | 18.0 | 3.0 | 0.0 | 0.0 | 6,570 |
| | Audio equipment: Subwoofer | 0.0 | 18.0 | 7.8 | 0.6 | 0.6 | 6,570 |
| | Media player: Blu-ray | 2.5 | 20.8 | 7.0 | 0.1 | 0.8 | 8,505 |
| | Media player: DVD | 2.5 | 20.8 | 5.0 | 2.0 | 2.3 | 8,505 |
| | Media player: DVD-R | 2.5 | 20.8 | 7.0 | 3.0 | 3.4 | 8,505 |
| | Media player: DVD/VCR | 2.5 | 20.4 | 8.0 | 4.0 | 4.4 | 8,359 |
| | Media player: VCR | 2.2 | 21.4 | 6.0 | 3.0 | 3.3 | 8,614 |
| | Set-top box: Cable | 0.0 | 16.5 | 25.0 | 16.0 | 16.0 | 6,023 |
| | Set-top box: Cable with DVR | 0.0 | 16.5 | 45.0 | 43.0 | 43.0 | 6,023 |
| | Set-top box: Satellite | 0.0 | 15.1 | 10.0 | 15.0 | 15.0 | 5,512 |
| | Set-top box: Satellite with DVR | 0.0 | 15.1 | 27.0 | 28.0 | 28.0 | 5,512 |
| | Set-top box: Stand-alone DVR | 0.0 | 18.3 | 27.0 | 27.0 | 27.0 | 6,680 |
| | Television: CRT | 0.0 | 18.7 | 5.3 | 1.6 | 1.6 | 6,826 |
| | Television: LCD | 0.0 | 18.7 | 2.2 | 0.5 | 0.5 | 6,826 |
| | Television: Plasma | 0.0 | 18.7 | 0.9 | 0.6 | 0.6 | 6,826 |
| | Television: Projection | 0.0 | 18.7 | 4.4 | 7.0 | 7.0 | 6,826 |
| | Video game console: Nintendo Wii | 1.5 | 21.4 | 10.5 | 1.9 | 2.5 | 8,359 |
| | Video game console: Wii U | 1.5 | 21.4 | 34.0 | 0.4 | 2.6 | 8,359 |
| | Video game console: PlayStation 2 | 1.5 | 21.4 | 17.0 | 0.2 | 1.3 | 8,359 |

499 Derived from New York State Energy Research and Development Authority (NYSERDA), "Advanced Power Strip Research Report." August 2011.

| System type | Peripheral device | Daily standby hours | Daily off hours | Standby power (W) | Off power (W) | Weighted W/hr | Annual APS hours |
|---|---|---|---|---|---|---|---|
| Home entertainment | Video game console: PlayStation 3 | 1.5 | 21.4 | 152.9 | 1.1 | 11.0 | 8,359 |
| | Video game console: PlayStation 4 | 1.5 | 21.4 | 137.0 | 6.4 | 14.9 | 8,359 |
| | Video game console: XBOX | 1.5 | 21.4 | 68.0 | 2.0 | 6.3 | 8,359 |
| | Video game console: XBOX 360 | 1.5 | 21.4 | 117.5 | 3.1 | 10.6 | 8,359 |
| | Video game console: XBOX One | 1.5 | 21.4 | 112.0 | 11.9 | 18.4 | 8,359 |
| Home office | Computer: Desktop | 4.1 | 16.7 | 11.6 | 3.3 | 4.9 | 7,592 |
| | Computer: Laptop | 4.1 | 16.7 | 7.6 | 4.4 | 5.0 | 7,592 |
| | Computer monitor: CRT | 2.4 | 16.5 | 7.6 | 1.5 | 2.3 | 6,899 |
| | Computer monitor: LCD | 2.4 | 16.5 | 1.9 | 1.1 | 1.2 | 6,899 |
| | Computer speakers | 0.0 | 18.7 | 3.7 | 2.3 | 2.3 | 6,826 |
| | Copier | 0.0 | 23.5 | 2.8 | 1.5 | 1.5 | 8,578 |
| | Fax machine: Inkjet | 0.5 | 23.3 | 6.0 | 5.3 | 5.3 | 8,687 |
| | Fax machine: Laser | 0.5 | 23.3 | 5.3 | 2.2 | 2.3 | 8,687 |
| | Printer: Inkjet | 4.4 | 19.5 | 2.5 | 1.3 | 1.5 | 8,724 |
| | Printer: Laser | 4.4 | 19.5 | 9.0 | 3.3 | 4.3 | 8,724 |
| | Scanner | 0.0 | 23.5 | 3.6 | 2.1 | 2.1 | 8,578 |

## *Energy Savings Algorithms*

### Tier 1 APS

Energy savings for a Tier 1 APS in use for home entertainment or home office are calculated using the following algorithm, where kWh saved is calculated and summed for all peripheral devices.

$$Energy\ Savings\ [\Delta kWh] = \sum \frac{W_i \times H_i}{1{,}000} \times ISR$$

**Equation 156**

*Where:*

| | | |
|---|---|---|
| *W* | = | *Weighted watts per hour consumed in standby/off mode for each peripheral device (see* Table 395*)* |
| *H* | = | *Annual hours per year controlled by APS (see Table 395)* |
| *1,000* | = | *Constant to convert from W to kW* |
| *ISR* | = | *In-service rate or the percentage of units rebated that are installed, see Table 396* |

### Tier 2 APS

Energy savings for a Tier 2 APS are calculated using the average household home entertainment and home office usages, multiplied by an assumed energy reduction percentage.

$$\Delta kWh_{Home\ Entertainment} = kWh_{TV} \times ERP \times ISR$$

**Equation 157**

$$\Delta kWh_{Home\ Office} = kWh_{Comp} \times ERP \times ISR$$

**Equation 158**

$$\Delta kWh_{Unspecified} = \frac{kWh_{TV} + kWh_{Comp}}{2} \times ERP \times ISR$$

**Equation 159**

*Where:*

| | | |
|---|---|---|
| $kWh_{TV}$ | = | *Average annual energy consumption of Tier 2 qualifying TV systems; default = 602.8 kWh*[500] |

[500] New York State Energy Research and Development Authority (NYSERDA), “Advanced Power Strip Research Report”. August 2011. Page 30.

| | | |
|---|---|---|
| *$kWh_{Comp}$* | = | *Average annual energy consumption of Tier 2 qualifying computer systems; default = 197.9 kWh*[501] |
| *ERP* | = | *Energy reduction percentage (default = 47.5%*[502]*)* |

**Table 396. APS—In-Service Rates by Program Type**

| Program type | ISR |
|---|---|
| All[503] | 0.83 |

## *Demand Savings Algorithms*

### Tier 1 and Tier 2 APS

Demand savings for a Tier 1 APS in use for a home entertainment system or home office are calculated using the following algorithm, where kWh saved is calculated and summed for all peripheral devices. Demand savings for a Tier 2 APS are calculated using the average household home office and home entertainment center usages, multiplied by an assumed energy reduction percentage.

$$Peak\ Demand\ Savings\ [\Delta kW] = \sum \frac{\Delta kWh}{hours} \times CF_{S/W}$$

**Equation 160**

*Where:*

| | | |
|---|---|---|
| *hours* | = | *Annual hours per year controlled by APS (see Table 395 for Tier 1 APS; assume 4,380 for Tier 2 APS*[504]*)* |
| *$CF_{S/W}$* | = | *Seasonal peak coincidence factor (see Table 397)*[505] |

**Table 397. APS—Coincidence Factors[506]**

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 0.33 | 0.43 | 0.36 | 0.30 | 0.66 |
| Winter | 0.89 | 0.88 | 0.86 | 0.85 | 0.87 |

501 New York State Energy Research and Development Authority (NYSERDA), “Advanced Power Strip Research Report”. August 2011. Page 30.

502 Average of ERP from Northeast Energy Efficiency Partnerships (NEEP), “Case Study: Tier 2 Advanced Power Strips and Efficiency Programs”. April 2015.

503 MidAmerican Energy Company & Tetra Tech "Residential Assessment Impact and Process Evaluation FINAL". December 22, 2020, APPENDIX B: IN-SERVICE RATES ANALYSIS, p. 47.

504 Estimated based on assumption that approximately half of savings are during active hours (assumed to be 5.3 hours/day, or 1,936 hours/year) and half during standby hours (8,760-1,936 = 6,824 hours/year). The resulting weighted average is 4,380 hours/year.

505 Derived using Electric Power Research Institute (EPRI) End Use Load Shapes for Residential TV and PC. http://loadshape.epri.com/enduse.

506 See Volume 1, Section 4.

## Deemed Energy Savings Tables

Refer to Table 398 and Table 399. The savings presented in these tables must be adjusted by applying the program-specific ISR values specified in Table 396.

## Deemed Summer Demand Savings Tables

Refer to Table 398 and Table 399. The savings presented in these tables must be adjusted by applying the program-specific ISR values specified in Table 396Table 18.

## Deemed Winter Demand Savings Tables

Refer to Table 398 and Table 399. The savings presented in these tables must be adjusted by applying the program-specific ISR values specified in Table 396.

**Table 398. APS—Tier 1 Unadjusted Savings Before Applying ISR[507]**

| System type | kWh savings | Summer kW savings | | | | | Winter kW savings | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 |
| Home entertainment[508] | 269.9 | 0.0132 | 0.0174 | 0.0143 | 0.0119 | 0.0265 | 0.0358 | 0.0354 | 0.0345 | 0.0342 | 0.0348 |
| Home office[509] | 87.1 | 0.0037 | 0.0049 | 0.0041 | 0.0034 | 0.0075 | 0.0101 | 0.0100 | 0.0098 | 0.0097 | 0.0098 |
| Upstream/midstream[510] | 178.5 | 0.0084 | 0.0112 | 0.0092 | 0.0077 | 0.0170 | 0.0230 | 0.0227 | 0.0221 | 0.0219 | 0.0223 |

**Table 399. APS—Tier 2 Unadjusted Savings Before Applying ISR[511]**

| System type | kWh savings | Summer kW savings | | | | | Winter kW savings | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone 5 |
| Home entertainment | 286.3 | 0.021 | 0.028 | 0.023 | 0.019 | 0.043 | 0.058 | 0.058 | 0.056 | 0.056 | 0.057 |
| Home office | 94.0 | 0.007 | 0.009 | 0.008 | 0.006 | 0.014 | 0.019 | 0.019 | 0.018 | 0.018 | 0.019 |
| Upstream/midstream | 190.2 | 0.014 | 0.019 | 0.015 | 0.013 | 0.029 | 0.039 | 0.038 | 0.037 | 0.037 | 0.038 |

507 Apply in-service rate to adjust savings for specific program delivery type.
508 Assuming audio equipment: AV receiver, media player: average, set-top box: average, and video game console: average.
509 Assuming computer: desktop, computer monitor: LCD, computer speakers, and printer: average.
510 Average of *home entertainment* and *home office system* averages.
511 Apply in-service rate to adjust savings for specific program delivery type.

## 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) is 10 years for a Tier 1 APS, according to the 2011 NYSERDA Advanced Power Strip Research Report.[512] While Tier 2 APS is not covered by the NYSERDA report, assume the same 10-year EUL for Tier 2 APS.

# 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
- Unit quantity
- Manufacturer and model number
- APS type (Tier 1 or Tier 2)
- System type (home entertainment, home office, unspecified)
- Proof of purchase – including date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification.

# 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.

[512] New York State Energy Research and Development Authority (NYSERDA), “Advanced Power Strip Research Report”. August 2011. Page 30.

## Document Revision History

**Table 400. APS—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v7.0 | 10/2019 | TRM v7.0 origin. |
| v8.0 | 10/2020 | TRM v8.0 update. No revision. |
| v9.0 | 10/2021 | TRM v9.0 update. Updated savings with current coincidence factors. |
| v10.0 | 10/2022 | TRM v10.0 update. Corrected typos in deemed savings tables from TRM v9.0 update. |
| v11.0 | 10/2023 | TRM v11.0 update. Added in-service rates. |

## 2.5.11 ENERGY STAR® Electric Vehicle Supply Equipment

**TRM Measure ID:** R-AP-EV

**Market Sector:** Residential

**Measure Category:** Appliance

**Applicable Business Types:** Single-family, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type:** Retrofit, new construction

**Program Delivery Type:** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

### Measure Description

This measure applies to the installation of ENERGY STAR qualified Level 2 electric vehicle supply equipment (EVSE) at a residential site. EVSE is the infrastructure that enables plug-in electric vehicles (PEV) to charge onboard batteries. Level 2 EVSE require 240-volt electrical service. This measure provides deemed savings for the energy efficiency improvement of an ENERGY STAR EVSE over a standard or non-ENERGY STAR EVSE.

### Eligibility Criteria

Eligible equipment includes an ENERGY STAR qualified Level 2 EVSE installed at a residence. The EVSE may be installed for use on either an all-battery electric vehicle (BEV) or a plug-in hybrid electric vehicle (PHEV). Multifamily buildings should use the commercial EVSE measure.

### Baseline Condition

The baseline condition is a non-ENERGY STAR qualified Level 2 EVSE.

### High-Efficiency Condition

The high-efficiency EVSE is a Level 2 EVSE compliant with ENERGY STAR Final Version 1.1 specification for eligible EVSE, effective March 31, 2021.[513] Energy efficiency service providers are expected to comply with the latest ENERGY STAR requirements.

[513] ENERGY STAR EVSE Final Version 1.1 Program Requirements. https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20V1.1%20DC%20EVSE%20Final%20Specification_0.pdf.

## Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

Savings for EVSE come from efficiency gains of the ENERGY STAR equipment during operating modes when the vehicle is plugged in but not charging and when not plugged in. Deemed savings are calculated according to the following algorithms.

### *Demand Savings Algorithms*

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{\Delta kWh \times HCF \times DCF}{days_c \times hours_{p,c}}$$

**Equation 161**

*Where:*

| | | |
|---|---|---|
| $\Delta kWh_{SS}$ | = | *Steady state energy savings (Table 402)* |
| *HCF* | = | *Hourly coincidence factor (Table 401)* |
| *DCF* | = | *Daily coincidence factor*[514] *= 0.88* |
| $days_c$ | = | *Number of charging days = 321* |
| $hours_{p,c}$ | = | *Hours per day vehicle is plugged in and charging = 2.4 hr* [515] |

**Table 401. EVSE—Coincidence Factors**[516]

| Climate zone | Summer | Winter |
|---|---|---|
| Zone 1: Amarillo | 0.044 | 0.058 |
| Zone 2: Dallas | 0.040 | 0.053 |
| Zone 3: Houston | 0.043 | 0.041 |
| Zone 4: Corpus Christi | 0.042 | 0.059 |
| Zone 5: El Paso | 0.033 | 0.085 |

## Deemed Energy Savings Tables

Table 402 presents the deemed energy savings per EVSE. Networked chargers refer to EVSE that are connected remotely to a larger network and are part of an infrastructure system of connected chargers.

[514] Idaho National Lab (INL) EV Project, June 2015, "Characterize the Demand and Energy Characteristics of Residential Electric Vehicle Supply Equipment," page 6. Eighty-eight percent of PEV owners charge every day.
[515] INL, page 5. A vehicle plugged in for 11.7 hours and charging for 2.4 hours leaves 9.3 hours when it is plugged in and not charging.
[516] Probability weighted peak load factors are calculated according to the method in Section 4 of the Texas TRM Vol 1 using data from 3 studies: CCET Wind Integration in ERCOT, Avista Utilities Semi-Annual Report on Electric Vehicle Supply, and Xcel CO EVCS Pilot.

**Table 402. EVSE—Energy Savings (kWh)[517]**

| EVSE type | Steady state charging (kWh) | Standby mode (kWh) | Total savings (kWh) |
|---|---|---|---|
| Non-networked charger | 18 | 22 | 40 |
| Networked charger | | 53 | 71 |

## Deemed Summer and Winter Demand Savings Tables

Table 403 presents the deemed summer and winter peak kW savings per EVSE.

**Table 403. EVSE—Summer/Winter Peak Demand Savings (kW)[518]**

| Climate Zone | Summer | Winter |
|---|---|---|
| Zone 1: Amarillo | 0.0009 | 0.0012 |
| Zone 2: Dallas | 0.0008 | 0.0011 |
| Zone 3: Houston | 0.0009 | 0.0008 |
| Zone 4: Corpus Christi | 0.0009 | 0.0012 |
| Zone 5: El Paso | 0.0007 | 0.0017 |

## 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 an EVSE is assumed to be 10 years.[519]

# 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:

- Climate zone or county

[517] ENERGY STAR Market and Industry Scoping Report Electric Vehicle Supply Equipment (EVSE), September 2013. https://www.energystar.gov/sites/default/files/asset/document/Electric_Vehicle_Scoping_Report.pdf.

[518] Demand savings are only presented for steady state charging because those savings are higher than demand for plugged-in standby mode.

[519] US Department of Energy Vehicle Technologies Office, November 2015, “Costs Associated with Non-Residential Electric Vehicle Supply Equipment” p. 21. https://afdc.energy.gov/files/u/publication/evse_cost_report_2015.pdf.

- Manufacturer and model number
- EVSE type (networked, non-networked)
- ESVE quantity
- ENERGY STAR certificate matching EVSE model number
- Vehicle year, make, and model (if available)
- Estimated number of miles driven per day (if available)

# 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 404. EVSE—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v7.0 | 10/2019 | TRM v7.0 origin. |
| v8.0 | 10/2020 | TRM v8.0 update. Updated deemed savings tables |
| v9.0 | 10/2021 | TRM v9.0 update. Updated documentation requirements. |
| v10.0 | 10/2022 | TRM v10.0 update. Verified compliance with ENERGY STAR Final Version 1.1 Requirements. Updated savings calculation assumptions, deemed savings, and documentation requirements. |
| v11.0 | 10/2023 | TRM v11.0 update. Updated algorithm with days coefficient. Updated documentation requirements. |

## 2.5.12 Induction Cooking

**TRM Measure ID:** R-AP-IC

**Market Sector:** Residential

**Measure Category:** Appliances

**Applicable Building Types:** Single-family, multifamily, manufactured

**Fuels Affected:** Electricity

**Decision/Action Type(s):** Retrofit, new construction

**Program Delivery Type(s):** Prescriptive

**Deemed Savings Type:** Look-up tables

**Savings Methodology:** Engineering algorithms and estimates

## Measure Description

Residential cooking appliances include ovens, cooktops, and full ranges. A full range consists of an oven with a built-in cooktop. An induction range is an electric oven with a built-in induction cooktop.

Induction technology works on the principle of magnetic induction, where excited eddy currents in ferromagnetic cookware within the presence of an oscillating magnetic field dissipate heat through the Joule effect. This heat is directly generated by the cookware and is transmitted to the food within it, lessening thermal condition heat loss between the heating element and the cookware. Induction cooktops include a switching-power electronics circuit that delivers high-frequency current to a planar coil of wire embedded in the cooking surface. The cookware is magnetically coupled to the coil by the oscillating magnetic field. Current flows in the cooking vessel due to the low resistance of the metal. Resistance is a function of permeability and resistivity of the cookware as well as the frequency of excitation. Typical induction cooktops operate at switching frequency between 25 kHz and 50 kHz, which restricts coupling to ferromagnetic cookware such as cast iron, and some alloys of stainless steel.[520]

According to manufacturers, induction cooktops heat food faster, are easier to clean, are less likely to burn those using them, and have a higher cooking efficiency than electric resistance cooktops.

## Eligibility Criteria

This measure requires the installation of an electric range with an induction cooktop or a standalone induction cooktop in a residential application. This measure assumes the use of small cookware typical of residential applications.

[520] Sweeney, M., J. Dols, B. Fortenbery, and F. Sharp (EPRI), "Induction Cooking Technology Design and Assessment." Proceedings of the 2014 ACEEE Summer Study on Energy Efficiency in Buildings, p. 9-370. https://www.aceee.org/files/proceedings/2014/data/papers/9-702.pdf.

## Baseline Condition

The baseline condition is defined as an electric range with electric resistance cooktop or a standalone electric resistance cooktop. This measure assumes a default of four burners.

**Table 405. Induction Cooking—Baseline Electric Resistance Cooktop Energy Consumption[521]**

| Number of burners | Electric cooktop baseline kWh |
|---|---:|
| 0 | 84 |
| 1 | 89 |
| 2 | 95 |
| 3 | 101 |
| 4 | 106 |
| 5 | 112 |
| 6 | 118 |
| 7+ | 124 |

## High-Efficiency Condition

The high efficiency condition is defined as an electric range with an induction cooktop or a standalone induction cooktop.

# Energy and Demand Savings Methodology

## Savings Algorithms and Input Variables

### *Energy Savings Algorithms*

Energy savings are calculated as the difference between the baseline and high-efficiency condition unit energy consumption (UEC). These exclude HVAC interactive effects or savings due to reduced kitchen hood consumption. Range oven cooking efficiency varies by cooktop type. Ranges with electric resistance and induction cooktops both have electric resistance oven components. Therefore, baseline and high-efficiency condition oven cooking efficiencies are equivalent and are excluded from the savings calculation.

$$Energy\ Savings\ [\Delta kWh] = UEC_{base} - UEC_{IC}$$

**Equation 162**

521 "Plug Loads and Lighting Modeling," Codes and Standards Enhancement Initiative (CASE). 2016 California Building Energy Efficiency Standards. June 2016. Table 35. https://www.caetrm.com/media/reference-documents/2016_T24CASE_Report_-_Plug_Load_and_Ltg_Modeling_-_June_2016.pdf.

$$UEC_{IC} = UEC_{base} \times \frac{CE_{base}}{CE_{IC}}$$

**Equation 163**

*Where:*

| | | |
|---|---|---|
| $UEC_{base}$ | = | *Baseline annual unit energy consumption [kWh]; see Table 405* |
| $UEC_{IC}$ | = | *Induction cooking annual unit energy consumption [kWh]* |
| $CE_{base}$ | = | *Baseline cooking efficiency = 75 percent*[522] |
| $CE_{IC}$ | = | *Induction cooking efficiency = 85 percent*[523] |

## *Summer Demand Savings Algorithms*

$$Peak\ Demand\ Savings\ [\Delta kW] = \frac{kWh_{savings}}{8{,}760} \times CF_{S/W}$$

**Equation 164**

| | | |
|---|---|---|
| 8,760 | = | *Total hours per year* |
| $CF_{S/W}$ | = | *Seasonal peak coincidence factor (Table 406)* |

**Table 406. Induction Cooking—Coincidence Factors[524]**

| Season | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| Summer | 0.003 | 0.003 | 0.003 | 0.003 | 0.002 |
| Winter | 0.009 | 0.008 | 0.007 | 0.008 | 0.010 |

522 "2021-2022 Residential Induction Cooking Tops," ENERGY STAR. https://www.energystar.gov/about/2021_residential_induction_cooking_tops#:~:text=The%20per%20unit%20efficiency%20of,times%20more%20efficient%20than%20gas.

523 Ibid.

524 Calculated according to TX TRM Volume 1, Section 4 using data from the US DOE Building America B10 Benchmark load profiles for cooking equipment. Summer profiles include April through September, and winter profiles include October through March. https://www.energy.gov/eere/buildings/building-america-analysis-spreadsheets.

## Deemed Energy Savings Tables

For all applications, this measure assumes a default value of four burners.[525]

**Table 407. Induction Cooking—Energy Savings (kWh)**

| Number of burners | kWh savings |
|---|---|
| 4 | 12 |

## Deemed Summer Demand Savings Tables

For all applications, this measure assumes a default value of four burners.

**Table 408. Induction Cooking—Summer Peak Demand Savings (kW)**

| Number of burners | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| 4 | 0.000004 | 0.000004 | 0.000004 | 0.000004 | 0.000003 |

## Deemed Winter Demand Savings Tables

For all applications, this measure assumes a default value of four burners.

**Table 409. Induction Cooking—Winter Peak Demand Savings (kW)**

| Number of burners | Climate Zone 1: Amarillo | Climate Zone 2: Dallas | Climate Zone 3: Houston | Climate Zone 4: Corpus Christi | Climate Zone 5: El Paso |
|---|---|---|---|---|---|
| 4 | 0.000013 | 0.000011 | 0.000010 | 0.000011 | 0.000014 |

## 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.

[525] Savings for 0–7+ burners only vary from 10–15 kWh.

## Measure Life and Lifetime Savings

The estimated useful life (EUL) of an induction cooktop is 16 years based on the average lifetime specified for electric cooktops in the 2016 DOE life-cycle cost tool for residential cooking products.[526]

## 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 (new construction, retrofit)
- Baseline unit type (electric range with electric resistance cooktop, standalone electric resistance cooktop)
- New unit type (electric range with induction cooktop, standalone induction cooktop)
- Manufacturer and model number
- Unit quantity
- Burner quantity
- Proof of purchase – with date of purchase and quantity
    - Alternative: photo of unit installed or another pre-approved method of installation verification

## 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.

[526] US Department of Energy (DOE), Energy Efficiency and Renewable Energy Office (EERE). 2016 SNOPR Analytical Tools: Life-Cycle Cost and Payback Period Analysis Spreadsheet. "Cooking_Pds_LCC_SNOPR_DOE_2016_publication.xlsm." Dockett EERE-2014-BT-STD-0005.

## Document Revision History

**Table 410. Induction Cooking—Revision History**

| TRM version | Date | Description of change |
|---|---|---|
| v10.0 | 10/2022 | TRM v10.0 origin. |
| v11.0 | 10/2023 | TRM v11.0 update. Updated documentation requirements. |