Public Utility Commission of Texas

Texas Technical Reference Manual

Version 3.1

Volume 2: Residential Measures

Guide for PY2016 Implementation

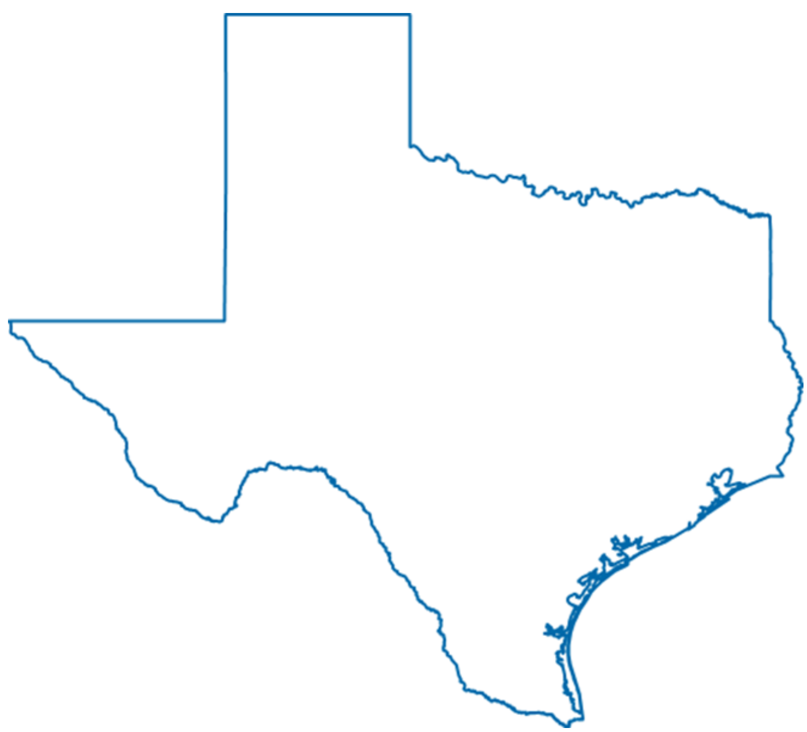

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Table of Contents

1 Introduction 1-1

2 Residential Measures 2-1

2.1 Residential: Lighting 2-1

2.1.1 Standard Compact Fluorescent Lamps Measure Overview................................ 2-1

2.1.2 Specialty Compact Fluorescent Lamps Measure Overview.............................. 2-11

2.1.3 ENERGY STAR® Omni-Directional LED Lamps Measure Overview 2-27

2.1.4 ENERGY STAR® Specialty and Directional LED Lamps Measure Overview.... 2-36

2.2 Residential: Heating, Ventilation, and Air Conditioning 2-50

2.2.1 Duct Efficiency Improvement Measure Overview 2-50

2.2.2 Central Air Conditioner Measure Overview 2-58

2.2.3 Ground Source Heat Pump Measure Overview 2-79

2.2.4 Central Heat Pump Measure Overview 2-87

2.2.5 Room Air Conditioner Measure Overview 2-119

2.3 Residential: Building Envelope 2-128

2.3.1 Air Infiltration Measure Overview 2-128

2.3.2 Ceiling Insulation Measure Overview 2-137

2.3.3 Wall Insulation Measure Overview 2-150

2.3.4 Floor Insulation Measure Overview 2-157

2.3.5 ENERGY STAR® Windows Measure Overview 2-166

2.3.6 Solar Screens Measure Overview 2-171

2.4 Residential: Water Heating 2-179

2.4.1 Faucet Aerators Measure Overview 2-179

2.4.2 Low-Flow Showerheads Measure Overview 2-186

2.4.3 Water Heater Pipe Insulation Measure Overview 2-195

2.4.4 Water Heater Tank Insulation Measure Overview 2-201

2.4.5 Water Heater Installation – Electric Tankless and Fuel Substitution Measure Overview 2-206

2.4.6 Heat Pump Water Heater Measure Overview 2-214

2.4.7 Water Heater Replacement – Solar Water Heating Measure Overview........... 2-222

2.5 Residential: Appliances 2-227

2.5.1 ENERGY STAR® Ceiling Fans Measure Overview.. 2-227

2.5.2 ENERGY STAR® Clothes Washer Measure Overview 2-235

2.5.3 ENERGY STAR® Dishwasher Measure Overview... 2-243

2.5.4 ENERGY STAR® Refrigerator Measure Overview... 2-249

2.6 Residential: Renewable Energy Systems 2-262

2.6.1 Solar Photovoltaic (PV) Measure Overview... 2-262

2.7 Residential: Load Management 2-267

2.7.1 Direct Load Control of Outdoor Compressor Units Measure Overview............ 2-267

2.7.2 Direct Load Control of Swimming Pool Pump Motors Measure Overview 2-273

2.8 Residential: Appliance Recycling 2-278
2.8.1 Refrigerator/Freezer Recycling Measure Overview 2-278

List of Figures

Figure 2-1: Unit Replacement Percentages upon Compressor Failure 2-62
Figure 2-2: Survival Function for Central Air Conditioners 2-64
Figure 2-3: Unit Replacement Percentages upon Compressor Failure 2-92
Figure 2-4: Survival Function for Central Heat Pumps 2-94
Figure 2-5: Survival Function for Room Air Conditioners 2-124
Figure 2-6: Shower, Bath, and Sink Hot Water Use Profile 2-184
Figure 2-7: Shower, Bath, and Sink Hot Water Use Profile 2-192
Figure 2-8: Survival Function for ENERGY STAR® Refrigerators 2-258
Figure 2-9: Primary Load Reductions (kW/Household), DLC Switch on Residential HVAC Compressor Unit 2-269
Figure 2-10: Average Hourly Pool Pump Demand 2-275

List of Tables

Table 1-1: Residential Deemed Savings by Measure Category 1-2
Table 2-1: ENERGY STAR® Standard CFLs – EISA Baselines 2-2
Table 2-2: ENERGY STAR® Standard CFLs – Default Equivalent Wattages if Lumen Output Unknown 2-4
Table 2-3: ENERGY STAR® Standard CFLs – Interactive Effects Factor for 2-5
Table 2-4: ENERGY STAR® Standard CFLs – Coincidence Factors 2-6
Table 2-5: ENERGY STAR® Standard CFLs – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties 2-7
Table 2-6: ENERGY STAR® Standard CFLs – Estimated Useful Life 2-9
Table 2-7: Residential Compact Fluorescent Lamp Revision History 2-10
Table 2-8: ENERGY STAR® CFLs – Default Equivalent Wattages if Lumen Output Unknown 2-12
Table 2-9: DOE-Ruling Exempt Reflectors – Default Wattages 2-13
Table 2-10: EISA-Affected Specialty CFL Baselines (Non-Reflectors) 2-14
Table 2-11: EISA-Exempt Specialty CFL Baselines (Non-Reflectors) 2-15
Table 2-12: DOE IRL Ruling-Affected Specialty CFL Baselines (Reflectors), ... 2-16
Table 2-13: DOE-Ruling Exempt Reflectors 2-17
Table 2-14: ENERGY STAR® Specialty CFLs – Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties 2-20
Table 2-15: ENERGY STAR® CFLs – Coincidence Factors 2-21

Table 2-16: ENERGY STAR® CFLs – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties....2-22
Table 2-17: ENERGY STAR® Specialty CFLs – Estimated Useful Life....2-25
Table 2-18: Residential Specialty Compact Fluorescent Lamp Revision History....2-26
Table 2-19: ENERGY STAR® Omni-Directional LEDs – EISA Baselines....2-28
Table 2-20: ENERGY STAR® Omni-Directional LEDs – Default Equivalent Wattages if Lumen Output Unknown....2-30
Table 2-21: ENERGY STAR® Omni-Directional LEDs Interactive Effects for Cooling Energy Savings and Heating Energy Penalties....2-31
Table 2-22: ENERGY STAR® LEDs – Coincidence Factors....2-32
Table 2-23: ENERGY STAR® Omni-directional LEDs – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties....2-33
Table 2-24: ENERGY STAR® Omni-Directional LEDs – Estimated Useful Life....2-34
Table 2-25: Residential Omni-Directional LED Lamp Revision History....2-35
Table 2-26: ENERGY STAR® Specialty LEDs – Default Equivalent Wattages if Lumen Output Unknown....2-37
Table 2-27: DOE-Ruling Exempt Reflectors – Default Wattages....2-38
Table 2-28: EISA-Affected Specialty LED Baselines (Non-Reflectors)....2-39
Table 2-29: EISA-Exempt Specialty LED Baselines (Non-Reflectors)....2-40
Table 2-30: DOE IRL Ruling-Affected Specialty LED Baselines (Reflectors),....2-41
Table 2-31: DOE-Ruling Exempt Reflectors....2-42
Table 2-32: ENERGY STAR® Specialty and Directional LEDs – Interactive Effects for Cooling Energy Savings and Heating Energy Penalties....2-45
Table 2-33: ENERGY STAR® LEDs – Coincidence Factors....2-46
Table 2-34: ENERGY STAR® Specialty and Directional LEDs – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties....2-47
Table 2-35: Residential Specialty and Directional LED Lamp Revision History....2-49
Table 2-36: Duct Sealing – Applicability....2-51
Table 2-37: Equivalent Full Load Cooling Hours....2-52
Table 2-38: Seasonal Specific Enthalpy (Btu/lb)....2-53
Table 2-39: Density of Outdoor Air (lb/cu. ft.)....2-53
Table 2-40: Heating Degree Days and Design Temperatures....2-54
Table 2-41: Duct Efficiency Improvement Revision History....2-57
Table 2-42: Central Air Conditioner Baseline Efficiencies....2-60
Table 2-43: Central Air Conditioner CEE Tier 1 Requirements....2-60
Table 2-44: Air Conditioner Capacity Curve Coefficients....2-61

Table 2-45: Air Conditioner EIR Curve Coefficients....2-61
Table 2-46: Remaining Useful Life of Replaced Unit....2-63
Table 2-47: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 1....2-65
Table 2-48: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 2....2-65
Table 2-49: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 3....2-66
Table 2-50: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 4....2-66
Table 2-51: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 5....2-66
Table 2-52: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 1 .2-67
Table 2-53: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 2 .2-67
Table 2-54: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 3 .2-68
Table 2-55: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 4 .2-68
Table 2-56: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 5 .2-68
Table 2-57: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 1....2-69
Table 2-58: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 2....2-69
Table 2-59: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 3....2-70
Table 2-60: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 4....2-70
Table 2-61: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 5....2-70
Table 2-62: Demand Savings (kW) for 14.0 SEER New Construction Baseline – Zone 1....2-71
Table 2-63: Demand Savings (kW) for 14.0 SEER New Construction Baseline – Zone 2....2-71
Table 2-64: Demand Savings (kW) for 14.0 SEER New Construction Baseline – Zone 3....2-72
Table 2-65: Demand Savings (kW) for 14.0 SEER New Construction Baseline – Zone 4....2-72
Table 2-66: Demand Savings (kW) for 14.0 SEER New Construction Burnout Baseline – Zone 5....2-72
Table 2-67: Demand Savings (kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 1 .2-73
Table 2-68: Demand Savings (kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 2 .2-73
Table 2-69: Demand Savings (kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 3 .2-74
Table 2-70: Demand Savings (kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 4 .2-74
Table 2-71: Demand Savings (kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 4 .2-74
Table 2-72: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 1....2-75
Table 2-73: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 2....2-75
Table 2-74: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 3....2-76
Table 2-75: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 4....2-76
Table 2-76: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 5....2-76
Table 2-77: Residential Central Air Conditioner Revision History....2-78
Table 2-78: Ground Source Heat Pump Baseline Efficiencies....2-80

Table 2-79: Ground Source Heat Pump ENERGY STAR® Tier 3 Requirements 2-80
Table 2-80: Equivalent full load cooling/heating hours..2-83
Table 2-81: Energy Savings for Desuperheaters...2-84
Table 2-82: Summer Peak Demand Savings for Desuperheaters 2-84
Table 2-83: Ground Source Heat Pump Revision History..2-86
Table 2-84: Central Heat Pump Baseline Efficiencies 2-89
Table 2-85: Central Heat Pump CEE Tier 1 Requirements 2-89
Table 2-86: Heat Pump Capacity Curve Coefficients...2-91
Table 2-87: Heat Pump EIR Curve Coefficients 2-91
Table 2-88: Remaining Useful Life of Replaced Unit 2-93
Table 2-89: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 1 2-95
Table 2-90: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 2 2-95
Table 2-91: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 3 2-96
Table 2-92: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 4 2-96
Table 2-93: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 5 2-96
Table 2-94: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 1 2-97
Table 2-95: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 2 2-97
Table 2-96: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 3 2-97
Table 2-97: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 4 2-98
Table 2-98: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 5 2-98
Table 2-99: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 1 2-99
Table 2-100: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 2 2-99
Table 2-101: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 3 2-99
Table 2-102: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 4 2-100

Table 2-103: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 5 2-100

Table 2-104: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 1....2-101

Table 2-105: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 2....2-101

Table 2-106: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 3....2-101

Table 2-107: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 4....2-102

Table 2-108: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 5....2-102

Table 2-109: Energy Savings (Heating kWh Only) for 3.41 HSPF Baseline – Zone 1....2-103

Table 2-110: Energy Savings (Heating kWh Only) for 3.41HSPF Baseline – Zone 2 2-103

Table 2-111: Energy Savings (Heating kWh Only) for 3.41 HSPF Baseline – Zone 3....2-103

Table 2-112: Energy Savings (Heating kWh Only) for 3.41 HSPF Baseline – Zone 4....2-104

Table 2-113: Energy Savings (Heating kWh Only) for 3.41 HSPF Baseline – Zone 5....2-104

Table 2-114: Demand Savings (Summer kW) for 14.0 SEER New Construction Baseline – Zone 1 2-105

Table 2-115: Demand Savings (Summer kW) for 14.0 SEER New Construction Baseline – Zone 2 2-105

Table 2-116: Demand Savings (Summer kW) for 14.0 SEER New Construction Baseline – Zone 3 2-106

Table 2-117: Demand Savings (Summer kW) for 14.0 SEER New Construction Baseline – Zone 4 2-106

Table 2-118: Demand Savings (Summer kW) for 14.0 SEER New Construction Baseline – Zone 5 2-107

Table 2-119: Demand Savings (Summer kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 1 2-107

Table 2-120: Demand Savings (Summer kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 2 2-108

Table 2-121: Demand Savings (Summer kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 3 2-108

Table 2-122: Demand Savings (Summer kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 4 2-109

Table 2-123: Demand Savings (Summer kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 5 2-109

Table 2-124: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 1 2-110

Table 2-125: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 2 2-110

Table 2-126: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 3 2-111

Table 2-127: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 4 2-111

Table 2-128: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 5 2-112

Table 2-129: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 1 2-112

Table 2-130: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 2 2-113

Table 2-131: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 3 2-113

Table 2-132: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 4 2-113

Table 2-133: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 5 2-114

Table 2-134: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 1....................2-114

Table 2-135: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 2....................2-115

Table 2-136: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 3....................2-115

Table 2-137: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 4....................2-115

Table 2-138: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 5....................2-116

Table 2-139: Central Heat Pump Revision History 2-118

Table 2-140: Room Air Conditioner Baseline Efficiencies for New Construction, Replace-on-Burnout, and Early Retirement 2-120

Table 2-141: Room Air Conditioner Efficient Condition Specifications....................2-121

Table 2-142: Room Air Conditioner Annual Operating Hours for Cooling 2-122

Table 2-143: Remaining Useful Life (RUL) of Replaced Room Air Conditioner 2-123

Table 2-144: Room Air Conditioner Revision History....................2-127

Table 2-145: N Factors 2-131

Table 2-146: Energy Savings V_E per CFM_{50} Reduction 2-133

Table 2-147: Peak Summer Demand Savings V_S per CFM_{50} Reduction....................2-133

Table 2-148: Peak Winter Demand Savings V_W per CFM_{50} Reduction 2-134

Table 2-149: Air Infiltration Revision History....................2-136

Table 2-150: Residential Ceiling Insulation – Prototypical Home Characteristics, Climate Zones 1-4 2-140

Table 2-151: R-38 Adjustment Factors....................2-141

Table 2-152: Evaporative Cooling Adjustment Factor....................2-141

Table 2-153: Climate Zone 1: Panhandle Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)....................2-142

Table 2-154: Climate Zone 2: North Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)....................2-142

Table 2-155: Climate Zone 3: South Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)....................2-143

Table 2-156: Climate Zone 4: Valley Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh) 2-143

Table 2-157: Climate Zone 5: West Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh) 2-144

Table 2-158: Climate Zone 1: Panhandle Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW) 2-144

Table 2-159: Climate Zone 2: North Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW) 2-145

Table 2-160: Climate Zone 3: South Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW) 2-145

Table 2-161: Climate Zone 4: Valley Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW) 2-145

Table 2-162: Climate Zone 5: West Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW) 2-146

Table 2-163: Climate Zone 1: Panhandle Region – Residential Ceiling Insulation Deemed Winter Demand Savings (kW) 2-146

Table 2-164: Climate Zone 2: North Region – Residential Ceiling Insulation Deemed Winter Demand Savings (kW) 2-147

Table 2-165: Climate Zone 3: South Region - Residential Ceiling Insulation Deemed Winter Demand Savings (kW) 2-147

Table 2-166: Climate Zone 4: Valley Region – Residential Ceiling Insulation Deemed Winter Demand Savings (kW) 2-147

Table 2-167: Climate Zone 5: West Region – Residential Ceiling Insulation Deemed Winter Demand Savings (kW) 2-148

Table 2-168: Ceiling Insulation Revision History 2-149

Table 2-169: Residential Wall Insulation – Prototypical Home Characteristics, Climate Zones 1-4 2-152

Table 2-170: Evaporative Cooling Adjustment Factor 2-153

Table 2-171: All Climate Zones: Residential Wall Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh) 2-154

Table 2-172: All Climate Zones – Residential Wall Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW) 2-154

Table 2-173: All Climate Zones – Residential Wall Insulation with Refrigerated Air Conditioning Deemed Winter Demand Savings (kW) 2-155

Table 2-174: Wall Insulation Revision History 2-156

Table 2-175: Residential Floor Insulation – Prototypical Home Characteristics, Climate Zones 1-4 2-159

Table 2-176: Evaporative Cooling Adjustment Factor 2-160

Table 2-177: Climate Zone 1: Panhandle Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh) 2-161

Table 2-178: Climate Zone 2: North Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh) 2-161

Table 2-179: Climate Zone 3: South Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)....2-161

Table 2-180: Climate Zone 4: Valley Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)....2-162

Table 2-181: Climate Zone 5: West Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)....2-162

Table 2-182: Climate Zone 1: Panhandle Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)....2-162

Table 2-183: Climate Zone 2: North Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)....2-162

Table 2-184: Climate Zone 3: South Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)....2-163

Table 2-185: Climate Zone 4: Valley Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)....2-163

Table 2-186: Climate Zone 5: West Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)....2-163

Table 2-187: Climate Zone 5: West Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Winter Demand Savings (kW)....2-164

Table 2-188: Floor Insulation Revision History....2-165

Table 2-189: ENERGY STAR® Windows Specifications, January 2010....2-167

Table 2-190: Evaporative Cooling Adjustment Factor....2-167

Table 2-191: Residential ENERGY STAR® Windows Deemed Annual Energy Savings (kWh)....2-168

Table 2-192: Residential ENERGY STAR® Windows Deemed Demand Savings (kW)....2-169

Table 2-193: ENERGY STAR® Windows Revision History....2-170

Table 2-194: Residential Solar Screens – Prototypical Home Characteristics, Climate Zones 1-4....2-173

Table 2-195: Evaporative Cooling Adjustment Factor....2-175

Table 2-196: Deemed Energy (kWh) Savings per Square Foot of Solar Screen with Refrigerated Air Conditioning....2-176

Table 2-197: Deemed Summer Peak Demand (kW) Savings per Square Foot of Solar Screen with Refrigerated Air Conditioning....2-176

Table 2-198: Deemed Winter Peak Demand (kW) Savings per Square Foot of Solar Screen with Refrigerated Air Conditioning....2-177

Table 2-199: Solar Screens Revision History....2-178

Table 2-200: Faucet Aerators – Applicability....2-179

Table 2-201: Faucet Aerators – Baseline and Efficiency Standard....2-180

Table 2-202: Estimated Aerator Hot Water Usage Reduction....2-181

Table 2-203: Water Mains Temperature....2-183

Table 2-204: Water Fixture Peak Demand Ratios 2-183
Table 2-205: Faucet Aerators Revision History 2-185
Table 2-206: Low-Flow Showerheads – Applicability..2-186
Table 2-207: Low-Flow Showerhead – Baseline and Efficiency Standards 2-187
Table 2-208: Estimated Showerhead Hot Water Usage Reduction 2-189
Table 2-209: Water Mains Temperature..2-191
Table 2-210: Water Fixture Peak Demand Ratios 2-191
Table 2-211: Low-Flow Showerheads Revision History..2-194
Table 2-212: Water Heater Pipe Insulation – Applicability 2-195
Table 2-213: Water Heater Pipe Insulation – Baseline Standard..2-196
Table 2-214: Water Heater Pipe Insulation – Efficiency Standard 2-196
Table 2-215: Estimated Pipe Surface Area 2-197
Table 2-216: Ambient Temperatures per Climate Zone..2-198
Table 2-217: Water Heater Pipe Insulation Revision History 2-200
Table 2-218: Water Heater Tank Insulation – Applicability 2-201
Table 2-219: Estimated Tank Area..2-202
Table 2-220: Ambient Temperatures per Climate Zone..2-203
Table 2-221: Water Heater Tank Insulation Revision History 2-205
Table 2-222: Water Heater Replacement – Applicability 2-207
Table 2-223: Water Heater Replacement – Baseline 2-207
Table 2-224: Water Heater Replacement – Efficiency Standards..2-208
Table 2-225: Storage Water Heater Energy Factors for Common Tank Volumes (not exhaustive) 2-208
Table 2-226: Water Heater Consumption (gal/year)*..2-209
Table 2-227: Water Mains Temperature..2-210
Table 2-228: Water Heater Installation – Electric Tankless and Fuel Substitution Revision History 2-213
Table 2-229: Heat Pump Water Heaters – Applicability..2-215
Table 2-230: Federal Standard for Residential Water Heaters 2-215
Table 2-231: Heat Pump Water Heaters – Minimum Required Energy Factors for Post-2004 Water Heaters..2-215
Table 2-232: Climate Zone 1: Amarillo, TX – Residential HPWH Deemed Annual Energy Savings (kWh)..2-217
Table 2-233: Climate Zone 2: Dallas, TX – Residential HPWH Deemed Annual Energy Savings (kWh) 2-217
Table 2-234: Climate Zone 3: Houston, TX – Residential HPWH Deemed Annual Energy Savings (kWh)..2-217

Table 2-235: Climate Zone 4: Corpus Christi, TX – Residential HPWH Deemed Annual Energy Savings (kWh)....2-217
Table 2-236: Climate Zone 5: El Paso, TX – Residential HPWH Deemed Annual Energy Savings (kWh)....2-217
Table 2-237: Climate Zone 1: Amarillo, TX – Residential HPWH Deemed Demand Savings (kW)....2-218
Table 2-238: Climate Zone 2: Dallas, TX – Residential HPWH Deemed Demand Savings (kW)....2-218
Table 2-239: Climate Zone 3: Houston, TX – Residential HPWH Deemed Demand Savings (kW)....2-218
Table 2-240: Climate Zone 4: Corpus Christi, TX – Residential HPWH Deemed Demand Savings (kW)....2-218
Table 2-241: Climate Zone 5: El Paso, TX – Residential HPWH Deemed Demand Savings (kW)....2-218
Table 2-242: Climate Zone 1: Amarillo, TX – Residential HPWH Deemed Demand Savings (kW)....2-219
Table 2-243: Climate Zone 2: Dallas, TX – Residential HPWH Deemed Demand Savings (kW)....2-219
Table 2-244: Climate Zone 3: Houston, TX – Residential HPWH Deemed Demand Savings (kW)....2-219
Table 2-245: Climate Zone 4: Corpus Christi, TX – Residential HPWH Deemed Demand Savings (kW)....2-219
Table 2-246: Climate Zone 5: El Paso, TX – Residential HPWH Deemed Demand Savings (kW)....2-219
Table 2-247: Heat Pump Water Heater Revision History....2-221
Table 2-248: Solar Water Heating Energy Savings (kWh)....2-224
Table 2-249: Solar Water Heating Demand Savings (kW)....2-225
Table 2-250: Water Heater Replacement – Solar Water Heating Revision History....2-226
Table 2-251: ENERGY STAR® Specifications for Ceiling Fans....2-228
Table 2-252: ENERGY STAR® Ceiling Fans – Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties....2-230
Table 2-253: Ceiling Fan Motor Wattages....2-231
Table 2-254: Ceiling Fan Operating Percentages....2-231
Table 2-255 ENERGY STAR® Ceiling Fans – Lighting Coincidence Factors....2-232
Table 2-256: ENERGY STAR® Ceiling Fans – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties....2-232
Table 2-257: ENERGY STAR® Ceiling Fan Revision History....2-234
Table 2-258: Federal Standard for Clothes Washers....2-236
Table 2-259: ENERGY STAR® Specifications for Residential Clothes Washers....2-236

Table 2-260: ENERGY STAR® Clothes Washer Characteristics 2-239
Table 2-261: ENERGY STAR® Clothes Washer Coincidence Factors................................2-239
Table 2-262: ENERGY STAR® Clothes Washer Energy Savings (kWh) 2-240
Table 2-263: ENERGY STAR® Clothes Washer Summer Peak Demand Savings (kW).......2-240
Table 2-264: All Climate Zones – ENERGY STAR® Clothes Washer Winter Demand Savings (kW) 2-241
Table 2-265: ENERGY STAR® Clothes Washer Revision History......................................2-242
Table 2-266 Federal Standard for Dishwashers 2-244
Table 2-267 ENERGY STAR® Specifications for Dishwashers 2-244
Table 2-268: ENERGY STAR® Dishwasher Coincidence Factors 2-246
Table 2-269: ENERGY STAR® Dishwasher Energy Savings 2-246
Table 270: ENERGY STAR® Dishwasher Summer Peak Demand Savings (kW) 2-246
Table 271: ENERGY STAR® Dishwasher Winter Peak Demand Savings (kW) 2-247
Table 2-272: ENERGY STAR® Dishwasher Revision History 2-248
Table 2-273: ENERGY STAR® Specifications for Refrigerators..2-251
Table 2-274: Formulas to Calculate the ENERGY STAR® Criteria for each Refrigerator Product Category by Adjusted Volume...2-252
Table 2-275: ENERGY STAR® Refrigerator Load Shape Adjustment Factors.....................2-256
Table 2-276: Remaining Useful Life (RUL) of Replaced Refrigerator 2-257
Table 2-277: ENERGY STAR® Refrigerator Revision History...2-261
Table 2-278: Residential Solar Electric (Photovoltaic) Energy Systems Revision History.....2-266
Table 2-279: Typical Hourly Load Reductions, Compressor Units on Residential HVAC Systems 2-270
Table 2-280: Direct Load Control of Outdoor Compressor Units Summer Peak Demand Savings 2-270
Table 2-281: Residential Direct Load Control of Outdoor Compressor Units Revision History 2-272
Table 2-282: Direct Load Control of Swimming Pool Pump Motors Summer Peak Demand Savings..2-276
Table 2-283: Residential Direct Load Control of Swimming Pool Pump Motors Revision History 2-277
Table 2-284: Load Shape Adjustment Factors 2-280
Table 2-285: Residential Refrigerator/Freezer Recycling Revision History...........................2-281

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TRM Technical Support

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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. TRM v3.1 serves as a centralized source of deemed savings values. Where appropriate, Measurement & Verification (M&V) methods by measure category are noted for informational purposes only regarding the basis of projected and claimed savings.

Table 1-1 provides an overview of the residential measures contained within this TRM 3.1 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.

Table 1-1: Residential Deemed Savings by Measure Category

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calcu-lator	M&V	3.1 Update
Lighting	Standard Compact Fluorescent Lamps	–	–	X	–	–	Modification of in-service rate, revision of inter-active effects factors to reflect indoor-specific values for additional heating and cooling equipment types. Provided default input assumptions for upstream lighting programs. Restricted estimated measure life to several discrete values.
	Specialty Compact Fluorescent Lamps	–	–	X	–	–	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. Restricted estimated measure life to several discrete values.
	ENERGY STAR® Omni-Directional LED Lamps	–	–	X	–	–	Modification of in-service rate, revision of inter-active 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.
	ENERGY STAR® Specialty and Directional LED Lamps	–	–	X	–	–	Modification of in-service rate, revision of inter-active 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.

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calcu-lator	M&V	3.1 Update
HVAC	Duct Efficiency Improvement	–	–	X	–	X	Update of reference sources for air temperatures and densities, heating degree-days. Cooling demand savings required to be claimed.
	Central Air Conditioner	–	X	–	–	–	Removal of legacy language around baseline. Extension of Early Retirement savings tables to higher SEER values.
	Ground Source Heat Pump	–	X	X	–	–	No revision
	Central Heat Pump	–	X	–	–	–	Revision of cooling savings to reflect heat-pump-specific performance curves. Extension of Early Retirement cooling savings tables to higher SEER values. Clarification around summer demand savings for single-stage and two-stage units.
	Room Air Conditioner	–	–	X	–	–	No revision
Building Envelope	Air Infiltration	–	X	–	–	X	Provided clarification around effects of occupancy on minimum final ventilation.
	Ceiling Insulation	–	X	–	–	–	Provided example savings calculations. Clarified that no heating demand savings are to be claimed for homes with a gas furnace.
	Wall Insulation	–	X	–	–	–	Provided example savings calculations.
	Floor Insulation	–	X	–	–	–	Provided example savings calculations.
	ENERGY STAR® Windows	–	X	–	–	–	Provided example savings calculations. Consolidated table formats.
	Solar Screens	–	X	–	–	–	Provided example savings calculations.
Domestic	Faucet	–	–	X	–	–	Supplemented reference

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calcu-lator	M&V	3.1 Update
Water Heating	Aerators						for water heater set point temperature.
	Low-Flow Showerheads	–	–	X	–	–	Provided clarification that savings are to be awarded per showerhead. Supplemented reference for water heater set point temperature.
	Water Heater Pipe Insulation	–	–	X	–	–	Supplemented reference for water heater set point temperature.
	Water Heater Tank Insulation	–	–	X	–	–	Supplemented reference for water heater set point temperature.
	Water Heater Installation – Electric Tankless and Fuel Substitution	–	–	X	–	–	Clarified baseline for water heaters greater than 55 gallons.
	Heat Pump Water Heater	–	X	–	–	–	No revision.
	Water Heater Replacement –Solar Water Heating	–	X	–	–	–	No revision.
Appliances	ENERGY STAR® Ceiling Fans	–	–	X	–	–	Revision of interactive effects factors to reflect indoor-specific values for additional heating and cooling equipment types.
	ENERGY STAR® Clothes Washer	–	X	–	–	–	New ENERGY STAR® algorithms and default assumptions incorporated.
	ENERGY STAR® Dishwasher	–	X	–	–	–	Final ENERGY STAR® specification incorporated into measure. Consolidated table formats.
	ENERGY STAR® Refrigerator	–	–	X	–	X	Correction to legacy LSAF. Revision to align with ENERGY STAR® calculator and specification.
Renewable Energy Systems	Solar Photovoltaic (PV)	–	–	X	X	X	No revision.
Load Management	Direct Load Control of	X	–	–	–	–	Added reference to M&V Protocols volume for

Measure Category	Measure Description	Point Estimates	Deemed Savings Tables	Savings Algorithm	Calcu-lator	M&V	3.1 Update
	Outdoor Compressor Units						alternative savings calculation methodology.
	Direct Load Control of Swimming Pool Pump Motors	X	–	–	–	–	Added reference to M&V Protocols volume for alternative savings calculation methodology.
Appliance Recycling	Refrigerator/Freezer Recycling	X	–	X	–	–	No revision.

2 RESIDENTIAL MEASURES

2.1 RESIDENTIAL: LIGHTING

2.1.1 Standard Compact Fluorescent Lamps Measure Overview

TRM Measure ID: R-LT-CF

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive and Direct Install

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure provides a method for calculating savings for replacement of an incandescent lamp with a standard CFL in residential applications.

A standard lamp is also called a general service lamp. General service lamps are omnidirectional bulbs that are A, BT, P, PS, S, or T shape bulbs (as defined by the ANSI Standard Lamp Shapes). These lamps are not globe, bullet, candle, flood, reflector, or decorative-shaped (B, BA, C, CA, DC, F, G, R, BR, ER, MR, MRX, or PAR shapes). These bulbs do encompass both twist/spiral and A-lamp shaped CFLs.

Please see www.lightingfacts.com/Library/Content/EISA for more information on general service lamps and CFLs.

Eligibility Criteria

Customer eligibility to be awarded these deemed savings is at the discretion of the utility for different program and customer types. See program-specific manuals to determine customer eligibility.

These savings values rely on usage patterns specific to indoor applications, and therefore should not be applied to outdoor lighting. However, this should not be construed to restrict upstream lighting programs, through which customers purchase efficient lighting products in-store. Future versions of this document may provide savings specific to outdoor and/or upstream applications.

Baseline Condition

The baseline is assumed to be the Energy Independence and Security Act of 2007 (EISA)-mandated maximum wattage for a general service or standard incandescent or halogen lamp (see Table 2-1). Baseline wattages should be adjusted as EISA regulations dictate higher efficiency standards. The second tier of EISA 2007 (EISA Tier 2) regulation goes into effect beginning January 2020. At that time, general service lamps must comply with a 45 lumen-per-watt efficacy standard. However, due to expected lamp replacement schedules, as well as retailer sell-through of existing lighting stock, the 1st Tier EISA baseline will be retained until 2021 when the 2nd Tier EISA baseline will be applied.[1] Nevertheless, incentivized lamps installed in 2020 will be awarded savings against the 2nd Tier EISA baseline since this will be the standard in effect at the time of installation.

Table 2-1: ENERGY STAR® Standard CFLs – EISA Baselines[2]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage Pre-EISA 2007	1st Tier EISA 2007 (W_{base})	2nd Tier Eisa 2007 (W_{base}) [3]	Effective Dates For 2nd Tier EISA 2007 Standards*
310	749	40	29	12	1/1/2020
750	1,049	60	43	20	1/1/2020
1,050	1,489	75	53	28	1/1/2020
1,490	2,600	100	72	45	1/1/2020

*While 2nd Tier EISA standards are effective beginning in 2020, 1st Tier EISA baselines will be used until 2021.

[1] This is consistent with the one-year lag applied in the Arkansas TRM Version 4.0 to new standards effective before July 1 of a given year. Arkansas Technical Reference Manual, Version 4.0. Prepared for the Arkansas Public Service Commission. Approved in Docket 10-100-R. Section II – Protocol E. Page 48. http://www.apscservices.info/EEInfo/TRM4.pdf.

[2] In new ENERGY STAR® lighting standards effective September 2014, lumen bins associated with incandescent wattages have been assigned that do not align with those set out in EISA 2007. Due to the likelihood of continuing sell-through of existing ENERGY STAR® lighting and the on-going use of the EISA bin definitions, this TRM maintains the EISA lumen bins for assigning baseline wattage. Future iterations of the Texas TRM, however, may incorporate these new ENERGY STAR® lumen bins for baseline wattage estimates.

[3] Wattages developed using the 45 lumens-per-watt standard for the midpoint of the provided lumen range.

High-Efficiency Condition

New CFLs must be standard (general service) ENERGY STAR® -qualified CFLs as outlined in the latest ENERGY STAR® specification.[4] These CFLs are designed to replace incandescent lamps of the following ANSI Standard Lamp Shape: A, BT, P, PS, S and T.[5] These lamps have medium screw or pin bases, are designed for light output between 310 and 2600 lumens, and are capable of operating at a voltage range at least partially within 110 and 130 volts.[6]

See the ENERGY STAR® website for more information on the specification in effect: http://www.energystar.gov/products/certified-products/detail/light-bulbs.

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 2-1) and the wattage of a comparable CFL. A CFL is considered comparable to the baseline lamp if they are aligned on the lumen output ranges set out in EISA 2007.

Energy Savings

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

1. **First Tier EISA Baseline = 2021 – installation year = 5 years**
2. **The remaining time in the EUL period**

For the first tier EISA baseline period:

$$\Delta kWh = \frac{\left(W_{base,FT} - W_{post}\right)}{1000} \times HOU \times ISR \times IEF_E$$

Equation 1

For the remaining time in the EUL period, use the second tier EISA baseline:

$$\Delta kWh = \frac{\left(W_{base,ST} - W_{post}\right)}{1000} \times HOU \times ISR \times IEF_E$$

Equation 2

4 http://www.energystar.gov/products/certified-products/detail/light-bulbs
5 https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf
6 http://lightingfacts.com/Library/Content/EISA

Annual energy (kWh) savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[7]

Where:

$W_{base,FT}$ = *First-tier EISA baseline wattage corresponding with the lumen output of the purchased CFL lamp for the year purchased/installed. First tier EISA baseline lamp wattage provided in Table 2-1 under the column "Incandescent Equivalent 1st Tier EISA 2007" (if unknown, see Table 2-2 for 1st Tier EISA 2007 default wattages).*

Table 2-2: ENERGY STAR® Standard CFLs – Default Equivalent Wattages if Lumen Output Unknown

Wattage Range of Installed CFL[8]	9–11 W	12–15 W	18–20 W	23–27 W
If Unknown: Default Installed CFL Wattage[9]	9 W	13 W	19 W	24 W
1st Tier EISA 2007 Default Baseline	29 W	43 W	53 W	72 W
2nd Tier EISA 2007 Default Baseline	12 W	20 W	28 W	45 W

$W_{base,ST}$ = *Second-tier EISA baseline wattage corresponding with the lumen output of the purchased CFL lamp for the year purchased/installed. Second tier EISA baseline lamp wattage provided in Table 2-1 under the column "Incandescent Equivalent 2nd Tier EISA 2007" (if unknown, see Table 2-2 for 2nd Tier EISA 2007 default wattages).*

W_{post} = *Actual wattage of CFL purchased/installed*

HOU = *Average hours of use per year = 803 hours (calculated based on an average daily usage of 2.2 hours per day[10])*

IEF_E = *Interactive Effects Factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 2-3).*

7 While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

8 Wattage ranges from ENERGY STAR® light bulb savings calculator. Updated June 2015. http://www.energystar.gov/products/certified-products/detail/light-bulbs.

9 ENERGY STAR® Certified Light Bulbs. https://www.energystar.gov/productfinder/download/certified-light-bulbs/. Accessed October 6, 2015. Mean wattages of omnidirectional, general purpose replacement CFL lamps by incandescent wattage equivalent.

10 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 Associates. June 2009.

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 = 0.97* [11]

Table 2-3: ENERGY STAR® Standard CFLs – Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties[12]

IEF_E					
Heating/Cooling Type*	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Gas Heat with AC	1.09	1.15	1.16	1.18	1.13
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	0.86	1.03	1.08	1.13	1.00
Electric Resistance Heat with AC	0.65	0.91	1.00	1.07	0.88
Electric Resistance Heat with no AC	0.56	0.75	0.84	0.89	0.74
No heat with AC	1.09	1.15	1.16	1.18	1.13
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	0.87	1.03	1.08	1.12	1.01
Upstream Lighting	0.89	1.03	1.07	1.10	1.01
* IEF for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.					

Demand Savings

Summer and winter demand savings are determined by applying a coincidence factor associated with each season. Annual summer or winter peak demand (kW) savings must be calculated separately for two time periods:

1. **First Tier EISA Baseline = 2021 – installation year = 5 years**
2. **The remaining time in the EUL period**

For the first tier EISA baseline period:

[11] 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.

[12] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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.

$$\Delta kW summer = \frac{(W_{base,FT} - W_{post})}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 3

$$\Delta kW_{winter} = \frac{(W_{base,FT} - W_{post})}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 4

For the remaining time in the EUL period, use the second tier EISA baseline:

$$\Delta \mathbf{kW}_{\mathbf{summer}} = \frac{(\mathbf{W}_{\mathbf{base,ST}} - \mathbf{W}_{\mathbf{post}})}{\mathbf{1000}} \times \mathbf{CF}_{\mathbf{summer}} \times \mathbf{ISR} \times \mathbf{IEF}_{\mathbf{D,summer}}$$

Equation 5

$$\Delta kW_{winter} = \frac{(W_{base,ST} - W_{post})}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 6

Annual summer or winter peak demand savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[13]

Where:

CF = *Coincidence Factor (see Table 2-4)*

IEF_D = *Interactive Effects Factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 2-5)*

Table 2-4: ENERGY STAR® Standard CFLs – Coincidence Factors[14]

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	0.277	0.232	0.199	0.267	0.357

[13] While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

[14] See Volume 1, Appendix B.

Table 2-5: ENERGY STAR® Standard CFLs – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[15]

$IEF_{D,summer}$					
Heating/Cooling Type*	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Gas Heat with AC	1.25	1.45	1.48	1.53	1.39
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	1.25	1.45	1.48	1.53	1.39
Electric Resistance Heat with AC	1.25	1.45	1.48	1.53	1.39
Electric Resistance Heat with no AC	1.00	1.00	1.00	1.00	1.00
No heat with AC	1.25	1.45	1.48	1.53	1.39
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	1.24	1.43	1.46	1.51	1.37
Upstream Lighting	1.20	1.36	1.39	1.43	1.31
$IEF_{D,winter}$					
Heating/Cooling Type*	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Gas Heat with AC	1.00	1.00	1.00	1.00	1.00
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	0.49	0.60	0.66	0.69	0.61
Electric Resistance Heat with AC	0.49	0.60	0.66	0.69	0.61
Electric Resistance Heat with no AC	0.49	0.60	0.66	0.69	0.61
No heat with AC	1.00	1.00	1.00	1.00	1.00
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	0.75	0.80	0.83	0.85	0.81
Upstream Lighting	0.78	0.83	0.85	0.86	0.83
* IEF for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.					

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.

[15] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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 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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The average measure life is based upon rated lamp life of the CFL. 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 CFLs. The algorithms below are designed to provide EISA Tier 1 and EISA Tier 2 measure lives, each to be applied to the appropriate tier of EISA savings.

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

Equation 7

$$EUL_{Tier1} = 2021 - Purchase\ Year$$

Equation 8

$$EUL_{Tier2} = EUL_{Total} - EUL_{Tier1}$$

Equation 9

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.*[16]
DF	=	*0.85 degradation factor*[17]

[16] Minimum lifetime requirement under ENERGY STAR® Lamps Specification V1.1, effective September 30, 2014. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

HOU	=	*2.2 hours per day*[18]
2021	=	*One-year lag applied to year that EISA Tier 1 energy efficiency standard ends*

Table 2-6: ENERGY STAR® Standard CFLs – Estimated Useful Life

Range of Rated Measure Life (Hours)	Rated Measure Life Assumed (Hours)	Total Measure Life (Years)	EISA First Tier Standard Baseline Measure Life (Years)	EISA Second Tier Measure Life (Years)
10,000–11,000	10,000	11	5	6
11,001–13,500	12,000	13	5	8
13,501–17,500	15,000	16	5	11
≥ 17,501	20,000	20*	5	15

* Measure life capped at 20 years.

Program Tracking Data & 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:

- Number of CFLs installed
- Wattage of each installed CFL
- Lumen output of each installed CFL
- Manufacturer-rated lifetime of each installed CFL in hours
- Heating system type (gas, electric resistance, heat pump) for each home in which a CFL is installed
- Location of installed lamp (conditioned, unconditioned, or outdoor)
- Program type (direct install, retail)

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

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

[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 Associates. June 2009.

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.

- Docket No. 39899. 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, Southwestern Electric Power Company, Texas-New Mexico Power Company, and Southwestern Public Service Company to Revise Existing Commission-Approved Deemed Savings for CFLs in Residential Hard-to-Reach Programs. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

- Energy Independence and Security Act of 2007
- ENERGY STAR® specifications for CFL lamps

Document Revision History

Table 2-7: Residential Compact Fluorescent Lamp 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 corrections due to phase-in of EISA regulations, updated EUL from DEER 2014. Legacy EISA tables removed.
v2.1	1/30/2015	TRM v2.1 update. No revision.
v3.0	4/10//2015	TRM v3.0 update. Introduction of interactive effects factors and in-service rates. Incorporation of Second Tier EISA standards. New peak savings calculated according to revised peak definition. Modified estimation of measure life.
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. Restricted estimated measure life to several discrete values.
v3.1	March 2016	Updated summer and winter coincidence factors.

2.1.2 Specialty Compact Fluorescent Lamps Measure Overview

TRM Measure ID: R-LT-SCF

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive and Direct Install

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure provides a method for calculating savings for replacement of a specialty incandescent or halogen lamp with an ENERGY STAR®-qualified specialty CFL in residential applications. These lamps include reflectors, G-shape lamps, T-shape lamps, B, BA, CA, F G16-1/2, G25, G30, S or M14 lamps.

Eligibility Criteria

Customer eligibility to be awarded these deemed savings is at the discretion of the utility for different program and customer types. See program-specific manuals to determine customer eligibility.

These savings values rely on usage patterns specific to indoor applications, and therefore should not be applied to outdoor lighting. However, this should not be construed to restrict upstream lighting programs, through which customers purchase efficient lighting products in-store. Future versions of this document may provide savings specific to outdoor and/or upstream applications.

Baseline Condition

The baseline wattage will be determined based on the bulb shape of the installed lamp as outlined below.

Some baseline conditions for specialty CFLs are affected by EISA and/or a DOE 2009 ruling on incandescent reflector lamps (IRLs). Based on the shape, lumen output, and/or wattage-equivalent of the installed lamp, the appropriate baseline shall be determined from one of the following categories:

- Non-Reflector Lamps, affected by EISA 2007
- Non-Reflector Lamps, not affected by EISA 2007
- Reflector Lamps affected by the DOE ruling in 2009 on IRLs
- Reflector Lamps not affected by the DOE ruling in 2009 on IRLs

Appropriate baseline wattages are presented in Table 2-10 through Table 2-13. If a baseline cannot be determined using these tables, the following guidelines may be used to determine appropriate default baseline wattage:

- **Non-Reflector Lamps, affected by EISA 2007:** using the exact or range of the installed wattage, determine the appropriate First Tier or Second Tier EISA baseline default wattage in Table 2-8.

Table 2-8: ENERGY STAR® CFLs – Default Equivalent Wattages if Lumen Output Unknown

Wattage Range of Installed CFL[19]	9–11 W	12–15 W	18–20 W	23–27 W
If Unknown: Default Installed CFL Wattage[20]	9 W	13 W	19 W	24 W
1st Tier EISA 2007 Default Baseline	29 W	43 W	53 W	72 W
2nd Tier EISA 2007 Default Baseline	12 W	20 W	28 W	45 W

- **Non-Reflector Lamps, not affected by EISA 2007:** 60 watts[21]
- **Reflector Lamps affected by the DOE ruling in 2009 on IRLs:** 60 watts[22]
- **Reflector Lamps not affected by the DOE ruling in 2009 on IRLs:** the appropriate default baseline may be determined using Table 2-9.

[19] Wattage ranges from ENERGY STAR® light bulb savings calculator. Updated June 2015. http://www.energystar.gov/products/certified-products/detail/light-bulbs.

[20] ENERGY STAR® Certified Light Bulbs. https://www.energystar.gov/productfinder/download/certified-light-bulbs/. Accessed October 6, 2015. Mean wattages of omnidirectional, general purpose replacement CFL lamps by incandescent wattage equivalent.

[21] A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009)

[22] Ibid.

Table 2-9: DOE-Ruling Exempt Reflectors – Default Wattages

Lamp Type	W_{base}
BR30 (65 W)	65 W
BR40 (65 W)	
ER40 (65 W)	
R20 (≤ 45 W)	45 W
BR30 (≤ 50 W)	50 W
BR40 (≤ 50 watt)	
ER30 (≤ 50 watt)	
ER40 (≤ 50 watt)	
Indeterminate	60 W[23]

EISA Standards: Baseline for Non-Reflector Lamps

EISA-affected

EISA-affected bulbs are:

- **G-shape lamps with a diameter less than 5 inches;**
- **T-shape lamps greater than 40 watts or a length of 10 inches or less; and**
- **B, BA, CA, F G16-1/2, G25, G30, S or M14 lamps greater than 40 watts.[24]**

Baseline wattages should be adjusted as EISA regulations dictate higher efficiency standards. The second tier of EISA 2007 (EISA Tier 2) regulation goes into effect beginning January 2020. However, due to expected lamp replacement schedules, as well as retailer sell-through of existing lighting stock, the 1st Tier EISA baseline will be retained until 2021 when the 2nd Tier EISA baseline will be applied.[25] Nevertheless, incentivized lamps installed in 2020 will be awarded savings against the 2nd Tier EISA baseline since this will be the standard in effect at the time of installation.

[23] Ibid.
[24] http://www.lightingfacts.com/Library/Content/EISA
[25] This is consistent with the one-year lag applied in the Arkansas TRM Version 4.0 to new standards effective before July 1 of a given year.
Arkansas Technical Reference Manual, Version 4.0. Prepared for the Arkansas Public Service Commission. Approved in Docket 10-100-R. Section II – Protocol E. Page 48. http://www.apscservices.info/EEInfo/TRM4.pdf.

Table 2-10: EISA-Affected Specialty CFL Baselines (Non-Reflectors)[26]

Lamp Type	Minimum Lumens	Maximum Lumens	Incandescent Equivalent 1st Tier EISA 2007 ($W_{base,FT}$)	Incandescent Equivalent 2nd Tier Eisa 2007 ($W_{base,ST}$)[27]	Effective Dates For 2nd Tier EISA 2007 Standards*
• G-shape lamps with a diameter less than 5 inches • T-shape lamps greater than 40 watts or a length of 10 inches or less • B, BA, CA, F G16-1/2, G25, G30, S or M14 lamps greater than 40 watts	310	749	29	12	1/1/2020
	750	1,049	43	20	1/1/2020
	1,050	1,489	53	28	1/1/2020
	1,490	2,600	72	45	1/1/2020

*While 2nd Tier EISA standards are effective beginning in 2020, 1st Tier EISA baselines will be used until 2021.

EISA-exempt

EISA-exempt bulbs are:

- **Appliance lamps, black light lamps, bug lamps, colored lamps, infrared lamps, left-hand thread lamps, marine lamps, marine signal service lamps, mine service lamps, plant light lamps, reflector lamps, rough service lamps, shatter-resistant lamps, sign service lamps, silver bowl lamps, showcase lamps, 3-way incandescent lamps, and vibration service lamps;**
- **G-shape lamp with a diameter of 5 inches or more;**
- **T-shape lamp of 40 watts or less or a length of more than 10 inches; and**
- **B, BA, CA, F, G16-1/2, G25, G30, S or M14 lamp of 40 watts or less.**[28]

[26] Ibid.
[27] Wattages developed using the 45 lumens-per-watt standard for the midpoint of the provided lumen range.
[28] http://www.lightingfacts.com/Library/Content/EISA.

Table 2-11: EISA-Exempt Specialty CFL Baselines (Non-Reflectors)

Lamp Type	Minimum Lumens	Maximum Lumens	W_{base}
• Appliance lamps, black light lamps, bug lamps, colored lamps, infrared lamps, left-hand thread lamp, marine lamp, marine signal service lamp, mine service lamp, plant light lamp, reflector lamp, rough service lamp, shatter-resistant lamp, sign service lamp, silver bowl lamp, showcase lamp, 3-way incandescent lamp, vibration service lamp • G-shape lamp with a diameter of 5 inches or more • T-shape lamp of 40 watts or less or a length of more than 10 inches • B, BA, CA, F, G16-1/2, G25, G30, S or M14 lamp of 40 watts or less	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 60 watts.[29]		

DOE Standards for Incandescent Reflector Lamps (IRLs): Baseline for Reflector Lamps

DOE Ruling-affected

Certain types of incandescent reflector bulbs are affected by a DOE 2009 ruling on reflector lamps. Products affected by the IRL ruling are:

- **R, PAR, ER, BR, BPAR lamps;**
- **BR and ER lamps rated at more than 50 watts;**
- **Reflector lamps between 2.25” (R18) and 2.75” (R22) in diameter; and**
- **40-205 watt incandescent PAR lamps.[30]**

Where available, the nameplate wattage of the removed lamp should be used as the baseline. Otherwise, the baseline wattage can be determined according to the lumen range of the installed lamp (see Table 2-12).

[29] A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009)

[30] http://www.gelighting.com/LightingWeb/na/resources/legislation/2009-department-of-energy-regulations/ http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/58 http://www.bulbrite.com/eisa.php

Table 2-12: DOE IRL Ruling-Affected Specialty CFL Baselines (Reflectors)[31,32]

Lamp Type	Lumen Range	W_{base}
BR19	300-500	50
BR30	600-800	75
	801-1000	85
BR38	600-900	75
	901-1400	150
BR40	600-700	75
	701-900	85
	901-950	100
	951-1300	120
	1301-1700	125
	1701-2000	150
	2001-2400	200
ER30	300-450	50
	451-701	75
ER40	1000-1300	120
PAR20	300-450	50
	451-550	40
	551-650	50
PAR30	450-550	35
	551-600	40
	601-850	50
	851-950	60
	951-1200	75

[31] Wattage values and lumen ranged from a review of GE, Osram Sylvania, and Philips catalogs in January 2015, as well as the Illinois TRM 2014.
GE Lighting catalog: http://www.gelighting.com/LightingWeb/na/smartcatalogs/Lighting_and_Ballasts_Section_1_Incandescent_Lamps.pdf
Sylvania catalog: http://assets.sylvania.com/assets/documents/complete-catalog.b176dbb1-d6e0-40f0-ab92-e768e58f5dc1.pdf
Philips catalog: http://www.usa.lighting.philips.com/connect/tools_literature/downloads/sg100-2013.pdf
Illinois TRM 2014: http://www.ilsag.info/technical-reference-manual.html

[32] Table 2-12 is based on manufacturers' lumen and wattage data for the most commonly used reflector lamps. However, other manufacturers' ratings may differ from this list. Where available, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer.

Lamp Type	Lumen Range	W_{base}
PAR38	550-750	65
	751-1100	75
	1101-1300	100
	1301-1600	120
	1601-2500	150
	2501-3500	175
R20	401-500	50
	501-600	75
	601-1000	100
R30	700-800	75
	801-950	110
	951-1100	125
R40	1300-1900	125

DOE Ruling-exempt

The DOE 2009 ruling standards do not apply to the following types of IRLs:

- **IRLs rated at 50 watts or less that are ER30, BR30, BR40, or ER40 lamps;**
- **IRLs rated at 65 watts that are BR30, BR40, or ER40 lamps; and**
- **R20 IRLs rated 45 watts or less.**[33]

Table 2-13: DOE-Ruling Exempt Reflectors

Lamp Type	W_{base}
BR30 (65 watt)	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 65 watts.
BR40 (65 watt)	
ER40 (65 watt)	
R20 (≤ 45 watt)	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 45 watts.
BR30 (≤ 50 watt)	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 50 watts.
BR40 (≤ 50 watt)	
ER30 (≤ 50 watt)	
ER40 (≤ 50 watt)	

[33] http://www.gelighting.com/LightingWeb/na/resources/legislation/2009-department-of-energy-regulations/
http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/58

High-Efficiency Condition

New CFLs must be ENERGY STAR® specialty CFLs as outlined in the latest ENERGY STAR® specification.[34] These lamps include reflectors, G-shape lamps, T-shape lamps, B, BA, CA, F G16-1/2, G25, G30, S or M14 lamps.

These ENERGY STAR® specialty CFLs are the equivalent of the specialty incandescent or halogen lamps being replaced. The high-efficiency condition is the wattage of the lamp installed.

See the ENERGY STAR® website for more information on the specification in effect: http://www.energystar.gov/products/certified-products/detail/light-bulbs.

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 comparable CFL.

Energy Savings

For EISA-affected lamps only, annual energy (kWh) savings must be calculated separately for two time periods:

1. **First Tier EISA Baseline = 2021 – installation year = 5 years**
2. **The remaining time in the EUL period**

For the first tier EISA baseline period:

$$\Delta kWh = \frac{(W_{base,FT} - W_{post})}{1000} \times HOU \times ISR \times IEF_E$$

Equation 10

For the remaining time in the EUL period, use the second tier EISA baseline:

$$\Delta kWh = \frac{(W_{base,ST} - W_{post})}{1000} \times HOU \times ISR \times IEF_E$$

Equation 11

[34] http://www.energystar.gov/products/certified-products/detail/light-bulbs

Annual energy (kWh) savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[35]

For EISA- exempt lamps and reflectors (both DOE ruling-exempt and DOE ruling-affected), annual energy (kWh) savings are not calculated using the two tiered system. Instead, annual energy (kWh) savings are calculated using one algorithm.

$$\Delta \boldsymbol{kWh} = \frac{(\boldsymbol{W_{base}} - \boldsymbol{W_{post}})}{\boldsymbol{1000}} \times \boldsymbol{HOU} \times \boldsymbol{ISR} \times \boldsymbol{IEF_E}$$

Equation 12

Where:

$W_{base,FT}$ = *First tier EISA baseline wattage corresponding with the lumen output of the purchased CFL lamp for the year purchased/installed. First tier EISA baseline lamp wattage provided in Table 2-10 under the column "Incandescent Equivalent 1st Tier EISA 2007."*

$W_{base,ST}$ = *Second tier EISA baseline wattage corresponding with the lumen output of the purchased CFL lamp for the year purchased/installed. Second tier EISA baseline lamp wattage provided in Table 2-10 under the column "Incandescent Equivalent 2nd Tier EISA 2007."*

W_{base} = *EISA-exempt specialty lamp or a DOE ruling-exempt reflector, use the nameplate wattage (see Table 2-11 and Table 2-13). If a DOE-ruling-affected IRL, use the wattages provided in Table 2-12.*

W_{post} = *Actual wattage of CFL purchased/installed*

HOU = *Average hours of use per year = 803 hours (calculated based on an average daily usage of 2.2 hours per day[36])*

IEF_E = *Interactive Effects Factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 2-14).*

[35] While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

[36] 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 Associates. June 2009.

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 = 0.97*[37]

Table 2-14: ENERGY STAR® Specialty CFLs – Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties

IEF_E					
Heating/Cooling Type*	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Gas Heat with AC	1.09	1.15	1.16	1.18	1.13
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	0.86	1.03	1.08	1.13	1.00
Electric Resistance Heat with AC	0.65	0.91	1.00	1.07	0.88
Electric Resistance Heat with no AC	0.56	0.75	0.84	0.89	0.74
No heat with AC	1.09	1.15	1.16	1.18	1.13
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	0.87	1.03	1.08	1.12	1.01
Upstream Lighting	0.89	1.03	1.07	1.10	1.01
* IEF for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.					

Demand Savings

Summer and winter demand savings are determined by applying a coincidence factor associated with each season. For EISA-affected specialty lamps only, peak demand (kW) savings must be calculated separately for two time periods:

1. **First Tier EISA Baseline = 2021 – installation year = 5 years**
2. **The remaining time in the EUL period**

For the first tier EISA baseline period:

$$\Delta kW_{summer} = \frac{(W_{base,FT} - W_{post})}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 13

$$\Delta kW_{winter} = \frac{(W_{base,FT} - W_{post})}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

[37] 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

[38] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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.

Equation 14

For the remaining time in the EUL period, use the second tier EISA baseline:

$$\Delta kW_{summer} = \frac{(W_{base,ST} - W_{post})}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 15

$$\Delta kW_{winter} = \frac{(W_{base,ST} - W_{post})}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 16

Annual summer or winter peak demand savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[39]

<u>For EISA- exempt lamps and reflectors (both DOE ruling-exempt and DOE ruling-affected)</u>, peak demand (kW) savings are not calculated using the two tiered system. Instead, peak demand (kW) savings are calculated using one algorithm, depending on the season of the savings.

$$\Delta kW_{summer} = \frac{(W_{base} - W_{post})}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 17

$$\Delta kW_{winter} = \frac{(W_{base} - W_{post})}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 18

Where:

CF = *Coincidence Factor (see Table 2-15)*

IEF_D = *Interactive Effects Factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 2-16).*

Table 2-15: ENERGY STAR® CFLs – Coincidence Factors40

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	0.277	0.232	0.199	0.267	0.357

[39] While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

[40] See Volume 1, Appendix B.

Table 2-16: ENERGY STAR® CFLs – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[41]

$IEF_{D,summer}$					
Heating/Cooling Type	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Gas Heat with AC	1.25	1.45	1.48	1.53	1.39
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	1.25	1.45	1.48	1.53	1.39
Electric Resistance Heat with AC	1.25	1.45	1.48	1.53	1.39
Electric Resistance Heat with no AC	1.00	1.00	1.00	1.00	1.00
No heat with AC	1.25	1.45	1.48	1.53	1.39
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	1.24	1.43	1.46	1.51	1.37
Upstream Lighting	1.20	1.36	1.39	1.43	1.31
$IEF_{D,winter}$					
Heating/Cooling Type	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Gas Heat with AC	1.00	1.00	1.00	1.00	1.00
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	0.49	0.60	0.66	0.69	0.61
Electric Resistance Heat with AC	0.49	0.60	0.66	0.69	0.61
Electric Resistance Heat with no AC	0.49	0.60	0.66	0.69	0.61
No heat with AC	1.00	1.00	1.00	1.00	1.00
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	0.75	0.80	0.83	0.85	0.81
Upstream Lighting	0.78	0.83	0.85	0.86	0.83
* IEF for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.					

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.

[41] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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 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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The average measure life is based upon rated lamp life of the specialty CFL shown in the following table. The measure life assumes an average daily 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 CFLs.

For an EISA-affected lamp, the following algorithms are designed to provide EISA Tier 1 and EISA Tier 2 measure lives, each to be applied to the appropriate tier of EISA savings.

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

Equation 19

$$EUL_{Tier1} = 2021 - Purchase\ Year$$

Equation 20

$$EUL_{Tier2} = EUL_{Total} - EUL_{Tier1}$$

Equation 21

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.*[43]

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[43] Minimum lifetime requirement under ENERGY STAR® Lamps Specification V1.1, effective 9/30/2014. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf

DF = 0.85 degradation factor[44]

HOU = 2.2 hours per day[45]

2021 = *One-year lag applied to year that EISA Tier 1 energy efficiency standard ends*

For EISA-exempt lamps and reflectors (both DOE ruling-exempt and DOE ruling-affected), use the following algorithm to calculate the measure life.

$$\boldsymbol{EUL = \frac{Rated\ Life \times DF}{HOU \times 365.25}}$$

Equation 22

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.*[46]

DF = *0.85 degradation factor*[47]

HOU = *2.2 hours per day*[48]

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

[45] 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 Associates. June 2009.

[46] Minimum lifetime requirement under ENERGY STAR® Lamps Specification V1.1, effective 9/30/2014. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Lamps%20V1%201_Specification.pdf.

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

[48] 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 Associates. June 2009.

Table 2-17: ENERGY STAR® Specialty CFLs – Estimated Useful Life

Range of Rated Measure Life (Hours)	Rate Measure Life Assumed (Hours)	Total Measure Life (Years)	If Applicable:	
			EISA First Tier Standard Baseline Measure Life (Years)	EISA Second Tier Measure Life (Years)
10,000–11,000	10,000	11	5	6
11,001–13,500	12,000	13	5	8
13,501–17,500	15,000	16	5	11
≥ 17,501	20,000	20*	5	15

* Measure life capped at 20 years.

Program Tracking Data & 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:

- Number of CFLs installed
- ANSI C79.1-2002 nomenclature of CFL installed (G40, PAR, etc.)
- Wattage of each installed CFL
- Lumen output of each installed CFL
- Wattage of replaced lamp
- Manufacturer-rated lifetime of each installed CFL in hours
- Heating system type (gas, electric resistance, heat pump) for each home in which a CFL is installed
- Location of installed lamp (conditioned, unconditioned, or outdoor)
- Program type (direct install, retail)
- Baseline calculation methodology (replaced lamp nameplate wattage, EISA-affected non-reflector, EISA-exempt non-reflector, DOE ruling-affected reflector, DOE ruling-exempt reflector, manufacturer-rated equivalent incandescent wattage, or default wattage)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- Energy Independence and Security Act of 2007
- *Energy Conservation Program: Energy Conservation Standards and Test Procedures for General Service Fluorescent Lamps and Incandescent Reflector Lamps*, Energy Efficiency and Renewable Energy Office (EERE), 2009
- ENERGY STAR® specifications for CFL lamps

Document Revision History

Table 2-18: Residential Specialty Compact Fluorescent Lamp 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. Restricted estimated measure life to several discrete values.
v3.1	March 2016	Updated summer and winter coincidence factors.

2.1.3 ENERGY STAR® Omni-Directional LED Lamps Measure Overview

TRM Measure ID: R-LT-OLED

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive and Direct Install

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure provides a method for calculating savings for replacement of an incandescent lamp with an omni-directional LED[49] in a residential application. Using ANSI C79.1-2002 nomenclature, the applicable omni-directional LED lamp types are: A, BT, P, PS, S, and T.

Eligibility Criteria

Customer eligibility to be awarded these deemed savings is at the discretion of the utility for different program and customer types. See program-specific manuals to determine customer eligibility.

These savings values rely on usage patterns specific to indoor applications, and therefore should not be applied to outdoor lighting. However, this should not be construed to restrict upstream lighting programs, through which customers purchase efficient lighting products in-store. Future versions of this document may provide savings specific to outdoor and/or upstream applications.

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[49] According to ENERGY STAR® omni-directional LED products "…shall have an even distribution of luminous intensity (candelas) within the 0° to 135° zone (vertically axially symmetrical). Luminous intensity at any angle within this zone shall not differ from the mean luminous intensity for the entire 0° to 135° zone by more than 20%. At least 5% of total flux (lumens) must be emitted in the 135°-180° zone. Distribution shall be vertically symmetrical as measured in three vertical planes at 0°, 45°, and 90°." http://www.energystar.gov/ia/partners/product_specs/program_reqs/Integral_LED_Lamps_Program_Requirements.pdf.

Baseline Condition

The baseline is assumed to be the EISA-mandated maximum wattage for a general service or standard incandescent or halogen lamp (see Table 2-19).Baseline wattages should be adjusted as EISA regulations dictate higher efficiency baseline lamps. The second tier of EISA 2007 regulations go into effect beginning January 2020. At that time, general service lamps must comply with a 45 lumen per watt efficacy standard. However, due to expected lamp replacement schedules, as well as retailer sell-through of existing lighting stock, the 1st Tier EISA baseline will be retained until 2021 when the 2nd Tier EISA baseline will be applied.[50] Nevertheless, incentivized lamps installed in 2020 will be awarded savings against the 2nd Tier EISA baseline since this will be the standard in effect at the time of installation.

Table 2-19: ENERGY STAR® Omni-Directional LEDs – EISA Baselines[51]

Minimum Lumens	Maximum Lumens	Incandescent Equivalent Wattage Pre-EISA 2007	1st Tier EISA 2007 (W_{base})	2nd Tier Eisa 2007 (W_{base}) [52]	Effective Dates For 2nd Tier EISA 2007 Standards*
310	749	40	29	12	1/1/2020
750	1,049	60	43	20	1/1/2020
1,050	1,489	75	53	28	1/1/2020
1,490	2,600	100	72	45	1/1/2020

* While 2nd Tier EISA standards are effective beginning in 2020, 1st Tier EISA baselines will be used until 2021.

High-Efficiency Condition

LEDs must be ENERGY STAR® -qualified for the relevant lamp shape being removed as outlined in the latest ENERGY STAR® specification.[53] Using ANSI C79.1-2002 nomenclature, the applicable omni-directional LED lamp types are: A, BT, P, PS, S, and T.

The high-efficiency condition is the wattage of the lamp installed.

See the ENERGY STAR® website for more information on the specification in effect: http://www.energystar.gov/products/certified-products/detail/light-bulbs.

[50] This is consistent with the one-year lag applied in the Arkansas TRM Version 4.0 to new standards effective before July 1 of a given year. Arkansas Technical Reference Manual, Version 4.0. Prepared for the Arkansas Public Service Commission. Approved in Docket 10-100-R. Section II – Protocol E. Page 48. http://www.apscservices.info/EEInfo/TRM4.pdf.

[51] In new ENERGY STAR® lighting standards effective September 2014, lumen bins associated with incandescent wattages have been assigned that do not align with those set out in EISA 2007. Due to the likelihood of continuing sell-through of existing ENERGY STAR® lighting and the on-going use of the EISA bin definitions, this TRM maintains the EISA lumen bins for assigning baseline wattage. Future iterations of the Texas TRM, however, may incorporate these new ENERGY STAR® lumen bins for baseline wattage estimates.

[52] Wattages developed using the 45 lumens-per-watt standard for the midpoint of the provided lumen range.

[53] http://www.energystar.gov/products/certified-products/detail/light-bulbs.

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 2-19) and the wattage of a comparable omni-directional LED. An LED is considered comparable to the baseline lamp if they are aligned on the lumen output ranges set out in EISA 2007.

Energy Savings

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

1. **First Tier EISA Baseline = 2021 – installation year = 5 years**
2. **The remaining time in the EUL period**

For the first tier EISA baseline period:

$$\Delta \boldsymbol{kWh} = \frac{(\boldsymbol{W_{base,FT}} - \boldsymbol{W_{post}})}{\mathbf{1000}} \times \boldsymbol{Hours} \times \boldsymbol{ISR} \times \boldsymbol{IEF_E}$$

Equation 23

For the remaining time in the EUL period, use the second tier EISA baseline:

$$\Delta \boldsymbol{kWh} = \frac{(\boldsymbol{W_{base,ST}} - \boldsymbol{W_{post}})}{\mathbf{1000}} \times \boldsymbol{Hours} \times \boldsymbol{ISR} \times \boldsymbol{IEF_E}$$

Equation 24

Annual energy (kWh) savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[54]

Where:

$W_{base,FT}$ = *First tier EISA baseline wattage corresponding with the lumen output of the purchased LED lamp for the year purchased/installed. First tier EISA baseline lamp wattage provided in Table 2-19 under the column "Incandescent Equivalent 1st Tier EISA 2007" (if unknown, see Table 2-20 for 1st Tier EISA 2007 default wattages).*

[54] While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

Table 2-20: ENERGY STAR® Omni-Directional LEDs – Default Equivalent Wattages if Lumen Output Unknown

Wattage Range of Installed LED[55]	5–8 W	8.5–12 W	12.5–16 W	17–23 W
If Unknown: Default Installed LED Wattage[56]	7 W	10 W	12 W	17 W
1st Tier EISA 2007 Default Baseline	29 W	43 W	53 W	72 W
2nd Tier EISA 2007 Default Baseline	12 W	20 W	28 W	45 W

$W_{base,ST}$ = *Second tier EISA baseline wattage corresponding with the lumen output of the purchased LED lamp for the year purchased/installed. Second tier EISA baseline lamp wattage provided in Table 2-19 under the column "Incandescent Equivalent 2nd Tier EISA 2007" (if unknown, see Table 2-20 for 2nd Tier EISA 2007 default wattages).*

W_{post} = *Actual wattage of LED purchased/installed*

HOU = *Average hours of use per year = 803 hours (calculated based on an average daily usage of 2.2 hours per day[57])*

IEF_E = *Interactive Effects Factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 2-21).*

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 = 0.97*[58]

55 Wattage ranges from ENERGY STAR® light bulb savings calculator. Updated June 2015. http://www.energystar.gov/products/certified-products/detail/light-bulbs.

56 ENERGY STAR® Certified Light Bulbs. https://www.energystar.gov/productfinder/download/certified-light-bulbs/. Accessed October 6, 2015. Mean wattages of omnidirectional, general purpose replacement LED lamps by incandescent wattage equivalent.

57 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 Associates. June 2009.

58 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 2-21: ENERGY STAR® Omni-Directional LEDs Interactive Effects for Cooling Energy Savings and Heating Energy Penalties[59]

IEF$_E$					
Heating/Cooling Type*	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
Gas Heat with AC	1.09	1.15	1.16	1.18	1.13
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	0.86	1.03	1.08	1.13	1.00
Electric Resistance Heat with AC	0.65	0.91	1.00	1.07	0.88
Electric Resistance Heat with no AC	0.56	0.75	0.84	0.89	0.74
No heat with AC	1.09	1.15	1.16	1.18	1.13
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	0.87	1.03	1.08	1.12	1.01
Upstream Lighting	0.89	1.03	1.07	1.10	1.01
* IEF for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.					

Demand Savings

Summer and winter demand savings are determined by applying a coincidence factor associated with each season. Annual summer or winter peak demand (kW) savings must be calculated separately for two time periods:

1. **First Tier EISA Baseline = 2021 – installation year = 5 years**
2. **The remaining time in the EUL period**

For the first tier EISA baseline period:

$$\Delta kWsummer = \frac{(W_{base,FT} - W_{post})}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 25

$$\Delta kWwinter = \frac{(W_{base,FT} - W_{post})}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 26

[59] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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.

For the remaining time in the EUL period, use the second tier EISA baseline:

$$\Delta kW_{summer} = \frac{(W_{base,ST} - W_{post})}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 27

$$\Delta kW_{winter} = \frac{(W_{base,ST} - W_{post})}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 28

Annual summer or winter peak demand savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[60]

Where:

CF = *Coincidence Factor (see Table 2-22)*

IEF_D = *Interactive Effects Factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (see Table 2-23).*

Table 2-22: ENERGY STAR® LEDs – Coincidence Factors[61]

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	0.277	0.232	0.199	0.267	0.357

[60] While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

[61] See Volume 1, Appendix B.

Table 2-23: ENERGY STAR® Omni-directional LEDs – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[62]

$IEF_{D,summer}$					
Heating/Cooling Type*	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Gas Heat with AC	1.25	1.45	1.48	1.53	1.39
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	1.25	1.45	1.48	1.53	1.39
Electric Resistance Heat with AC	1.25	1.45	1.48	1.53	1.39
Electric Resistance Heat with no AC	1.00	1.00	1.00	1.00	1.00
No heat with AC	1.25	1.45	1.48	1.53	1.39
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	1.24	1.43	1.46	1.51	1.37
Upstream Lighting	1.20	1.36	1.39	1.43	1.31
$IEF_{D,winter}$					
Heating/Cooling Type*	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Gas Heat with AC	1.00	1.00	1.00	1.00	1.00
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	0.49	0.60	0.66	0.69	0.61
Electric Resistance Heat with AC	0.49	0.60	0.66	0.69	0.61
Electric Resistance Heat with no AC	0.49	0.60	0.66	0.69	0.61
No heat with AC	1.00	1.00	1.00	1.00	1.00
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	0.75	0.80	0.83	0.85	0.81
Upstream Lighting	0.78	0.83	0.85	0.86	0.83
* IEF for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.					

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.

[62] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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 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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The measure life for indoor and outdoor LED omni-directional lamps is capped at 20 years.[63] Due to the EISA standards, the savings over the useful life will need to be adjusted to account for second tier EISA standards for all years as of 2021.

Table 2-24: ENERGY STAR® Omni-Directional LEDs – Estimated Useful Life

Total Measure Life (Years)	EISA First Tier Standard Baseline Measure Life (Years)	EISA Second Tier Measure Life (Years)
20	5	15

Program Tracking Data & 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:

- Number of LEDs installed
- Wattage of each installed LED
- Lumen output of each installed LED
- Wattage of replaced lamp
- Manufacturer-rated lifetime of each installed LED in hours

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63 Mid-Atlantic Technical Reference Manual Version 5.0. Prepared by Shelter Analytics. Facilitated and Managed by the Northeast Energy Efficiency Partnerships (NEEP). June 2015. http://www.neep.org/sites/default/files/resources/Mid-Atlantic_TRM_V5_FINAL_5-26-2015.pdf.

- Heating system type (gas, electric resistance, heat pump) for each home in which an LED is installed
- Location of installed lamp (conditioned, unconditioned, or outdoor)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- Energy Independence and Security Act of 2007
- ENERGY STAR® specifications for LED lamps

Document Revision History

Table 2-25: Residential Omni-Directional LED Lamp 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	March 2016	Updated summer and winter coincidence factors.

2.1.4 ENERGY STAR® Specialty and Directional LED Lamps Measure Overview

TRM Measure ID: R-LT-DLED

Market Sector: Residential

Measure Category: Lighting

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive and Direct Install

Deemed Savings Type: Deemed Savings Calculations

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® -qualified LED lamp. These lamps include reflectors, G-shape lamps, T-shape lamps, B, BA, CA, F G16-1/2, G25, G30, S or M14 lamps.[64]

Eligibility Criteria

Customer eligibility to be awarded these deemed savings is at the discretion of the utility for different program and customer types. See program-specific manuals to determine customer eligibility.

These savings values rely on usage patterns specific to indoor applications, and therefore should not be applied to outdoor lighting. However, this should not be construed to restrict upstream lighting programs, through which customers purchase efficient lighting products in-store. Future versions of this document may provide savings specific to outdoor and/or upstream applications.

[64] http://www.energystar.gov/products/certified-products/detail/light-bulbs.

Baseline Condition

The baseline wattage will be determined based on the bulb shape of the installed lamp as outlined below.

Some baseline conditions for specialty LEDs are affected by EISA and/or a DOE 2009 ruling on incandescent reflector lamps (IRLs). Based on the shape, lumen output, and/or wattage-equivalent of the installed lamp, the appropriate baseline shall be determined from one of the following categories:

- **Non-Reflector Lamps, affected by EISA 2007**
- **Non-Reflector Lamps, not affected by EISA 2007**
- **Reflector Lamps affected by the DOE ruling in 2009 on IRLs**
- **Reflector Lamps not affected by the DOE ruling in 2009 on IRLs**

Appropriate baseline wattages are presented in Table 2-28 through Table 2-31. If a baseline cannot be determined using these tables, the following guidelines may be used to determine appropriate default baseline wattage:

- **Non-Reflector Lamps, affected by EISA 2007:** using the exact or range of the installed wattage, determine the appropriate First Tier or Second Tier EISA baseline default wattage in Table 2-26.

Table 2-26: ENERGY STAR® Specialty LEDs – Default Equivalent Wattages if Lumen Output Unknown

Wattage Range of Installed LED[65]	5–8 W	8.5–12 W	12.5–16 W	17–23 W
If Unknown: Default Installed LED Wattage[66]	7 W	10 W	12 W	17 W
1st Tier EISA 2007 Default Baseline	29 W	43 W	53 W	72 W
2nd Tier EISA 2007 Default Baseline	12 W	20 W	28 W	45 W

- **Non-Reflector Lamps, not affected by EISA 2007: 60 watts**[67]
- **Reflector Lamps affected by the DOE ruling in 2009 on IRLs:** 60 watts[68]
- **Reflector Lamps not affected by the DOE ruling in 2009 on IRLs:** the appropriate default baseline may be determined using Table 2-27.

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65 Wattage ranges from ENERGY STAR® light bulb savings calculator. Updated June 2015. http://www.energystar.gov/products/certified-products/detail/light-bulbs.

66 ENERGY STAR® Certified Light Bulbs. https://www.energystar.gov/productfinder/download/certified-light-bulbs. Accessed October 6, 2015. Mean wattages of omnidirectional, general purpose replacement LED lamps by incandescent wattage equivalent.

67 A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009)

68 Ibid.

Table 2-27: DOE-Ruling Exempt Reflectors – Default Wattages

Lamp Type	W_{base}
BR30 (65 W)	65 W
BR40 (65 W)	
ER40 (65 W)	
R20 (≤ 45 W)	45 W
BR30 (≤ 50 W)	50 W
BR40 (≤ 50 watt)	
ER30 (≤ 50 watt)	
ER40 (≤ 50 watt)	
Indeterminate	60 W[69]

EISA Standards: Baseline for Non-Reflector Lamps

EISA-affected

EISA-affected bulbs are:

- **G-shape lamps with a diameter less than 5 inches;**
- **T-shape lamps greater than 40 watts or a length of 10 inches or less; and**
- **B, BA, CA, F G16-1/2, G25, G30, S or M14 lamps greater than 40 watts.[70]**

Baseline wattages should be adjusted as EISA regulations dictate higher efficiency standards. The second tier of EISA 2007 (EISA Tier 2) regulation goes into effect beginning January 2020. However, due to expected lamp replacement schedules, as well as retailer sell-through of existing lighting stock, the 1st Tier EISA baseline will be retained until 2021 when the 2nd Tier EISA baseline will be applied.[71] Nevertheless, incentivized lamps installed in 2020 will be awarded savings against the 2nd Tier EISA baseline since this will be the standard in effect at the time of installation.

69 Ibid.

70 http://www.lightingfacts.com/Library/Content/EISA.

71 This is consistent with the one-year lag applied in the Arkansas TRM Version 4.0 to new standards effective before July 1 of a given year. Arkansas Technical Reference Manual, Version 4.0. Prepared for the Arkansas Public Service Commission. Approved in Docket 10-100-R. Section II – Protocol E. Page 48. http://www.apscservices.info/EEInfo/TRM4.pdf.

Table 2-28: EISA-Affected Specialty LED Baselines (Non-Reflectors)[72]

Lamp Type	Minimum Lumens	Maximum Lumens	Incandescent Equivalent 1st Tier EISA 2007 ($W_{base,FT}$)	Incandescent Equivalent 2nd Tier Eisa 2007 ($W_{base,ST}$)[73]	Effective Dates For 2nd Tier EISA 2007 Standards*
• G-shape lamps with a diameter less than 5 inches • T-shape lamps greater than 40 watts or a length of 10 inches or less • B, BA, CA, F G16-1/2, G25, G30, S or M14 lamps greater than 40 watts	310	749	29	12	1/1/2020
	750	1,049	43	20	1/1/2020
	1,050	1,489	53	28	1/1/2020
	1,490	2,600	72	45	1/1/2020

* While 2nd Tier EISA standards are effective beginning in 2020, 1st Tier EISA baselines will be used until 2021.

EISA-exempt

EISA-exempt bulbs are:

- **Appliance lamps, black light lamps, bug lamps, colored lamps, infrared lamps, left-hand thread lamps, marine lamps, marine signal service lamps, mine service lamps, plant light lamps, reflector lamps, rough service lamps, shatter-resistant lamps, sign service lamps, silver bowl lamps, showcase lamps, 3-way incandescent lamps, and vibration service lamps;**
- **G-shape lamp with a diameter of 5 inches or more;**
- **T-shape lamp of 40 watts or less or a length of more than 10 inches; and**
- **B, BA, CA, F, G16-1/2, G25, G30, S or M14 lamp of 40 watts or less.[74]**

[72] Ibid.

[73] Wattages developed using the 45 lumens-per-watt standard for the midpoint of the provided lumen range.

[74] http://www.lightingfacts.com/Library/Content/EISA.

Table 2-29: EISA-Exempt Specialty LED Baselines (Non-Reflectors)

Lamp Type	Minimum Lumens	Maximum Lumens	W_{base}
• Appliance lamps, black light lamps, bug lamps, colored lamps, infrared lamps, left-hand thread lamp, marine lamp, marine signal service lamp, mine service lamp, plant light lamp, reflector lamp, rough service lamp, shatter-resistant lamp, sign service lamp, silver bowl lamp, showcase lamp, 3-way incandescent lamp, vibration service lamp • G-shape lamp with a diameter of 5 inches or more • T-shape lamp of 40 watts or less or a length of more than 10 inches • B, BA, CA, F, G16-1/2, G25, G30, S or M14 lamp of 40 watts or less	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 60 watts.[75]		

DOE Standards for Incandescent Reflector Lamps (IRLs): Baseline for Reflector Lamps

DOE Ruling-affected

Certain types of incandescent reflector bulbs are affected by a DOE 2009 ruling on reflector lamps. Products affected by the IRL ruling are:

- **R, PAR, ER, BR, BPAR lamps;**
- **BR and ER lamps rated at more than 50 watts;**
- **Reflector lamps between 2.25” (R18) and 2.75” (R22) in diameter; and**
- **40-205 watt incandescent PAR lamps.[76]**

Where available, the nameplate wattage of the removed lamp should be used as the baseline. Otherwise, the baseline wattage can be determined according to the lumen range of the installed lamp (see Table 2-30).

[75] A 2006-2008 California Upstream Lighting Evaluation found an average incandescent wattage of 61.7 Watts (KEMA, Inc, The Cadmus Group, Itron, Inc, PA Consulting Group, Jai J. Mitchell Analytics, Draft Evaluation Report: Upstream Lighting Program. Prepared for the California Public Utilities Commission, Energy Division. December 10, 2009)

[76] http://www.gelighting.com/LightingWeb/na/resources/legislation/2009-department-of-energy-regulations/
http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/58
http://www.bulbrite.com/eisa.php

Table 2-30: DOE IRL Ruling-Affected Specialty LED Baselines (Reflectors)[77,78]

Lamp Type	Lumen Range	W_{base}
BR19	300-500	50
BR30	600-800	75
	801-1000	85
BR38	600-900	75
	901-1400	150
BR40	600-700	75
	701-900	85
	901-950	100
	951-1300	120
	1301-1700	125
	1701-2000	150
	2001-2400	200
ER30	300-450	50
	451-701	75
ER40	1000-1300	120
PAR20	300-450	50
	451-550	40
	551-650	50
PAR30	450-550	35
	551-600	40
	601-850	50
	851-950	60
	951-1200	75

77 Wattage values and lumen ranged from a review of GE, Osram Sylvania, and Philips catalogs in January 2015, as well as the Illinois TRM 2014.
GE Lighting catalog: http://www.gelighting.com/LightingWeb/na/smartcatalogs/Lighting_and_Ballasts_Section_1_Incandescent_Lamps.pdf
Sylvania catalog: http://assets.sylvania.com/assets/documents/complete-catalog.b176dbb1-d6e0-40f0-ab92-e768e58f5dc1.pdf
Philips catalog: http://www.usa.lighting.philips.com/connect/tools_literature/downloads/sg100-2013.pdf
Illinois TRM 2014: http://www.ilsag.info/technical-reference-manual.html

78 Table 2-30 is based on manufacturers' lumen and wattage data for the most commonly used reflector lamps. However, other manufacturers' ratings may differ from this list. Where available, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer.

Lamp Type	Lumen Range	W_{base}
PAR38	550-750	65
	751-1100	75
	1101-1300	100
	1301-1600	120
	1601-2500	150
	2501-3500	175
R20	401-500	50
	501-600	75
	601-1000	100
R30	700-800	75
	801-950	110
	951-1100	125
R40	1300-1900	125

DOE Ruling-exempt

The DOE 2009 ruling standards do not apply to the following types of IRLs:

- **IRLs rated at 50 watts or less that are ER30, BR30, BR40, or ER40 lamps;**
- **IRLs rated at 65 watts that are BR30, BR40, or ER40 lamps; and**
- **R20 IRLs rated 45 watts or less.**[79]

Table 2-31: DOE-Ruling Exempt Reflectors

Lamp Type	W_{base}
BR30 (65 watt)	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 65 watts.
BR40 (65 watt)	
ER40 (65 watt)	
R20 (≤ 45 watt)	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 45 watts.
BR30 (≤ 50 watt)	Nameplate wattage on the removed product. If unknown, utilities may rely on the rated incandescent wattage equivalent of the newly installed lamp as provided by the manufacturer if available. Otherwise, use 50 watts.
BR40 (≤ 50 watt)	
ER30 (≤ 50 watt)	
ER40 (≤ 50 watt)	

[79] http://www.gelighting.com/LightingWeb/na/resources/legislation/2009-department-of-energy-regulations/. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/58.

High-Efficiency Condition

LEDs must be ENERGY STAR® -qualified for the relevant lamp shape being removed as outlined in the latest ENERGY STAR® specification.[80] These lamps include reflectors, G-shape lamps, T-shape lamps, B, BA, CA, F G16-1/2, G25, G30, S or M14 lamps.

The high-efficiency condition is the wattage of the lamp installed.

See the ENERGY STAR® website for more information on the specification in effect: http://www.energystar.gov/products/certified-products/detail/light-bulbs.

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.

Energy Savings

For EISA-affected lamps only, annual energy (kWh) savings must be calculated separately for two time periods:

- **First Tier EISA Baseline = 2021 – installation year = 5 years**
- **The remaining time in the EUL period**

For the first tier EISA baseline period:

$$\Delta kWh = \frac{(W_{base,FT} - W_{post})}{1000} \times HOU \times ISR \times IEF_E$$

Equation 29

For the remaining time in the EUL period, use the second tier EISA baseline:

$$\Delta kWh = \frac{(W_{base,ST} - W_{post})}{1000} \times HOU \times ISR \times IEF_E$$

Equation 30

Annual energy (kWh) savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[81]

80 http://www.energystar.gov/products/certified-products/detail/light-bulbs

81 While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

For EISA- exempt lamps and reflectors (both DOE ruling-exempt and DOE ruling-affected), annual energy (kWh) savings are not calculated using the two tiered system. Instead, annual energy (kWh) savings are calculated using one algorithm.

$$\Delta kWh = \frac{(W_{base} - W_{post})}{1000} \times HOU \times ISR \times IEF_E$$

Equation 31

Where:

$W_{base,FT}$ = *First tier EISA baseline wattage corresponding with the lumen output of the purchased LED lamp for the year purchased/installed. First tier EISA baseline lamp wattage provided in Table 2-28 under the column "Incandescent Equivalent 1st Tier EISA 2007."*

$W_{base,ST}$ = *Second tier EISA baseline wattage corresponding with the lumen output of the purchased LED lamp for the year purchased/installed. Second tier EISA baseline lamp wattage provided in Table 2-28 under the column "Incandescent Equivalent 2nd Tier EISA 2007".*

W_{base} = *EISA-exempt specialty lamp or a DOE ruling-exempt reflector, use the nameplate wattage (see Table 2-29and Table 2-31). If a DOE-ruling-affected IRL, use the wattages provided in Table 2-30.*

W_{post} = *Actual wattage of LED purchased/installed*

HOU = *Average hours of use per year = 803 hours (calculated based on an average daily usage of 2.2 hours per day[82])*

IEF_E = *Interactive Effects Factor to account for cooling energy savings and heating energy penalties associated with lighting power reductions (see Table 2-32).*

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 = 0.97*[83]

82 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 Associates. June 2009.

83 Dimetrosky, S., Parkinson, K. nd 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 2-32: ENERGY STAR® Specialty and Directional LEDs – Interactive Effects for Cooling Energy Savings and Heating Energy Penalties[84]

IEF$_E$					
Heating/Cooling Type	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
Gas Heat with AC	1.09	1.15	1.16	1.18	1.13
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	0.86	1.03	1.08	1.13	1.00
Electric Resistance Heat with AC	0.65	0.91	1.00	1.07	0.88
Electric Resistance Heat with no AC	0.56	0.75	0.84	0.89	0.74
No heat with AC	1.09	1.15	1.16	1.18	1.13
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	0.87	1.03	1.08	1.12	1.01
Upstream Lighting	0.89	1.03	1.07	1.10	1.01
* IEF for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.					

Demand Savings

Summer and winter demand savings are determined by applying a coincidence factor associated with each season. For EISA-affected specialty lamps only, peak demand (kW) savings must be calculated separately for two time periods:

- **First Tier EISA Baseline = 2021 – installation year = 5 years**
- **The remaining time in the EUL period**

For the first tier EISA baseline period:

$$\Delta kW_{summer} = \frac{\left(W_{base,FT} - W_{post}\right)}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 32

$$\Delta kW_{winter} = \frac{\left(W_{base,FT} - W_{post}\right)}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 33

[84] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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.

For the remaining time in the EUL period, use the second tier EISA baseline:

$$\Delta kW_{summer} = \frac{(W_{base,ST} - W_{post})}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 34

$$\Delta kW_{winter} = \frac{(W_{base,ST} - W_{post})}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 35

Annual summer or winter peak demand savings are calculated by weighting the EISA first and second tier savings by the EISA first tier period and the remainder of the EUL period, as outlined in Volume 3, Appendix D of this document.[85]

For EISA- exempt lamps and reflectors (both DOE ruling-exempt and DOE ruling-affected), peak demand (kW) savings are not calculated using the two tiered system. Instead, peak demand (kW) savings are calculated using one algorithm, depending on the season of the savings.

$$\Delta kW_{summer} = \frac{(W_{base} - W_{post})}{1000} \times CF_{summer} \times ISR \times IEF_{D,summer}$$

Equation 36

$$\Delta kW_{winter} = \frac{(W_{base} - W_{post})}{1000} \times CF_{winter} \times ISR \times IEF_{D,winter}$$

Equation 37

Where:

CF = *Coincidence Factor (Table 2-33)*

IEF_D = *Interactive Effects Factor to account for cooling demand savings or heating demand penalties associated with lighting power reductions (seeTable 2-34).*

Table 2-33: ENERGY STAR® LEDs – Coincidence Factors[86]

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	0.277	0.232	0.199	0.267	0.357

[85] While this appendix addresses early retirement installations, it is applicable to scenarios in which the baseline changes over the lifetime of the measure. For the purposes of this appendix, savings claimed against the Tier 1 EISA baseline may be treated as early retirement savings, and savings claimed against the Tier 2 EISA baseline may be treated as replace-on-burnout savings.

[86] See Volume 1, Appendix B.

Table 2-34: ENERGY STAR® Specialty and Directional LEDs – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[87]

$IEF_{D,summer}$					
Heating/Cooling Type	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Gas Heat with AC	1.25	1.45	1.48	1.53	1.39
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	1.25	1.45	1.48	1.53	1.39
Electric Resistance Heat with AC	1.25	1.45	1.48	1.53	1.39
Electric Resistance Heat with no AC	1.00	1.00	1.00	1.00	1.00
No heat with AC	1.25	1.45	1.48	1.53	1.39
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	1.24	1.43	1.46	1.51	1.37
Upstream Lighting	1.20	1.36	1.39	1.43	1.31
$IEF_{D,winter}$					
Heating/Cooling Type	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Gas Heat with AC	1.00	1.00	1.00	1.00	1.00
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	0.49	0.60	0.66	0.69	0.61
Electric Resistance Heat with AC	0.49	0.60	0.66	0.69	0.61
Electric Resistance Heat with no AC	0.49	0.60	0.66	0.69	0.61
No heat with AC	1.00	1.00	1.00	1.00	1.00
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	0.75	0.80	0.83	0.85	0.81
Upstream Lighting	0.78	0.83	0.85	0.86	0.83
* IEF for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.					

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.

[87] Calculated using IEFs from Cadmus report, weighted using TMY CDD and HDD for Texas, and adjusted to exclude 16% 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 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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The measure life for indoor and outdoor LED reflector and decorative lamps is capped at 20 years.[88]

Program Tracking Data & 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:

- Number of LEDs installed
- ANSI C79.1-2002 nomenclature of CFL installed (G40, PAR, etc.)
- Wattage of each installed LED
- Lumen output of each installed LED
- Wattage of replaced lamp
- Manufacturer-rated lifetime of each installed LED in hours
- Heating system type (gas, electric resistance, heat pump) for each home in which a LED is installed
- Location of installed lamp (conditioned, unconditioned, or outdoor)

[88] Mid-Atlantic Technical Reference Manual Version 5.0. Prepared by Shelter Analytics. Facilitated and Managed by the Northeast Energy Efficiency Partnerships (NEEP). June 2015. http://www.neep.org/sites/default/files/resources/Mid-Atlantic_TRM_V5_FINAL_5-26-2015.pdf.

- Baseline calculation methodology (replaced lamp nameplate wattage, EISA-affected non-reflector, EISA-exempt non-reflector, DOE ruling-affected reflector, DOE ruling-exempt reflector, manufacturer-rated equivalent incandescent wattage, or default wattage)

References and Efficiency Standards

Petitions and Rulings

Not applicable.

Relevant Standards and Reference Sources

- Energy Independence and Security Act of 2007
- Energy Conservation Program: Energy Conservation Standards and Test Procedures for General Service Fluorescent Lamps and Incandescent Reflector Lamps, Energy Efficiency and Renewable Energy Office (EERE), 2009
- ENERGY STAR® specifications for LED lamps

Document Revision History

Table 2-35: Residential Specialty and Directional LED Lamp 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	March 2016	Updated summer and winter coincidence factors.

2.2 RESIDENTIAL: HEATING, VENTILATION, AND AIR CONDITIONING

2.2.1 Duct Efficiency Improvement Measure Overview

TRM Measure ID: R-HV-DE

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure involves sealing leaks in supply and return ducts of the HVAC distribution systems of homes or converted residences with either central air conditioning or a ducted heating system.

Eligibility Criteria

All residential customers with refrigerated air cooling are eligible for this measure.

Duct leakage should be assessed following Building Performance Institute (BPI) standards through testing. In some limited cases, where testing is not possible or unsafe (e.g. due to potential presence of asbestos), visual assessment may be satisfactory. The 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.[89]

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[89] 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."*

Utility program manuals should be consulted for health and safety considerations related to implementation of duct efficiency measures and/or testing procedures.

Duct sealing is a residential retrofit measure.

Table 2-36: Duct Sealing – Applicability

Application Type	Applicable	Notes
Retrofit	Y	Leakage-to-outside testing is required
New Construction	N	

Baseline Condition

The savings calculation methods for this measure are valid up to a maximum pre-installation leakage rate of 35 percent of total fan flow.[90] 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.[91]

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[92] are exempt from the cap limiting the maximum pre-installation leakage rate to 35 percent of total fan flow.

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 energy savings requires duct leakage-to-outside testing using a combination duct pressurization and house pressurization.

Duct Leakage Testing

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

[90] $Total\ Fan\ Flow = Cooling\ Capacity\ (tons) \times 400$
[91] Based on data collected by Frontier Associates, LLC for investor-owned utilities in Texas.
[92] 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).

must submit the intended method(s) and may be required to provide the utility with evidence of competency, such as Home Energy Rating System (HERS) or North American Technician Excellence (NATE) certification. Leakage rates must be measured and reported at the average air distribution system operating pressure (25 Pa).[93]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Energy Savings

The energy savings to be claimed for this measure shall be the sum of the cooling and heating energy savings for the appropriate equipment types.

Cooling Energy Savings (Electric)

$$kWh_{savings,C} = \frac{(DL_{pre} - DL_{post}) \times EFLH_C \times (h_{out}\rho_{out} - h_{in}\rho_{in}) \times 60}{1,000 \times SEER}$$

Equation 38

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)*

$EFLH_C$ = *Equivalent full load cooling hours (Table 2-37)*[94]

h = *Outdoor/Indoor seasonal specific enthalpy (Table 2-38) (Btu/lb)*[95]

ρ_{out} = *Density of outdoor air (Table 2-39) (lb/cu. ft.)*[96]

Table 2-37: Equivalent Full Load Cooling Hours

Climate Zone	$EFLH_C$
Climate Zone 1: Panhandle	1,142
Climate Zone 2: North	1,926
Climate Zone 3: South	2,209
Climate Zone 4: Valley	2,958
Climate Zone 5: West	1,524

[93] See RESNET Technical Committee, Proposed Amendment: Chapter 8 RESNET Standards, 800 RESNET Standard for Performance Testing and Work Scope: Enclosure and Air Distribution Leakage Testing; Section 803.2 and Table 803.1.

[94] ENERGY STAR® Central A/C Savings Calculator: https://www.energystar.gov/products/certified-products/detail/air-conditioning-central.

[95] ANSI/ASHRAE Standard 152-2004, Table 6.3b.

[96] ASHRAE Fundamentals 2013, Chapter 1: Psychometrics, Equation 11, Equation 41, Table 2.

Table 2-38: Seasonal Specific Enthalpy (Btu/lb)

Climate Zone	h_{out}	h_{in}
Climate Zone 1: Panhandle	32	28
Climate Zone 2: North	36	29
Climate Zone 3: South	37	30
Climate Zone 4: Valley	39	31
Climate Zone 5: West	29	26

Table 2-39: Density of Outdoor Air (lb/cu. ft.)

Climate Zone	Summer Temp. (°F)[97]	ρ_{out}
Climate Zone 1: Panhandle	93	0.0741
Climate Zone 2: North	97	0.0739
Climate Zone 3: South	93	0.0741
Climate Zone 4: Valley	93	0.0741
Climate Zone 5: West	99	0.0738

ρ_{in} = *Density of conditioned air at 75°F (lb/cu. ft.) = 0.0756 (default)*[98]

60 = *Constant to convert from minutes to hours*

1,000 = *Constant to convert from W to kW*

SEER = *Seasonal Energy Efficiency Ratio of existing system (Btu/W·hr) = 13 (default)*[99]

Heating Energy Savings (Heat Pump)

$$kWh_{savings,H} = \frac{(DL_{pre} - DL_{post}) \times 60 \times 0.77 \times HDD \times 24 \times 0.018}{1{,}000 \times HSPF}$$

Equation 39

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)*

60 = *Constant to convert from minutes to hours*

0.77 = *Factor to correlate design load hours to EFLH under actual working conditions (to account for the fact that people do not always operate their heating system when the outside temperature is less than 65°F)*[100]

[97] ANSI/ASHRAE Standard 152-2004, Table 6.3b.
[98] ASHRAE Fundamentals 2013, Chapter 1: Psychometrics, Equation 11, Equation 41, Table 2.
[99] The DOE minimum allowed SEER for new air conditioners after January 23, 2006 and before January 1, 2015 is 13.0 SEER. While minimum air conditioner efficiency standards increase in 2015, the previous standard is used here to reflect typical efficiency of installed units.
[100] Manual J, Volume 7: Appendix A-4.

HDD = *Heating degree days (Table 2-40)*[101]

Table 2-40: Heating Degree Days and Design Temperatures

Climate Zone	HDD	Winter Temp. (°F)[102]
Climate Zone 1: Panhandle	4,565	12
Climate Zone 2: North	2,567	24
Climate Zone 3: South	1,686	34
Climate Zone 4: Valley	1,129	36
Climate Zone 5: West	2,677	25

24 = *Constant to convert from days to hours*

0.018 = *Volumetric heat capacity of air (Btu/cu. ft.°F)*

1,000 = *Constant to convert from W to kW*

HSPF = *Heating Seasonal Performance Factor of existing system (Btu/W·hr)*

= *7.7 (default)*[103]

Heating Energy Savings (Electric Resistance)

$$kWh_{savings,H} = \frac{(DL_{pre} - DL_{post}) \times 60 \times 0.77 \times HDD \times 24 \times 0.018}{3,412}$$

Equation 40

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)*

60 = *Constant to convert from minutes to hours*

0.77 = *Factor to correlate design load hours to EFLH under actual working conditions (to account for the fact that people do not always operate their heating system when the outside temperature is less than 65°F)*[104]

HDD = *Heating degree days (Table 2-40)*[105]

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[101] National Solar Radiation Data Base – 1991-2005 Update: Typical Meteorological Year 3 (TMY3): http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/. Calculated using a base temperature of 65°F.

[102] ANSI/ASHRAE Standard 152-2004, Table 6.3b.

[103] The DOE minimum allowed HSPF for new heat pumps after January 23, 2006 and before January 1, 2015 is 7.7 HSPF. While minimum heat pump efficiency standards increase in 2015, the previous standard is used here to reflect typical efficiency of installed units.

[104] Manual J, Volume 7: Appendix A-4.

[105] National Climatic Data Center: http://www.ncdc.noaa.gov/oa/climate/online/ccd/nrmhdd.html.

24	=	*Constant to convert from days to hours*
0.018	=	*Volumetric heat capacity of air (Btu/cu. ft.°F)*
3,412	=	*Constant to convert from Btu to kWh*

Demand Savings

Cooling demand savings are to be claimed for this measure. Heating demand savings will be added in a future version of this document.

Cooling Demand Savings (Electric)

$$kW_{savings,C} = \frac{kWh_{savings,C}}{EFLH_C} \times 1.163 \times CF$$

Equation 41

Where:

$kWh_{savings,C}$	=	*Calculated kWh savings for cooling*
$EFLH_C$	=	*Equivalent full load cooling hours*[106] *(Table 2-37)*
1.163	=	*Constant to convert efficiency from SEER to EER*[107]
CF	=	*Coincidence factor*[108] *= 0.87*

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.

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106 ENERGY STAR® Central A/C Savings Calculator http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CA.

107 Department of Energy: Building America House Simulation Protocols, p.7 (revised October 2010). Approximation: $EER = 1.12 \times SEER - 0.02 \times SEER^2$

108 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential air conditioners be sized at 115% of the maximum cooling requirement of the house. Assuming that the house's maximum cooling occurs during the hours 4 to 5 PM, the guideline leads to a coincidence factor for residential HVAC measures of 1.0/1.15 = 0.87.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

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 18.0 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[109]

Program Tracking Data & 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
- Heating type (gas, resistance heat, heat pump)
- Cooling capacity of home HVAC units (tons)
- Pre-improvement duct leakage at 25 Pa (cu. ft./min)
- Post-improvement duct leakage at 25 Pa (cu. ft./min)

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

This section is not applicable.

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[109] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

Document Revision History

Table 2-41: Duct Efficiency Improvement 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.

2.2.2 Central Air Conditioner Measure Overview

TRM Measure ID: R-HV-AC

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction, Early Retirement

Program Delivery Type(s): Prescriptive, Direct Install (Early Retirement)

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

Residential replacement of an existing central air conditioning system with a new central air conditioning system in an existing building, or the installation of a new central air conditioning system in a new residential construction. A new central air conditioning system includes an entire packaged unit, or a split system consisting of an indoor unit with a matching remote condensing unit.

Prior to July 1, 2016, utilities may, at their discretion, claim savings according to TRM v2.1. A settlement between the U.S. Department of Energy and the American Public Gas Association permits distributors and retailers to sell split-system central air conditioners that do not meet regional standards without penalty until July 1, 2016, provided they comply with federal standards and were manufactured before January 1, 2015.[110] After July 1, 2016, the Department of Energy's enhanced regional standards for Texas[111] will determine the baseline and efficient conditions, as provided below.

[110] "Due to the uncertainty created by the litigation and in an exercise of its enforcement discretion, DOE will not seek civil penalties for violations of the regional standards applicable to central air conditioners that occur prior to July 1, 2016, provided that the violations are related to the distribution in commerce (including sales by retailers and installation) of units manufactured prior to January 1, 2015. DOE will continue to enforce the base national standard for central air conditioners and central air conditioning heat pumps."
American Public Gas Association v. United States Department of Energy, et al. "JOINT MOTION OF ALL PARTIES AND INTERVENORS TO VACATE IN PART AND REMAND FOR FURTHER RULEMAKING." USCA Case No. 11-1485. http://causeofaction.org/assets/uploads/2014/03/Joint-Motion.pdf. Filed March 11, 2014.

[111] DOE minimum efficiency standard for residential air conditioners/heat pumps. https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

Eligibility Criteria

Newly installed units must have a cooling capacity of less than 65,000 Btu/hour (5.4 tons) to be eligible for these deemed savings.

Air conditioning equipment shall be properly sized to dwelling based on ASHRAE or ACCA Manual J standards.

Manufacturer data sheets on installed air conditioning equipment or AHRI reference numbers must be provided.

Utilities should refer to the January 2015 memo, "Considerations for early replacement of residential equipment,"[112] when designing programs that permit savings to be claimed for early retirement. In order to receive early retirement savings, the unit to be replaced must be functioning at the time of removal and have a remaining useful life of five years or more. To determine the remaining useful life of an existing unit; see Table 2-46.

Baseline Condition

New construction baseline efficiency values for air conditioners are compliant with the current federal standard,[113] effective January 1, 2015.

For replace-on-burnout (ROB) projects, the baseline is reduced to 13.08 SEER. This value incorporates an adjustment to the baseline SEER value to reflect the percentage of current non-program replacements that do not include the installation of an AHRI-matched system.[114]

For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER for systems installed before January 23, 2006. Systems installed on or after January 23, 2006 should not use the ER baseline, as the ER baseline increases to 13 SEER at that time. There is no significant difference between the 13 SEER ER and 13.08 SEER ROB baseline efficiencies.

112 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.

113 DOE minimum efficiency standard for residential air conditioners/heat pumps. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

114 Frontier Associates 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. http://interchange.puc.state.tx.us/WebApp/Interchange/application/dbapps/filings/pgSearch.asp. Adapted for new 14 SEER baseline.

Table 2-42: Central Air Conditioner Baseline Efficiencies

Project Type	Cooling Mode
New Construction	14.00 SEER
Replace-on-Burnout	13.08 SEER
Early Retirement (before 1/23/2006)	10.00 SEER

High-Efficiency Condition

Table 2-43 displays the Consortium for Energy Efficiency (CEE) requirements for eligible Tier 1 air conditioners as of January 1, 2009. Energy efficiency service providers are expected to comply with the latest CEE Tier 1 requirements.

Table 2-43: Central Air Conditioner CEE Tier 1 Requirements

SEER	EER
14.5	12.0

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

New Construction and Replace-on-Burnout

Energy and summer demand savings were estimated using air conditioner performance curves developed by the National Renewable Energy Laboratory[115] for typical units in each of the following SEER ranges:

- Baseline units
- 14.5 – 14.9
- 15.0 – 15.9
- 16.0 – 16.9
- 17.0 – 17.9
- 18.0 – 20.9
- 21.0 and above

14.5 – 16.9 SEER units were assumed to be single stage. 17.0 SEER and above units were assumed to be multi-stage.

[115] D. Cutler et al., Improved Modeling of Residential Air Conditioners and Heat Pumps for Energy Calculations. National Renewable Energy Laboratory. NREL/TP-5500-56354. January 2013. Tables 12 and 13. http://www.nrel.gov/docs/fy13osti/56354.pdf.

These performance curves provide the capacity and efficiency of the air conditioners operating in cooling mode across a wide range of outside air temperatures. Unit loading was estimated as a function of outside air temperature, and hours of cooling mode operation under different loadings were estimated using bin weather data for each weather zone.

Summer demand savings are estimated according to expected unit performance under design conditions. For all weather zones, it is assumed that typical HVAC systems are sized to 115 percent of their design cooling load (oversized by 15 percent). Air conditioner system output was then compared to its loading under design conditions.

The model uses the following set of normalized performance curves to scale the rated performance values as a function of outdoor dry-bulb temperature ranging from 65 to 115 degrees Fahrenheit. The total capacity and Energy Input Ratio (EIR = 1/COP) curves are a function of entering wet-bulb temperature (EWB) and outdoor dry-bulb temperature (ODB) and are both quadratic curve fits of the form:

$$y = a + b \times T_{EWB} + c \times T_{EWB}^2 + d \times T_{ODB} + e \times T_{ODB}^2 + f \times T_{EWB} \times T_{ODB}$$

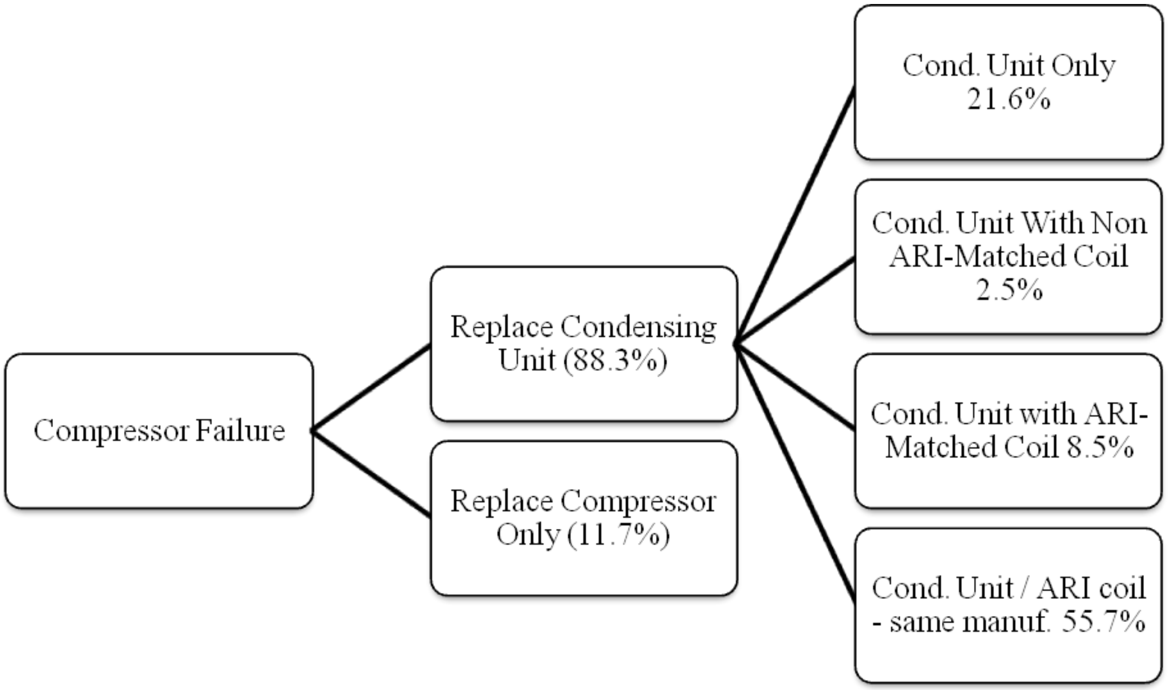
Table 2-44: Air Conditioner Capacity Curve Coefficients

Coefficient	Single Stage	Multi-Stage/Speed	
		Low	High
a	3.670270705	3.940185508	3.109456535
b	-0.098652414	-0.104723455	-0.085520461
c	0.000955906	0.001019298	0.000863238
d	0.006552414	0.006471171	0.00863049
e	-0.0000156	-0.00000953	-0.000021
f	-0.000131877	-0.000161658	-0.000140186

Table 2-45: Air Conditioner EIR Curve Coefficients

Coefficient	Single Stage	Multi-Stage/Speed	
		Low	High
a	-3.302695861	-3.87752688	-1.990708931
b	0.137871531	0.164566276	0.093969249
c	-0.001056996	-0.001272755	-0.00073335
d	-0.012573945	-0.019956043	-0.009062553
e	0.000214638	0.000256512	0.000165099
f	-0.000145054	-0.000133539	-0.0000997

To estimate the baseline SEER value for retrofit installations, Texas A&M's Energy Systems Laboratory (ESL) surveyed dealers across the State to determine installation practices. The research found that in the event of a compressor failure out of warranty, dealers replaced the compressor 11.7% of the time, and replaced the condensing unit 88.3% of the time. Further, the condensing unit replacements consist of condensing unit-only replacements, replacements with mismatched evaporator coils, and replacements with matching evaporator coils. The percentages for these installations are as follows:



Source: Docket No. 36780

Figure 2-1: Unit Replacement Percentages upon Compressor Failure

To calculate a weighted average SEER for these installations, ESL assumed that a compressor-only replacement resulted in no increase in SEER, and that the SEER of a condensing unit installed without a matching coil would be 85% of the SEER value for a matched system. The ESL estimate of the baseline SEER for replacement AC units is given by the following equation:

$$\begin{aligned} SEER_{Base} = & \left(SEER_{Compressor\ Replacement}\right) \times (Actual\ \%\ Compressor\ Replacement) \\ & + \left(SEER_{Condenser\ Replacement}\right) \times (Actual\ \%\ Condenser\ Replacement) \\ & + \left(SEER_{System\ Replacement}\right) \times (Actual\ \%\ System\ Replacement) \end{aligned}$$

Substituting ESL SEER estimates and survey data provides the following baseline SEER estimate:

$$SEER_{Base} = (9.5) \times (11.7\%) + (11.05) \times (24.1\%) + (13.5) \times (64.2\%) = 12.44$$

Adjusting for the increased 14 SEER baseline:

$$SEER_{Base} = (10.5) \times (11.7\%) + (11.9) \times (24.1\%) + (14) \times (64.2\%) = 13.08$$

In new construction, there is no possibility of a partial system (e.g. condensing unit-only) changeout, so the 13.08 baseline would not be appropriate. Therefore, the baseline for new construction installations is set at the federal government's minimum efficiency standard of 14 SEER.

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 (18 – 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 Volume 3, Appendix D of this document.

Where:

RUL = *Remaining Useful Life (see Table 2-46)*

Table 2-46*EUL*= *Estimated Useful Life = 18 years*

Table 2-46: Remaining Useful Life of Replaced Unit

Age of Replaced Unit (years)	Remaining Useful Life (years)	Age of Replaced Unit (years)	Remaining Useful Life (years)
2	15.8	14	8.6
3	14.9	15	8.2
4	14.1	16	7.9
5	13.3	17	7.6
6	12.6	18	7.0
7	11.9	19	6.0
8	11.3	20	5.0
9	10.8	21	4.0
10	10.3	22	3.0
11	9.8	23	2.0
12	9.4	24	1.0
13	9.0	25[116,117]	0.0

116 RULs are capped at the 75th percentile of equipment age, 25 years, as determined based on DOE survival curves (see
Figure 2-2). Systems older than 25 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

117 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

Derivation of RULs

Central air conditioners have an estimated useful life of 18 years. This estimate is consistent with the age at which approximately 50 percent of the central air conditioners installed in a given year will no longer be in service, as described by the survival function in Figure 2-2.

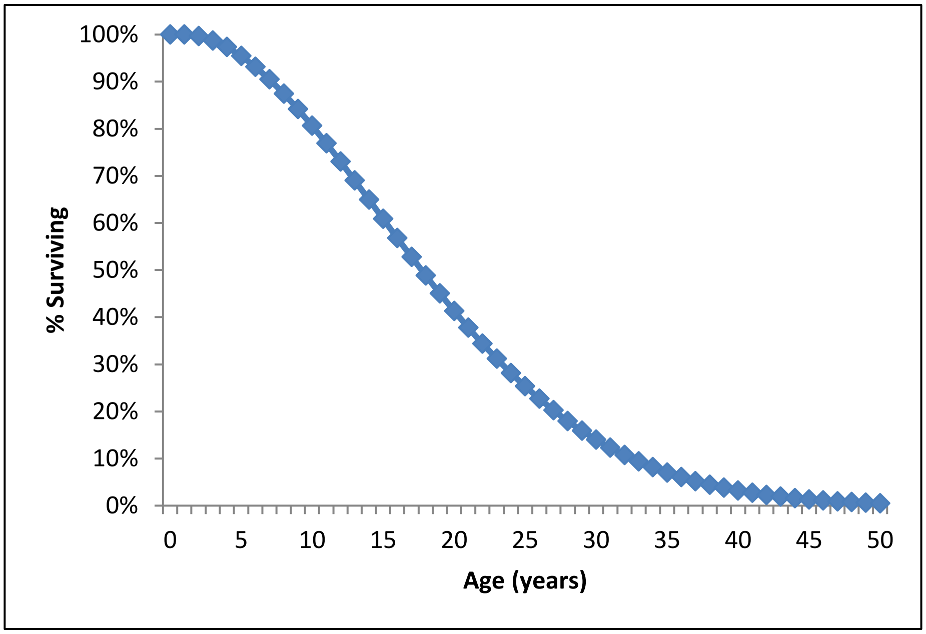


Figure 2-2: Survival Function for Central Air Conditioners[118]

The method for estimating the remaining useful life (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 2-2. The age of the central air conditioner being replaced is found on the horizontal axis, and the corresponding percentage of surviving air conditioners 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

Table 2-47 through Table 2-51 present the energy savings (kWh) associated with central air conditioners installed in new homes.

Table 2-52 through Table 2-56 present energy savings associated with replace-on-burnout of central air conditioners.

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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.

118 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.

Table 2-57 through Table 2-61 present energy savings associated with early retirement of central air conditioners.

New Construction

Table 2-47 through Table 2-51 present the energy savings (kWh) associated with central air conditioners installed in new homes (14 SEER baseline) for the five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-47: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	78	178	278	447	527	712
2.0	104	237	370	596	703	949
2.5	130	296	463	745	879	1,186
3.0	156	356	556	894	1,055	1,423
3.5	181	415	648	1,043	1,230	1,661
4.0	207	474	741	1,192	1,406	1,898
5.0	259	593	926	1,490	1,758	2,372

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-48: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	118	269	421	704	823	1,107
2.0	157	359	561	938	1,097	1,477
2.5	196	449	702	1,173	1,372	1,846
3.0	236	539	842	1,407	1,646	2,215
3.5	275	629	982	1,642	1,920	2,584
4.0	314	718	1,122	1,876	2,195	2,953
5.0	393	898	1,403	2,345	2,743	3,691

Climate Zone 3: South Region, Houston Weather Data

Table 2-49: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	125	285	446	784	907	1,211
2.0	166	380	594	1,045	1,210	1,614
2.5	208	475	743	1,306	1,512	2,018
3.0	249	570	891	1,567	1,814	2,421
3.5	291	665	1,040	1,828	2,117	2,825
4.0	333	760	1,188	2,089	2,419	3,228
5.0	416	950	1,485	2,612	3,024	4,035

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-50: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	145	331	518	904	1,048	1,402
2.0	193	442	690	1,205	1,397	1,869
2.5	242	552	863	1,506	1,746	2,336
3.0	290	663	1,035	1,807	2,095	2,804
3.5	338	773	1,208	2,108	2,444	3,271
4.0	387	884	1,381	2,409	2,793	3,738
5.0	483	1,105	1,726	3,012	3,492	4,673

Climate Zone 5: West Region El Paso Weather Data

Table 2-51: Energy Savings (kWh) for 14.0 SEER New Construction Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	101	232	362	622	723	969
2.0	135	309	483	829	965	1,292
2.5	169	386	603	1,037	1,206	1,615
3.0	203	463	724	1,244	1,447	1,939
3.5	236	540	844	1,451	1,688	2,262
4.0	270	618	965	1,659	1,929	2,585
5.0	338	772	1,206	2,073	2,412	3,231

Replace-on-Burnout

Table 2-52 through Table 2-56 present the energy savings (kWh) associated with central air conditioners installed in replace-on-burnout homes (13.08 SEER baseline) for the five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-52: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	215	315	415	584	664	849
2.0	286	419	553	779	885	1,131
2.5	358	524	691	973	1,107	1,414
3.0	429	629	829	1,168	1,328	1,697
3.5	501	734	967	1,362	1,550	1,980
4.0	572	839	1,106	1,557	1,771	2,263
5.0	715	1,049	1,382	1,712	1,991	2,638

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-53: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	325	477	628	911	1,030	1,315
2.0	433	636	838	1,214	1,374	1,753
2.5	542	794	1,047	1,518	1,717	2,191
3.0	650	953	1,256	1,822	2,060	2,629
3.5	759	1,112	1,466	2,125	2,404	3,068
4.0	867	1,271	1,675	2,429	2,747	3,506
5.0	1,084	1,589	2,094	3,036	3,434	4,382

Climate Zone 3: South Region, Houston Weather Data

Table 2-54: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	344	504	665	1,003	1,127	1,430
2.0	459	673	886	1,337	1,502	1,906
2.5	573	841	1,108	1,671	1,878	2,383
3.0	688	1,009	1,330	2,006	2,253	2,860
3.5	803	1,177	1,551	2,340	2,629	3,336
4.0	918	1,345	1,773	2,674	3,004	3,813
5.0	1,147	1,682	2,216	3,343	3,755	4,766

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-55: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	400	586	773	1,158	1,302	1,657
2.0	533	782	1,030	1,545	1,737	2,209
2.5	666	977	1,288	1,931	2,171	2,761
3.0	800	1,173	1,545	2,317	2,605	3,314
3.5	933	1,368	1,803	2,703	3,039	3,866
4.0	1,066	1,563	2,060	3,089	3,473	4,418
5.0	1,333	1,954	2,576	3,861	4,342	5,523

Climate Zone 5: West Region El Paso Weather Data

Table 2-56: Energy Savings (kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	280	410	540	800	902	1,147
2.0	373	546	720	1,067	1,202	1,530
2.5	466	683	900	1,334	1,503	1,912
3.0	559	820	1,080	1,600	1,803	2,295
3.5	652	956	1,260	1,867	2,104	2,677
4.0	745	1,093	1,440	2,134	2,404	3,060
5.0	932	1,366	1,800	2,667	3,006	3,825

Early Retirement

Table 2-57 through Table 2-61 present the early retirement energy savings (kWh) associated with central air conditioners installed in homes for the five Texas climate zones. These savings can be used with the replace-on-burnout energy savings in Table 2-52 through Table 2-56 to calculate annual savings.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-57: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	856	956	1,056	1,225	1,305	1,490
2.0	1,141	1,274	1,408	1,633	1,740	1,986
2.5	1,426	1,593	1,759	2,042	2,175	2,483
3.0	1,711	1,911	2,111	2,450	2,610	2,979
3.5	1,996	2,230	2,463	2,858	3,045	3,476
4.0	2,282	2,548	2,815	3,267	3,480	3,972
5.0	2,852	3,185	3,519	4,083	4,351	4,965

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-58: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,296	1,448	1,600	1,882	2,002	2,286
2.0	1,729	1,931	2,133	2,510	2,669	3,048
2.5	2,161	2,413	2,666	3,137	3,336	3,810
3.0	2,593	2,896	3,199	3,764	4,003	4,572
3.5	3,025	3,379	3,732	4,392	4,670	5,334
4.0	3,457	3,861	4,265	5,019	5,337	6,096
5.0	4,322	4,827	5,332	6,274	6,672	7,620

Climate Zone 3: South Region, Houston Weather Data

Table 2-59: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,372	1,533	1,693	2,031	2,155	2,458
2.0	1,830	2,043	2,257	2,708	2,873	3,277
2.5	2,287	2,554	2,822	3,385	3,591	4,097
3.0	2,744	3,065	3,386	4,062	4,309	4,916
3.5	3,202	3,576	3,950	4,739	5,027	5,735
4.0	3,659	4,087	4,514	5,416	5,746	6,554
5.0	4,574	5,108	5,643	6,770	7,182	8,193

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-60: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,595	1,781	1,967	2,353	2,497	2,852
2.0	2,126	2,375	2,623	3,138	3,330	3,802
2.5	2,658	2,968	3,279	3,922	4,162	4,753
3.0	3,189	3,562	3,935	4,706	4,994	5,703
3.5	3,721	4,156	4,591	5,491	5,827	6,654
4.0	4,252	4,749	5,247	6,275	6,659	7,604
5.0	5,316	5,937	6,558	7,844	8,324	9,505

Climate Zone 5: West Region El Paso Weather Data

Table 2-61: Energy Savings (kWh) for 10.0 SEER Early Retirement Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,115	1,245	1,375	1,635	1,737	1,983
2.0	1,486	1,660	1,834	2,180	2,316	2,643
2.5	1,858	2,075	2,292	2,726	2,895	3,304
3.0	2,229	2,490	2,751	3,271	3,474	3,965
3.5	2,601	2,905	3,209	3,816	4,053	4,626
4.0	2,973	3,320	3,667	4,361	4,632	5,287
5.0	3,716	4,150	4,584	5,451	5,789	6,609

Deemed Summer Demand Savings Tables

New Construction

Table 2-62 through Table 2-66 present the summer demand savings (kW) associated with central air conditioners installed in new homes (14.0 SEER baseline) for the five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-62: Demand Savings (kW) for 14.0 SEER New Construction Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.05	0.12	0.19	0.19	0.26	0.38
2.0	0.07	0.16	0.25	0.26	0.34	0.51
2.5	0.09	0.20	0.32	0.32	0.43	0.63
3.0	0.11	0.24	0.38	0.39	0.51	0.76
3.5	0.12	0.28	0.44	0.45	0.60	0.89
4.0	0.14	0.33	0.51	0.52	0.69	1.02
5.0	0.18	0.41	0.64	0.65	0.86	1.27

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-63: Demand Savings (kW) for 14.0 SEER New Construction Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.06	0.13	0.20	0.20	0.27	0.39
2.0	0.08	0.17	0.27	0.26	0.35	0.52
2.5	0.10	0.22	0.34	0.33	0.44	0.66
3.0	0.11	0.26	0.41	0.39	0.53	0.79
3.5	0.13	0.30	0.48	0.46	0.62	0.92
4.0	0.15	0.35	0.54	0.53	0.71	1.05
5.0	0.19	0.43	0.68	0.66	0.88	1.31

Climate Zone 3: South Region, Houston Weather Data

Table 2-64: Demand Savings (kW) for 14.0 SEER New Construction Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.05	0.12	0.19	0.19	0.26	0.38
2.0	0.07	0.16	0.25	0.26	0.34	0.51
2.5	0.09	0.20	0.32	0.32	0.43	0.63
3.0	0.11	0.24	0.38	0.39	0.51	0.76
3.5	0.12	0.28	0.44	0.45	0.60	0.89
4.0	0.14	0.33	0.51	0.52	0.69	1.02
5.0	0.18	0.41	0.64	0.65	0.86	1.27

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-65: Demand Savings (kW) for 14.0 SEER New Construction Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.05	0.12	0.19	0.19	0.26	0.38
2.0	0.07	0.16	0.25	0.26	0.34	0.51
2.5	0.09	0.20	0.32	0.32	0.43	0.63
3.0	0.11	0.24	0.38	0.39	0.51	0.76
3.5	0.12	0.28	0.44	0.45	0.60	0.89
4.0	0.14	0.33	0.51	0.52	0.69	1.02
5.0	0.18	0.41	0.64	0.65	0.86	1.27

Climate Zone 5: West Region El Paso Weather Data

Table 2-66: Demand Savings (kW) for 14.0 SEER New Construction Burnout Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.06	0.13	0.20	0.20	0.27	0.39
2.0	0.08	0.17	0.27	0.26	0.35	0.52
2.5	0.10	0.22	0.34	0.33	0.44	0.66
3.0	0.11	0.26	0.41	0.39	0.53	0.79
3.5	0.13	0.30	0.48	0.46	0.62	0.92
4.0	0.15	0.35	0.54	0.53	0.71	1.05
5.0	0.19	0.43	0.68	0.66	0.88	1.31

Replace-on-Burnout

Table 2-67 through Table 2-71 present the summer demand savings (kW) associated with central air conditioners installed in replace-on-burnout homes (13.08 SEER baseline) for the five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-67: Demand Savings (kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.15	0.22	0.28	0.29	0.35	0.47
2.0	0.20	0.29	0.38	0.38	0.47	0.63
2.5	0.25	0.36	0.47	0.48	0.58	0.79
3.0	0.29	0.43	0.57	0.58	0.70	0.95
3.5	0.34	0.50	0.66	0.67	0.82	1.11
4.0	0.39	0.58	0.76	0.77	0.94	1.27
5.0	0.49	0.72	0.95	0.96	1.17	1.58

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-68: Demand Savings (kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.16	0.23	0.30	0.30	0.37	0.49
2.0	0.21	0.31	0.41	0.40	0.49	0.66
2.5	0.26	0.38	0.51	0.50	0.61	0.82
3.0	0.31	0.46	0.61	0.60	0.73	0.99
3.5	0.37	0.54	0.71	0.69	0.85	1.15
4.0	0.42	0.62	0.81	0.79	0.98	1.32
5.0	0.52	0.77	1.01	0.99	1.22	1.65

Climate Zone 3: South Region, Houston Weather Data

Table 2-69: Demand Savings (kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.15	0.22	0.28	0.29	0.35	0.47
2.0	0.20	0.29	0.38	0.38	0.47	0.63
2.5	0.25	0.36	0.47	0.48	0.58	0.79
3.0	0.29	0.43	0.57	0.58	0.70	0.95
3.5	0.34	0.50	0.66	0.67	0.82	1.11
4.0	0.39	0.58	0.76	0.77	0.94	1.27
5.0	0.49	0.72	0.95	0.96	1.17	1.58

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-70: Demand Savings (kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.15	0.22	0.28	0.29	0.35	0.47
2.0	0.20	0.29	0.38	0.38	0.47	0.63
2.5	0.25	0.36	0.47	0.48	0.58	0.79
3.0	0.29	0.43	0.57	0.58	0.70	0.95
3.5	0.34	0.50	0.66	0.67	0.82	1.11
4.0	0.39	0.58	0.76	0.77	0.94	1.27
5.0	0.49	0.72	0.95	0.96	1.17	1.58

Climate Zone 5: West Region El Paso Weather Data

Table 2-71: Demand Savings (kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.16	0.23	0.30	0.30	0.37	0.49
2.0	0.21	0.31	0.41	0.40	0.49	0.66
2.5	0.26	0.38	0.51	0.50	0.61	0.82
3.0	0.31	0.46	0.61	0.60	0.73	0.99
3.5	0.37	0.54	0.71	0.69	0.85	1.15
4.0	0.42	0.62	0.81	0.79	0.98	1.32
5.0	0.52	0.77	1.01	0.99	1.22	1.65

Early Retirement

Table 2-72 through Table 2-76 present the early retirement summer demand savings (kW) associated with central air conditioners installed in homes for the five Texas climate zones. These savings can be used with the replace-on-burnout energy savings in Table 2-67 through Table 2-71 to calculate summer demand savings.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-72: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.59	0.66	0.72	0.73	0.79	0.91
2.0	0.78	0.87	0.97	0.97	1.05	1.22
2.5	0.98	1.09	1.21	1.21	1.32	1.52
3.0	1.17	1.31	1.45	1.46	1.58	1.83
3.5	1.37	1.53	1.69	1.70	1.85	2.13
4.0	1.57	1.75	1.93	1.94	2.11	2.44
5.0	1.96	2.19	2.41	2.43	2.64	3.05

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-73: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.63	0.70	0.77	0.77	0.84	0.96
2.0	0.84	0.93	1.03	1.02	1.11	1.28
2.5	1.05	1.17	1.29	1.28	1.39	1.61
3.0	1.26	1.40	1.55	1.54	1.67	1.93
3.5	1.46	1.64	1.81	1.79	1.95	2.25
4.0	1.67	1.87	2.06	2.05	2.23	2.57
5.0	2.09	2.34	2.58	2.56	2.79	3.21

Climate Zone 3: South Region, Houston Weather Data

Table 2-74: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.59	0.66	0.72	0.73	0.79	0.91
2.0	0.78	0.87	0.97	0.97	1.05	1.22
2.5	0.98	1.09	1.21	1.21	1.32	1.52
3.0	1.17	1.31	1.45	1.46	1.58	1.83
3.5	1.37	1.53	1.69	1.70	1.85	2.13
4.0	1.57	1.75	1.93	1.94	2.11	2.44
5.0	1.96	2.19	2.41	2.43	2.64	3.05

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-75: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.59	0.66	0.72	0.73	0.79	0.91
2.0	0.78	0.87	0.97	0.97	1.05	1.22
2.5	0.98	1.09	1.21	1.21	1.32	1.52
3.0	1.17	1.31	1.45	1.46	1.58	1.83
3.5	1.37	1.53	1.69	1.70	1.85	2.13
4.0	1.57	1.75	1.93	1.94	2.11	2.44
5.0	1.96	2.19	2.41	2.43	2.64	3.05

Climate Zone 5: West Region El Paso Weather Data

Table 2-76: Demand Savings (kW) for 10.0 SEER Early Retirement Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	0.63	0.70	0.77	0.77	0.84	0.96
2.0	0.84	0.93	1.03	1.02	1.11	1.28
2.5	1.05	1.17	1.29	1.28	1.39	1.61
3.0	1.26	1.40	1.55	1.54	1.67	1.93
3.5	1.46	1.64	1.81	1.79	1.95	2.25
4.0	1.67	1.87	2.06	2.05	2.23	2.57
5.0	2.09	2.34	2.58	2.56	2.79	3.21

Deemed Winter Demand Savings Tables

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a central air conditioning unit is 18 years based on the current DOE Final Rule standards for central air conditioners.[119]

Program Tracking Data & 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:

- Decision/action type (early retirement, replace-on-burnout, new construction)
- Cooling capacity of the installed unit (tons)
- Seasonal Energy Efficiency Ratio (SEER) of the installed unit
- Climate zone of the site
- Age of replaced unit (Early Retirement only)
- Recommended: retired unit model number, serial number, and manufacturer (Early Retirement only)
- Recommended: photograph of retired unit nameplate (Early Retirement only)
- Recommended: customer responses to survey questionnaire for early retirement eligibility determination (Early Retirement only)

[119] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. Accessed 10/21/2014. 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.

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- ASHRAE 90.1-1999 (Residential Buildings)
- ACCA Manual J Residential Load Calculation (8th Edition)[120]

Document Revision History

Table 2-77: Residential Central Air Conditioner 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 Associates, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. Reversion to TRM v1.0 savings tables to reflect deferred enforcement of new regional standards. A court-ordered settlement allows SEER 13 split-system units to be sold without penalty until July 1, 2016.
v3.0	4/10/2015	TRM v3.0 update. Savings values incorporated corresponding with federal and regional standards effective January 1, 2015. 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.
v3.1	11/05/2015	TRM v3.1 update. Removal of legacy language around baseline. Extension of Early Retirement savings tables to higher SEER values.

120 https://www.acca.org/store/product.php?pid=172.

2.2.3 Ground Source Heat Pump Measure Overview

TRM Measure ID: R-HV-GH

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values and Calculations

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® Tier 3 geothermal heat pump key product criteria. The deemed savings are dependent upon the energy efficiency rating (EER) and coefficient of performance (COP) of the installed equipment. Savings calculations are presented for systems both 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 electric resistance furnace for replace-on-burnout projects. New construction baseline efficiency values for ASHPs are compliant with the current federal minimum standard,[121] effective January 1, 2015.

[121] DOE minimum efficiency standard for residential air conditioners/heat pumps. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

For replace-on-burnout (ROB) projects, the cooling baseline is reduced to 13.08 SEER. This value incorporates an adjustment to the baseline SEER value to reflect the percentage of current replacements that do not include the installation of an AHRI-matched system.[122] The heating baseline for replace-on-burnout projects is dependent on the heating type of the baseline equipment.

Table 2-78: Ground Source Heat Pump Baseline Efficiencies

<table>
<tr><th>Project Type</th><th>Cooling Mode[123]</th><th>Heating Mode[124]</th></tr>
<tr><td>New Construction</td><td>11.8 EER
(14 SEER)</td><td>2.4 COP
(8.2 HSPF)</td></tr>
<tr><td>ROB – Air Source Heat Pump Baseline</td><td rowspan="2">11.4 EER
(13.08 SEER)</td><td>2.4 COP
(8.2 HSPF)</td></tr>
<tr><td>ROB – Electric Resistance Baseline</td><td>1 COP
(3.41 HSPF)</td></tr>
</table>

High-Efficiency Condition

Table 2-79 displays the ENERGY STAR® requirements for eligible Tier 3 geothermal heat pumps as of January 1, 2012. Energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Table 2-79: Ground Source Heat Pump ENERGY STAR® Tier 3 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

The specifications in the charts above apply to single-stage models. Multi-stage models may be qualified based on:[125]

[122] Frontier Associates 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. http://interchange.puc.state.tx.us/WebApp/Interchange/application/dbapps/filings/pgSearch.asp. Adapted for new 14 SEER baseline.

[123] Code specified EER value converted to SEER using $EER = -0.02 \times SEER^2 + 1.12 \times SEER$. National Renewable Energy Laboratory (NREL). "Building America House Simulation Protocols." U.S. Department of Energy. Revised October 2010. http://www.nrel.gov/docs/fy11osti/49246.pdf.

[124] Code specified HSPF value converted to COP using $COP = HSPF \times 1{,}055\ J/Btu \div 3{,}600\ J/W\text{-}h$.

[125] Geothermal Heat Pumps Key Product Criteria, https://www.energystar.gov/index.cfm?c=geo_heat.pr_crit_geo_heat_pumps. Accessed February 2014.

- $EER = (highest\ rated\ capacity\ EER + lowest\ rated\ capacity\ EER) \div 2$
- $COP = (highest\ rated\ capacity\ COP + lowest\ rated\ capacity\ COP) \div 2$

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 ground source heat pumps in Texas.[126] 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 replacement of air source heat pumps with ground source heat pumps. These estimates were found to be within 5% of actual post-retrofit savings. Building models were developed using TRNSYS.[127]

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 ground source heat pumps 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.

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 ground source heat pump, as shown in Table 2-81 and Table, respectively.

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[126] 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. http://web.ornl.gov/~webworks/cppr/y2001/pres/112677.pdf.

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

Energy Savings Algorithms

$$kWh_{Savings} = kWh_{Savings,Summer} + kWh_{Savings,Winter} + kWh_{desuperheater}$$

Equation 42

$$kWh_{Savings,C} = CAP_C \times \frac{1\ kW}{1,000\ W} \times EFLH_C \times \left(\frac{1}{SEER_{Base}} - \frac{1}{EER_{GSHP}}\right)$$

Equation 43

$$kWh_{Savings,H} = CAP_H \times \frac{1\ kWh}{1,000\ Wh} \times EFLH_H \times \left(\frac{1}{HSPF_{Base}} - \frac{1}{3.412 \times COP_{GSHP}}\right)$$

Equation 44

Where:

$kWh_{desuperheater}$ = *Energy savings (kWh) associated with installation of a desuperheater (see Table 2-81). These savings should only be added if a desuperheater is installed.*

CAP_C = *Rated equipment cooling capacity of the installed GSHP (Btu/hr)*

CAP_H = *Rated equipment heating capacity of the installed GSHP (Btu/hr)*

$EFLH_C$ = *Equivalent full load hours for cooling)*

$EFLH_H$ = *Equivalent full load hours for heating (Table 2-80)*

$SEER_{Base}$ = *Seasonal Energy Efficiency Ratio of the baseline cooling equipment (Table 2-78)*

EER_{GSHP} = *Energy Efficiency Ratio of the installed GSHP*

$HSPF_{Base}$ = *Heating Seasonal Performance Factor of the baseline heating equipment (Table 2-78)*

COP_{GSHP} = *Coefficient of Performance of the installed GSHP*

Table 2-80: Equivalent full load cooling/heating hours[128]

Climate Zone	$EFLH_C$	$EFLH_H$
Climate Zone 1: Panhandle	1,142	1,880
Climate Zone 2: North	1,926	1,343
Climate Zone 3: South	2,209	1,127
Climate Zone 4: Valley	2,958	776
Climate Zone 5: West	1,524	1,559

Demand Savings Algorithms

$$kW_{Savings,C} = CAP_C \times \frac{1\ kW}{1,000\ W} \times \left(\frac{1}{EER_{Base}} - \frac{1}{EER_{GSHP}}\right) \times CF_C + kW_{desuperheater}$$

Equation 45

$$kW_{Savings,H} = CAP_H \times \frac{1\ kWh}{3,412\ Btu} \times \left(\frac{1}{COP_{Base}} - \frac{1}{COP_{GSHP}}\right) \times CF_H$$

Equation 46

Where:

CAP_C	=	*Rated equipment cooling capacity of the installed GSHP (Btu/hr)*
CAP_H	=	*Rated equipment heating capacity of the installed GSHP (Btu/hr)*
EER_{Base}	=	*Energy Efficiency Ratio of the baseline cooling equipment (Table 2-78)*
EER_{GSHP}	=	*Energy Efficiency Ratio of the installed GSHP*
COP_{Base}	=	*Coefficient of Performance of the baseline heating equipment (Table 2-78)*
COP_{GSHP}	=	*Coefficient of Performance of the installed GSHP*
CF_C	=	*Coincidence Factor = 0.87 (default)*[129]

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[128] ENERGY STAR® Central AC/HP Savings Calculator. http://www.energystar.gov/certified-products/detail/heat_pumps_air_source.

[129] Air Conditioning Contractors of America (ACCA) Manual S allows residential air conditioners to be sized at 115% of the maximum cooling requirement of the house. Assuming that the house's maximum cooling occurs during the hours of 4 to 5 PM, the guideline leads to a summer coincidence factor for residential HVAC measures of 1.0/1.15 = 0.87.

CF_H	=	*Coincidence Factor = 0.83 (default)*[130]
$kW_{desuperheater}$	=	*Summer demand savings (kW) associated with installation of a desuperheater (seeTable 2-82). These savings should only be added if a desuperheater is installed.*

Deemed Energy Savings Tables

Table 2-81: Energy Savings for Desuperheaters

Climate Zone	kWh/ton
Climate Zone 1: Panhandle	612
Climate Zone 2: North	791
Climate Zone 3: South	802
Climate Zone 4: Valley	847
Climate Zone 5: West	791

Deemed Summer Demand Savings Tables

Table 2-82: Summer Peak Demand Savings for Desuperheaters

Climate Zone	kW/ton
Climate Zone 1: Panhandle	0.440
Climate Zone 2: North	0.405
Climate Zone 3: South	0.405
Climate Zone 4: Valley	0.410
Climate Zone 5: West	0.405

Deemed Winter Demand Savings Tables

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

[130] Air Conditioning Contractors of America (ACCA) Manual S allows residential heat pumps to be sized at 115% of the maximum cooling requirement of the house (for cooling dominated climates). Based on AHRI data for 1.5 to 5 ton heat pump systems, the average ratio of rated heating capacity to cooling capacity is 0.96. Assuming that the house's maximum cooling occurs during the hours of 4 to 5 PM, the guideline leads to a winter coincidence factor for residential HVAC measures of 0.96/1.15 = 0.83

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a high-efficiency ground source heat pump unit is 20 years.

This value is consistent with the EUL reported in the Department of Energy GSHP guide.[131]

Program Tracking Data & Evaluation Requirements

It is required that the following list of primary inputs and contextual data be specified and tracked by the program database to inform the evaluation and apply the savings properly:

- Decision/action type (new construction, replace-on-burnout)
- Replaced unit type (heat pump, electric resistance)
- Cooling and heating capacity (Btu/hr)
- Energy Efficiency Ratio (EER) of the unit installed
- Coefficient of Performance (COP) of the unit installed
- Climate zone of the site
- Whether a desuperheater was also installed or present

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- ISO/AHRI 13256-1
- 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. http://web.ornl.gov/~webworks/cppr/y2001/pres/112677.pdf
- The applicable version of ENERGY STAR®'s specifications and requirements addressing residential ground source heat pumps.

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

Document Revision History

Table 2-83: Ground Source Heat Pump 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 Associates, 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.

2.2.4 Central Heat Pump Measure Overview

TRM Measure ID: R-HV-HP

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction, Early Retirement

Program Delivery Type(s): Prescriptive, Direct Install (Early Retirement)

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

Residential replacement of existing heating and cooling equipment with a new central air-source heat pump in an existing building, or the installation of a new central heat pump in a new residential construction. A new central heat pump includes an entire packaged unit, or a split system consisting of an indoor unit with a matching remote condensing unit.

All measure installation standards and baseline data from the central air conditioner measure shall apply to the heat pump measure.

Eligibility Criteria

Newly installed units must have a cooling capacity of less than 65,000 Btu/hour (5.4 tons) to be eligible for these deemed savings. Gas furnaces are not eligible to be awarded savings for replacement through this measure.

Equipment shall be properly sized to dwelling based on ASHRAE or ACCA Manual J standards. Manufacturer data sheets on installed heat pump equipment or AHRI reference numbers must be provided.

Utilities should refer to the January 2015 memo, “Considerations for early replacement of residential equipment,”[132] when designing programs that permit savings to be claimed for early

[132] 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.

retirement. In order to receive early retirement savings, the unit to be replaced must be functioning at the time of removal and have a remaining useful life of five years or more. To determine the remaining useful life of an existing unit, see Table 2-88.

Baseline Condition

New Construction, Replace-on-Burnout, or Early Retirement of an Air-Source Heat Pump

New construction baseline efficiency values for heat pumps are compliant with the current federal minimum standard,[133] effective January 1, 2015. The baseline is assumed to be a new heat pump system with an AHRI-listed SEER rating of 14.0.

For replace-on-burnout (ROB) projects, the cooling baseline is reduced to 13.08 SEER. This value incorporates an adjustment to the baseline SEER value to reflect the percentage of current replacements that do not include the installation of an AHRI-matched system.[134]

For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER for systems installed before January 23, 2006. Systems installed on or after January 23, 2006 should not use the ER baseline, as the ER baseline increases to 13 SEER at that time. There is no significant difference between the 13 SEER ER and 13.08 SEER ROB baseline efficiencies.

Heating baseline efficiency values for heat pumps are compliant with the current federal minimum standard, effective January 1, 2015. These standards specify an HSPF of 8.2 for split systems, or 8.0 for packaged systems. This baseline reflects updates to federal standards that take effect January 1, 2015, as defined in the Department of Energy (DOE) energy efficiency standards (10 CFR Part 430).[135]

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

By the nature of the technology, all electric resistance furnaces have the same efficiency with HSPF = 3.41.[136] 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.

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133 DOE minimum efficiency standard for residential air conditioners/heat pumps. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/75.

134 Frontier Associates 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. http://interchange.puc.state.tx.us/WebApp/Interchange/application/dbapps/filings/pgSearch.asp. Adapted for new 14 SEER baseline.

135 *10 CFR Part 430.32(c)2. Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters; Final Rule*. Online. Available: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Accessed February 2014.

136 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 = 3.41.

For ROB projects, cooling savings are the same as for new construction and ROB of an air-source heat pump. For early retirement (ER) projects, the cooling baseline is reduced to 10 SEER for systems installed before January 23, 2006. Systems installed on or after January 23, 2006 should not use the ER baseline, as the ER baseline increases to 13 SEER at that time. There is no significant difference between the 13 SEER ER and 13.08 ROB baseline efficiencies. Early retirement projects do not commonly replace HVAC units without an electric resistance furnace.

Table 2-84: Central Heat Pump Baseline Efficiencies

Project Type	Cooling Mode	Heating Mode
New Construction	14 SEER	8.2 HSPF
Replace-on-Burnout, Heat Pump	13.08 SEER	8.2 HSPF
Replace-on-Burnout, Electric Resistance Furnace		3.41 HSPF
Early Retirement, Heat Pump	10 SEER	8.2 HSPF*
Early Retirement, Electric Resistance Furnace		3.41 HSPF

* It is rare for early retirement projects to replace a pre-existing heat pump. For these measures, heating savings for the replace-on-burnout of a heat pump shall be used instead.

High-Efficiency Condition

Table 2-85 displays the Consortium for Energy Efficiency (CEE) requirements for eligible Tier 1 heat pumps as of January 1, 2009. Energy efficiency service providers are expected to at least comply with the latest CEE Tier 1 requirements.

Table 2-85: Central Heat Pump CEE Tier 1 Requirements

SEER	EER	HSPF
14.5	12.0	8.5

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Replace-on-Burnout or New Construction

Energy, summer demand, and winter demand savings were estimated using heat pump performance curves developed by the National Renewable Energy Laboratory[137] for typical units in each of the following SEER ranges:

- Baseline units

137 D. Cutler et al. Improved Modeling of Residential Air Conditioners and Heat Pumps for Energy Calculations. National Renewable Energy Laboratory. NREL/TP-5500-56354. January 2013. Tables 12 and 13. http://www.nrel.gov/docs/fy13osti/56354.pdf

- 14.5 – 14.9
- 15.0 – 15.9
- 16.0 – 16.9
- 17.0 – 17.9
- 18.0 – 20.9
- 21.0 and above

14.5 – 16.9 SEER units were assumed to be single stage. 17.0 and above SEER units were assumed to be multi-stage.

These performance curves provide the capacity and efficiency of the air conditioners operating in cooling mode across a wide range of outside air temperatures. Unit loading was estimated as a function of outside air temperature, and hours of cooling mode operation under different loadings were estimated using bin weather data for each weather zone. In heating mode, predicted HVAC operation was limited to meeting 77 percent of load, using a factor applied in Manual J to correlate design load hours to equivalent full load hours under actual operating conditions, taking into account that heating systems are not always operated even when outdoor conditions indicate they should.

Summer and winter demand savings are estimated according to expected unit performance under design conditions. For all weather zones, it is assumed that typical HVAC systems are sized to 115 percent of their design cooling load (oversized by 15 percent). Heating mode capacity was related to rated cooling capacity using the rated capacity in cooling and heating mode of the residential market heat pump products of four major manufacturers according to data exported from AHRI. Data were exported from the AHRI directory and the average ratio for each equipment size (1 ton, 1.5 ton, 2 ton, etc.) of heating capacity to cooling capacity was multiplied by the rated (cooling side) capacity to estimate the heat pump capacity. Heat pump system output was then compared to its loading under design conditions.

The model uses the following set of normalized performance curves to scale the rated performance values as a function of outdoor dry-bulb temperature ranging from 65 to 115 degrees Fahrenheit. The total capacity and Energy Input Ratio (EIR = 1/COP) curves are a function of entering wet-bulb temperature (EWB) and outdoor dry-bulb temperature (ODB) and are both quadratic curve fits of the form:

$$\boldsymbol{y = a + b \times T_{EWB} + c \times T_{EWB}^2 + d \times T_{ODB} + e \times T_{ODB}^2 + f \times T_{EWB} \times T_{ODB}}$$

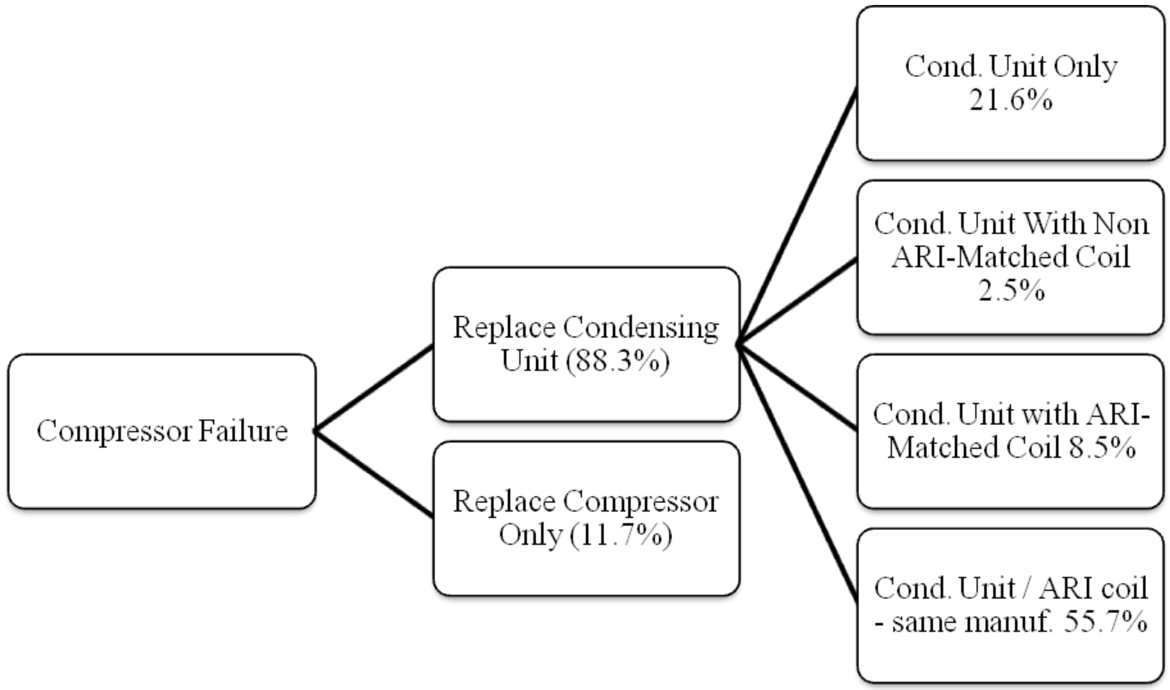
Table 2-86: Heat Pump Capacity Curve Coefficients

Coefficient	Cooling			Heating
	Single Stage	Multi-Stage/Speed		Single Stage
		Low	High	
a	3.68637657	3.998418659	3.466810106	0.566333415
b	-0.098352478	-0.108728222	-0.091476056	-0.000744164
c	0.000956357	0.001056818	0.000901205	-0.0000103
d	0.005838141	0.007512314	0.004163355	0.009414634
e	-0.0000127	-0.0000139	-0.00000919	0.0000506
f	-0.000131702	-0.000164716	-0.000110829	-0.00000675

Table 2-87: Heat Pump EIR Curve Coefficients

Coefficient	Cooling			Heating
	Single Stage	Multi-Stage/Speed		Single Stage
		Low	High	
a	-3.437356399	-4.282911381	-3.557757517	0.718398423
b	0.136656399	0.181023691	0.112737397	0.003498178
c	-0.001049231	-0.001357391	-0.000731381	0.000142202
d	-0.0079378	-0.026310378	0.01384877	-0.005724331
e	0.000185435	0.000333282	0.000132645	0.00014085
f	-0.0001441	-0.000197405	-0.000338716	-0.000215321

To estimate the baseline SEER value for retrofit installations, Texas A&M's Energy Systems Laboratory (ESL) surveyed dealers across the State to determine installation practices. The research found that in the event of a compressor failure out of warranty, dealers replaced the compressor 11.7% of the time, and replaced the condensing unit 88.3% of the time. Further, the condensing unit replacements consist of condensing unit-only replacements, replacements with mismatched evaporator coils, and replacements with matching evaporator coils. The percentages for these installations are as follows:



Source: Docket No. 36780

Figure 2-3: Unit Replacement Percentages upon Compressor Failure

To calculate a weighted average SEER for these installations, ESL assumed that a compressor-only replacement resulted in no increase in SEER, and that the SEER of a condensing unit installed without a matching coil would be 85% of the SEER value for a matched system. The ESL estimate of the baseline SEER for replacement AC units is given by the following equation:

$$\begin{aligned} \boldsymbol{SEER_{Base}} = {} & (\boldsymbol{SEER_{Compressor\ Replacement}}) \times (\boldsymbol{Actual}\ \%\ \boldsymbol{Compressor\ Replacement}) \\ & + (\boldsymbol{SEER_{Condenser\ Replacement}}) \times (\boldsymbol{Actual}\ \%\ \boldsymbol{Condenser\ Replacement}) \\ & + (\boldsymbol{SEER_{System\ Replacement}}) \times (\boldsymbol{Actual}\ \%\ \boldsymbol{System\ Replacement}) \end{aligned}$$

Equation 47

Substituting ESL SEER estimates and survey data provides the following baseline SEER estimate:

$$\boldsymbol{SEER_{Base}} = (\mathbf{9.5}) \times (\mathbf{11.7}\%) + (\mathbf{11.05}) \times (\mathbf{24.1}\%) + (\mathbf{13.5}) \times (\mathbf{64.2}\%) = \mathbf{12.44}$$

Adjusting for the increased 14 SEER baseline:

$$\boldsymbol{SEER_{Base}} = (\mathbf{10.5}) \times (\mathbf{11.7}\%) + (\mathbf{11.9}) \times (\mathbf{24.1}\%) + (\mathbf{14}) \times (\mathbf{64.2}\%) = \mathbf{13.08}$$

In new construction, there is no possibility of a partial system (e.g. condensing unit-only) changeout, so the 13.08 baseline would not be appropriate. Therefore, the baseline for new construction installations is set at the federal government’s minimum efficiency standard of 14 SEER.

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 (15 – 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 Volume 3, Appendix D of this document.

Where:

RUL = *Remaining Useful Life (see Table 2-88)*

EUL = *Estimated Useful Life = 15 years*

Table 2-88: Remaining Useful Life of Replaced Unit

Age of Replaced Unit (years)	Remaining Useful Life (years)	Age of Replaced Unit (years)	Remaining Useful Life (years)
2	12.7	12	7.9
3	12.0	13	7.6
4	11.3	14	7.0
5	10.7	15	6.0
6	10.2	16	5.0
7	9.7	17	4.0
8	9.3	18	3.0
9	8.9	19	2.0
10	8.5	20	1.0
11	8.2	21[138,139]	0.0

138 RULs are capped at the 75th percentile of equipment age, 21 years, as determined based on DOE survival curves (see Figure 2-2). Systems older than 21 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

139 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.

Derivation of RULs

Central heat pumps have an estimated useful life of 15 years. This estimate is consistent with the age at which approximately 50 percent of the central heat pumps installed in a given year will no longer be in service, as described by the survival function in Figure 2-4.

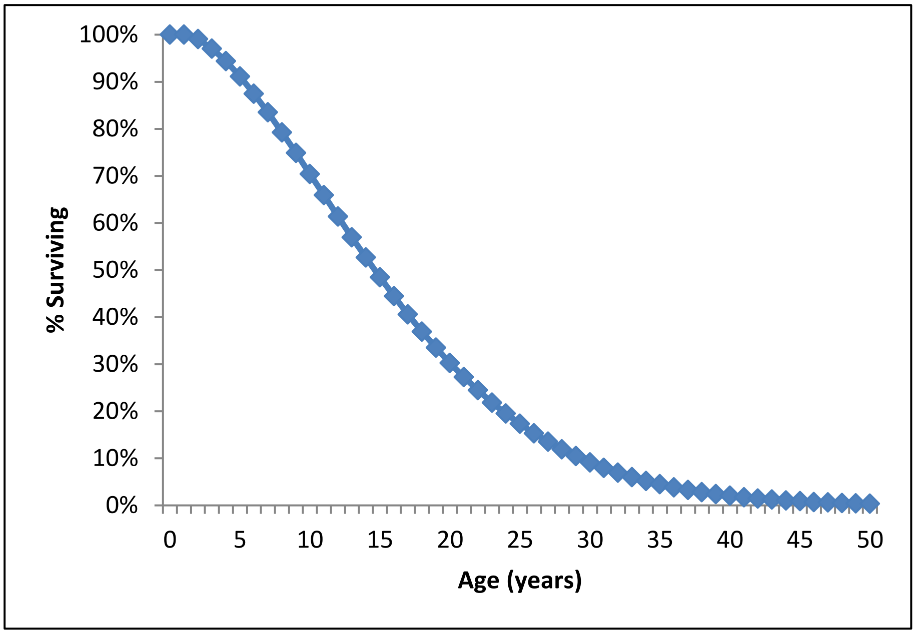


Figure 2-4: Survival Function for Central Heat Pumps[140]

The method for estimating the remaining useful life (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 2-4. The age of the central heat pump being replaced is found on the horizontal axis, and the corresponding percentage of surviving heat pumps 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.

140 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.

Deemed Energy Savings Tables

Cooling, New Construction

Table 2-89 through Table 2-93 present the energy savings (kWh) for cooling load types associated with a central heat pump being installed during new construction for all five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-89: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	78	179	279	427	509	697
2.0	104	238	373	570	679	930
2.5	130	298	466	712	849	1,162
3.0	156	358	559	855	1,019	1,394
3.5	183	417	652	997	1,188	1,627
4.0	209	477	745	1,140	1,358	1,859
5.0	261	596	931	1,425	1,698	2,324

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-90: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	118	271	423	673	795	1,085
2.0	158	361	564	897	1,060	1,447
2.5	197	451	705	1,122	1,325	1,808
3.0	237	542	846	1,346	1,590	2,170
3.5	276	632	987	1,571	1,855	2,531
4.0	316	722	1,128	1,795	2,120	2,893
5.0	395	903	1,410	2,244	2,650	3,616

Climate Zone 3: South Region, Houston Weather Data

Table 2-91: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	126	287	449	771	896	1,204
2.0	168	383	598	1,027	1,195	1,605
2.5	209	479	748	1,284	1,494	2,007
3.0	251	574	898	1,541	1,792	2,408
3.5	293	670	1,047	1,798	2,091	2,809
4.0	335	766	1,197	2,055	2,390	3,211
5.0	419	957	1,496	2,568	2,987	4,014

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-92: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	146	334	522	897	1,043	1,401
2.0	195	445	695	1,196	1,390	1,868
2.5	243	556	869	1,495	1,738	2,336
3.0	292	668	1,043	1,794	2,085	2,803
3.5	341	779	1,217	2,093	2,433	3,270
4.0	389	890	1,391	2,392	2,780	3,737
5.0	487	1,113	1,738	2,989	3,475	4,671

Climate Zone 5: West Region El Paso Weather Data

Table 2-93: Energy Savings (Cooling kWh) for 14.0 SEER New Construction Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	102	233	364	596	700	951
2.0	136	311	485	795	933	1,268
2.5	170	388	607	994	1,166	1,585
3.0	204	466	728	1,193	1,400	1,901
3.5	238	544	849	1,391	1,633	2,218
4.0	272	621	971	1,590	1,866	2,535
5.0	340	776	1,213	1,988	2,333	3,169

Cooling, Replace-on-Burnout

Table 2-94 through Table 2-98 present the energy savings (kWh) for cooling load types associated with a central heat pump replacing on burnout an HVAC system for all five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-94: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	216	316	417	565	647	835
2.0	288	422	556	753	862	1,113
2.5	360	527	695	942	1,078	1,391
3.0	432	633	834	1,130	1,294	1,670
3.5	504	738	973	1,318	1,509	1,948
4.0	575	844	1,112	1,507	1,725	2,226
5.0	719	1,055	1,390	1,883	2,156	2,783

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-95: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	327	479	631	881	1,003	1,293
2.0	436	639	842	1,175	1,338	1,724
2.5	545	799	1,052	1,469	1,672	2,155
3.0	654	958	1,263	1,763	2,007	2,586
3.5	762	1,118	1,473	2,057	2,341	3,018
4.0	871	1,278	1,684	2,350	2,675	3,449
5.0	1,089	1,597	2,105	2,938	3,344	4,311

Climate Zone 3: South Region, Houston Weather Data

Table 2-96: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	347	508	670	991	1,117	1,425
2.0	462	678	893	1,322	1,489	1,900
2.5	578	847	1,116	1,652	1,862	2,375
3.0	693	1,016	1,339	1,983	2,234	2,850
3.5	809	1,186	1,563	2,313	2,606	3,325
4.0	924	1,355	1,786	2,644	2,979	3,800
5.0	1,155	1,694	2,232	3,305	3,724	4,750

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-97: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	403	591	778	1,154	1,299	1,658
2.0	537	787	1,038	1,538	1,733	2,211
2.5	671	984	1,297	1,923	2,166	2,764
3.0	806	1,181	1,557	2,307	2,599	3,316
3.5	940	1,378	1,816	2,692	3,032	3,869
4.0	1,074	1,575	2,076	3,076	3,465	4,422
5.0	1,343	1,969	2,594	3,845	4,331	5,527

Climate Zone 5: West Region El Paso Weather Data

Table 2-98: Energy Savings (Cooling kWh) for 13.08 SEER Replace-on-Burnout Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	281	412	543	775	879	1,130
2.0	375	550	724	1,034	1,172	1,507
2.5	469	687	905	1,292	1,465	1,883
3.0	562	824	1,086	1,551	1,758	2,260
23.5	656	962	1,267	1,809	2,051	2,636
4.0	750	1,099	1,448	2,068	2,344	3,013
5.0	937	1,374	1,811	2,585	2,930	3,766

Cooling, Early Retirement

Table 2-99 through Table 2-103 present the cooling energy savings (kWh) associated with the installation of a central heat pump following the early retirement of an HVAC system for all five Texas climate zones. These savings can be used with the replace-on-burnout energy savings in Table 2-66 through Table 2-71 to calculate annual cooling savings.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-99: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	861	961	1,062	1,210	1,292	1,480
2.0	1,147	1,282	1,416	1,613	1,722	1,973
2.5	1,434	1,602	1,770	2,016	2,153	2,466
3.0	1,721	1,922	2,124	2,420	2,583	2,959
3.5	2,008	2,243	2,477	2,823	3,014	3,452
4.0	2,295	2,563	2,831	3,226	3,444	3,946
5.0	2,869	3,204	3,539	4,033	4,305	4,932

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-100: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,303	1,455	1,608	1,858	1,980	2,270
2.0	1,738	1,941	2,144	2,477	2,639	3,026
2.5	2,172	2,426	2,680	3,096	3,299	3,783
3.0	2,606	2,911	3,216	3,716	3,959	4,539
3.5	3,041	3,396	3,752	4,335	4,619	5,296
4.0	3,475	3,881	4,287	4,954	5,279	6,052
5.0	4,344	4,852	5,359	6,193	6,599	7,565

Climate Zone 3: South Region, Houston Weather Data

Table 2-101: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,382	1,544	1,705	2,027	2,153	2,461
2.0	1,843	2,058	2,274	2,703	2,870	3,281
2.5	2,304	2,573	2,842	3,378	3,588	4,101
3.0	2,764	3,087	3,411	4,054	4,305	4,921
3.5	3,225	3,602	3,979	4,730	5,023	5,741
4.0	3,686	4,117	4,547	5,406	5,740	6,562
5.0	4,607	5,146	5,684	6,757	7,176	8,202

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-102: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,606	1,794	1,982	2,357	2,503	2,862
2.0	2,142	2,392	2,643	3,143	3,337	3,816
2.5	2,677	2,990	3,303	3,929	4,172	4,770
3.0	3,213	3,588	3,964	4,714	5,006	5,723
3.5	3,748	4,186	4,624	5,500	5,840	6,677
4.0	4,284	4,784	5,285	6,286	6,675	7,631
5.0	5,355	5,980	6,606	7,857	8,343	9,539

Climate Zone 5: West Region El Paso Weather Data

Table 2-103: Energy Savings (Cooling kWh) for 10.0 SEER Early Retirement Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9	18.0–20.9	21.0+
1.5	1,121	1,252	1,383	1,615	1,719	1,970
2.0	1,495	1,669	1,844	2,154	2,292	2,626
2.5	1,868	2,087	2,305	2,692	2,865	3,283
3.0	2,242	2,504	2,766	3,231	3,438	3,940
3.5	2,616	2,921	3,227	3,769	4,011	4,596
4.0	2,989	3,339	3,688	4,308	4,584	5,253
5.0	3,737	4,173	4,610	5,385	5,730	6,566

Heating, New Construction or Replace-on-Burnout of a Heat Pump

Table 2-104 through Table 2-108 present the energy savings (kWh) for heating load types associated with a central heat pump being installed during new construction or replacing a burned-out central heat pump for all five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-104: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	119	193	329	451	508	562
2.0	159	257	438	601	677	749
2.5	198	321	548	752	846	936
3.0	238	385	657	902	1,015	1,123
3.5	278	450	767	1,052	1,185	1,311
4.0	317	514	876	1,203	1,354	1,498
5.0	397	642	1,096	1,503	1,692	1,872

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-105: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	68	111	188	259	291	322
2.0	91	147	251	345	388	429
2.5	114	184	314	431	485	537
3.0	136	221	377	517	582	644
3.5	159	258	440	603	679	752
4.0	182	295	503	690	776	859
5.0	227	368	628	862	970	1,074

Climate Zone 3: South Region, Houston Weather Data

Table 2-106: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	36	59	101	138	155	172
2.0	49	79	134	184	207	229
2.5	61	98	168	230	259	286
3.0	73	118	201	276	311	344
3.5	85	138	235	322	362	401
4.0	97	157	268	368	414	458
5.0	121	197	335	460	518	573

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-107: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	28	45	77	106	120	132
2.0	37	61	103	142	160	177
2.5	47	76	129	177	199	221
3.0	56	91	155	213	239	265
3.5	65	106	181	248	279	309
4.0	75	121	207	284	319	353
5.0	93	151	258	354	399	441

Climate Zone 5: West Region El Paso Weather Data

Table 2-108: Energy Savings (Heating kWh) for 8.2 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	69	111	190	261	294	325
2.0	92	149	253	348	391	433
2.5	115	186	317	435	489	541
3.0	138	223	380	522	587	650
3.5	161	260	444	609	685	758
4.0	183	297	507	696	783	866
5.0	229	372	634	869	979	1,083

Heating, Replace-on-Burnout – Replacement of an Electric Resistance Furnace

Table 2-109 through Table 2-113 present the energy savings (kWh) per heating load type associated with a central heat pump replacing on burnout an electric resistance furnace for all five Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-109: Energy Savings (Heating kWh Only) for 3.41 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	5,847	5,921	6,057	6,179	6,236	6,290
2.0	7,796	7,894	8,075	8,238	8,314	8,386
2.5	9,745	9,868	10,094	10,298	10,393	10,483
3.0	11,694	11,841	12,113	12,358	12,471	12,579
3.5	13,643	13,815	14,132	14,417	14,550	14,676
4.0	15,591	15,788	16,151	16,477	16,628	16,772
5.0	19,489	19,735	20,188	20,596	20,785	20,965

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-110: Energy Savings (Heating kWh Only) for 3.41HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	3,411	3,453	3,531	3,601	3,634	3,665
2.0	4,548	4,605	4,708	4,802	4,845	4,887
2.5	5,685	5,756	5,886	6,002	6,057	6,108
3.0	6,822	6,907	7,063	7,203	7,268	7,330
3.5	7,959	8,058	8,240	8,403	8,479	8,552
4.0	9,096	9,209	9,417	9,604	9,691	9,773
5.0	11,370	11,511	11,771	12,005	12,113	12,217

Climate Zone 3: South Region, Houston Weather Data

Table 2-111: Energy Savings (Heating kWh Only) for 3.41 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	1,828	1,850	1,892	1,929	1,947	1,963
2.0	2,437	2,467	2,522	2,572	2,595	2,617
2.5	3,046	3,084	3,153	3,215	3,244	3,272
3.0	3,655	3,700	3,783	3,858	3,893	3,926
3.5	4,264	4,317	4,414	4,501	4,542	4,580
4.0	4,874	4,934	5,045	5,144	5,191	5,235
5.0	6,092	6,167	6,306	6,431	6,488	6,543

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-112: Energy Savings (Heating kWh Only) for 3.41 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	1,410	1,427	1,459	1,488	1,502	1,514
2.0	1,880	1,903	1,946	1,984	2,002	2,019
2.5	2,350	2,379	2,432	2,480	2,503	2,524
3.0	2,820	2,855	2,919	2,977	3,003	3,029
3.5	3,290	3,331	3,405	3,473	3,504	3,533
4.0	3,760	3,806	3,892	3,969	4,004	4,038
5.0	4,700	4,758	4,865	4,961	5,005	5,048

Climate Zone 5: West Region El Paso Weather Data

Table 2-113: Energy Savings (Heating kWh Only) for 3.41 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	3,444	3,487	3,566	3,636	3,669	3,701
2.0	4,593	4,650	4,754	4,849	4,892	4,934
2.5	5,741	5,812	5,943	6,061	6,115	6,168
3.0	6,889	6,974	7,131	7,273	7,339	7,401
3.5	8,037	8,137	8,320	8,485	8,562	8,635
4.0	9,185	9,299	9,509	9,697	9,785	9,868
5.0	11,482	11,624	11,886	12,122	12,231	12,335

Heating, Early Retirement – Replacement of a Heat Pump

See Table 2-104 through Table 2-108 for the energy savings (kWh) per heating load type associated with a central heat pump replacing another heat pump for all five Texas climate zones. As early retirement of a central heat pump is rare, replace-on-burnout heating savings are awarded for this measure.

Heating, Early Retirement – Replacement of an Electric Resistance Furnace

See Table 2-109 through Table 2-113 for the energy savings (kWh) per heating load type associated with a central heat pump replacing an electric resistance furnace for all five Texas climate zones.

Deemed Summer Demand Savings Tables

New Construction

Table 2-114 through Table 2-118 present the summer demand savings (kW) associated with a central heat pump being installed during new construction for all 5 Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-114: Demand Savings (Summer kW) for 14.0 SEER New Construction Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.05	0.12	0.19	0.17	0.23	0.36
2.0	0.07	0.16	0.25	0.22	0.31	0.48
2.5	0.09	0.20	0.32	0.28	0.38	0.60
3.0	0.11	0.24	0.38	0.33	0.46	0.72
3.5	0.12	0.29	0.45	0.39	0.54	0.84
4.0	0.14	0.33	0.51	0.44	0.62	0.96
5.0	0.18	0.41	0.64	0.56	0.77	1.19

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-115: Demand Savings (Summer kW) for 14.0 SEER New Construction Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.06	0.13	0.20	0.15	0.22	0.35
2.0	0.08	0.17	0.27	0.20	0.29	0.47
2.5	0.09	0.22	0.34	0.25	0.36	0.59
3.0	0.11	0.26	0.41	0.30	0.44	0.70
3.5	0.13	0.30	0.47	0.35	0.51	0.82
4.0	0.15	0.35	0.54	0.40	0.58	0.94
5.0	0.19	0.43	0.68	0.49	0.73	1.17

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 3: South Region, Houston Weather Data

Table 2-116: Demand Savings (Summer kW) for 14.0 SEER New Construction Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.05	0.12	0.19	0.17	0.23	0.36
2.0	0.07	0.16	0.25	0.22	0.31	0.48
2.5	0.09	0.20	0.32	0.28	0.38	0.60
3.0	0.11	0.24	0.38	0.33	0.46	0.72
3.5	0.12	0.29	0.45	0.39	0.54	0.84
4.0	0.14	0.33	0.51	0.44	0.62	0.96
5.0	0.18	0.41	0.64	0.56	0.77	1.19

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-117: Demand Savings (Summer kW) for 14.0 SEER New Construction Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.05	0.12	0.19	0.17	0.23	0.36
2.0	0.07	0.16	0.25	0.22	0.31	0.48
2.5	0.09	0.20	0.32	0.28	0.38	0.60
3.0	0.11	0.24	0.38	0.33	0.46	0.72
3.5	0.12	0.29	0.45	0.39	0.54	0.84
4.0	0.14	0.33	0.51	0.44	0.62	0.96
5.0	0.18	0.41	0.64	0.56	0.77	1.19

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 5: West Region El Paso Weather Data

Table 2-118: Demand Savings (Summer kW) for 14.0 SEER New Construction Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.06	0.13	0.20	0.15	0.22	0.35
2.0	0.08	0.17	0.27	0.20	0.29	0.47
2.5	0.09	0.22	0.34	0.25	0.36	0.59
3.0	0.11	0.26	0.41	0.30	0.44	0.70
3.5	0.13	0.30	0.47	0.35	0.51	0.82
4.0	0.15	0.35	0.54	0.40	0.58	0.94
5.0	0.19	0.43	0.68	0.49	0.73	1.17

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Replace-on-Burnout

Table 2-119 through Table 2-123 present the summer demand savings (kW) associated with a central heat pump replacing on burnout an HVAC system for all 5 Texas climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-119: Demand Savings (Summer kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.15	0.22	0.29	0.26	0.32	0.45
2.0	0.20	0.29	0.38	0.35	0.43	0.60
2.5	0.25	0.36	0.48	0.43	0.54	0.75
3.0	0.30	0.43	0.57	0.52	0.65	0.90
3.5	0.34	0.50	0.67	0.61	0.76	1.06
4.0	0.39	0.58	0.76	0.69	0.87	1.21
5.0	0.49	0.72	0.95	0.87	1.08	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-120: Demand Savings (Summer kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.16	0.23	0.30	0.25	0.32	0.45
2.0	0.21	0.31	0.40	0.33	0.43	0.60
2.5	0.26	0.38	0.51	0.41	0.53	0.75
3.0	0.31	0.46	0.61	0.50	0.64	0.90
3.5	0.37	0.54	0.71	0.58	0.74	1.05
4.0	0.42	0.61	0.81	0.66	0.85	1.21
5.0	0.52	0.77	1.01	0.83	1.06	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 3: South Region, Houston Weather Data

Table 2-121: Demand Savings (Summer kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.15	0.22	0.29	0.26	0.32	0.45
2.0	0.20	0.29	0.38	0.35	0.43	0.60
2.5	0.25	0.36	0.48	0.43	0.54	0.75
3.0	0.30	0.43	0.57	0.52	0.65	0.90
3.5	0.34	0.50	0.67	0.61	0.76	1.06
4.0	0.39	0.58	0.76	0.69	0.87	1.21
5.0	0.49	0.72	0.95	0.87	1.08	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-122: Demand Savings (Summer kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.15	0.22	0.29	0.26	0.32	0.45
2.0	0.20	0.29	0.38	0.35	0.43	0.60
2.5	0.25	0.36	0.48	0.43	0.54	0.75
3.0	0.30	0.43	0.57	0.52	0.65	0.90
3.5	0.34	0.50	0.67	0.61	0.76	1.06
4.0	0.39	0.58	0.76	0.69	0.87	1.21
5.0	0.49	0.72	0.95	0.87	1.08	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 5: West Region El Paso Weather Data

Table 2-123: Demand Savings (Summer kW) for 13.08 SEER Replace-on-Burnout Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.16	0.23	0.30	0.25	0.32	0.45
2.0	0.21	0.31	0.40	0.33	0.43	0.60
2.5	0.26	0.38	0.51	0.41	0.53	0.75
3.0	0.31	0.46	0.61	0.50	0.64	0.90
3.5	0.37	0.54	0.71	0.58	0.74	1.05
4.0	0.42	0.61	0.81	0.66	0.85	1.21
5.0	0.52	0.77	1.01	0.83	1.06	1.51

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Early Retirement

Table 2-124 through Table 2-128 present the summer demand savings (kW) associated with a central heat pump replacing an HVAC system for all five Texas climate zones. These savings can be used with the replace-on-burnout energy savings in Table 2-119 through Table 2-123 to calculate summer demand savings.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-124: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 1

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.59	0.66	0.73	0.70	0.77	0.89
2.0	0.78	0.88	0.97	0.94	1.02	1.19
2.5	0.98	1.10	1.21	1.17	1.28	1.49
3.0	1.18	1.31	1.45	1.40	1.53	1.79
3.5	1.37	1.53	1.69	1.64	1.79	2.08
4.0	1.57	1.75	1.94	1.87	2.04	2.38
5.0	1.96	2.19	2.42	2.34	2.55	2.98

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-125: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 2

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.63	0.70	0.77	0.72	0.79	0.92
2.0	0.84	0.93	1.03	0.96	1.05	1.23
2.5	1.04	1.17	1.29	1.20	1.31	1.54
3.0	1.25	1.40	1.55	1.44	1.58	1.84
3.5	1.46	1.63	1.80	1.68	1.84	2.15
4.0	1.67	1.87	2.06	1.91	2.10	2.46
5.0	2.09	2.33	2.58	2.39	2.63	3.07

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 3: South Region, Houston Weather Data

Table 2-126: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 3

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.59	0.66	0.73	0.70	0.77	0.89
2.0	0.78	0.88	0.97	0.94	1.02	1.19
2.5	0.98	1.10	1.21	1.17	1.28	1.49
3.0	1.18	1.31	1.45	1.40	1.53	1.79
3.5	1.37	1.53	1.69	1.64	1.79	2.08
4.0	1.57	1.75	1.94	1.87	2.04	2.38
5.0	1.96	2.19	2.42	2.34	2.55	2.98

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-127: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 4

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.59	0.66	0.73	0.70	0.77	0.89
2.0	0.78	0.88	0.97	0.94	1.02	1.19
2.5	0.98	1.10	1.21	1.17	1.28	1.49
3.0	1.18	1.31	1.45	1.40	1.53	1.79
3.5	1.37	1.53	1.69	1.64	1.79	2.08
4.0	1.57	1.75	1.94	1.87	2.04	2.38
5.0	1.96	2.19	2.42	2.34	2.55	2.98

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Climate Zone 5: West Region El Paso Weather Data

Table 2-128: Demand Savings (Summer kW) for 10.0 SEER Early Retirement Baseline – Zone 5

Size (tons)	SEER Range					
	14.5–14.9	15.0–15.9	16.0–16.9	17.0–17.9*	18.0–20.9	21.0+
1.5	0.63	0.70	0.77	0.72	0.79	0.92
2.0	0.84	0.93	1.03	0.96	1.05	1.23
2.5	1.04	1.17	1.29	1.20	1.31	1.54
3.0	1.25	1.40	1.55	1.44	1.58	1.84
3.5	1.46	1.63	1.80	1.68	1.84	2.15
4.0	1.67	1.87	2.06	1.91	2.10	2.46
5.0	2.09	2.33	2.58	2.39	2.63	3.07

* Heat pumps 17 SEER or greater are assumed to be two-stage heat pumps, while those under 17 SEER are assumed to be single-stage heat pumps. This results in slightly lower summer demand savings for 17.0-17.9 SEER heat pumps as compared to 16.0-16.9 SEER units.

Deemed Winter Demand Savings Tables

New Construction or Replace-on-Burnout of a Heat Pump

Table 2-129 through Table 2-133 present the winter demand savings (kW) associated with a central heat pump being installed during new construction or replacing a burned-out central heat pump.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-129: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.05	0.08	0.08	0.14	0.19	0.21
2.0	0.07	0.11	0.11	0.18	0.25	0.29
2.5	0.08	0.14	0.14	0.23	0.32	0.36
3.0	0.10	0.16	0.16	0.28	0.38	0.43
3.5	0.12	0.19	0.19	0.32	0.44	0.50
4.0	0.13	0.22	0.22	0.37	0.51	0.57
5.0	0.17	0.27	0.27	0.46	0.63	0.71

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-130: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.05	0.08	0.08	0.13	0.18	0.21
2.0	0.06	0.10	0.10	0.18	0.24	0.27
2.5	0.08	0.13	0.13	0.22	0.30	0.34
3.0	0.10	0.16	0.16	0.27	0.37	0.41
3.5	0.11	0.18	0.18	0.31	0.43	0.48
4.0	0.13	0.21	0.21	0.36	0.49	0.55
5.0	0.16	0.26	0.26	0.44	0.61	0.69

Climate Zone 3: South Region, Houston Weather Data

Table 2-131: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.04	0.06	0.06	0.11	0.15	0.17
2.0	0.05	0.09	0.09	0.15	0.20	0.22
2.5	0.07	0.11	0.11	0.18	0.25	0.28
3.0	0.08	0.13	0.13	0.22	0.30	0.34
3.5	0.09	0.15	0.15	0.25	0.35	0.39
4.0	0.11	0.17	0.17	0.29	0.40	0.45
5.0	0.13	0.21	0.21	0.36	0.50	0.56

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-132: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.03	0.05	0.05	0.09	0.13	0.14
2.0	0.04	0.07	0.07	0.12	0.17	0.19
2.5	0.06	0.09	0.09	0.15	0.21	0.24
3.0	0.07	0.11	0.11	0.18	0.25	0.28
3.5	0.08	0.13	0.13	0.21	0.29	0.33
4.0	0.09	0.14	0.14	0.25	0.34	0.38
5.0	0.11	0.18	0.18	0.31	0.42	0.47

Climate Zone 5: West Region El Paso Weather Data

Table 2-133: Demand Savings (Winter kW) for 8.2 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	0.05	0.08	0.08	0.13	0.18	0.20
2.0	0.06	0.10	0.10	0.17	0.24	0.27
2.5	0.08	0.13	0.13	0.22	0.30	0.33
3.0	0.09	0.15	0.15	0.26	0.36	0.40
3.5	0.11	0.18	0.18	0.30	0.42	0.47
4.0	0.13	0.20	0.20	0.35	0.47	0.53
5.0	0.16	0.25	0.25	0.43	0.59	0.67

Replace-on-Burnout – Replacement of Electric Resistance Furnace

Table 2-134 through Table 2-138 present the winter demand savings (kW) per heating load type associated with a central heat pump replacing an electric resistance furnace for all five climate zones.

Climate Zone 1: Panhandle Region, Amarillo Weather Data

Table 2-134: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 1

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	2.05	2.08	2.14	2.19	2.21	2.24
2.0	2.73	2.78	2.85	2.92	2.95	2.98
2.5	3.42	3.47	3.57	3.65	3.69	3.73
3.0	4.10	4.16	4.28	4.38	4.43	4.47
3.5	4.79	4.86	4.99	5.11	5.17	5.22
4.0	5.47	5.55	5.70	5.84	5.91	5.97
5.0	6.84	6.94	7.13	7.30	7.38	7.46

Climate Zone 2: North Region, Dallas / Ft. Worth Weather Data

Table 2-135: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 2

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	2.33	2.36	2.41	2.46	2.49	2.51
2.0	3.11	3.15	3.22	3.29	3.32	3.35
2.5	3.88	3.93	4.02	4.11	4.15	4.18
3.0	4.66	4.72	4.83	4.93	4.97	5.02
3.5	5.44	5.51	5.63	5.75	5.80	5.85
4.0	6.21	6.29	6.44	6.57	6.63	6.69
5.0	7.77	7.87	8.05	8.21	8.29	8.36

Climate Zone 3: South Region, Houston Weather Data

Table 2-136: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 3

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	1.94	1.97	2.01	2.05	2.07	2.09
2.0	2.59	2.62	2.68	2.74	2.76	2.79
2.5	3.24	3.28	3.35	3.42	3.45	3.48
3.0	3.89	3.94	4.03	4.11	4.14	4.18
3.5	4.53	4.59	4.70	4.79	4.84	4.88
4.0	5.18	5.25	5.37	5.48	5.53	5.57
5.0	6.48	6.56	6.71	6.84	6.91	6.97

Climate Zone 4: Valley Region Corpus Christi Weather Data

Table 2-137: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 4

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	1.66	1.69	1.72	1.76	1.77	1.79
2.0	2.22	2.25	2.30	2.34	2.36	2.38
2.5	2.77	2.81	2.87	2.93	2.96	2.98
3.0	3.33	3.37	3.45	3.52	3.55	3.58
3.5	3.88	3.93	4.02	4.10	4.14	4.17
4.0	4.44	4.49	4.60	4.69	4.73	4.77
5.0	5.55	5.62	5.74	5.86	5.91	5.96

Climate Zone 5: West Region El Paso Weather Data

Table 2-138: Demand Savings (Winter kW) for 3.41 HSPF Baseline – Zone 5

Size (tons)	HSPF Range					
	8.5	8.6 – 8.9	9.0 – 9.2	9.3 – 9.4	9.5 – 9.6	≥ 9.7
1.5	2.27	2.30	2.36	2.41	2.43	2.45
2.0	3.03	3.07	3.14	3.21	3.24	3.27
2.5	3.79	3.84	3.93	4.01	4.05	4.08
3.0	4.55	4.61	4.72	4.81	4.86	4.90
3.5	5.31	5.38	5.50	5.61	5.67	5.72
4.0	6.07	6.14	6.29	6.42	6.48	6.53
5.0	7.58	7.68	7.86	8.02	8.09	8.17

Early Retirement – Replacement of a Heat Pump

See Table 2-129 through Table 2-133 for the winter demand savings (kW) associated with a central heat pump replacing another heat pump for all five Texas climate zones. As early retirement of a central heat pump is rare, replace-on-burnout winter peak demand savings are awarded for this measure.

Early Retirement – Replacement of an Electric Resistance Furnace

See Table 2-134 through Table 2-138 for the winter demand savings (kW) associated with a central heat pump replacing an electric resistance furnace for all five Texas climate zones

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a central heat pump unit is 15 years based on the current DOE Final Rule standards for central heat pumps.[141]

[141] Final Rule: Standards, Federal Register, 76 FR 37408 (June 27, 2011) and associated Technical Support Document. Accessed 10/21/2014. 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.

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 Heat Pumps.[142]

Program Tracking Data & 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:

- Decision/action type (early retirement, replace-on-burnout, new construction)
- Cooling capacity of the installed unit (tons)
- Seasonal Energy Efficiency Ratio (SEER) of the installed unit
- Heating Seasonal Performance Factor (HSPF) of the installed unit
- Climate zone of the site
- Type of unit replaced (e.g., electric resistance furnace, air source heat pump)
- Age of the replaced unit (Early Retirement only)
- Recommended: retired unit model number, serial number, and manufacturer (Early Retirement only)
- Recommended: photograph of retired unit nameplate (Early Retirement only)
- Recommended: customer responses to survey questionnaire for early retirement eligibility determination (Early Retirement only)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- ASHRAE 90.1-1999 (Residential Buildings)
- ACCA Manual J Residential Load Calculation (8th Edition)[143]

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

143 https://www.acca.org/store/product.php?pid=172.

Document Revision History

Table 2-139: Central Heat Pump 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 Associates, 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.
v3,1	11/05/2015	TRM v3.1 update. Revision of cooling savings to reflect heat-pump-specific performance curves. Extension of Early Retirement cooling savings tables to higher SEER values. Clarification around summer demand savings for single-stage and two-stage units.

2.2.5 Room Air Conditioner Measure Overview

TRM Measure ID: R-HV-WA

Market Sector: Residential

Measure Category: HVAC

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction, Early Retirement

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 high-efficiency room air conditioner in a newly-constructed home or a room air conditioner replaced with a higher efficiency room air conditioner in a dwelling occupied by a residential energy consumer.

Eligibility Criteria

The deemed savings apply only to a room air conditioner replaced with a higher efficiency room air conditioner.

Utilities should refer to the January 2015 memo, "Considerations for early replacement of residential equipment,"[144] when designing programs that permit savings to be claimed for early retirement. To qualify for early retirement, the room air conditioner must replace an existing, working unit with an age of at least four years but no greater than 20 years.

In order to be awarded early retirement savings, the unit to be replaced must be functioning at the time of removal.

[144] 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.

Baseline Condition

For new construction and replace-on-burnout, the baseline is assumed to be a new room air conditioning unit with a CEER rating that is compliant with the current federal standard,[145] effective June 1, 2014. The new standard is stated in terms of the Combined Energy Efficiency Ratio (CEER), which accounts for standby/off-mode energy usage. The new standard is stated in terms of the 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.

Table 2-140: Room Air Conditioner Baseline Efficiencies for New Construction, Replace-on-Burnout, and Early Retirement

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	NC/ROB Baseline CEER
No	Yes	< 8,000	9.7	11.0
		> 8,000 and < 14,000	9.8	10.9
		> 14,000 and < 20,000	9.7	10.7
		> 20,000 and < 25,000	8.5	9.4
		> 25,000	8.5	9.0
No	No	< 8,000	9.0	10.0
		> 8,000 and < 11,000	8.5	9.6
		> 11,000 and < 14,000	8.5	9.5
		> 14,000 and < 20,000	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

145 DOE minimum efficiency standard for residential room air conditioners. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41.

High-Efficiency Condition

ENERGY STAR® specifications effective October 30, 2015 are provided in Table 2-141 as the efficient condition.[146] Energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Table 2-141: Room Air Conditioner Efficient Condition Specifications

Reverse Cycle (Yes/No)	Louvered Sides (Yes/No)	Capacity (Btu/hr)	Minimum CEER as of October 30, 2015
No	Yes	< 8,000	12.1
		≥ 8,000 and < 14,000	12.0
		≥ 14,000 and < 20,000	11.8
		≥ 20,000 and < 25,000	10.3
		≥ 25,000	9.9
No	No	< 8,000	11.0
		≥ 8,000 and < 11,000	10.6
		≥ 11,000 and < 14,000	10.5
		≥ 14,000 and < 20,000	10.2
		≥ 20,000	10.3
Yes	Yes	< 20,000	10.8
		≥ 20,000	10.2
Yes	No	< 14,000	10.2
		≥ 14,000	9.6
Casement-only		All capacities	10.5
Casement-slider		All capacities	11.4

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Peak demand and annual energy savings for room air conditioners should be calculated as shown next.

[146] ENERGY STAR® Program Requirements Product Specification for Room Air Conditioners: Eligibility Criteria Version 4.0. http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Final%20Version%204.0%20Room%20Air%20Conditioners%20Specification.pdf. February 20, 2015.

New Construction or Replace-on-Burnout

Energy Savings Algorithms

$$kWh_{Savings,C} = CAP \times \frac{1\ kW}{1,000\ W} \times AOH_C \times \left(\frac{1}{CEER_{Base}} - \frac{1}{CEER_{RAC}}\right)$$

Equation 48

Where:

CAP	=	*Rated equipment cooling capacity of the installed room air conditioner (Btu/hr)*
AOH_C	=	*Annual operating hours for cooling (Table 2-142)*
$CEER_{Base}$	=	*Combined Energy Efficiency Ratio of the baseline cooling equipment (Table 2-140)*
$CEER_{RAC}$	=	*Combined Energy Efficiency Ratio of the installed room air conditioner*

Table 2-142: Room Air Conditioner Annual Operating Hours for Cooling[147]

Climate Zone	AOH_C
Climate Zone 1: Panhandle	820
Climate Zone 2: North	1,374
Climate Zone 3: South	1,308
Climate Zone 4: Valley	2,150
Climate Zone 5: West	1,204

Demand Savings Algorithms

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

Equation 49

Where:

CAP	=	*Rated equipment cooling capacity of the installed room air conditioner (Btu/hr)*

[147] Association of Home Appliance Manufacturers (AHAM) Room Air Conditioner Cooling Calculator. http://www.cooloff.org/sub_cool.html.

$CEER_{Base}$ = *Combined Energy Efficiency Ratio of the baseline cooling equipment (Table 2-140)*

$CEER_{RAC}$ = *Combined Energy Efficiency Ratio of the installed room air conditioner*

CF = *Coincidence Factor = 0.87 (default)*[148]

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 (8 – 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 Volume 3, Appendix D of this document.

Where:

RUL = *Remaining Useful Life (see Table 2-143)*

EUL = *Estimated Useful Life = 8 years*

Table 2-143: Remaining Useful Life (RUL) of Replaced Room Air Conditioner

Age of Replaced Unit (years)	RUL (years)	Age of Replaced Unit (years)	RUL (years)
4	5.2	9	4.0
5	5.2	10	3.0
6	5.2	11	2.0
7	5.2	12	1.0
8	5.0	13[149,150]	0.0

148 Air Conditioning Contractors of America (ACCA) Manual S recommends that residential air conditioners be sized at 115% of the maximum cooling requirement of the house. Assuming that the house's maximum cooling occurs during the hours of 4 to 5 PM, the guideline leads to a coincidence factor for residential HVAC measures of 1.0/1.15 = 0.87.

149 RULs are capped at the 75th percentile of equipment age, 13 years, based on DOE survival curves. Systems older than 13 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

150 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

Room air conditioners have an estimated useful life of 8 years. This estimate is consistent with the age at which approximately 50 percent of the room air conditioners installed in a given year will no longer be in service, as described by the survival function in Figure 2-5.

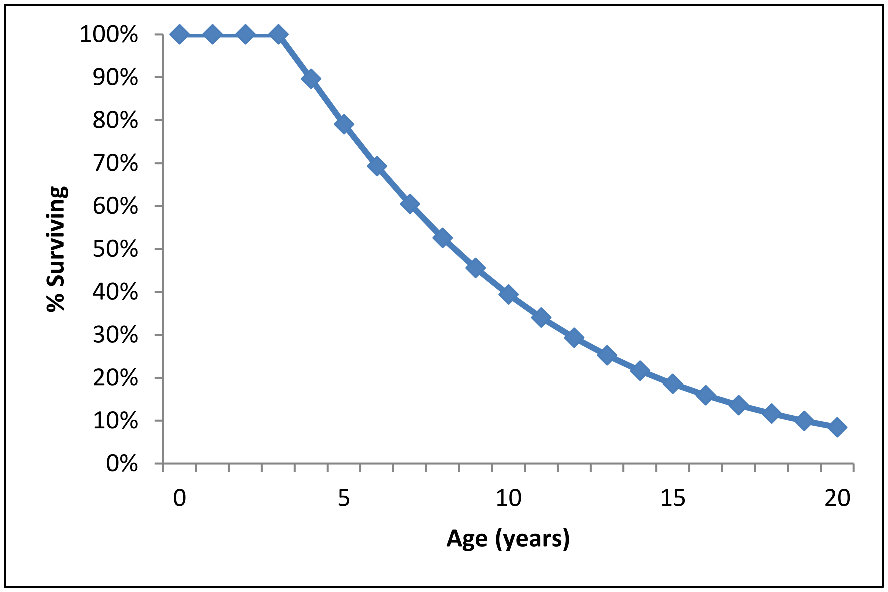
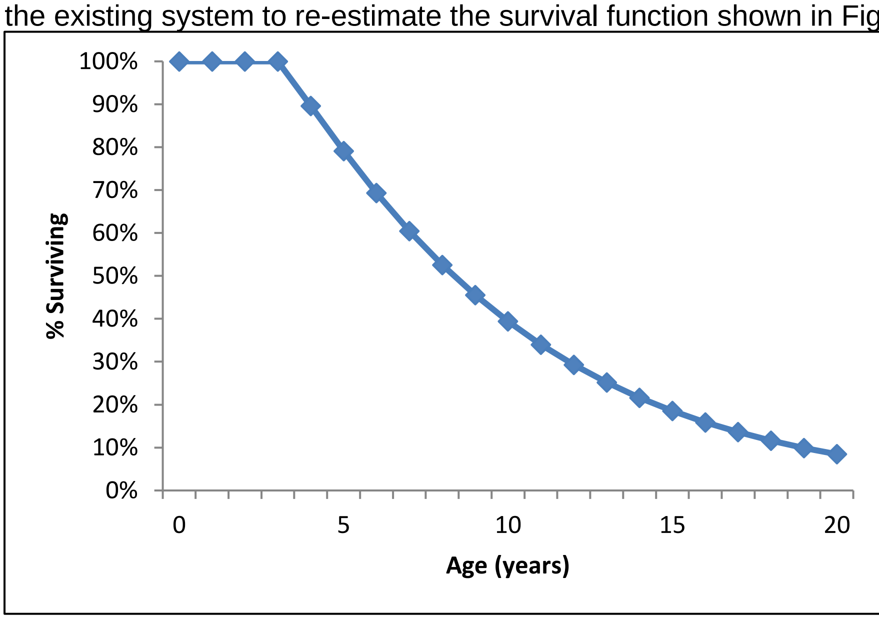


Figure 2-5: Survival Function for Room Air Conditioners[151]

The method for estimating the remaining useful life (RUL) of a replaced system uses the age of the existing system to re-estimate the survival function shown in Figure 2-5.



151 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: http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053.

Figure 2-5The age of the room air conditioner being replaced is found on the horizontal axis, and the corresponding percentage of surviving room air conditioners 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.

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 50

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 51

Where:

CAP = *Rated equipment cooling capacity of the installed room air conditioner (Btu/hr)*

AOH_C = *Annual operating hours for cooling (Table 2-142)*

$CEER_{ROB}$ = *Combined Energy Efficiency Ratio of the replace-on-burnout baseline cooling equipment (Table 2-140)*

EER_{ER} = *Energy Efficiency Ratio of the early retirement baseline cooling equipment (Table 2-140)*

$CEER_{RAC}$ = *Combined Energy Efficiency Ratio of the installed room air conditioner*

Summer Demand Savings Algorithms

To calculate demand savings for the early retirement of a room air conditioner, 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:

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

Equation 52

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

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

Equation 53

Deemed Energy Savings Tables

Replace-on-Burnout

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

Early Retirement

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

Replace-on-Burnout

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

Early Retirement

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

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a room air conditioning unit is 8 years based on the Technical Support Document for the current DOE Final Rule standards for room air conditioners.[152]

This value is consistent with the EUL reported in the Department of Energy 76 Final Rule 52852 Technical Support Document for Energy Conservation Standards for Room Air Conditioners.[153]

Program Tracking Data & 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:

- Decision/action type (Early Retirement, Replace-on-Burnout, New Construction)
- Cooling capacity of the installed unit (Btu/hr)
- Combined Energy Efficiency Ratio (CEER) of the unit installed
- Climate zone of the site
- Age of the replaced unit (Early Retirement only)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for room air conditioners.
- Code of Federal Regulations, 10 CFR 430.32(b)

[152] The median lifetime was calculated using the survival function outlined in the DOE Technical Support Document. Final Rule: Standards, Federal Register, 76 FR 22454 (April 21, 2011) and associated Technical Support Document. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2007-BT-STD-0010-0053.

[153] Department of Energy, Federal Register, 76 FR 52852, Technical Support Document: 8.2.2.6 Product Lifetime. April 2011. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/41.

Document Revision History

Table 2-144: Room Air Conditioner 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 Associates, 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.

2.3 RESIDENTIAL: BUILDING ENVELOPE

2.3.1 Air Infiltration Measure Overview

TRM Measure ID: R-BE-AI

Market Sector: Residential

Measure Category: Building Envelope

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Algorithm and Estimates

Measure Description

This measure reduces air infiltration into the residence, using pre- and post-treatment blower door air pressure readings to confirm air leakage reduction. Homes treated for air infiltration reduction must have electric air conditioning to qualify for these deemed savings values.

Eligibility Criteria

There is an upper limit of 5.2 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. At their utility's discretion, this cap may not apply to homes implementing the measure under low-income programs.[154] Utilities may require certification or competency testing of personnel who will perform the blower door tests.

[154] 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).

Air leakage should be assessed following Building Performance Institute (BPI) standards through testing. In some limited cases, where testing is not possible or unsafe (e.g. due to potential presence of asbestos), 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.[155]

Utilities' program manuals should be consulted for health and safety considerations related to 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 2013 Lawrence Berkeley National Laboratory (LBNL) analysis of air leakage measurements of US houses.[156] The LBNL study showed that approximately 95 percent of the home infiltration rates were below a normalized leakage rate of 2.0. Normalized leakage can be converted to CFM_{50}/ft^2 using Equation 54 through Equation 56.

$$NL = 1,000 \times \frac{ELA_4}{A \times 0.3048^2} \times \left(\frac{H \times 0.3048}{2.5\,m}\right)^{0.3}$$

Equation 54

$$Q_{50} = ELA_4 \Big/ \left(\sqrt{\frac{\rho}{2(4\,Pa)}} \times \left(\frac{4\,Pa}{50\,Pa}\right)^{0.65}\right)$$

Equation 55

$$CFM_{50,pre}/ft^2 = \frac{Q_{50} \times 60 \times 35.3147}{A}$$

Equation 56

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155 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."*

156 Chan, W.R., Joh, J., and Sherman, M. H. Analysis of air leakage measurements of US houses. Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory (LBNL), p. 616-625.

Where:

NL	=	*Normalized Leakage = 2.0 from LBNL study*
ELA_4	=	*Area of an orifice that would result in the same air-flow through the building envelope at a pressure difference of 4 Pa (m^2)*
A	=	*Average area of a home in Texas from RECS 2009 (ft^2) = 1,757 ft^2*
H	=	*Ceiling height (ft) = 8.5 (default)* [157]
0.3048	=	*Constant to convert from feet to meters*
Q_{50}	=	*Leakage rate at 50 Pa (m^3/s)*
ρ	=	*1.2 kg/m^3 from LBNL study*
$CFM_{50,pre}/ft^2$	=	*Maximum per-square-foot pre-installation infiltration rate*
60	=	*Constant to convert from minutes to seconds*
35.3147	=	*Constant to convert from cubic meters to cubic feet*

Using the above approach, the maximum per-square-foot pre-installation infiltration rate is 5.2. 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}/ft^2 of 5.2 or lower.

High-Efficiency Condition

Blower door air pressure measurements will be used to ensure that air infiltration in a residence shall not be less than the standards set forth in Equation 57, based on floor area and number of bedrooms.[158] These calculated minimum CFM_{50} values assume two occupants for a one-bedroom dwelling unit and an additional person for each additional bedroom. 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 2-145).

$$\boldsymbol{Min\ CFM_{50}} = [\mathbf{0.03} \times \boldsymbol{A_{Floor}} + \mathbf{7.5} \times \boldsymbol{OCC}] \times \boldsymbol{N}$$

Equation 57

Where:

$Min\ CFM_{50}$	=	*Minimum final ventilation rate (CFM_{50})*

157 Typical ceiling height of 8 feet adjusted to account for greater ceiling heights in some areas of a typical residence.

158 ASHRAE 62.2-2013. CFM_{Nat} values converted to CFM_{50} values by multiplying by appropriate N factor.

A_{Floor}	=	*Floor area (ft²)*
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 2-145)*

Table 2-145: N Factors[159]

Shielding	Number of Stories		
	Single Story	Two Story	3 or More Stories
Well shielded	22.2	17.8	15.5
Normal	18.5	14.8	13.0
Exposed	16.7	13.3	11.7

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

For climate zones 1 through 4, building load simulation software that calculates hourly load data was used to create energy and summer peak demand savings for a series of models. The software used was ESPRE 2.1 (EPRI Simplified Program for Residential Energy.) The base model of the prototype home was a model that was calibrated to residential load data by Planergy, Inc. The load data used for calibration was based on the South Texas End-Use Study, 1990 by Central Power and Light.

Building shell measures are sensitive to weather, and Texas is somewhat unique because there is a great difference in weather patterns between Amarillo in the northern panhandle and Corpus Christi in south Texas. A series of models were created to determine the difference in weather data throughout the eight weather regions in Texas as defined in the Model Energy Code. In an effort to simplify deemed savings values, available TMY weather data from ten different regions was analyzed. Based on the results, the different weather regions were collapsed down to the following four regions.

- Climate Zone 1: Panhandle Region (Amarillo weather data)
- Climate Zone 2: North Region (Dallas weather data)
- Climate Zone 3: South Region (Houston weather data)
- Climate Zone 4: Valley Region (Corpus Christi weather data)

Savings values for climate zone 5 (West Region) were appended at a later date. The deemed savings estimates for climate zone 5 were developed using demand and energy savings calculated using EnergyGauge, a DOE-2 based residential load simulator, for a prototypical

[159] 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. http://www.waptac.org/data/files/Website_docs/Technical_Tools/Building%20Tightness%20Limits.pdf.

home.[160] The weather inputs used for the simulation are TMY3 weather data for the El Paso International Airport.

The model runs calculated energy use for the prototypical home prior to the air infiltration reduction. Next, change-case models were run to calculate energy use after steps had been taken to reduce air infiltration in the home.

For climate zone 5, summer peak savings were calculated by taking the difference in demand at the hour when the summer peak is likely to occur. The day of the peak was determined based on TMY3 weather data: the summer peak day, June 15, had the most extreme combination of high temperature and cooling degree days. A day in June, rather than August, was chosen, as the modeling software is agnostic to the month of the year, and only time of day and weather factors are important to estimating demand. The hour of the peak was assumed to be 3-4pm in the summer, based on the historic occurrence of system peak for the El Paso system.

In order to develop winter peak savings values for all climate zones, a whole home simulation model was developed using EnergyGauge. Prototypical home characteristics were selected using available data on the construction, occupancy, and equipment characteristics of Texas homes.[161] The predicted annual energy consumption of the model was benchmarked using data from the Energy Information Administration’s Residential Energy Consumption Survey (RECS) for homes of similar heating types and floor area. Base and change case models were run using parameters matching the baseline and efficiency conditions of the measure. From the hourly output for each run, a winter peak load factor representing the relationship between energy savings and winter peak savings was calculated as follows:

$$\boldsymbol{Winter\ Peak\ Load\ Factor} = \frac{\boldsymbol{Modeled\ Annual\ Energy\ Savings}}{\boldsymbol{8,760 \times Modeled\ Winter\ Peak\ Demand\ Savings}}$$

The winter peak load factor was then applied to the existing deemed savings to derive a value for the winter peak demand savings as follows:

$$\boldsymbol{Winter\ Peak\ Demand\ Savings} = \frac{\boldsymbol{Existing\ Annual\ Energy\ Savings}}{\boldsymbol{8,760 \times Winter\ Peak\ Load\ Factor}}$$

Deemed Energy Savings Tables

Table 2-146 presents the energy savings per CFM50 reduction for a residential air sealing project. The following formula shall be used to calculate deemed energy savings for infiltration efficiency improvements.

160 For a list of input values used in these models refer to 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.

161 For a list of input values used in these models refer to 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.

$$\boldsymbol{Deemed\ Energy\ Savings} = \boldsymbol{CFM_{50}} \times \boldsymbol{V_E}$$

Equation 58

Where:

CFM_{50} = *Air infiltration reduction in Cubic Feet per Minute at 50 Pascal*

V_E = *Corresponding value in Table 2-146*

Table 2-146: Energy Savings V_E per CFM_{50} Reduction

Region	kWh Impact per CFM_{50} Reduction		
	Gas Heat	Resistance Heat	Heat Pump Heat
Climate Zone 1: Panhandle	0.1262	1.6673	0.7933
Climate Zone 2: North	0.1929	1.0565	0.5046
Climate Zone 3: South	0.2694	0.7945	0.4438
Climate Zone 4: Valley	0.6268	0.9732	0.7368
Climate Zone 5: West	0.1212	0.8096	0.5046*

* Savings specific to homes in climate zone 5 with heat pumps installed are not currently available for this measure. In their absence, savings values associated with climate zone 2 may be used instead.

Deemed Summer Demand Savings Tables

Table 2-147 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.

$$\boldsymbol{Deemed\ Summer\ Demand\ Savings} = \boldsymbol{CFM_{50}} \times \boldsymbol{V_S}$$

Equation 59

Where:

CFM_{50} = *Air infiltration reduction in Cubic Feet per Minute at 50 Pascal*

V_S = *Corresponding value in Table 2-147*

Table 2-147: Peak Summer Demand Savings V_S per CFM_{50} Reduction

Region	Summer kW Impact per CFM_{50} Reduction
Climate Zone 1: Panhandle	0.00024
Climate Zone 2: North	0.00019
Climate Zone 3: South	0.00026
Climate Zone 4: Valley	0.00043
Climate Zone 5: West	0.00021

Deemed Winter Demand Savings Tables

Table 2-148presents 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:

$$\boldsymbol{Deemed\ Winter\ Demand\ Savings = CFM_{50} \times V_W}$$

Equation 60

Where:

CFM_{50} = *Air infiltration reduction in Cubic Feet per Minute at 50 Pascal*

V_W = *Corresponding value in Table 2-148*

Table 2-148: Peak Winter Demand Savings V_W per CFM_{50} Reduction

Region	Winter kW Impact per CFM_{50} Reduction	
	Electric Resistance	Heat Pump[162]
Climate Zone 1: Panhandle	0.000842	0.000553
Climate Zone 2: North	0.000616	0.000261
Climate Zone 3: South	0.000486	0.000221
Climate Zone 4: Valley	0.000528	0.000305
Climate Zone 5: West	0.000534	0.000261*

* Savings specific to homes in climate zone 5 with heat pumps installed are not currently available for this measure. In their absence, savings values associated with climate zone 2 may be used instead.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

According to the DEER Final Report December 2008, the estimated useful life is 11 years for air infiltration reduction.

162 Savings specific to homes in climate zone 5 with heat pumps installed are not currently available for this measure. In their absence, savings values associated with climate zone 2 may be used instead.

Program Tracking Data & 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
- Pre-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Post-retrofit air infiltration in cubic feet per minute at 50 Pascal
- Heating type (gas, resistance heat, heat pump)
- Square footage of the house
- Shielding level (well shielded, normal, exposed)
- Number of bedrooms
- Number of stories
- Number of occupants

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates 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

This section is not applicable.

Document Revision History

Table 2-149: 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.

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, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

Ceiling insulation savings are calculated per square foot of treated ceiling area above a conditioned space. To qualify for these deemed savings values, ceiling insulation may be added only for customers with electric air conditioning in their homes, or for customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs

Eligibility Criteria

This measure applies to customers with electric air conditioning in their homes, or to customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Baseline Condition

In existing construction, ceiling insulation levels vary greatly depending on the age of the home, type of insulation, and activity in the attic (such as using the attic for storage and HVAC equipment). Deemed savings tables are based on the current level of ceiling insulation in the home from R-0 to R-22. The current insulation level of each home will 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, the existing R-value will be based upon the R-value of the existing insulation prior to removal.

High-Efficiency Condition

A ceiling insulation level of R-30 is recommended throughout Texas as prescribed by the Department of Energy. The combined R-values of the existing insulation and the insulation being added will total at least R-30. Deemed savings are also provided for R-38 insulation. The R-value of the existing insulation can be no greater than R-22.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

For climate zones 1 through 4, building load simulation software that calculates hourly load data was used to create energy and summer peak demand savings for a series of models. The software used was ESPRE 2.1 (EPRI Simplified Program for Residential Energy.) The base model of the prototype home was a model that was calibrated to residential load data by Planergy, Inc. The load data used for calibration was based on the South Texas End-Use Study, 1990 by Central Power and Light.

Building shell measures are sensitive to weather, and Texas is somewhat unique because there is a great difference in weather patterns between Amarillo in the northern panhandle and Corpus Christi in south Texas. A series of models were created to determine the difference in weather data throughout the eight weather regions in Texas as defined in the Model Energy Code. In an effort to simplify deemed savings values, available TMY weather data from ten different regions was analyzed. Based on the results, the different weather regions were collapsed down to the following four regions.

- Climate Zone 1: Panhandle Region (Amarillo weather data)
- Climate Zone 2: North Region (Dallas weather data)
- Climate Zone 3: South Region (Houston weather data)
- Climate Zone 4: Valley Region (Corpus Christi weather data)

Savings values for climate zone 5 (West Region) were appended at a later date. The deemed savings estimates for climate zone 5 were developed using demand and energy savings calculated using EnergyGauge, a DOE-2 based residential load simulator, for a prototypical home. Prototypical home characteristics used for these models may have been modified from those shown in Table 2-150.[163] The weather inputs used for the simulation are TMY3 weather data for the El Paso International Airport.

The model runs calculated energy use for the prototypical home prior to the installation of the ceiling insulation measure. Next, change-case models were run to calculate energy use with the ceiling insulation measure in place.

[163] For a list of input values used in these models refer to 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.

For climate zone 5, summer peak savings were calculated by taking the difference in demand at the hour when the summer peak is likely to occur. The day of the peak was determined based on TMY3 weather data: the summer peak day, June 15, had the most extreme combination of high temperature and cooling degree days. A day in June, rather than August, was chosen, as the modeling software is agnostic to the month of the year, and only time of day and weather factors are important to estimating demand. The hour of the peak was assumed to be 3-4pm in the summer, based on the historic occurrence of system peak for the El Paso system.

In order to develop winter peak savings values for all climate zones, a whole home simulation model was developed using EnergyGauge. Prototypical home characteristics (which may diverge from those outlined in Table 2-150) were selected using available data on the construction, occupancy, and equipment characteristics of Texas homes.[164] The predicted annual energy consumption of the model was benchmarked using data from the Energy Information Administration's Residential Energy Consumption Survey (RECS) for homes of similar heating types and floor area. Base and change case models were run using parameters matching the baseline and efficiency conditions of the measure. From the hourly output for each run, a winter peak load factor representing the relationship between energy savings and winter peak savings was calculated as follows:

$$\textit{Winter Peak Load Factor} = \frac{\textit{Modeled Annual Energy Savings}}{8{,}760 \times \textit{Modeled Winter Peak Demand Savings}}$$

Equation 61

The winter peak load factor was then applied to the existing deemed savings to derive a value for the winter peak demand savings as follows:

$$\textit{Winter Peak Demand Savings} = \frac{\textit{Existing Annual Energy Savings}}{8{,}760 \times \textit{Winter Peak Load Factor}}$$

Equation 62

[164] For a list of input values used in these models refer to 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.

Table 2-150: Residential Ceiling Insulation – Prototypical Home Characteristics, Climate Zones 1-4

Shell Characteristic	Value	Source
Conditioned Area	1,850 square feet	South Texas End Use Study, Central Power and Light, 1990, Table 3-1 average sq. ft. conditioned area – 1854 sq. ft.; Entergy 1984 Baseline Study, average sq. ft. single family home 1834 sq. ft.; baseline data from SPS and AEP utilities efficiency programs is similar for existing homes (sq. ft. within 7% of 1850 sq. ft.)
Foundation	Slab-on-grade, no edge insulation	Entergy 1984 Baseline Study single family homes 56% slab foundation, 44% pier & beam; pier & beam foundation varies 1-4% in energy and demand from slab foundation model
Base Ceiling Insulation	R-0 to R-22	Existing insulation level
Change Ceiling Insulation	R-30	Efficiency measure - retrofit insulation level as required by DOE and Texas Department of Housing and Community Affairs programs in Texas
Wall Insulation	R-10.26	ESPRE default based on wood frame, 4" wall stud, sheathing, siding or brick, R-11 insulation with ½" gypsum, SPS Baseline data for 1998 IRP average wall insulation R-10.94
Window Area	10.2% of floor area (~13-15% of wall area)	Average window area per wall used during calibration of model; window area equal for each wall orientation
Air Infiltration	1.1 and 0.9 ACH (winter, summer)	Average air changes per hour of air infiltration for existing homes used during calibration of model
Window U-value	0.72	WTU Baseline Survey, 1996 and WTU's Residential MARS database; U-0.72 represents a mix of single and double pane windows in existing homes
Thermostat Settings	70 winter; 78 summer	Average thermostat settings used during calibration of model
Orientation	Square house	To average effect of orientation of building due to a wide variety of building configurations and orientations; walls are equal area and face north/south/east/west
Duct Losses	25% overall loss (thermal and air leakage)	Average duct losses for existing homes used during calibration of model
Air Conditioning	10.0 SEER	SPS Baseline data for 1998 IRP, residential AC replacement programs average SEER 10.2 of 1,010 replaced units, NAECA standard is 10.0
Gas Heating	78 AFUE	Annual Fuel Utilization Efficiency - base gas furnace efficiency
Electric Resistance Heat	COP 1.0	Coefficient of Performance for central electric resistance heating systems
Heat Pump	10.0 SEER and 7.2 HSPF	SPS Baseline data for 1998 IRP, residential AC replacement programs average SEER 10.2 of 1,010 replaced units. Average HSPF based on Carrier Product Data 1999, 10.0 SEER

Deemed savings for R-38 insulation are currently estimated by applying an adjustment factor to modeled savings for R-30 insulation. The following adjustment factors were developed by applying the UAΔT heat transfer relationship, where the U-factor (thermal transmittance) is proportional to the 1 divided by the R-value (thermal resistance). The AΔT component is consistent for both the R-30 and R-38 cases and cancels out to yield the following:

$$\boldsymbol{Adjustment\ Factor} = \frac{{}^{\mathbf{1}}\!/_{\boldsymbol{Base\ R\ Value}} - {}^{\mathbf{1}}\!/_{\mathbf{38}}}{{}^{\mathbf{1}}\!/_{\boldsymbol{Base\ R\ Value}} - {}^{\mathbf{1}}\!/_{\mathbf{30}}}$$

Equation 63

The adjustment factors will be replaced with energy model estimates in TRM v4.0.

Table 2-151: R-38 Adjustment Factors

Base R-Value	R-0	R-1 to R-4	R-5 to R-8	R-9 to R-14	R-15 to R-22
Adjustment Factor	1.01	1.02	1.06	1.14	1.39

For homes with evaporative cooling units installed, energy models were used to estimate an appropriate adjustment factor for cooling-side energy and demand savings. This factor should be applied against deemed cooling energy and summer demand savings values from the following tables for homes with refrigerated air conditioning. The factor should not be applied to winter demand savings. This factor will be updated with new energy model estimates in TRM v4.0.

Table 2-152: Evaporative Cooling Adjustment Factor

Climate Zone	Climate Zone 1: Panhandle	Climate Zone 2: North	Climate Zone 3: South	Climate Zone 4: Valley	Climate Zone 5: West
Adjustment Factor	35.0%	31.3%	31.0%	31.0%	33.6%

Examples

Example 1. 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.

$$kWh\ savings = (1.59 \times 33.6\%) \times 400 + 1.96 \times 400 = 997.7\ \text{kWh}$$

$$Summer\ kW\ savings = (0.001224 \times 33.6\%) \times 400 = 0.165\ \text{kW}$$

$$Winter\ kW\ savings = 0.001438 \times 400 = 0.575\ \text{kW}$$

Example 2. 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-30.

$$kWh\ savings = 0.32 \times 550 + 0.38 \times 550 = 385.0\ \text{kWh}$$

$$Summer\ kW\ savings = 0.000297 \times 550 = 0.163\ \text{kW}$$

$$Winter\ kW\ savings = 0.000195 \times 550 = 0.107\ \text{kW}$$

Deemed Energy Savings Tables

Table 2-153 through Table 2-157 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.

Climate Zone 1: Panhandle Region

Table 2-153: Climate Zone 1: Panhandle Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)

Ceiling Insulation Base R-value	R-30 Installed (kWh/ft^2)				R-38 Installed (kWh/ft^2)			
	Cooling Savings	Heating Savings			Cooling Savings	Heating Savings		
		Gas	Electric Resistance	Heat Pump		Gas	Electric Resistance	Heat Pump
R-0	0.86	0.00	9.13	4.18	0.87	0.00	9.20	4.21
R-1 to R-4	0.52	0.00	5.91	2.62	0.53	0.00	6.03	2.67
R-5 to R-8	0.24	0.00	2.95	1.24	0.25	0.00	3.13	1.31
R-9 to R-14	0.11	0.00	1.56	0.65	0.13	0.00	1.77	0.74
R-15 to R-22	0.05	0.00	0.66	0.26	0.07	0.00	0.92	0.36

Climate Zone 2: North Region

Table 2-154: Climate Zone 2: North Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)

Ceiling Insulation Base R-value	R-30 Installed (kWh/ft^2)				R-38 Installed (kWh/ft^2)			
	Cooling Savings	Heating Savings			Cooling Savings	Heating Savings		
		Gas	Electric Resistance	Heat Pump		Gas	Electric Resistance	Heat Pump
R-0	1.22	0.00	5.49	1.94	1.23	0.00	5.53	1.95
R-1 to R-4	0.79	0.00	3.53	1.28	0.81	0.00	3.60	1.31
R-5 to R-8	0.40	0.00	1.75	0.64	0.42	0.00	1.85	0.68
R-9 to R-14	0.21	0.00	0.92	0.33	0.24	0.00	1.05	0.38
R-15 to R-22	0.09	0.00	0.38	0.14	0.13	0.00	0.53	0.20

Climate Zone 3: South Region

Table 2-155: Climate Zone 3: South Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)

Ceiling Insulation Base R-value	R-30 Installed (kWh/ft^2)				R-38 Installed (kWh/ft^2)			
	Cooling Savings	Heating Savings			Cooling Savings	Heating Savings		
		Gas	Electric Resistance	Heat Pump		Gas	Electric Resistance	Heat Pump
R-0	1.00	0.00	3.40	1.14	1.01	0.00	3.42	1.15
R-1 to R-4	0.64	0.00	2.17	0.76	0.65	0.00	2.21	0.78
R-5 to R-8	0.32	0.00	1.06	0.38	0.34	0.00	1.12	0.40
R-9 to R-14	0.17	0.00	0.55	0.19	0.19	0.00	0.63	0.22
R-15 to R-22	0.07	0.00	0.23	0.08	0.10	0.00	0.32	0.11

Climate Zone 4: Valley Region

Table 2-156: Climate Zone 4: Valley Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)

Ceiling Insulation Base R-value	R-30 Installed (kWh/ft^2)				R-38 Installed (kWh/ft^2)			
	Cooling Savings	Heating Savings			Cooling Savings	Heating Savings		
		Gas	Electric Resistance	Heat Pump		Gas	Electric Resistance	Heat Pump
R-0	1.30	0.00	2.34	0.80	1.31	0.00	2.36	0.81
R-1 to R-4	0.85	0.00	1.48	0.54	0.87	0.00	1.51	0.55
R-5 to R-8	0.44	0.00	0.71	0.26	0.47	0.00	0.75	0.28
R-9 to R-14	0.23	0.00	0.37	0.14	0.26	0.00	0.42	0.16
R-15 to R-22	0.10	0.00	0.15	0.05	0.14	0.00	0.21	0.07

Climate Zone 5: West Region

Table 2-157: Climate Zone 5: West Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)

Ceiling Insulation Base R-value	R-30 Installed (kWh/ft^2)				R-38 Installed (kWh/ft^2)			
	Cooling Savings	Heating Savings			Cooling Savings	Heating Savings		
		Gas	Electric Resistance	Heat Pump		Gas	Electric Resistance	Heat Pump
R-0	2.59	0.00	3.07	1.94	2.61	0.00	3.09	1.95
R-1 to R-4	1.56	0.00	1.92	1.28	1.59	0.00	1.96	1.31
R-5 to R-8	1.12	0.00	1.16	0.64	1.19	0.00	1.23	0.68
R-9 to R-14	0.74	0.00	0.80	0.33	0.84	0.00	0.91	0.38
R-15 to R-22	0.51	0.00	0.59	0.14	0.71	0.00	0.82	0.20

* Savings specific to climate zone 5 with heat pumps installed are not currently available for this measure. In their absence, savings values associated with climate zone 2 may be used instead.

Deemed Summer Demand Savings Tables

Table 2-158 through Table 2-162 present the summer demand savings (kW) associated with ceiling insulation for the five Texas climate zones.

Climate Zone 1: Panhandle Region

Table 2-158: Climate Zone 1: Panhandle Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)

Ceiling Insulation Base R-value	R-30 Installed (kW/ft^2)		R-38 Installed (kW/ft^2)	
	Gas or Electric Resistance	Heat Pump	Gas or Electric Resistance	Heat Pump
R-0	0.000973	0.000973	0.000980	0.000980
R-1 to R-4	0.000608	0.000622	0.000620	0.000634
R-5 to R-8	0.000297	0.000311	0.000315	0.000329
R-9 to R-14	0.000153	0.000153	0.000174	0.000174
R-15 to R-22	0.000068	0.000074	0.000095	0.000103

Climate Zone 2: North Region

Table 2-159: Climate Zone 2: North Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)

Ceiling Insulation Base R-value	R-30 Installed (kW/ft^2)		R-38 Installed (kW/ft^2)	
	Gas or Electric Resistance	Heat Pump	Gas or Electric Resistance	Heat Pump
R-0	0.001027	0.001027	0.001034	0.001034
R-1 to R-4	0.000622	0.000662	0.000634	0.000675
R-5 to R-8	0.000297	0.000311	0.000315	0.000329
R-9 to R-14	0.000153	0.000162	0.000174	0.000184
R-15 to R-22	0.000074	0.000074	0.000103	0.000103

Climate Zone 3: South Region

Table 2-160: Climate Zone 3: South Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)

Ceiling Insulation Base R-value	R-30 Installed (kW/ft^2)		R-38 Installed (kW/ft^2)	
	Gas or Electric Resistance	Heat Pump	Gas or Electric Resistance	Heat Pump
R-0	0.000973	0.000973	0.000980	0.000980
R-1 to R-4	0.000608	0.000622	0.000620	0.000634
R-5 to R-8	0.000297	0.000297	0.000315	0.000315
R-9 to R-14	0.000153	0.000153	0.000174	0.000174
R-15 to R-22	0.000074	0.000074	0.000103	0.000103

Climate Zone 4: Valley Region

Table 2-161: Climate Zone 4: Valley Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)

Ceiling Insulation Base R-value	R-30 Installed (kW/ft^2)		R-38 Installed (kW/ft^2)	
	Gas or Electric Resistance	Heat Pump	Gas or Electric Resistance	Heat Pump
R-0	0.001027	0.001027	0.001034	0.001034
R-1 to R-4	0.000622	0.000649	0.000634	0.000662
R-5 to R-8	0.000284	0.000297	0.000301	0.000315
R-9 to R-14	0.000135	0.000153	0.000154	0.000174
R-15 to R-22	0.000068	0.000074	0.000095	0.000103

Climate Zone 5: West Region

Table 2-162: Climate Zone 5: West Region – Residential Ceiling Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)

Ceiling Insulation Base R-value	R-30 Installed (kW/ft^2)		R-38 Installed (kW/ft^2)	
	Gas or Electric Resistance	Heat Pump	Gas or Electric Resistance	Heat Pump
R-0	0.002053	0.001027	0.002068	0.001034
R-1 to R-4	0.001200	0.000662	0.001224	0.000675
R-5 to R-8	0.000860	0.000311	0.000911	0.000329
R-9 to R-14	0.000531	0.000162	0.000604	0.000184
R-15 to R-22	0.000275	0.000074	0.000384	0.000103

* Savings specific to climate zone 5 with heat pumps installed are not currently available for this measure. In their absence, savings values associated with climate zone 2 may be used instead.

Deemed Winter Demand Savings Tables

Table 2-163 through Table 2-167 present the winter demand savings associated with ceiling insulation for the five Texas climate zones.

Climate Zone 1: Panhandle Region

Table 2-163: Climate Zone 1: Panhandle Region – Residential Ceiling Insulation Deemed Winter Demand Savings (kW)

Ceiling Insulation Base R-value	R-30 Installed (kW/ft^2)			R-38 Installed (kW/ft^2)		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	0	0.003988	0.001239	0	0.004017	0.001248
R-1 to R-4	0	0.002468	0.000672	0	0.002517	0.000685
R-5 to R-8	0	0.001062	0.000300	0	0.001125	0.000318
R-9 to R-14	0	0.000584	0.000249	0	0.000664	0.000283
R-15 to R-22	0	0.000268	0.000125	0	0.000374	0.000174

Climate Zone 2: North Region

Table 2-164: Climate Zone 2: North Region – Residential Ceiling Insulation Deemed Winter Demand Savings (kW)

Ceiling Insulation Base R-value	R-30 Installed (kW/ft^2)			R-38 Installed (kW/ft^2)		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	0	0.002992	0.001053	0	0.003014	0.001061
R-1 to R-4	0	0.001869	0.000661	0	0.001906	0.000674
R-5 to R-8	0	0.000796	0.000272	0	0.000843	0.000288
R-9 to R-14	0	0.000459	0.000150	0	0.000522	0.000171
R-15 to R-22	0	0.000208	0.000089	0	0.000290	0.000124

Climate Zone 3: South Region

Table 2-165: Climate Zone 3: South Region - Residential Ceiling Insulation Deemed Winter Demand Savings (kW)

Ceiling Insulation Base R-value	R-30 Installed (kW/ft^2)			R-38 Installed (kW/ft^2)		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	0	0.002192	0.000766	0	0.002208	0.000772
R-1 to R-4	0	0.001355	0.000492	0	0.001382	0.000502
R-5 to R-8	0	0.000565	0.000195	0	0.000599	0.000207
R-9 to R-14	0	0.000329	0.000118	0	0.000374	0.000134
R-15 to R-22	0	0.000151	0.000067	0	0.000211	0.000093

Climate Zone 4: Valley Region

Table 2-166: Climate Zone 4: Valley Region – Residential Ceiling Insulation Deemed Winter Demand Savings (kW)

Ceiling Insulation Base R-value	R-30 Installed (kW/ft^2)			R-38 Installed (kW/ft^2)		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	0	0.001802	0.000748	0	0.001815	0.000753
R-1 to R-4	0	0.001120	0.000488	0	0.001142	0.000498
R-5 to R-8	0	0.000483	0.000196	0	0.000512	0.000208
R-9 to R-14	0	0.000275	0.000114	0	0.000313	0.000130
R-15 to R-22	0	0.000123	0.000059	0	0.000172	0.000082

Climate Zone 5: West Region

**Table 2-167: Climate Zone 5: West Region –
Residential Ceiling Insulation Deemed Winter Demand Savings (kW)**

Ceiling Insulation Base R-value	R-30 Installed (kW/ft^2)			R-38 Installed (kW/ft^2)		
	Gas	Electric Resistance	Heat Pump	Gas	Electric Resistance	Heat Pump
R-0	0	0.002348	0.001053	0	0.002365	0.001061
R-1 to R-4	0	0.001410	0.000661	0	0.001438	0.000674
R-5 to R-8	0	0.000775	0.000272	0	0.000821	0.000288
R-9 to R-14	0	0.000571	0.000150	0	0.000649	0.000171
R-15 to R-22	0	0.000458	0.000089	0	0.000639	0.000124

* Savings specific to climate zone 5 with heat pumps installed are not currently available for this measure. In their absence, savings values associated with climate zone 2 may be used instead.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

According to the GDS Associates Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures (2007),[165] the Estimated Useful Life is 25 years for ceiling insulation.

Program Tracking Data & Evaluation Requirements

It is required that the following list of primary inputs and contextual data be specified and tracked by the program database to inform the evaluation and apply the savings properly:

- The climate zone
- Base R-value of original insulation
- R-value of installed insulation
- Space cooling system type (evaporative cooling, refrigerated air conditioning)

165 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_MeasureLifeStudyLights&HVACGDS_1Jun2007.pdf

- Space heating system type (gas, electric, heat pump)
- Square footage of ceiling insulation installed above a conditioned space

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates 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

This section is not applicable.

Document Revision History

Table 2-168: 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	TRV 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.

2.3.3 Wall Insulation Measure Overview

TRM Measure ID: R-BE-WI

Market Sector: Residential

Measure Category: Building Envelope

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

Wall insulation savings are per square foot of treated wall area (gross wall area less window and door area), and are based on R-0 increased to R-13. To qualify for these deemed savings values, wall insulation may be added only for customers with electric air conditioning in their homes, or for customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Eligibility Criteria

This measure applies to customers with electric air conditioning in their homes, or to customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Baseline Condition

The baseline is considered to be a house with no wall insulation in the 4 inches wall cavity.

High-Efficiency Condition

The standard throughout Texas for adding wall insulation to an existing wall cavity is R-13, as prescribed by United States Department of Energy (DOE) and Texas Department of Housing & Community Affairs (TDHCA) programs. To qualify for the incentive, there must be no existing wall insulation.

Under the Hard-To-Reach Standard Offer template, 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.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Building load simulation software that calculates hourly load data was used to create energy and summer peak demand savings for a series of models. The software used was ESPRE 2.1 (EPRI Simplified Program for Residential Energy.) The base model of the prototype home was a model that was calibrated to residential load data by Planergy, Inc. The load data used for calibration was the South Texas End-Use Study, 1990 by Central Power and Light.

Building shell measures are sensitive to weather and Texas is somewhat unique because there is a great difference in weather patterns between Amarillo in the northern panhandle and Corpus Christi in south Texas. A series of models were created to determine the difference in weather data throughout the eight weather regions in Texas as defined in the Model Energy Code. In an effort to simplify deemed savings values, available TMY weather data from ten different regions was analyzed. Based on the results, the different weather regions were collapsed down to the following four regions.

- Climate Zone 1: Panhandle Region (Amarillo weather data)
- Climate Zone 2: North Region (Dallas weather data)
- Climate Zone 3: South Region (Houston weather data)
- Climate Zone 4: Valley Region (Corpus Christi weather data)

Savings values for climate zone 5 (West Region) were appended at a later date. The deemed savings estimates for this zone were developed using demand and energy savings calculated using EnergyGauge, a DOE-2 based residential load simulator, for a prototypical home. Prototypical home characteristics used for these models were modified from those shown in Table 2-169.[166] The weather inputs used for the simulation are TMY3 weather data for the El Paso International Airport.

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 in place.

For climate zone 5, summer and winter peak savings were calculated by taking the difference in demand at the hour when the summer and winter peak are likely to occur. The days of the peaks were determined based on TMY3 weather data: the winter peak day, December 27, was chosen as the day with the most extreme combination of low temperature and heating degree days while the summer peak day, June 15, had the most extreme combination of high temperature and cooling degree days. A day in June, rather than August, was chosen, as the

[166] For a list of input values used in these models refer to Docket No. 22241, Item 58. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas and Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.

modeling software is agnostic to the month of the year, and only time of day and weather factors are important to estimating demand. The hour of the peak was assumed to be 7-8am for the winter and 3-4pm in the summer, based on the historic occurrence of system peak for the El Paso system.

Table 2-169: Residential Wall Insulation – Prototypical Home Characteristics, Climate Zones 1-4

Shell Characteristic	Value	Source
Conditioned Area	1,850 square feet	South Texas End Use Study, Central Power and Light, 1990, Table 3-1 average sq. ft conditioned area – 1854 sq. ft.; Entergy 1984 Baseline Study, average sq. ft. single family home 1834 sq. ft.; baseline data from SPS and AEP utilities efficiency programs is similar for existing homes (sq. ft. within 7% of 1850 sq. ft.)
Foundation	Slab-on-grade, no edge insulation	Entergy 1984 Baseline Study single family homes 56% slab foundation, 44% pier & beam; pier & beam foundation varies 1-4% in energy and demand from slab foundation model
Ceiling Insulation	R-19	Average insulation level in an existing home used in model; SPS Baseline data for 1998 IRP, residential AC replacement programs average ceiling insulation level for existing homes R-20.51 of 1,010 homes in efficiency programs
Base Wall Insulation	R-2.84	ESPRE default based on wood frame, 4" wall stud, sheathing, siding or brick, no insulation with ½" gypsum
Change Wall Insulation	R-13	Efficiency measure - retrofit insulation level as required by DOE and Texas Department of Housing and Community Affairs programs
Window Area	10.2% of floor area (~13-15% of wall area)	Average window area per wall used during calibration of model; window area equal for each wall orientation
Air Infiltration	1.1 and 0.9 ACH (winter, summer)	Average air changes per hour of air infiltration for existing homes used during calibration of model
Window U-value	0.72	WTU Baseline Survey, 1996 and WTU's Residential MARS database; U-0.72 represents a mix of single and double pane windows in existing homes
Thermostat Settings	70 winter; 78 summer	Average thermostat settings used during calibration of model
Orientation	Square house	To average effect of orientation of building due to a wide variety of building configurations and orientations; walls are equal area and face north/south/east/west
Duct Losses	25% overall loss (thermal and air leakage)	Average duct losses for existing homes used during calibration of model
Air Conditioning	10.0 SEER	SPS Baseline data for 1998 IRP, residential AC replacement programs average SEER 10.2 of 1,010 replaced units
Gas Heating	78 AFUE	Annual Fuel Utilization Efficiency - base gas furnace efficiency
Electric-Resistance Heat	COP 1.0	Coefficient of Performance for central electric resistance heating systems
Heat Pump	10.0 SEER and 7.2	SPS Baseline data for 1998 IRP, residential AC replacement

Shell Characteristic	Value	Source
	HSPF	programs average SEER 10.2 of 1,010 replaced units. Average HSPF based on Carrier Product Data 1999, 10.0 SEER

For homes with evaporative cooling units installed, energy models were used to estimate an appropriate adjustment factor for cooling-side energy and demand savings. This factor should be applied against deemed cooling energy and summer demand savings values from the following tables for homes with refrigerated air conditioning. The factor should not be applied to winter demand savings. This factor will be updated with new energy model estimates in TRM v4.0.

Table 2-170: Evaporative Cooling Adjustment Factor

Climate Zone	Climate Zone 1: Panhandle	Climate Zone 2: North	Climate Zone 3: South	Climate Zone 4: Valley	Climate Zone 5: West
Adjustment Factor	35.0%	31.3%	31.0%	31.0%	33.6%

Examples

Example 1. A home in Climate Zone 1 with evaporative cooling and an electric resistance furnace insulates 150 square feet.

$$kWh\ savings = (0.336 \times 35.0\%) \times 150 + 10.678 \times 150 = 1{,}619.3\ \text{kWh}$$

$$Summer\ kW\ savings = (0.0005892 \times 35.0\%) \times 150 = 0.031\ \text{kW}$$

$$Winter\ kW\ savings = N/A$$

Example 2. A home in Climate Zone 4 with a central air conditioning unit and a gas furnace insulates 180 square feet.

$$kWh\ savings = 0.282 \times 180 = 50.8\ \text{kWh}$$

$$Summer\ kW\ savings = 0.0007576 \times 180 = 0.136\ \text{kW}$$

$$Winter\ kW\ savings = N/A$$

Deemed Energy Savings Tables

Table 2-171 presents the deemed energy savings values for all five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

Table 2-171: All Climate Zones: Residential Wall Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)

Climate Zone	Cooling Savings (kWh/sq. ft.)	Heating Savings (kWh/sq. ft.)		
		Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	0.336	No Savings	10.678	6.160
Climate Zone 2: North	0.459	No Savings	6.584	2.531
Climate Zone 3: South	0.242	No Savings	4.287	1.484
Climate Zone 4: Valley	0.282	No Savings	2.991	1.028
Climate Zone 5: West	0.997	No Savings	3.218	2.531

* Savings specific to climate zone 5 with heat pumps installed are not currently available for this measure. In their absence, savings values associated with climate zone 2 may be used instead.

Deemed Summer Demand Savings Tables

Table 2-172 presents the deemed summer demand savings tables for all five Texas climate zones.

Table 2-172: All Climate Zones – Residential Wall Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)

Climate Zone	kW Savings per sq. ft. by Heating Type	
	Gas and Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	0.0005892	0.0005892
Climate Zone 2: North	0.0007576	0.0008418
Climate Zone 3: South	0.0006734	0.0006734
Climate Zone 4: Valley	0.0007576	0.0007576
Climate Zone 5: West	0.000695	0.0008418

* Savings specific to climate zone 5 with heat pumps installed are not currently available for this measure. In their absence, savings values associated with climate zone 2 may be used instead.

Deemed Winter Demand Savings

Table 2-173 presents the deemed winter demand savings for climate zone 5. Deemed winter demand savings for this measure are not currently available for the other climate zones. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Table 2-173: All Climate Zones – Residential Wall Insulation with Refrigerated Air Conditioning Deemed Winter Demand Savings (kW)

Climate Zone	kW Savings per sq. ft. for Electric Heat
Climate Zone 1: Panhandle	N/A
Climate Zone 2: North	N/A
Climate Zone 3: South	N/A
Climate Zone 4: Valley	N/A
Climate Zone 5: West	0.001218

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is 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 & 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
- Space heating system type (gas, electric, heat pump)
- Space cooling system type (evaporative cooling, refrigerated air conditioning)
- 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 Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.
- Docket No. 22241, Item 62. Petition by Frontier Associates 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

This section is not applicable.

Document Revision History

Table 2-174: 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.

2.3.4 Floor Insulation Measure Overview

TRM Measure ID: R-BE-FI

Market Sector: Residential

Measure Category: Building Envelope

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

Floor insulation savings are per square foot of treated floor area above a non-conditioned space. To qualify for these deemed savings values, floor insulation may be added only for customers with electric air conditioning in their homes, or for customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Eligibility Criteria

This measure applies to customers with electric air conditioning in their homes, or to customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Baseline Condition

The baseline is considered to be a house with pier and beam construction and no floor insulation against the floor of conditioned area.

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 & Community Affairs (TDHCA) programs. To qualify for the incentive, there must be no existing floor insulation. 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 remains 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 inches clearance from bottom of the insulation to the ground is required by Occupational Safety and Health Association (OSHA).

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Building load simulation software that calculates hourly load data was used to create energy and summer peak demand savings for a series of models. The software used was ESPRE 2.1 (EPRI Simplified Program for Residential Energy). The base model of the prototype home was a model that was calibrated to residential load data by Planergy, Inc. The load data used for calibration was the South Texas End-Use Study, 1990 by Central Power and Light.

Building shell measures are sensitive to weather, and Texas is somewhat unique because there is a great difference in weather patterns between Amarillo in the northern panhandle and Corpus Christi in south Texas. A series of models were created to determine the difference in weather data throughout the eight weather regions in Texas as defined in the Model Energy Code. In an effort to simplify deemed savings values, available TMY weather data from ten different regions was analyzed. Based on the results, the different weather regions were collapsed down to the following four regions.

- Climate Zone 1: Panhandle Region (Amarillo weather data)
- Climate Zone 2: North Region (Dallas weather data)
- Climate Zone 3: South Region (Houston weather data)
- Climate Zone 4: Valley Region (Corpus Christi weather data)

Savings values for climate zone 5 (West Region) were appended at a later date. The deemed savings estimates for this zone were developed using demand and energy savings calculated using EnergyGauge, a DOE-2 based residential load simulator, for a prototypical home. Prototypical home characteristics used for these models were modified from those shown in Table 2-175[167]. The weather inputs used for the simulation are TMY3 weather data for the El Paso International Airport.

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.

For climate zone 5, summer and winter peak savings were calculated by taking the difference in demand at the hour when the summer and winter peak are likely to occur. The days of the peaks were determined based on TMY3 weather data: the winter peak day, December 27, was

[167] For a list of input values used in these models refer to Docket No. 22241, Item 58. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas and Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.

chosen as the day with the most extreme combination of low temperature and heating degree days while the summer peak day, June 15, had the most extreme combination of high temperature and cooling degree days. A day in June, rather than August, was chosen, as the modeling software is agnostic to the month of the year, and only time of day and weather factors are important to estimating demand. The hour of the peak was assumed to be 7-8am for the winter and 3-4pm in the summer, based on the historic occurrence of system peak for the El Paso system.

Table 2-175: Residential Floor Insulation – Prototypical Home Characteristics, Climate Zones 1-4

Shell Characteristic	Value	Source
Conditioned Area (site-built)	1,850 square feet	South Texas End Use Study, Central Power and Light, 1990, Table 3-1 average sq. ft. conditioned area – 1854 sq. ft.; Entergy 1984 Baseline Study, average sq. ft. single family home 1834 sq. ft.; baseline data from SPS and AEP utilities efficiency programs is similar for existing homes (sq. ft. within 7% of 1850 sq. ft.)
Conditioned Area (manufactured home)	1,504 square feet	Average square footage of homes sold since 1983 (1.045 million) from The Manufactured Housing Industry in Texas, 1999 Report. Information in report received from the Texas Department of Housing Community Affairs and Texas Manufactured Housing Association member manufacturers and retailers. Percent of sales of new & used manufactured homes to total sales of new & used single family homes for metropolitan statistical areas is 34.3%.
Foundation	Pier and Beam	Entergy 1984 Baseline Study single family homes 56% slab foundation, 44% pier & beam; pier & beam foundation varies 1-4% in energy and demand from slab foundation model. Skirting around perimeter is assumed insulated and vented. Ground under home is assumed to be bare, without any type of moisture barrier.
Base Floor Insulation	R-2.36	ESPRE default based on hardwood floor without carpet or other 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 an R-15 loose-fill insulation for manufactured housing and other non-site-built homes.
Ceiling Insulation	R-19	Average insulation level in an existing home used in model; SPS Baseline data for 1998 IRP, residential AC replacement programs average ceiling insulation level for existing homes R-20.51 of 1,010 homes in efficiency programs
Wall Insulation	R-10.26	ESPRE default based on wood frame, 4" wall stud, sheathing, siding or brick, R-11 insulation with ½" gypsum, SPS Baseline data for 1998 IRP average wall insulation R-10.94
Window Area	10.2% of floor area (~13-15% of wall area)	Average window area per wall used during calibration of model; window area equal for each wall orientation

Shell Characteristic	Value	Source
Air Infiltration	1.1 and 0.9 ACH (winter, summer)	Average air changes per hour of air infiltration for existing homes used during calibration of model
Window U-value	0.72	WTU Baseline Survey, 1996 and WTU's Residential MARS database; U-0.72 represents a mix of single and double pane windows in existing homes
Thermostat Settings	70 winter; 78 summer	Average thermostat settings used during calibration of model
Orientation	Square house	To average effect of orientation of building due to a wide variety of building configurations and orientations; walls are equal area and face north/south/east/west
Duct Losses	25% overall loss (thermal and air leakage)	Average duct losses for existing homes used during calibration of model
Air Conditioning	10.0 SEER	SPS Baseline data for 1998 IRP, residential AC replacement programs average SEER 10.2 of 1,010 replaced units, NAECA standard is 10.0
Gas Heating	78 AFUE	Annual Fuel Utilization Efficiency - base gas furnace efficiency
Electric Resistance Heat	COP 1.0	Coefficient of Performance for central electric resistance heating systems
Heat Pump	10.0 SEER and 7.2 HSPF	SPS Baseline data for 1998 IRP, residential AC replacement programs average SEER 10.2 of 1,010 replaced units. Average HSPF based on Carrier Product Data 1999, 10.0 SEER

For homes with evaporative cooling units installed, energy models were used to estimate an appropriate adjustment factor for cooling-side energy and demand savings. This factor should be applied against deemed cooling energy and summer demand savings values from the following tables for homes with refrigerated air conditioning. The factor should not be applied to winter demand savings. This factor will be updated with new energy model estimates in TRM v4.0.

Table 2-176: Evaporative Cooling Adjustment Factor

Climate Zone	Climate Zone 1: Panhandle	Climate Zone 2: North	Climate Zone 3: South	Climate Zone 4: Valley	Climate Zone 5: West
Adjustment Factor	35.0%	31.3%	31.0%	31.0%	33.6%

Examples

Example 1. A manufactured home in Climate Zone 5 with evaporative cooling and an electric resistance furnace insulates 500 square feet.

$$kWh\ savings = (0.911 \times 33.6\%) \times 500 + 1.783 \times 500 = 1{,}044.5\ \text{kWh}$$

$$Summer\ kW\ savings = (0.000003 \times 33.6\%) \times 500 = 0.0005\ \text{kW}$$

$$Winter\ kW\ savings = 0.001278 \times 500 = 0.639\ \text{kW}$$

Example 2. A site-built home in Climate Zone 2 with an air-source heat pump insulates 825 square feet.

$$kWh\ savings = 0.065 \times 825 + 1.052 \times 825 = 921.5\ \text{kWh}$$

$$Summer\ kW\ savings = 0.00027 \times 825 = 0.223\ \text{kW}$$

$$Winter\ kW\ savings = N/A$$

Deemed Energy Savings Tables

Table 2-177 through Table 2-181 present the energy savings (kWh) for all five Texas climate zones. Annual energy savings are the sum of cooling and heating savings for the appropriate equipment types.

Table 2-177: Climate Zone 1: Panhandle Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)

Home Type	Cooling Savings (kWh/sq. ft.)	Heating Savings (kWh/sq. ft.)		
		Gas	Electric Resistance	Heat Pump
Site Built Home	No Savings	No Savings	5.001	2.598
Manufactured Home	No Savings	No Savings	4.983	2.512

Table 2-178: Climate Zone 2: North Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)

Home Type	Cooling Savings (kWh/sq. ft.)	Heating Savings (kWh/sq. ft.)		
		Gas	Electric Resistance	Heat Pump
Site Built Home	0.065	No Savings	2.867	1.052
Manufactured Home	0.035	No Savings	2.866	1.063

Table 2-179: Climate Zone 3: South Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)

Home Type	Cooling Savings (kWh/sq. ft.)	Heating Savings (kWh/sq. ft.)		
		Gas	Electric Resistance	Heat Pump
Site Built Home	No Savings	No Savings	1.708	0.583
Manufactured Home	No Savings	No Savings	1.659	0.557

Table 2-180: Climate Zone 4: Valley Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)

Home Type	Cooling Savings (kWh/sq. ft.)	Heating Savings (kWh/sq. ft.)		
		Gas	Electric Resistance	Heat Pump
Site Built Home	0.024	No Savings	1.143	0.404
Manufactured Home	No Savings	No Savings	1.128	0.404

Table 2-181: Climate Zone 5: West Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Annual Energy Savings (kWh)

Home Type	Cooling Savings (kWh/sq. ft.)	Heating Savings (kWh/sq. ft.)		
		Gas	Electric Resistance	Heat Pump
Site Built Home	0.313	No Savings	3.565	1.052
Manufactured Home	0.811	No Savings	1.783	1.063

* Savings specific to climate zone 5 with heat pumps installed are not currently available for this measure. In their absence, savings values associated with climate zone 2 may be used instead.

Deemed Summer Demand Savings Tables

Table 2-182 through Table 2-186 present the deemed summer demand savings (kW) for all five Texas climate zones.

Table 2-182: Climate Zone 1: Panhandle Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0.000216	0.000199
Electric Heat	0.000216	0.000199
Heat Pump	0.000216	0.000266

Table 2-183: Climate Zone 2: North Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0.000270	0.000266
Electric Heat	0.000270	0.000266
Heat Pump	0.000270	0.000266

Table 2-184: Climate Zone 3: South Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0.000216	0.000266
Electric Heat	0.000216	0.000266
Heat Pump	0.000216	0.000266

Table 2-185: Climate Zone 4: Valley Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0.000270	0.000266
Electric Heat	0.000270	0.000266
Heat Pump	0.000270	0.000266

Table 2-186: Climate Zone 5: West Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Summer Demand Savings (kW)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0.000505	0.000003
Electric Heat	0.000505	0.000003
Heat Pump	0.000270	0.000266

* Savings specific to climate zone 5 with heat pumps installed are not currently available for this measure. In their absence, savings values associated with climate zone 2 may be used instead.

Deemed Winter Demand Savings Tables

Table 2-187 presents the deemed winter demand savings for climate zone 5. Deemed winter demand savings for this measure are not currently available for the other climate zones. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Table 2-187: Climate Zone 5: West Region – Residential Floor Insulation with Refrigerated Air Conditioning Deemed Winter Demand Savings (kW)

Electric A/C and Heating Type	Site Built Home (per sq. ft.)	Manufactured Home (per sq. ft.)
Gas Heat	0	0
Electric Heat	0.001577	0.001278
Heat Pump	N/A	N/A

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is 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 & 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

- Space heating system type (gas, electric, heat pump)
- Space cooling system type (evaporative cooling or electric air conditioning)
- 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 Associates 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

This section is not applicable.

Document Revision History

Table 2-188: 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.

2.3.5 ENERGY STAR® Windows Measure Overview

TRM Measure ID: R-BE-EW

Market Sector: Residential

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Measure Category: Building Envelope

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

ENERGY STAR® windows savings are calculated on per square foot of window basis, inclusive of frame and sash. To qualify for these deemed savings values, ENERGY STAR® windows may be installed only for customers with electric air conditioning in their homes, or for customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Eligibility Criteria

This measure applies to customers with electric air conditioning in their homes, or to customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Baseline

The baseline is a double-glazed (i.e., double-pane), clear window with an aluminum frame, with a U-factor of 0.87, a solar heat gain coefficient (SHGC) of 0.66, and air infiltration of 1 CFM/ ft^2.

High-Efficiency Condition

For a window to qualify for these deemed savings, it must meet the relevant ENERGY STAR® criteria anywhere in the state. Table 2-189 lists the ENERGY STAR® specifications for windows as of January 2010. These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® code.

Table 2-189: ENERGY STAR® Windows Specifications, January 2010

U.S. Region, ENERGY STAR®	**U-Factor Btu/(h·ft²·°F)**	**Solar Heat Gain Coefficient (SHGC)**
North-Central	≤ 0.32	≤ 0.40
South-Central	≤ 0.35	≤ 0.30
Southern	≤ 0.60	≤ 0.27

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

To develop the recommended deemed savings values, we relied on information contained in the NFRC 900 database.[168] To develop deemed savings estimates from the NFRC 900 database, the following steps were taken:

- The difference in energy consumption and electrical demand between a home with base case and change case[169] windows was calculated from the database for the prototypes in Brownsville (Valley Region), San Antonio (South Region), Fort Worth (North Region) and Oklahoma City (a proxy for the Panhandle region).
- The heating fuel energy use reported in the NFRC 900 database was converted into electricity requirements and natural gas requirements, depending upon three alternative assumptions regarding the type of HVAC equipment present in the home (heat pumps, electric resistance heating, or natural gas heating).
- The “per-home” estimates were divided by the total assumed window area (231 sq. ft.) to derive “per-square foot of window” estimates.

For homes with evaporative cooling units installed, energy models were used to estimate an appropriate adjustment factor for cooling-side energy and demand savings. This factor should be applied against deemed cooling energy and summer demand savings values from the following tables for homes with refrigerated air conditioning. The factor should not be applied to winter demand savings. This factor will be updated with new energy model estimates in TRM v4.0.

Table 2-190: Evaporative Cooling Adjustment Factor

Climate Zone	**Climate Zone 1: Panhandle**	**Climate Zone 2: North**	**Climate Zone 3: South**	**Climate Zone 4: Valley**	**Climate Zone 5: West**
Adjustment Factor	35.0%	31.3%	31.0%	31.0%	33.6%

168 The National Fenestration Rating Council has developed a database of the annual energy impacts for various types of windows installed in a typical new, single family, single story residence in various U.S. cities. This database, called NFRC 900, contains results for four Texas cities: Brownsville, El Paso, Fort Worth and San Antonio. Here we will assume the results for Oklahoma City will serve as a reasonable proxy for the energy savings and demand reduction achievable in the Texas Panhandle. The NFRC 900 database was developed by LBNL.

169 The change case window assumed in the NFRC 900 database exceeds the minimum requirements (U-factor = 0.30, SHGC = 0.29, CFM/ft² = 0.15), and is more representative of higher-end windows, such as those manufactured by Andersen, Pella, or Marvin.

Examples

Example 1. A home in Climate Zone 1 with evaporative cooling and an electric resistance furnace installs 45 square feet of ENERGY STAR® windows.

$$kWh\ savings = (2.68 \times 35.0\%) \times 45 + 6.82 \times 45 = 349.1\ \mathrm{kWh}$$

$$Summer\ kW\ savings = (0.0033 \times 35.0\%) \times 45 = 0.052\ \mathrm{kW}$$

$$Winter\ kW\ savings = N/A$$

Example 2. A home in Climate Zone 5 with a central air conditioning unit and a gas furnace installs 30 square feet of ENERGY STAR® windows.

$$kWh\ savings = 3.46 \times 30 = 103.8\ \mathrm{kWh}$$

$$Summer\ kW\ savings = 0.0028 \times 30 = 0.084\ \mathrm{kW}$$

$$Winter\ kW\ savings = N/A$$

Deemed Energy Savings Tables

Table 2-191 presents 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.

Table 2-191: Residential ENERGY STAR® Windows Deemed Annual Energy Savings (kWh)

Climate Zone	Cooling Savings (kWh/sq. ft.)	Heating Savings (kWh/sq. ft.)		
		Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	2.68	No Savings	6.82	4.17
Climate Zone 2: North	3.46	No Savings	3.42	1.81
Climate Zone 3: South	3.81	No Savings	2.67	1.45
Climate Zone 4: Valley	4.72	No Savings	1.34	0.63
Climate Zone 5: West*	3.46	No Savings	3.42	1.81

* Savings specific to climate zone 5 are not currently available for this measure. In their absence, savings values associated with climate zone 2 may be used instead.

Deemed Summer Demand Savings Tables

Table 2-192 presents the summer demand savings tables for the five Texas climate zones.

Table 2-192: Residential ENERGY STAR® Windows Deemed Demand Savings (kW)

Climate Zone	Summer kW Savings (per sq. ft.)		
	Non-Electric Heating	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	0.0033	0.0033	0.0033
Climate Zone 2: North	0.0028	0.0028	0.0028
Climate Zone 3: South	0.0024	0.0024	0.0024
Climate Zone 4: Valley	0.0027	0.0027	0.0027
Climate Zone 5: West*	0.0028	0.0028	0.0028

* Savings specific to climate zone 5 are not currently available for this measure. In their absence, savings values associated with climate zone 2 may be used instead.

Deemed Winter Demand Savings Tables

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is 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.

Program Tracking Data & Evaluation Requirements

It is required that the following list of primary inputs and contextual data be specified and tracked by the program database to inform the evaluation and apply the savings properly:

- The climate zone
- Space heating system type (non-electric, electric resistance, heat pump)
- Space cooling system type (evaporative cooling or electric air conditioning)
- Area of ENERGY STAR® windows installed

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 48. Petition by Frontier Associates 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

This section is not applicable.

Document Revision History

Table 2-193: ENERGY STAR® 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.

2.3.6 Solar Screens Measure Overview

TRM Measure ID: R-BE-SC

Market Sector: Residential

Measure Category: Building Envelope

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Estimates

Measure Description

To qualify for these deemed savings values, solar screens may be installed only for customers with electric air conditioning in their homes, or for customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs. Deemed savings are calculated per square foot of window or door opening.

Eligibility Criteria

This measure applies to customers with electric air conditioning in their homes, or to customers who have evaporative cooling systems and who participate in hard-to-reach (HTR) programs.

Solar screens must be installed on windows that face east, west, or south, and that 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, east-, west-, or south-facing window with a solar heat gain coefficient of 0.75. Baseline window area is assumed to be 10.2 percent of the floor area.

High-Efficiency Condition

To qualify for solar screen deemed savings, windows must be facing predominately east, west, or south, and receive significant direct sun exposure. Solar screen material must reduce solar heat gain by at least 65 percent. Solar screens are not recommended for homes with electric heat.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

The RESFEN 3.1 model was developed by LBNL to calculate a prototype home's energy consumption and electrical demand under alternative assumptions regarding the home's windows. This software was used for deemed savings for the solar screen measure since this software was specifically developed to calculate the load attributed to windows.

The results from the RESFEN models were compared to models conducted with ESPRE hourly load simulation software as used for other deemed savings envelope measures. Extensive modeling was conducted in an effort to compare the two modeling software programs. When variables were equalized to the extent possible, the results were similar. The RESFEN software was used for deemed savings for the solar screen measure since it was specifically developed to calculate the load attributed to windows.

The weather regions used in the RESFEN modeling matched previous deemed savings models to the extent possible. Weather data corresponds as follows:

- Climate Zone 1: Panhandle Region (Oklahoma City, OK weather data)
- Climate Zone 2: North Region (Fort Worth weather data)
- Climate Zone 3: South Region (San Antonio weather data)
- Climate Zone 4: Valley Region (Brownsville weather data)

The RESFEN software is limited in allowing change for most envelope characteristics, however, an effort was made to match the deemed savings "prototype" house used in other deemed savings models.

Savings values for climate zone 5 (West Region) were appended at a later date. The deemed savings estimates for this zone were developed using demand and energy savings calculated using EnergyGauge, a DOE-2 based residential load simulator, for a prototypical home. Prototypical home characteristics used for these models were modified from those shown in Table 2-194.[170] The weather inputs used for the simulation are TMY3 weather data for the El Paso International Airport.

The model runs calculated energy use for the prototypical home prior to the installation of solar screens. Next, change-case models were run to calculate energy use with the solar screens in place.

[170] For a list of input values used in these models refer to Docket No. 22241, Item 62. Petition by Frontier Associates for Approval of Second Set of Deemed Savings Estimates. Public Utility Commission of Texas.

For climate zone 5, summer and winter peak savings were calculated by taking the difference in demand at the hour when the summer and winter peak are likely to occur. The days of the peaks were determined based on TMY3 weather data: the winter peak day, December 27, was chosen as the day with the most extreme combination of low temperature and heating degree days while the summer peak day, June 15, had the most extreme combination of high temperature and cooling degree days. A day in June, rather than August, was chosen, as the modeling software is agnostic to the month of the year, and only time of day and weather factors are important to estimating demand. The hour of the peak was assumed to be 7-8am for the winter and 3-4pm in the summer, based on the historic occurrence of system peak for the El Paso system.

Table 2-194: Residential Solar Screens – Prototypical Home Characteristics, Climate Zones 1-4

Shell Characteristic	Value	Source
Conditioned Area	1,850 square feet	South Texas End Use Study, Central Power and Light, 1990, Table 3-1 average sq. ft. conditioned area – 1854 sq. ft.; Entergy 1984 Baseline Study, average sq. ft. single family home 1834 sq. ft.; baseline data from SPS and AEP utilities efficiency programs is similar for existing homes (sq. ft. within 7% of 1850 sq. ft.)
Foundation	Slab-on-grade	
Slab Insulation	Climate Zone 1: R-2	
	All Other Zones: R-0	
Ceiling Insulation	Climate Zone 1: R-38	
	Climate Zone 2: R-30	
	Climate Zone 3: R-26	
	Climate Zone 4: R-19	
Wall Insulation	Climate Zone 1: R-19	
	Climate Zone 2: R-14	
	Climate Zone 3: R-11	
	Climate Zone 4: R-13	
Window Area	10.2% of floor area (~14% of wall area)	
Window U-Value	1.27	Average single pane, clear glass window with aluminum frame. This is the average of 1.25 as documented in the RESFEN Manual and 1.30 as documented in the NFRC 900 database for this type window.
Window SHGC	0.75	Represents the average from RESFEN (0.76) and the NFRC 900 (0.74) database for a single pane, clear glass window with an aluminum frame.
Air Leakage	0.30 CFM/ft^2	
Window Overhang/Shading	Typical	To represent statistically average solar gain reduction for a generic house, option includes: • Interior shades (Seasonal SHGC multiplier, summer = 0.80, winter = 0.90);

Shell Characteristic	Value	Source
Window Overhang/Shading		• 1' overhang; • and 67% transmitting same-height obstruction 20' away intended to represent adjacent buildings. To account for other sources of solar heat gain reduction (insect screens, trees, dirt on glass pane, building and window self-shading), the SHGC multiplier was further reduced by 0.1. This results in a final winter SHGC multiplier of 0.80 and a final summer SHGC multiplier of 0.70.
Air Infiltration	0.58 ACH	
Air Conditioning or Heat Pump	10.0 SEER	SPS Baseline data for 1998 IRP, residential AC replacement programs average SEER 10.2 of 1,010 replaced units
Gas Heating	78 AFUE	Annual Fuel Utilization Efficiency - base gas furnace efficiency

The model assumes the "average" solar screen installed blocks 80% of the solar heat gain attributed to the east, south and west facing windows. Performance data was available with sun angles at 30, 45 and 75 degrees to the window for a solar screen of this type. A 45° incident angle for direct radiation is typically chosen to represent average conditions.[171] Thus, the average shading coefficient for 1/8" and ¼" clear glass and different screen colors at 45 degrees is 0.305.[172]

Even though it is recommended that solar screens be removed during winter to allow the advantage of free heat from the sun, often they are 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. In these deemed savings models, it's assumed the screens remain in place year round.

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% improvement 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% and 4% improvement to the U-value of a window with a solar screen. A single pane, clear window has a 22% improvement with the addition of a solar screen, whereas a double pane, spectrally selective low-E window may only have a 4% improvement. The deemed savings models assume an average 10% improvement in thermal performance with the addition of a solar screen.

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171 "Effect of Shading Devices of Residential Energy Use in Austin, Texas" by the Center of Energy Studies, University of Texas at Austin, June 1988.

172 Performance data from Matrix, Inc., Mesa, Arizona testing facility for Phifer Wire Products' SunTex screen, blocks 80% of solar heat gain.

Window Frame

The window frame accounts for 10-30%[173] of the window area and since it's opaque and blocks sunlight from entering the home, it is factored into the model. An average of 15% frame area was incorporated into the performance of the window.

Homes with Evaporative Cooling

For homes with evaporative cooling units installed, energy models were used to estimate an appropriate adjustment factor for cooling-side energy and demand savings. This factor should be applied against deemed cooling energy and summer demand savings values from the following tables for homes with refrigerated air conditioning. The factor should not be applied to winter demand savings. This factor will be updated with new energy model estimates in TRM v4.0.

Table 2-195: Evaporative Cooling Adjustment Factor

Climate Zone	Climate Zone 1: Panhandle	Climate Zone 2: North	Climate Zone 3: South	Climate Zone 4: Valley	Climate Zone 5: West
Adjustment Factor	35.0%	31.3%	31.0%	31.0%	33.6%

Examples

Example 1. A home in Climate Zone 5 with evaporative cooling and an electric resistance furnace installs 60 square feet of solar screens.

$$kWh\ savings = (2.68 \times 33.6\%) \times 60 - 8.824 \times 60 = -475.4\ \mathrm{kWh}$$

$$Summer\ kW\ savings = (0.003412 \times 33.6\%) \times 60 = 0.069\ \mathrm{kW}$$

$$Winter\ kW\ savings = -0.004275 \times 60 = -0.257\ \mathrm{kW}$$

Example 2. A home in Climate Zone 4 with a central air conditioning unit and an electric resistance furnace installs 35 square feet of solar screens.

$$kWh\ savings = 7.038 \times 35 - 0.808 \times 35 = 218.1\ \mathrm{kWh}$$

$$Summer\ kW\ savings = 0.002756 \times 35 = 0.096\ \mathrm{kW}$$

$$Winter\ kW\ savings = N/A$$

Deemed Energy Savings Tables

Table 2-196 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.

[173] Residential Windows – A Guide to New Technologies and Energy Performance, 2000.

Table 2-196: Deemed Energy (kWh) Savings per Square Foot of Solar Screen with Refrigerated Air Conditioning

Climate Zone	Cooling Savings (kWh/sq. ft.)	Heating Savings (kWh/sq. ft.)		
		Gas	Electric Resistance	Heat Pump
Climate Zone 1: Panhandle	4.229	No Savings	-3.777	-2.311
Climate Zone 2: North	5.183	No Savings	-3.094	-1.643
Climate Zone 3: South	5.830	No Savings	-2.042	-1.102
Climate Zone 4: Valley	7.038	No Savings	-0.808	-0.382
Climate Zone 5: West	7.967	No Savings	-8.824	-1.643

* Savings specific to climate zone 5 with heat pumps installed are not currently available for this measure. In their absence, savings values associated with climate zone 2 may be used instead.

Deemed Summer Demand Savings Tables

Table 2-197 presents the deemed summer peak demand savings value per square foot of solar screen installed.

Table 2-197: Deemed Summer Peak Demand (kW) Savings per Square Foot of Solar Screen with Refrigerated Air Conditioning

Climate Zone	Summer Peak Average kW Savings (per sq. ft.)
Climate Zone 1: Panhandle	0.000954
Climate Zone 2: North	0.002438
Climate Zone 3: South	0.001590
Climate Zone 4: Valley	0.002756
Climate Zone 5: West	0.003412

Deemed Winter Demand Savings Tables

Table 2-198 presents the deemed winter peak demand savings value per square foot of solar screen installed for climate zone 5. Deemed winter demand savings for this measure are not currently available for the other climate zones. Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Table 2-198: Deemed Winter Peak Demand (kW) Savings per Square Foot of Solar Screen with Refrigerated Air Conditioning

Climate Zone	Winter Peak Average kW Savings (per sq. ft.)
Climate Zone 1: Panhandle	N/A
Climate Zone 2: North	N/A
Climate Zone 3: South	N/A
Climate Zone 4: Valley	N/A
Climate Zone 5: West	-0.004275

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of solar screens is established at 10 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[174]

Program Tracking Data & 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
- Space cooling system type (evaporative cooling, refrigerated air conditioning)
- Space heating system type (gas, electric, heat pump)
- Square footage of windows or door openings treated

[174] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates 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

This section is not applicable.

Document Revision History

Table 2-199: 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.

2.4 RESIDENTIAL: WATER HEATING

2.4.1 Faucet Aerators Measure Overview

TRM Measure ID: R-WH-FA

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

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-only installation of kitchen and bathroom faucet aerators. In order to be awarded these deemed savings, the fuel type of the water heater must be electricity.

Table 2-200: Faucet Aerators – Applicability

Application Type	Applicable
Retrofit	Y
New Construction	N

Baseline Condition

The 2.2 gallon per minute (GPM) baseline faucet flow rate is based on the Energy Policy Act of 1992 (EPAct 92). 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.[175]

Table 2-201: Faucet Aerators – Baseline and Efficiency Standard

Baseline	Efficiency Standard
2.2 GPM minimum	1.5 GPM maximum

High-Efficiency Condition

Aerators that have been defaced so as 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.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

Baseline and efficiency-standard water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA; the East Bay Municipal Utility District (CA); and Tampa, FL.[176,177,178] See Table 2-202 for derivation of water usage values.

To determine water consumption, the following formula was used:

$$\textit{Faucet use (gallons) per person per day} \times \textit{Occupants per home} \times \frac{365\frac{days}{year}}{\textit{Faucets per home}}$$

Equation 64

175 http://www.epa.gov/watersense/partners/faucets_final.html.

176 Seattle Home Water Conservation Study: "The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes." December 2000. http://www.allianceforwaterefficiency.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=856.

177 Residential Indoor Water Conservation Study: "Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single-Family Homes in the East Bay Municipal Utility District Service Area." July 2003. http://www5.ebmud.com/sites/default/files/pdfs/residential_indoor_wc_study_0.pdf.

178 Tampa Water Department Residential Water Conservation Study: "The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes." January 8, 2004..

Applying the formula to the values used for Texas from Table 2-202 returns the following values for baseline and post water consumption.

$$\boldsymbol{Baseline}: \mathbf{9.7 \times 2.79 \times {}^{365}/_{3.93} = 2,513}$$

Equation 65

$$\boldsymbol{Post}\ (\mathbf{1.5}\ \boldsymbol{GPM}): \mathbf{8.2 \times 2.79 \times {}^{365}/_{3.93} = 2,125}$$

Equation 66

$$\boldsymbol{Post}\ (\mathbf{1.0}\ \boldsymbol{GPM}): \mathbf{7.2 \times 2.79 \times {}^{365}/_{3.93} = 1,866}$$

Equation 67

Gallons of hot water saved per year can be found by subtracting the post consumption in gallons per year per aerator from the baseline consumption, and then multiplying the result by the percent hot water.

$$\boldsymbol{Gallons\ of\ hot\ water\ saved\ per\ year}\ (\mathbf{1.5}\ \boldsymbol{GPM}): (\mathbf{2,513 - 2,125}) \times \mathbf{0.669 = 260}$$

Equation 68

$$\boldsymbol{Gallons\ of\ hot\ water\ saved\ per\ year}\ (\mathbf{1.0}\ \boldsymbol{GPM}): (\mathbf{2,513 - 1,866}) \times \mathbf{0.669 = 433}$$

Equation 69

Table 2-202: Estimated Aerator Hot Water Usage Reduction

	Sample Studies			Average	Value used for Texas
	Seattle	Tampa	East Bay		
Faucet use gallons/person/day (baseline)	9.2	9.4	10.5	9.7	**9.7**
Faucet use gallons/person/day (1.5 GPM)	8.0	6.2	10.5	8.2	**8.2**
Faucet use gallons/person/day (1.0 GPM)*	N/A				**7.2**
Occupants per home**	2.54	2.92	2.56	2.67	**2.79**
Faucets per home***	N/A				**3.93**
Gallons/year/faucet (baseline)	N/A				**2,513**
Gallons/year /faucet (1.5 GPM)	N/A				**2,125**
Gallons/year /faucet (1.0 GPM)	N/A				**1,866**
Percent hot water	76.1%	not listed	57.6%	66.9%	**66.9%**
DHW gallons saved/year/faucet for 1.5 GPM	N/A				**260**
DHW gallons saved/year/faucet for 1.0 GPM	N/A				**433**

Notes:

*This value is a linear extrapolation of gallons per person per day from the baseline (2.2 GPM) and the 1.5 GPM case.

** Occupants per home for Texas from US Census Bureau, Texas, “Persons per household, 2007-2011.” Accessed January 2013 http://quickfacts.census.gov/qfd/states/48000.html.

*** Faucets per home assumed to be equal to one plus the number of half bathrooms and full bathrooms per home, taken from 2009 RECS, Table HC2.10.

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:

$$\boldsymbol{Energy\ Savings} = \frac{\boldsymbol{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplyAverage}) \times \left(\frac{1}{RE}\right)}}{\boldsymbol{Conversion\ Factor}}$$

Equation 70

Where:

ρ	=	*Water density, 8.33 lbs./gallon*
C_P	=	*Specific heat of water, 1 Btu/lb°F*
V	=	*Gallons of hot water saved per year per faucet (see Table 2-202)*
$T_{SetPoint}$	=	*Water heater setpoint (default value 120°F)*[179]
$T_{SupplyAverage}$	=	*Average supply water temperature (see Table 2-203)*
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.*[180]
ConversionFactor	=	*3,412 Btu/kWh*

Demand Savings Algorithms

Demand savings will be calculated using the following formula:

$$\boldsymbol{Demand\ Savings} = \frac{\boldsymbol{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplySeasonal}) \times \left(\frac{1}{RE}\right)}}{\boldsymbol{Conversion\ Factor}} \times \boldsymbol{Ratio_{annual\ kWh}^{Peak_{seasonal}kW}}$$

Equation 71

Where:

$T_{SupplySeasonal}$	=	*Seasonal supply water temperature (Table 2-203)*
$Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$	=	*Ratio of peak seasonal kW to annual kWh savings (Table 2-204)*

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179 120°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.

180 Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://www.ahrinet.org

Table 2-203: Water Mains Temperature

Climate Zone	Water Mains Temperature °F*		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Panhandle	62.9	73.8	53.7
Climate Zone 2: North	71.8	84.0	60.6
Climate Zone 3: South	74.7	84.5	65.5
Climate Zone 4: Valley	77.2	86.1	68.5
Climate Zone 5: West	70.4	81.5	60.4

* Based on typical meteorological year (TMY) dataset for TMY3: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

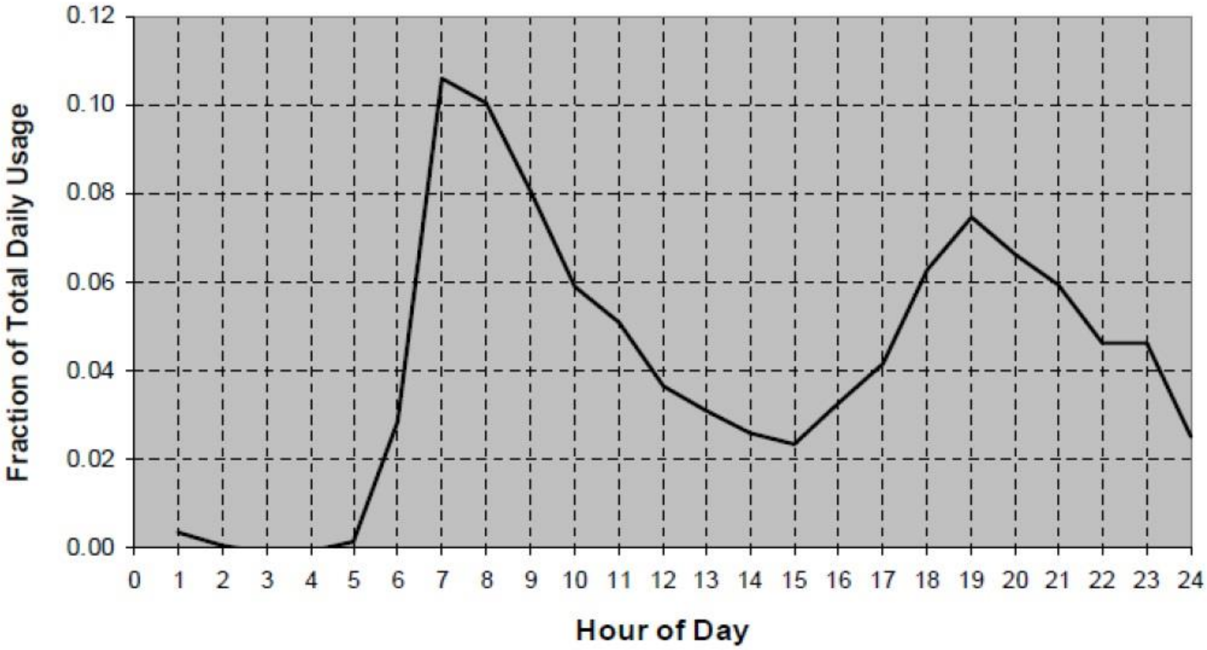
Table 2-204: Water Fixture Peak Demand Ratios

Peak Demand Ratios*	
Summer	**Winter**
0.000110	0.000274

* US Department of Energy's "Building America Performance Analysis Procedures for Existing Homes" combined domestic hot water use profile (http://www.nrel.gov/docs/fy06osti/38238.pdf).

The fixture peak demand ratios were derived by taking the fraction hot water use during the peak hour (summer: 4-5PM, winter: 7-8AM) to the total daily usage from the Building America Performance Analysis Procedures for Existing Homes, and dividing it by the number of days per year (365). The fraction of hot water use during the winter peak hour to total daily water usage is 0.1: $0.1/365 = 0.000274$. The summer peak hour to total daily water usage is 0.04: $0.04/365 = 0.000110$.

Figure 2-6: Shower, Bath, and Sink Hot Water Use Profile



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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a faucet aerator is established at 10 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[181]

Program Tracking Data & 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
- 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

This section is not applicable.

Document Revision History

Table 2-205: 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 set point temperature.

[181] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

2.4.2 Low-Flow Showerheads Measure Overview

TRM Measure ID: R-WH-SH

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

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 2.0, 1.7, or 1.5 gallons 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 measure in existing homes. In order to be awarded these deemed savings, the fuel type of the water heater must be electricity.

Table 2-206: Low-Flow Showerheads – Applicability

Application Type	Applicable
Retrofit	Y
New Construction	N

Baseline Condition

Federal standards set a maximum flow rate of 2.5 GPM,[182] while the US Environmental Protection Agency (EPA) WaterSense Program has implemented efficiency standards for showerheads requiring a maximum flow rate of 2.0 GPM.[183]

[182] http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/37

Table 2-207: Low-Flow Showerhead – Baseline and Efficiency Standards

Existing Showerhead Baseline Flow Rate	New Showerhead Flow Rate*
2.5 GPM maximum	1.5 GPM, 1.75 GPM or 2.0 GPM maximum

* All flow rate requirements listed here are the rated flow of the showerhead measured at 80 pounds per square inch of pressure (psi).

High-Efficiency Condition

In addition to the meeting the baseline requirements above, existing showerheads that have been defaced so as 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.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Estimated Hot Water Usage Reduction

Baseline and efficiency-standard water usages per capita were derived from an analysis of metered studies of residential water efficiency retrofit projects conducted for Seattle, WA; the East Bay Municipal Utility District (CA); and Tampa, FL.[184,185,186] See for derivation of water usage values.

To determine water consumption, the following formula was used:

$$\textit{Gallons per shower} \times \textit{Showers per person per day} \times 365\,\frac{days}{year} \times \frac{\textit{Occupants per home}}{\textit{Showerheads per home}}$$

Equation 72

[183] http://www.epa.gov/watersense/products/showerheads.html

[184] Seattle Home Water Conservation Study: "The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes." December 2000. http://allianceforwaterefficiency.org/WorkArea/linkit.aspx?LinkIdentifier=id&ItemID=856.

[185] Residential Indoor Water Conservation Study: "Evaluation of High Efficiency Indoor Plumbing Fixture Retrofits in Single-Family Homes in the East Bay Municipal Utility District Service Area." July 2003. http://www.ebmud.com/sites/default/files/pdfs/residential_indoor_wc_study_0.pdf.

[186] Tampa Water Department Residential Water Conservation Study: "The Impacts of High Efficiency Plumbing Fixture Retrofits in Single-Family Homes." January 8, 2004. www.cuwcc.org/WorkArea/downloadasset.aspx?id=12162.

Applying the formula to the values used for Texas fromTable 2-208 returns the following values for baseline and post water consumption:

$$\boldsymbol{Baseline\ (2.5\ GPM): 20.7 \times 0.69 \times 365 \times \left({}^{2.79}/_{1.68}\right) = 8,658}$$

$$\boldsymbol{Post\text{-}retrofit\ (2.0\ GPM): 16.5 \times 0.72 \times 365 \times \left({}^{2.79}/_{1.68}\right) = 7,201}$$

$$\boldsymbol{Post\text{-}retrofit\ (1.5\ GPM): 12.4 \times 0.72 \times 365 \times \left({}^{2.79}/_{1.68}\right) = 5,412}$$

Equation 73

Although the referenced studies do not provide data on 1.75 GPM showerheads, the consumption values for 2.5, 2.0, and 1.5 GPM roughly follow a linear pattern. Taking a simple average of the consumption for 2.0 and 1.5 GPM showerheads returns a value for a 1.75 GPM showerhead:

$$\boldsymbol{Post\text{-}retrofit\ (1.75\ GPM):\ (7,201 + 5,412)/2 = 6,306}$$

Equation 74

Gallons of hot water saved per year can be found by subtracting the post consumption in gallons per year per showerhead from the baseline consumption, and then multiplying the result by the percent hot water.

$$\boldsymbol{Gallons\ of\ hot\ water\ saved\ per\ year\ (2.0\ GPM): (8,658 - 7,201) \times 0.737 = 1,074}$$

$$\boldsymbol{Gallons\ of\ hot\ water\ saved\ per\ year\ (1.75\ GPM): (8,658 - 6,306) \times 0.737 = 1,733}$$

$$\boldsymbol{Gallons\ of\ hot\ water\ saved\ per\ year\ (1.5\ GPM): (8,658 - 5,412) \times 0.737 = 2,392}$$

Equation 75

Table 2-208: Estimated Showerhead Hot Water Usage Reduction

	Sample Studies			Average	Value used for Texas
	Seattle	Tampa	East Bay		
Gallons/shower @ 2.5 GPM (baseline)	19.8	20	22.3	20.7	**20.7**
Gallons/shower @ 2.0 GPM	15.8	16	17.8	16.5	**16.5**
Gallons/shower @ 1.5 GPM	11.9	12	13.4	12.4	**12.4**
Showers/person/day (baseline)	0.51	0.92	0.65	0.69	**0.69**
Showers/person/day (post)	0.59	0.82	0.74	0.72	**0.72**
Occupants per home*	2.54	2.92	2.56	2.67	**2.79**
Showerheads per home**	N/A				**1.68**
Gallons/year/showerhead @ 2.5 GPM (baseline)	N/A				**8,658**
Gallons/year/showerhead @ 2.0 GPM	N/A				**7,201**
Gallons/year/showerhead @ 1.75 GPM	N/A				**6,306**
Gallons/year/showerhead @ 1.5 GPM	N/A				**5,412**
Percent hot water	75.50%	not listed	71.90%	73.70%	**73.70%**
2.0 gpm showerhead DHW gallons saved/year	N/A				**1,074**
1.75 gpm showerhead DHW gallons saved/year	N/A				**1,733**
1.5 gpm showerhead DHW gallons saved/year	N/A				**2,392**

Notes:
* Occupants per home for Texas from US Census Bureau, Texas, "Persons per household, 2007-2011." Accessed January 2013 http://quickfacts.census.gov/qfd/states/48000.html.
** Showerheads per home assumed to be equal to the number of full bathrooms per home, taken from 2009 RECS, Table HC2.10.

Energy Savings Algorithms

Energy savings for this measure are calculated as follows:

$$\boldsymbol{Energy\ Savings\ per\ Showerhead} = \frac{\boldsymbol{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplyAverage}) \times \left(\frac{1}{RE}\right)}}{\boldsymbol{Conversion\ Factor}}$$

Equation 76

Where:

ρ = *Water density, 8.33 lbs/gallon*

C_P = *Specific heat of water, 1 Btu/lb°F*

V = *Gallons of hot water saved per year per showerhead (see Table 2-20).*

$T_{SetPoint}$ = *Water heater setpoint: 120°F*[187]

T_{Supply} = *Average supply water temperature (see*

Table 2-209*)*

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.[188]

ConversionFactor = *3,412 Btu/kWh*

Demand Savings Algorithms

Demand savings will be calculated using the following formula:

$$\textbf{Demand Savings per Showerhead} = \frac{\rho \times C_P \times V \times (T_{SetPoint} - T_{SupplySeasonal}) \times \left(\frac{1}{RE}\right)}{\textbf{Conversion Factor}} \times Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$$

Equation 77

Where:

$T_{SupplySeasonal}$ = *Seasonal supply water temperature (see*

Table 2-209*)*

$Ratio_{annual\ kWh}^{Peak_{seasonal}kW}$ = *Ratio of peak seasonal kW to annual kWh savings (see Table 2-210)*

[187] 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.

[188] 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.

Table 2-209: Water Mains Temperature

Climate Zone	Water Mains Temperature (°F)*		
	$T_{SupplyAverage}$	$T_{SupplySeasonal}$	
		Summer	Winter
Climate Zone 1: Panhandle	62.9	73.8	53.7
Climate Zone 2: North	71.8	84.0	60.6
Climate Zone 3: South	74.7	84.5	65.5
Climate Zone 4: Valley	77.2	86.1	68.5
Climate Zone 5: West	70.4	81.5	60.4

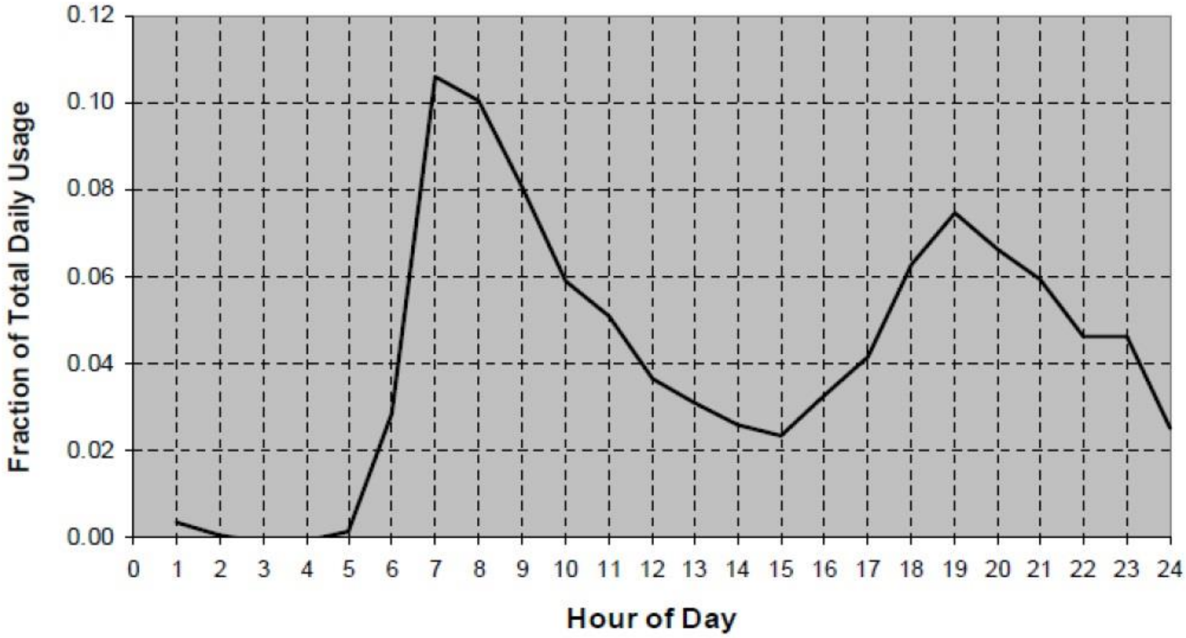
* Based on typical meteorological year (TMY) dataset for TMY3: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

Table 2-210: Water Fixture Peak Demand Ratios

Peak Demand Ratios*	
Summer	Winter
0.000110	0.000274

* US Department of Energy's "Building America Performance Analysis Procedures for Existing Homes" combined domestic hot water use profile (http://www.nrel.gov/docs/fy06osti/38238.pdf).

The fixture peak demand ratios were derived by taking the fraction hot water use during the peak hour (summer: 4-5pm, winter: 7-8am) to the total daily usage from the Building America Performance Analysis Procedures for Existing Homes, and dividing it by the number of days per year (365). The fraction of hot water use during the winter peak hour to total daily water usage is 0.1: $0.1/365 = 0.000274$. The summer peak hour to total daily water usage is 0.04: $0.04/365 = 0.000110$.



Source: Building America Performance Analysis Procedures for Existing Homes

Figure 2-7: Shower, Bath, and Sink Hot Water Use Profile

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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a low-flow showerhead is established at 10 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[189]

Program Tracking Data & 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
- 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

This section is not applicable.

[189] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

Document Revision History

Table 2-211: 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 set point temperature.

2.4.3 Water Heater Pipe Insulation Measure Overview

TRM Measure ID: R-WH-PI

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure requires the installation of pipe insulation on un-insulated 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. In order to be awarded these deemed savings, the fuel type of the water heater must be electricity.

Table 2-212: Water Heater Pipe Insulation – Applicability

Application Type	Applicable	Notes
Retrofit	Y	Savings cannot be claimed in conjunction with the installation of a new water heater.
New Construction	N	

Baseline Condition

The baseline is assumed to be a typical electric water heater with no heat traps and no insulation on water heater pipes.

Table 2-213: Water Heater Pipe Insulation – Baseline Standard

Baseline
Un-insulated hot water pipes

High-Efficiency Condition

The efficiency standard requires an insulation thickness R-3. The International Residential Code (IRC) 2009 section N1103.3: Mechanical system piping insulation requires R-3 insulation.

Table 2-214: Water Heater Pipe Insulation – Efficiency Standard

Efficiency Standard
Minimum insulation of R-3

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:

$$\boldsymbol{Energy\ savings\ per\ year} = \left(\boldsymbol{U_{pre}} - \boldsymbol{U_{post}}\right) \times \boldsymbol{A} \times \left(\boldsymbol{T_{pipe}} - \boldsymbol{T_{ambient\ annual}}\right) \times \left(\frac{\boldsymbol{1}}{\boldsymbol{RE}}\right) \times \frac{\boldsymbol{Hours_{Total}}}{\boldsymbol{conversion\ factor}}$$

Equation 78

Where:

U_{pre}[190] = $\frac{1}{2.03} = 0.49\ {}^{Btu}/_{hr \cdot sq.ft. \cdot {}^{\circ}\mathrm{F}}$

U_{post} = $\frac{1}{2.03 + R_{Insulation}}$

$\mathrm{R_{Insulation}}$ = *R-value of installed insulation*

A = *Pipe surface area insulated in square feet* (πDL) *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:*

[190] 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.

Table 2-215: Estimated Pipe Surface Area

Pipe Diameter (inches)	Pipe Surface Area (square feet)[191]
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)"

T_{pipe} *(°F)* = *120°F*[192]

$T_{ambientannual}$ *(°F)* = *Ambient annual temperature (see Table 2-216)*

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.*[193]

$Hours_{Total}$ = *8,760 hr per year*

Conversion factor = *3,412 Btu per kWh*

Demand Savings Algorithms

$$\textbf{Pipe Insulation Demand Savings } (\boldsymbol{kW}) = (\boldsymbol{U_{pre}} - \boldsymbol{U_{post}}) \times \boldsymbol{A} \times (\boldsymbol{T_{Pipe}} - \boldsymbol{T_{ambient\ seasonal}}) \times \left(\frac{\mathbf{1}}{\boldsymbol{RE}}\right) \times \frac{\mathbf{1}}{\boldsymbol{conversion\ factor}}$$

Equation 79

191 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

192 120°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.

193 Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://www.ahrinet.org.

Where:

$T_{ambientseasonal}(°F) =$ *Ambient seasonal temperature (see Table 2-216)*

Table 2-216: Ambient Temperatures per Climate Zone

Climate Zone		Ambient Temperature (°F)					
		Water Heater Location: Unconditioned Space*			Water Heater Location: Conditioned Space**		
		Annual	Peak Seasonal		Annual	Peak Seasonal	
			Summer	Winter		Summer	Winter
1	Panhandle	65.5	106	32	72.7	75.1	69.3
2	North	73.1	108.1	42			
3	South	76.3	108.2	46			
4	Valley	78.4	103	55			
5	West	71.8	108	41.1			

* Average ambient temperatures 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 & Cooling System Location Temperatures (Garage).
** Weighted average reported thermostat setpoints from RECS. Times associated with these setpoints are assumed to be the same as those assumed by ENERGY STAR®: http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats_guidelines.

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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of water heater pipe insulation installed for an electric water heater is established at 13 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[194]

Program Tracking Data & 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
- The R-value of the installed insulation
- 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

This section is not applicable.

[194] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

Document Revision History

Table 2-217: Water Heater 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 set point temperature.

2.4.4 Water Heater Tank Insulation Measure Overview

TRM Measure ID: R-WH-WJ

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure requires the installation of tank insulation on un-insulated water heater tanks that are served by an electric water heater.

Eligibility Criteria

Water heaters meeting the National Appliance Energy Conservation Act standards with respect to insulation and standby loss requirements are not eligible for this measure. To ensure compliance, the contractor shall inspect the build date listed on the existing water heater label and verify that the listed build date is before 1991.

Water heater pipe 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. In order to be awarded these deemed savings, the fuel type of the water heater must be electricity.

Table 2-218: Water Heater Tank Insulation – Applicability

Application Type	Applicable
Retrofit	Y
New Construction	N

Baseline Condition

The baseline is assumed to be a typical electric water heater with no insulation.

High-Efficiency Condition

There is no minimum insulation requirement. 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:

$$\textbf{Energy savings per year} = (U_{pre} - U_{post}) \times A \times (T_{tank} - T_{ambient\ annual}) \times \left(\frac{1}{RE}\right) \times \frac{Hours_{Total}}{conversion\ factor}$$

Equation 80

Where:

U_{pre} = *1/(5) Btu/hr sq.ft. °F*

U_{post} = *1/(5+$R_{Insulation}$)*

$R_{Insulation}$ = *R-value of installed insulation*

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 2-219.*

Table 2-219: Estimated Tank Area

Volume (gal)	A (sf.)*
30	17.45
40	21.81
50	22.63
60	26.94
80	30.36
120	38.73

* Tank area was obtained from a survey of electric water heater manufacturer data. Dimensions for each tank size were collected and averaged to determine a typical square footage of each size water heater. Accessed April 2013: http://www.hotwater.com/water-heaters/residential/conventional/electric/promax/standard/. Accessed April 2013: http://www.whirlpoolwaterheaters.com/products/electric-water-heaters/es40r92-45d/.

T_{tank} *(°F)* = *Average temperature of the tank, default use 120°F* [195]

$T_{ambientannual}$ *(°F)* = *Ambient annual temperature (see Table 2-220)*

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.* [196]

$Hours_{Total}$ = *8,760 hours per year*

Conversion factor = *3,412 Btu per kWh*

Demand Savings Algorithms

$$\textit{Tank Insulation Demand Savings } (kW) = (U_{pre} - U_{post}) \times A \times (T_{Tank} - T_{ambient\ seasonal}) \times \frac{1}{RE} \times \frac{1}{conversion\ factor}$$

Equation 81

Where:

$T_{ambientseasonal}$ *(°F)* = *Ambient seasonal temperature (see Table 2-220)*

Table 2-220: Ambient Temperatures per Climate Zone

<table>
<tr><th colspan="2" rowspan="4">Climate Zone</th><th colspan="6">Ambient Temperature (°F)</th></tr>
<tr><th colspan="3">Water Heater Location: Unconditioned Space</th><th colspan="3">Water Heater Location: Conditioned Space</th></tr>
<tr><th rowspan="2">Annual</th><th colspan="2">Peak Seasonal</th><th rowspan="2">Annual</th><th colspan="2">Peak Seasonal</th></tr>
<tr><th>Summer</th><th>Winter</th><th>Summer</th><th>Winter</th></tr>
<tr><td>1</td><td>Panhandle</td><td>65.5</td><td>106</td><td>32</td><td rowspan="5">72.7</td><td rowspan="5">75.1</td><td rowspan="5">69.3</td></tr>
<tr><td>2</td><td>North</td><td>73.1</td><td>108.1</td><td>42</td></tr>
<tr><td>3</td><td>South</td><td>76.3</td><td>108.2</td><td>46</td></tr>
<tr><td>4</td><td>Valley</td><td>78.4</td><td>103</td><td>55</td></tr>
<tr><td>5</td><td>West</td><td>71.8</td><td>108</td><td>41.1</td></tr>
</table>

* Average ambient temperatures were taken from TMY3 data, with a 7°F increase in winter and an 11°F incre in summer based on ASHRAE 152 Heating System & Cooling System Location Temperatures (Garage).
** Weighted average reported thermostat setpoints from RECS. Times associated with these setpoints are assumed to be the same as those assumed by ENERGY STAR®: http://www.energystar.gov/index.cfm?c=thermostats.pr_thermostats_guidelines.

[195] 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.

[196] Default values based on median recovery efficiency of residential water heaters by fuel type in the AHRI database, at http://www.ahrinet.org.

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

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) for storage water heater tank insulation is established at 7 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[197]

Program Tracking Data & 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
- Recovery Efficiency (RE) or COP, if available
- The R-value of the installed insulation
- Tank surface area insulated in square feet (πDL) with L (length) and D (tank diameter) in feet; if unable to determine tank area, tank volume must be recorded.

[197] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer2013-update-for-2014-codes.

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

This section is not applicable.

Document Revision History

Table 2-221: Water Heater 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 set point temperature.

2.4.5 Water Heater Installation – Electric Tankless and Fuel Substitution Measure Overview[198]

TRM Measure ID: R-WH-WH

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Replace-on-Burnout, Early Retirement, New Construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

This measure involves the installation of a new electric tankless or gas-fueled water heater (storage or tankless) in place of an electric storage water heater.

These deemed savings are calculated using the federal standards effective April 16, 2015. For measures installed prior to this date, utilities may, at their discretion, use the savings found in the Technical Reference Manual v.1.0 Implementation Guide (see http://www.texasefficiency.com/index.php/regulatory-filings/deemed-savings).

Eligibility Criteria

This measure involves the installation of a gas storage, gas tankless (instantaneous), or electric tankless water heater in place of an electric storage water heater, as long as the new unit meets all other requirements described below. Heat pump water heaters are not eligible for installation through this measure (see separate heat pump water heater measure). 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; therefore, deemed savings are only calculated for new gas storage, gas tankless, and electric tankless systems. Electric tankless water heaters may only replace systems with tanks less than 55 gallons. For

198 Previous versions of this measure included an incentive for installation of high efficiency conventional (electric resistance) storage water heaters. Increments to the federal standard for electric storage water heaters set to go into effect April 16, 2015, eliminate the feasibility of continuing to provide deemed savings for these units.

installation of an electric water heater with a tank size greater than 55 gallons, please refer to the heat pump water heater measure.

These deemed savings are for water heater replacements installed as a replace-on-burnout/new construction measure or as an early retirement measure. However, savings are calculated under the assumption of replace-on-burnout/new construction. 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. Relevant design documentation showing an electric storage water heater should also be provided.

Table 2-222: Water Heater Replacement – Applicability

Application Type	Applicable
Replace-on-Burnout	Y
Early Retirement	Y
New Construction	Y*

* Subject to documentation requirements described above.

Baseline Condition

The baseline condition is an electric storage water heater (EWH) with baseline efficiency determined by tank size according to the amended federal energy efficiency standards for residential water heaters with tank sizes 20 – 120 gallons, which take effect April 16, 2015, as published in 10 CFR Part 430.32 of the Federal Register:[199]

Table 2-223: Water Heater Replacement – Baseline

Rated Storage Volume	Energy Factor
≥ 20 gal and ≤ 55 gal	$0.960 – (0.0003*V_S)$
> 55 gal and ≤ 120 gal	$2.057 – (0.00113*V_S)$

V_s is the volume of the water heater's storage tank. The new DOE efficiency standard effectively requires heat pump water heaters (assuming electric water heating) for electric storage water heaters with tank size greater than 55 gallons. As such, electric water heaters with tanks greater than 55 gallons are not eligible for this measure. Instead, see the heat pump water heater measure. For smaller systems, the baseline technology remains an electric storage water heater with electric resistance as the primary heat source. This baseline assumes a replace-on-burnout scenario.

High-Efficiency Condition

For water heater replacement and fuel substitution, the new unit must meet the following federal minimum energy factor (EF). Water heaters must be installed in accordance with local code requirements.

[199] *10 CFR Part 430.32 Energy and water conservation standards and their effective dates*. Online. Available: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Accessed February 2014.

Table 2-224: Water Heater Replacement – Efficiency Standards

Energy Source	Tank Volume (unit being replaced)	Standard EF
Electric Tankless	≥ 20 gal and ≤ 55 gal	EF = 0.98*
	> 55 gal	N/A
Gas Tankless	≥ 20 gal	$EF = 0.82 – 0.0019 * V_s$
Gas Storage	≥ 20 gal and ≤ 55 gal	$EF = 0.675 – 0.0015 * V_s$
	> 55 gal	$EF = 0.8012 – 0.00078 * V_s$

* The lowest energy factor (EF) associated with an electric tankless water heater in the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) database is 0.98 as of March 2014. http://www.ahridirectory.org/ahridirectory/pages/home.aspx.

** V_s is the rated storage volume of the new water heater.

Table 2-225: Storage Water Heater Energy Factors for Common Tank Volumes (not exhaustive)

Fuel Type	Tank Volume (Gallons)			
	30	40	50	80
Baseline – Electric Storage	0.951	0.948	0.945	1.967[200]
Efficiency Standard – Gas Storage	0.630	0.615	0.600	0.739

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/new construction scenario, but may be used to award savings for early retirement projects.

[200] Baseline value from Heat Pump Water Heater (HPWH) measure. Used for fuel substitution savings calculation.

Electric Tankless Water Heater

Energy Savings Algorithm

$$kWh_{savings} = \frac{\rho \times C_p \times GPY \times (T_{SetPoint} - T_{Supply,ann}) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}{3,412 Btu/kWh}$$

Equation 82

Where:

ρ = *Water density, 8.33 lbs/gallons*

C_p = *Specific heat of water, 1 Btu/lb·°F*

GPY = *Estimated annual hot water use (gal/year), specified by number of bedrooms in the home in Table 2-226.*

Table 2-226: Water Heater Consumption (gal/year)*

Climate Zone		Number of Bedrooms			
		1	2	3	4
1	Panhandle	15,476	20,171	24,866	29,561
2	North	14,778	19,244	23,710	28,177
3	South	14,492	18,864	23,236	27,608
4	Valley	14,213	18,494	22,775	27,056
5	West	14,905	19,412	23,920	28,427

* Building America Research Benchmark Definition, December 2009 (http://www.nrel.gov/docs/fy10osti/47246.pdf).

$T_{SetPoint}$ = *Water heater set point = 120°F*[201]

$T_{Supply,ann}$ = *Annual average mains temperature from Table 2-227*

EF_{pre} = *Baseline value from Table 2-225, or calculated per Table 2-223*[202]

EF_{post} = *Energy Factor of new water heater*

Conversion Factor = *3,412 Btu/kWh*

201 120°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.

202 Note that for efficient water heater installations in newly-constructed homes, the baseline efficiency EF_{pre} is the efficiency of the electric storage water heater that would otherwise have been installed, according to appropriate design documentation.

Table 2-227: Water Mains Temperature

Climate Zone		Water Mains Temperature °F		
		T Supply Average	T Supply Seasonal	
			Summer	Winter
1	Panhandle	62.9	73.8	53.7
2	North	71.8	84.0	60.6
3	South	74.7	84.5	65.5
4	Valley	77.2	86.1	68.5
5	West	70.4	81.5	60.4

Based on typical meteorological year (TMY) dataset for TMY3: http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

Demand Savings Algorithm

$$SummerkW_{savings} = Ratio_{daily\ gal}^{Sum\ peak\ gal} \frac{\rho \times C_p \times GPY \times (T_{SetPoint} - T_{Supply,sum}) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}{365 \times 3{,}412 \frac{Btu}{kWh}}$$

Equation 83

$$WinterkW_{savings} = Ratio_{daily\ gal}^{Win\ peak\ gal} \frac{\rho \times C_p \times GPY \times (T_{SetPoint} - T_{Supply,win}) \times \left(\frac{1}{EF_{pre}} - \frac{1}{EF_{post}}\right)}{365 \times 3{,}412 \frac{Btu}{kWh}}$$

Equation 84

Where:

GPY = *Estimated annual hot water use (gal/year), specified by number of bedrooms in the home in Table 2-226*

$T_{Supply,sum}$ = *Summer average water mains temperature from Table 2-227*

$T_{Supply,win}$ = *Winter average water mains temperature from Table 2-227*

$Ratio_{dailygal}^{Sumpeakgal}$ = *Ratio of hot water use during the typical summer peak hour (4-5pm) to daily hot water use = 0.0436*

$Ratio_{dailygal}^{Winpeakgal}$ = *Ratio of average hot water use during the winter peak hour (8am) to daily hot water use = 0.0794*

Gas Storage or Tankless Water Heater (Fuel Substitution)

Energy and demand savings awarded for replacement of an electric water heater with a gas storage or gas tankless water heater award savings equal to the consumption of the unit replaced.

For gas storage water heaters with a tank size greater than 55 gallons, the appropriate baseline is a heat pump water heater. The baseline EF specified in Table 2-225 for a tank size of 80 gallons is calculated using the federal standard baseline condition specified in the Heat Pump Water Heater measure.

Energy Savings Algorithm

$$\boldsymbol{kWh_{savings}} = \frac{\boldsymbol{\rho \times C_p \times GPY \times (T_{SetPoint} - T_{Supply,ann}) \times \left(\frac{1}{EF_{pre}}\right)}}{\boldsymbol{3,412 \frac{Btu}{kWh}}}$$

Equation 85

Demand Savings Algorithm

$$SummerkW_{savings} = Ratio_{daily\ gal}^{Sum\ peak\ gal} \times \frac{\rho \times C_p \times GPY \times (T_{SetPoint} - T_{Supply,sum}) \times \left(\frac{1}{EF_{pre}}\right)}{365 \times 3{,}412 \frac{Btu}{kWh}}$$

Equation 86

$$WinterkW_{savings} = Ratio_{daily\ gal}^{Win\ peak\ gal} \times \frac{\rho \times C_p \times GPY \times (T_{SetPoint} - T_{Supply,win}) \times \left(\frac{1}{EF_{pre}}\right)}{365 \times 3{,}412 \frac{Btu}{kWh}}$$

Equation 87

Examples

Example 1. An old 40 gallon electric water heater in a two bedroom home in Dallas is replaced with a new, tankless electric water heater with an EF of 0.99

$$kWh\ savings = \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 71.8) \times \left(\frac{1}{0.948} - \frac{1}{0.99}\right)\right]}{3{,}412} = 101.3\ \text{kWh}$$

$$Summer\ kW\ savings = 0.0436 \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 84) \times \left(\frac{1}{0.948} - \frac{1}{0.99}\right)\right]}{365 \times 3{,}412} = 0.009\ \text{kW}$$

$$Winter\ kW\ savings = 0.0794 \frac{\left[8.33 \times 1 \times 19{,}244 \times (120 - 60.6) \times \left(\frac{1}{0.948} - \frac{1}{0.99}\right)\right]}{365 \times 3{,}412} = 0.026\ \text{kW}$$

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 an EF of 0.65

$$kWh\ savings = \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 70.4) \times \left(\frac{1}{0.951}\right)\right]}{3{,}412} = 1{,}897.8\ \mathrm{kWh}$$

$$Summer\ kW\ savings = 0.0436 \times \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 81.5) \times \left(\frac{1}{0.951}\right)\right]}{365 \times 3{,}412} = 0.176\ \mathrm{kW}$$

$$Winter\ kW\ savings = 0.0794 \times \frac{\left[8.33 \times 1 \times 14{,}905 \times (120 - 60.4) \times \left(\frac{1}{0.951}\right)\right]}{365 \times 3{,}412} = 0.496\ \mathrm{kW}$$

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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The average Estimated Useful Lives for equipment installed in this measure are: 20 years for a tankless water heater (gas or electric), or 11 years for a high efficiency gas water heater.

These values are consistent with the EULs reported in the 2014 California Database for Energy Efficiency Resources (DEER).[203]

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[203] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer-versions/deer2013-update-for-2014-codes.

Program Tracking Data & 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
- Volume of the replacement water heater in gallons (zero if tankless)
- Volume of the existing water heater in gallons
- EF of the replacement water heater
- Number of bedrooms
- Form signed by customer and utility representative indicating planned electric storage water heater installation (New Construction only)
- Design documents indicating planned electric storage water heater installation (New Construction only)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-228: Water Heater Installation – Electric Tankless and Fuel Substitution 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 updated to require electric tankless rather than electric storage water heater installation for non-fuel-switching option. Updated by Frontier Associates, March 2014, based on new federal standards.
v2.1	1/30/2015	TRM v2.1 update. New construction permitted to claim savings subject to documentation requirements. Gas-fueled tankless water heaters made eligible for installation.
v3.0	4/10/2015	TRM v3.0 update. Fuel substitution savings amended to reflect full consumption of electric unit replaced. Demand savings for installation of an electric tankless unit revised to reflect daily usage patterns.
v3.1	11/05/2015	TRM v3.1 update. Clarified baseline for water heaters greater than 55 gallons.

2.4.6 Heat Pump Water Heater Measure Overview

TRM Measure ID: R-WH-HW

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity and gas

Decision/Action Type(s): Replace-on-Burnout

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values (Lookup Tables)

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

The residential heat pump water heater (HPWH) measure involves the installation of an integrated or "drop-in" ENERGY STAR® HPWH. Deemed savings values are presented on a per-unit basis. Deemed savings variables include storage tank volume and HPWH installation location (in conditioned or unconditioned space). In addition, this measure accounts for the interactive air-conditioning energy savings and heating penalty associated with the HPWH when installed inside conditioned space.[204]

These deemed savings are calculated using the federal standards effective April 16, 2015. For measures installed prior to this date, utilities may, at their discretion, use the savings found in the Technical Reference Manual v.1.0 Implementation Guide (see http://www.texasefficiency.com/index.php/regulatory-filings/deemed-savings).

Eligibility Criteria

This measure applies to residential, electric, storage-type water heaters with storage capacities between 40 and 80 gallons. Heat pump add-ons to existing storage water heaters are ineligible. The measure does not apply to the replacement of gas water heaters.

These deemed savings are for Heat Pump Water Heaters installed as a replace-on-burnout measure or as an early retirement measure in existing homes. However, savings are calculated under the assumption of replace-on-burnout.

[204] Because the latest manufacturer standards effectively require heat pump water heaters (assuming electric water heating) for residential units with storage tank size greater than 55 gallons. As such, interactive effects are essentially the same for base and change case systems, so they are ignored.

Table 2-229: Heat Pump Water Heaters – Applicability

Application Type	Applicable	Notes
Replace-on-Burnout	Y	For replacement of electric storage water heater
Early Retirement	Y	Awarded savings calculated for replace-on-burnout
New Construction	N	

Baseline Condition

The baseline condition is an electric storage water heater (EWH) with baseline efficiency determined by tank size based on the amended federal energy efficiency standards for residential water heaters with tank sizes 20 – 120 gallons, as published in 10 CFR Part 430.32 of the Federal Register:[205]

Table 2-230: Federal Standard for Residential Water Heaters

Rated Storage Volume	Energy Factor
≥ 20 gal and ≤ 55 gal	$0.960 – (0.0003*V_S)$
> 55 gal and ≤ 120 gal	$2.057 – (0.00113*V_S)$

Application of this equation provides the following baseline efficiency levels for electric storage water heaters.

Table 2-231: Heat Pump Water Heaters –
Minimum Required Energy Factors for Post-2004 Water Heaters

Tank Size (Gallons)			
40	50	60	80
0.948	0.945	1.989	1.967

The new DOE efficiency standard effectively requires heat pump water heaters (assuming electric water heating) for storage water heaters with tank size greater than 55 gallons. As such, the baseline technology for water heaters with tanks greater than 55 gallons is a heat pump water heater. For smaller systems, the baseline technology remains an electric storage water heater with electric resistance as the primary heat source. This baseline assumes a replace-on-burnout scenario.

[205] *10 CFR Part 430.32 Energy and water conservation standards and their effective dates*. Online. Available: http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Accessed February 2014.

High-Efficiency Condition

The efficient condition (i.e., equipment eligible to receive an incentive through a program) is a heat pump water heater that meets ENERGY STAR® qualifications.[206] Heat pump water heaters depend on adequate ventilation for proper functioning, including adequate space for both inlet and outlet air flow, and should be installed in spaces in which 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.[207]

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Four basic variables specify the appropriate deemed demand and energy savings values for a given project:

- The climate zone
- The HPWH tank size
- The HPWH installed location (Conditioned vs. Unconditioned Space)
- For HPWH installations in conditioned space, the building heating type (electric resistance, air-source heat pump, or gas furnace)

Deemed savings are estimated using an energy factor (EF) of 2.4. This EF is the average efficiency of ENERGY STAR® HPWHs as of February 2014.[208]

Deemed Energy Savings Tables

Deemed savings are developed for heat pump water heaters in four size ranges: 40-49 gallon, 50-59 gallons, 60-79 gallons, and 80 or more gallon sizes. These sizes correspond to the four basic sizes of HPWHs commercially available at the time these deemed savings were developed, according to review of manufacturer data provided on the ENERGY STAR® and AHRI websites. Table 2-232 through Table 2-236 present the deemed saving tables for five Texas climate zones. These tables assume a replace-on-burnout scenario, but may be used to award savings for early retirement projects.

[206] ENERGY STAR® Requirements (as of February 2014): HPWH must have a maximum current rating of 24 amperes, voltage no greater than 250 volts, and a transfer of thermal energy from one temperature to a higher temperature level for the purpose of heating water. Unit must have "integrated" or "drop-in" configuration. EF ≥ 2.0, first-hour rating (FHR) ≥ 50 gallons/hour, Warranty ≥ 6 years on sealed systems, Safety UL 174 & UL 1995.

[207] Heat Pump Water Heaters. Department of Energy, May 2012. Online. Available: http://energy.gov/energysaver/articles/heat-pump-water-heaters. Accessed: February 22, 2013.

[208] As of February 2014, the ENERGY STAR® products list includes thirty residential heat pump water heaters with energy factors ranging from 2.2 to 2.75.

Table 2-232: Climate Zone 1: Amarillo, TX – Residential HPWH Deemed Annual Energy Savings (kWh)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	1,805	2,084	308	394
	Heat Pump	1,464	1,737	308	394
	Elec. Resistance	1,020	1,284	308	394
Unconditioned Space	N/A	1,645	1,916	320	409

Table 2-233: Climate Zone 2: Dallas, TX – Residential HPWH Deemed Annual Energy Savings (kWh)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	1,533	1,759	243	310
	Heat Pump	1,294	1,516	243	310
	Elec. Resistance	982	1,199	243	310
Unconditioned Space	N/A	1,362	1,585	245	313

Table 2-234: Climate Zone 3: Houston, TX – Residential HPWH Deemed Annual Energy Savings (kWh)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	1,449	1,657	223	285
	Heat Pump	1,213	1,417	223	285
	Elec. Resistance	906	1,105	223	285
Unconditioned Space	N/A	1,273	1,481	219	280

Table 2-235: Climate Zone 4: Corpus Christi, TX – Residential HPWH Deemed Annual Energy Savings (kWh)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	1,393	1,587	204	260
	Heat Pump	1,253	1,445	204	260
	Elec. Resistance	1,070	1,260	204	260
Unconditioned Space	N/A	1,193	1,387	199	255

Table 2-236: Climate Zone 5: El Paso, TX – Residential HPWH Deemed Annual Energy Savings (kWh)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	1,554	1,788	253	324
	Heat Pump	1,315	1,544	253	324
	Elec. Resistance	1,003	1,227	253	324
Unconditioned Space	N/A	1,409	1,639	255	326

Deemed Summer Demand Savings Tables

Table 2-237 through Table 2-241 present the deemed summer demand savings for heat pump water heaters across the five Texas climate zones.

Table 2-237: Climate Zone 1: Amarillo, TX – Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	All	0.26	0.30	0.04	0.04
Unconditioned Space	N/A	0.22	0.25	0.03	0.04

Table 2-238: Climate Zone 2: Dallas, TX – Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	All	0.20	0.22	0.02	0.03
Unconditioned Space	N/A	0.16	0.18	0.02	0.03

Table 2-239: Climate Zone 3: Houston, TX – Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	All	0.19	0.22	0.02	0.03
Unconditioned Space	N/A	0.15	0.18	0.02	0.03

Table 2-240: Climate Zone 4: Corpus Christi, TX – Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	All	0.18	0.21	0.02	0.03
Unconditioned Space	N/A	0.14	0.17	0.02	0.02

Table 2-241: Climate Zone 5: El Paso, TX – Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	All	0.21	0.24	0.03	0.03
Unconditioned Space	N/A	0.17	0.20	0.02	0.03

Deemed Winter Demand Savings Tables

Table 2-242 through Table 2-246 present the deemed winter demand savings for heat pump water heaters across the five Texas climate zones.

Table 2-242: Climate Zone 1: Amarillo, TX – Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	0.45	0.52	0.08	0.11
	Heat Pump	0.32	0.39	0.08	0.11
	Elec. Resistance	0.00	0.22	0.08	0.11
Unconditioned Space	N/A	0.41	0.48	0.09	0.12

Table 2-243: Climate Zone 2: Dallas, TX – Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	0.39	0.46	0.07	0.09
	Heat Pump	0.27	0.33	0.07	0.09
	Elec. Resistance	0.00	0.16	0.07	0.09
Unconditioned Space	N/A	0.37	0.43	0.08	0.10

Table 2-244: Climate Zone 3: Houston, TX – Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	0.35	0.41	0.07	0.08
	Heat Pump	0.23	0.28	0.07	0.08
	Elec. Resistance	0.00	0.12	0.07	0.08
Unconditioned Space	N/A	0.34	0.39	0.07	0.09

Table 2-245: Climate Zone 4: Corpus Christi, TX – Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	0.33	0.38	0.06	0.08
	Heat Pump	0.20	0.25	0.06	0.08
	Elec. Resistance	0.00	0.09	0.06	0.08
Unconditioned Space	N/A	0.32	0.37	0.06	0.08

Table 2-246: Climate Zone 5: El Paso, TX – Residential HPWH Deemed Demand Savings (kW)

Water Heater Location	Heating Type	HPWH Tank Size Range, Gallons			
		40	50	60	80
Conditioned Space	Gas	0.39	0.46	0.07	0.09
	Heat Pump	0.27	0.33	0.07	0.09
	Elec. Resistance	0.00	0.16	0.07	0.09
Unconditioned Space	N/A	0.37	0.43	0.08	0.10

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The Estimated Useful Life for this measure is 13 years. This EUL is consistent with the judgment of the American Council for an Energy-Efficient Economy as listed on its website.[209]

Program Tracking Data & 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
- The approximate volume of the replacement heat pump water heater tank in gallons
- The baseline energy factor (EF)
- The EF of the replacement water heater
- Water heater type (e.g., heat pump, electric resistance)
- The installed location (conditioned vs. unconditioned space)
- For heat pump water heater installations in conditioned space, the building heating type (electric resistance, air-source heat pump, or gas furnace)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

This section is not applicable.

[209] Water Heating. American Council for an Energy Efficient Economy. Online. Available: http://www.aceee.org/consumer/water-heating. Accessed: September 2011.

Document Revision History

Table 2-247: Heat Pump Water Heater 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 Associates, 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. No revision.
v3.1	11/05/2015	TRM v3.1 update. No revision.

2.4.7 Water Heater Replacement – Solar Water Heating Measure Overview

TRM Measure ID: R-WH-WS

Market Sector: Residential

Measure Category: Water Heating

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

Savings Methodology: Engineering Algorithms and Estimates

Measure Description

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. However, savings are calculated under the assumption of replace-on-burnout.

Baseline Condition

This section is not applicable.

High-Efficiency Condition

Only solar water heaters meeting the SRCC OG-300 standard (based on tank size and final Solar Energy Factor-SEF) qualify for these deemed savings estimates.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

Solar water heating values are on a per-unit basis. Deemed savings variables include tank volume and installed-unit Solar Energy Factor (SEF) as rated in the Solar Rating and Certification Corporation (SRCC) "Summary of SRCC Certified Solar Collector and Water Heating System Ratings." The Solar Energy Factor (SEF) 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 Energy Factor (EF) and listed in the Gas Appliance Manufacturers Association Directory of Certified Water Heating Products.

Both EF and SEF 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/.)

Examples

A passive Sun Earth CP-40 with a SEF of 1.4 would consume 2133 kWh (2987/1.4), saving 1323 kWh compared to a baseline 50 gallon water heater that consumes 3458 kWh (values based on Frontier data).

An active Heliotype HP 410 G 80 with a SEF of 2.0 would consume 1494 kWh (2987/2), saving 1965 kWh compared to the baseline 50 gallon water heater.

Use SRCC OG-300 Test to obtain SEF

SRCC = Solar Rating and Certification Corporation

OG-300 = test standard for SWH systems

SEF = Solar Energy Factor

Calculate kWh Savings

$$kWh\ savings = standard\ load \times \left(1 - \frac{EF}{SEF}\right) = (3{,}458) \times \left(1 - \frac{0.864}{2}\right) = 1{,}965 kWh$$

Deemed Energy Savings Tables

The following table presents the energy savings for solar water heaters based on tank size and final Solar Energy Factor (SEF).

Table 2-248: Solar Water Heating Energy Savings (kWh)

Water Heating Replacements – Solar Water Heating Energy Savings			
Approximate Volume (gal)	**80**	**50**	**30**
Baseline (DOE Standard) EF	**0.82**	**0.86**	**0.89**
SRCC OG-300 Solar Energy Factor	**Energy Savings (kWh)**		
1.0	637	471	368
1.1	909	743	640
1.2	1,135	969	866
1.3	1,326	1,160	1,057
1.4	1,490	1,324	1,221
1.5	1,633	1,467	1,364
1.6	1,757	1,591	1,488
1.7	1,867	1,701	1,598
1.8	1,965	1,799	1,696
1.9	2,052	1,886	1,783
2.0	2,131	1,965	1,862
2.1	2,202	2,036	1,933
2.2	2,266	2,100	1,997
2.3	2,325	2,159	2,056
2.4	2,379	2,213	2,110
2.5	2,429	2,263	2,160
2.6	2,475	2,309	2,206
2.7	2,518	2,352	2,249
2.8	2,557	2,391	2,288
2.9	2,594	2,428	2,325
3.0	2,628	2,462	2,359
3.1	2,660	2,494	2,391
3.2	2,691	2,525	2,422
3.3	2,719	2,553	2,450
3.4	2,745	2,579	2,476
3.5	2,771	2,605	2,502
3.6	2,794	2,628	2,525
3.7	2,817	2,651	2,548
3.8	2,838	2,672	2,569
3.9	2,858	2,692	2,589
4.0	2,877	2,711	2,608
4.1	2,895	2,729	2,626
4.2	2,913	2,747	2,644
4.3	2,929	2,763	2,660
4.4	2,945	2,779	2,676

Water Heating Replacements – Solar Water Heating Energy Savings			
Approximate Volume (gal)	**80**	**50**	**30**
Baseline (DOE Standard) EF	**0.82**	**0.86**	**0.89**
SRCC OG-300 Solar Energy Factor	**Energy Savings (kWh)**		
4.5	2,960	2,794	2,691
4.6	2,975	2,809	2,706
4.7	2,988	2,822	2,719
4.8	3,002	2,836	2,733
4.9	3,014	2,848	2,745
5.0	3,027	2,861	2,758

Source: Tim Merrigan, National Renewable Energy Laboratory (2001)

Deemed Summer Demand Savings Tables

The following table presents the demand savings for solar water heaters.

Table 2-249: Solar Water Heating Demand Savings (kW)

Solar Water Heating Demand Savings kW
0.42

Diversified value fully displaced during solar peak.

This value is consistent with Univ. of Texas study (0.4)

Deemed Winter Demand Savings Tables

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of a solar water heater is established at 15 years.

This value is consistent with the EUL reported in the 2014 California Database for Energy Efficiency Resources (DEER).[210]

Program Tracking Data & 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 approximate volume of the replacement water heater in gallons
- SRCC OG-300 Solar Energy Factor of the replacement unit

References and Efficiency Standards

Petitions and Rulings

- Docket No. 22241, Item 62. Petition by Frontier Associates 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

This section is not applicable.

Document Revision History

Table 2-250: Water Heater Replacement – Solar Water Heating 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.

[210] 2014 California Database for Energy Efficiency Resources. http://www.deeresources.com/index.php/deer-versions/deer2013-update-for-2014-codes.

2.5 RESIDENTIAL: APPLIANCES

2.5.1 ENERGY STAR® Ceiling Fans Measure Overview

TRM Measure ID: R-AP-FN

Market Sector: Residential

Measure Category: Appliances

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

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

This section is not applicable.

Baseline Condition

The baseline is a conventional non-ENERGY STAR® labeled ceiling fan and light kit.

High-Efficiency Condition

Table 2-251 displays the ENERGY STAR® requirements for eligible ceiling fans as of April 1, 2012. These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® code.

Table 2-251: ENERGY STAR® Specifications for Ceiling Fans

ENERGY STAR® Specifications for Ceiling Fans
1. Specification defines residential ceiling fan airflow efficiency on a performance basis: CFM of airflow per watt of power consumed by the motor and controls. Efficiency is measured on each of three speeds (low/medium/high).
2. At low speed, fans must have a minimum airflow of 1,250 CFM and an efficiency of 155 CFM/Watt
3. At medium speed, fans must have a minimum airflow of 3,000 CFM and an efficiency of 100 CFM/W.
4. At high speed, fans must have a minimum airflow of 5,000 CFM and an efficiency of 75 CFM/Watt
5. Qualifying ceiling fan models must come with a minimum 30-year motor warranty; one-year component(s) warranty; and light kit warranty specified in "ENERGY STAR® Program Requirements for Luminaires" document.[211]
6. Integral or attachable lighting, including separately sold ceiling fan light kits, must meet requirements provided in the "ENERGY STAR® Program Requirements for Luminaires" specification. [212]
7. Qualifying products must permit convenient consumer adjustment of fan speed, by means of one or more wall-mounted switch(es), a remote control, or readily accessible pull chains.

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.213 Default values were taken directly from the ENERGY STAR® Ceiling Fan Savings Calculator, unless otherwise specified.

$$kWh_{savings} = (kWh_{baseline} - kWh_{ES})_{fan} + (kWh_{baseline} - kWh_{ES})_{lgt} \times IEF_E$$

Equation 88

$$kWh_{baseline,Fan} = \frac{W_{Fan,baseline} \times AOH_{Fan}}{1,000}$$

Equation 89

[211] ENERGY STAR® Program Requirements for Luminaires. http://www.energystar.gov/ia/partners/product_specs/program_reqs/Final_Luminaires_V1_2.pdf?6d42-c7e4.
[212] Ibid.
[213] ENERGY STAR® Ceiling Fan Savings Calculator (updated September 2013). http://www.energystar.gov/products/certified-products/detail/ceiling-fans.

$$kWh_{ES,Fan} = \frac{W_{Fan,ES} \times AOH_{Fan}}{1,000}$$

Equation 90

$$W_{Fan} = (W_{LS} \times OP_{LS}) + (W_{MS} \times OP_{MS}) + (W_{HS} \times OP_{HS})$$

Equation 91

$$kWh_{baseline,Lgt} = \frac{W_{Lgt,baseline} \times AOH_{Lgt}}{1,000}$$

Equation 92

$$kWh_{ES,Lgt} = \frac{W_{Lgt,ES} \times AOH_{Lgt}}{1,000}$$

Equation 93

Where:

$kWh_{baseline}$ = *Non-ENERGY STAR® baseline energy usage*

kWh_{ES} = *ENERGY STAR® average energy usage*

IEF_E = *Energy Interactive Effects Factor (Table 2-3)*[214]

$W_{Lgt,baseline}$ = *Conventional lighting total wattage = 115 W (160 W default value from ENERGY STAR® calculator reduced to comply with EISA 2007 baseline wattages)*[215]

$W_{Lgt,ES}$ = *Actual wattage of installed ENERGY STAR® lighting; if unknown, 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 2-253*

$OP_{LS,MS,HS}$ = *Fan operating percentage at low, medium, and high speed; see Table 2-254*

AOH_{Lgt} = *Annual lighting operating hours = 803 hours/year (assuming 2.2 hours/day and 365 days/year operation)*[216]

AOH_{Fan} = *Annual fan operating hours = 1,095 hours/year (assuming 3.0 hours/day and 365 days/year operation)*

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[214] The assumed energy interactive effects factors are taken from the residential lighting measure.
[215] EISA 2007 baseline wattages are approximately 72% of standard incandescent wattages.
[216] The assumed annual operating hours are taken from the residential lighting measure.

$1{,}000 \quad = \quad Constant\ to\ convert\ from\ W\ to\ kW$

Table 2-252: ENERGY STAR® Ceiling Fans – Interactive Effects Factor for Cooling Energy Savings and Heating Energy Penalties[217]

IEF_E					
Heating/Cooling Type*	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Gas Heat with AC	1.09	1.15	1.16	1.18	1.13
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	0.86	1.03	1.08	1.13	1.00
Electric Resistance Heat with AC	0.65	0.91	1.00	1.07	0.88
Electric Resistance Heat with no AC	0.56	0.75	0.84	0.89	0.74
No heat with AC	1.09	1.15	1.16	1.18	1.13
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	0.87	1.03	1.08	1.12	1.01
Upstream Lighting	0.89	1.03	1.07	1.10	1.01
* IEF for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.					

217 Calculated using IEFs from Cadmus report and weighted using TMY CDD and HDD for Texas. 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 2-253: Ceiling Fan 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

Table 2-254: Ceiling Fan 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).

$$kW_{savings} = kW_{Fan} + kW_{Lgt}$$

Equation 94

$$kW_{Fan} = \frac{W_{Fan,baseline} - W_{Fan,ES}}{1,000} \times CF_{Fan}$$

Equation 95

$$kW_{Lgt} = \frac{W_{Lgt,baseline} - W_{Lgt,ES}}{1,000} \times CF_{Lgt} \times IEF_D$$

Equation 96

Where:

kW_{Fan} = *Fan demand savings*

CF_{Fan} = *Fan motor coincidence factor = 0.446*

kW_{Lgt} = *Lighting demand savings*

CF_{Lgt} = *Lighting coincidence factor (Table 2-284)*

IEF_D = *Demand Interactive Effects Factor (Table 2-256)*[218]

Table 2-255 ENERGY STAR® Ceiling Fans – Lighting Coincidence Factors[219]

Season	Climate Zone 1: Amarillo	Climate Zone 2: Dallas	Climate Zone 3: Houston	Climate Zone 4: Corpus Christi	Climate Zone5: El Paso
Summer	0.060	0.053	0.063	0.059	0.032
Winter	0.277	0.232	0.199	0.267	0.357

Table 2-256: ENERGY STAR® Ceiling Fans – Interactive Effects Factor for Cooling Demand Savings and Heating Demand Penalties[220]

$IEF_{D,summer}$					
Heating/Cooling Type*	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Gas Heat with AC	1.25	1.45	1.48	1.53	1.39
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	1.25	1.45	1.48	1.53	1.39
Electric Resistance Heat with AC	1.25	1.45	1.48	1.53	1.39
Electric Resistance Heat with no AC	1.00	1.00	1.00	1.00	1.00
No heat with AC	1.25	1.45	1.48	1.53	1.39
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	1.24	1.43	1.46	1.51	1.37
Upstream Lighting	1.20	1.36	1.39	1.43	1.31
$IEF_{D,winter}$					
Heating/Cooling Type*	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Gas Heat with AC	1.00	1.00	1.00	1.00	1.00
Gas Heat with no AC	1.00	1.00	1.00	1.00	1.00
Heat Pump	0.49	0.60	0.66	0.69	0.61
Electric Resistance Heat with AC	0.49	0.60	0.66	0.69	0.61
Electric Resistance Heat with no AC	0.49	0.60	0.66	0.69	0.61
No heat with AC	1.00	1.00	1.00	1.00	1.00
Unconditioned Space	1.00	1.00	1.00	1.00	1.00
Heating/Cooling Unknown	0.75	0.80	0.83	0.85	0.81
Upstream Lighting	0.78	0.83	0.85	0.86	0.83
* IEF for homes with no AC are most appropriate for customers with evaporative cooling or room air conditioners.					

[218] The assumed demand interactive effects factors are taken from the residential lighting measure.
[219] See Volume 1, Appendix B.
[220] Calculated using IEFs from Cadmus report and weighted using TMY CDD and HDD for Texas. 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 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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is 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.[221]

Program Tracking Data & 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 number of installed ENERGY STAR® ceiling fan and light kits.
- Wattage of installed lighting

[221] 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.

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.

Relevant Standards and Reference Sources

The applicable version of the ENERGY STAR® specifications and requirements for ceiling fans.

Document Revision History

Table 2-257: ENERGY STAR® Ceiling Fan 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 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	March 2016	Updated summer and winter coincidence factors.

2.5.2 ENERGY STAR® Clothes Washer Measure Overview

TRM Measure ID: R-AP-CW

Market Sector: Residential

Measure Category: Appliances

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

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 March 7, 2015.

Eligibility Criteria

This section is not applicable.

Baseline Condition

Effective March 7, 2015, the baseline is the Department of Energy (DOE) minimum efficiency standard[222] 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 consistent with the ENERGY STAR® appliance calculator. This baseline is schedule to change again on January 1, 2018.

[222] DOE minimum efficiency standard for residential clothes washers. https://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39.

Table 2-258: Federal Standard for Clothes Washers

Product Type	Current Criteria (as of March 7, 2015)	Proposed Changes for January 1, 2018
Top-loading, Standard (1.6 ft^3 or greater capacity)	IMEF ≥ 1.29 IWF≤ 8.4	IMEF ≥ 1.57 IWF≤ 6.5

IMEF = Integrated Modified Energy Factor (ft^3/kWh/cycle)

IWF = Integrated Water Factor (gallons/cycle/ft^3)

High-Efficiency Condition

The table below displays the ENERGY STAR® Final Version 7.0 requirements for eligible clothes washers effective March 7, 2015.[223] These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Table 2-259: ENERGY STAR® Specifications for Residential Clothes Washers

Product Type	Current Criteria (as of March 7, 2015)
ENERGY STAR® Residential Front-loading (> 2.5 ft^3)	IMEF ≥ 2.38 IWF≤ 3.7
ENERGY STAR® Residential Top-loading (> 2.5 ft^3)	IMEF ≥ 2.06 IWF ≤ 4.3
ENERGY STAR® Residential Small or Compact (< 2.5 ft^3)	IMEF ≥ 2.07 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.[224] Default values were taken directly from the ENERGY STAR® calculator. 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.

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 97

[223] Available for download at: http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Final%20Version%207.0%20Clothes%20Washer%20Program%20Requirements.pdf.

[224] ENERGY STAR® Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

Baseline Unit

$$kWh_{baseline} = kWh_{conv,machine} + kWh_{conv,WH} + kWh_{conv,dryer} + kWh_{conv,LPM}$$

Equation 98

$$kWh_{conv,machine} = MCF \times RUEC_{conv} \times \frac{LPY}{RLPY}$$

$$kWh_{conv,WH} = WHCF \times RUEC_{conv} \times \frac{LPY}{RLPY}$$

$$kWh_{conv,LPM} = kW_{conv,LPM} \times (8,760 - LPY)$$

$$kWh_{conv,dryer} = \left[\left(\frac{CAP_{conv}}{IMEF_{FS}} \times LPY\right) - \left(RUEC_{conv} \times \frac{LPY}{RLPY}\right) - kWh_{conv,LPM}\right] \times \frac{DU_{DW}}{DUF}$$

Equation 99

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)* [225]
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*
CAP_{conv}	=	*Average machine capacity = 4.5 ft³ (top-loading)*
$IMEF_{FS}$	=	*Federal standard integrated modified energy factor (Table 2-258)*

225 This value is taken from the ENERGY STAR® appliance calculator available September 2015, and corresponds with the federal standard after March 7, 2015.

MCF	=	*Machine consumption factor = 20%*
$WHCF$	=	*Water heater consumption factor = 80%*
DU_{DW}	=	*Dryer usage in households with both a washer and a dryer = 95%*
DUF	=	*Dryer use factor (percentage of washer loads dried in machine) = 91%*

ENERGY STAR® Unit

$$\boldsymbol{kWh_{ES} = kWh_{ES,machine} + kWh_{ES,WH} + kWh_{ES,dryer} + kWh_{ES,LPM}}$$

Equation 100

$$\boldsymbol{kWh_{ES,machine} = MCF \times RUEC_{ES} \times \frac{LPY}{RLPY}}$$

$$\boldsymbol{kWh_{ES,WH} = WHCF \times RUEC_{ES} \times \frac{LPY}{RLPY}}$$

$$\boldsymbol{kWh_{ES,LPM} = kW_{ES,LPM} \times (8,760 - LPY)}$$

$$\boldsymbol{kWh_{ES,dryer} = \left[\left(\frac{CAP_{ES}}{IMEF_{ES}} \times LPY\right) - \left(RUEC_{ES} \times \frac{LPY}{RLPY}\right) - kWh_{ES,LPM}\right] \times \frac{DU_{DW,ES}}{DUF}}$$

Equation 101

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 2-260)*
$kW_{ES,LPM}$	=	*Combined low-power mode wattage of ENERGY STAR® unit (see Table 2-260)*
$IMEF_{ES}$	=	*ENERGY STAR® integrated modified energy factor (Table 2-259)*
CAP_{ES}	=	*Average machine capacity (see Table 2-260)*

Table 2-260: ENERGY STAR® Clothes Washer Characteristics[226]

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)	109	2.1	0.00144

Summer Demand Savings Algorithms

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times CF$$

$$AOH = LPY \times d$$

Equation 102

Where:

AOH = *Annual operating hours*

CF = *Coincidence factor (Table 2-261)*

LPY = *Loads per year = 295*

d = *Average wash cycle duration = 1 hour*[227,228]

Table 2-261: ENERGY STAR® Clothes Washer Coincidence Factors[229]

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

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226 This value is taken from the ENERGY STAR® appliance calculator available September 2015, and corresponds with the ENERGY STAR® specification after March 7, 2015.

227 Weighted average of Consumer Reports Cycle Times for Top and Front-Loading Clothes Washers. Top: http://www.consumerreports.org/cro/appliances/laundry-and-cleaning/washing-machines/top-loading-washing-machine-ratings/ratings-overview.htm. Front: http://www.consumerreports.org/cro/appliances/laundry-and-cleaning/washing-machines/front-loading-washing-machine-ratings/ratings-overview.htm.

228 Consumer Reports. "Top-loading washers remain more popular with Americans". April 13, 2010. Weighted average of 75% Top-Loading Clothes Washers and 25% Front-Loading Clothes Washers. http://news.consumerreports.org/home/2010/04/best-front-loaders-top-loaders-which-is-more-popular-mold-vibration-washing-machine-reviews.html. This publication is available for purchase only.

229 See Volume 1, Appendix B.

Deemed Energy Savings Tables

Table 2-262: ENERGY STAR® Clothes Washer Energy Savings (kWh)

ENERGY STAR® Clothes Washer – Annual Energy Savings			
Type	**Water Heater Fuel Type**	**Dryer Fuel Type**	**kWh Savings**
Front-loading > 2.5 ft^3	Electric	Electric	548
	Electric	Gas	187
	Gas	Electric	396
	Gas	Gas	34
Top-loading > 2.5 ft^3	Electric	Electric	397
	Electric	Gas	114
	Gas	Electric	306
	Gas	Gas	23
All $\leq$ 2.5 ft^3	Electric	Electric	753
	Electric	Gas	203
	Gas	Electric	589
	Gas	Gas	39

Deemed Summer Demand Savings Tables

Table 2-263: ENERGY STAR® Clothes Washer Summer Peak Demand Savings (kW)

ENERGY STAR® Clothes Washer – Summer Demand Savings							
Washer Type	**Fuel Type**		**Summer Demand Savings (kW)**				
	Water Heater	**Dryer**	**Climate Zone 1**	**Climate Zone 2**	**Climate Zone 3**	**Climate Zone 4**	**Climate Zone 5**
Front-loading > 2.5 ft^3	Electric	Electric	0.075	0.074	0.075	0.076	0.076
	Electric	Gas	0.026	0.025	0.026	0.026	0.026
	Gas	Electric	0.054	0.054	0.054	0.055	0.055
	Gas	Gas	0.005	0.005	0.005	0.005	0.005
Top-loading > 2.5 ft^3	Electric	Electric	0.054	0.054	0.054	0.055	0.055
	Electric	Gas	0.016	0.015	0.016	0.016	0.016
	Gas	Electric	0.042	0.041	0.042	0.042	0.043
	Gas	Gas	0.003	0.003	0.003	0.003	0.003
All $\leq$ 2.5 ft^3	Electric	Electric	0.103	0.102	0.103	0.105	0.105
	Electric	Gas	0.028	0.028	0.028	0.028	0.028
	Gas	Electric	0.081	0.080	0.080	0.081	0.082
	Gas	Gas	0.005	0.005	0.005	0.005	0.005

Deemed Winter Demand Savings Tables

Table 2-264: All Climate Zones – ENERGY STAR® Clothes Washer Winter Demand Savings (kW)

ENERGY STAR® Clothes Washer – Winter Demand Savings							
Washer Type	Fuel Type		Winter Demand Savings (kW)				
	Water Heater	Dryer	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
Front-loading > 2.5 ft^3	Electric	Electric	0.079	0.080	0.080	0.083	0.072
	Electric	Gas	0.027	0.027	0.027	0.028	0.025
	Gas	Electric	0.057	0.058	0.058	0.060	0.052
	Gas	Gas	0.005	0.005	0.005	0.005	0.005
Top-loading > 2.5 ft^3	Electric	Electric	0.057	0.058	0.058	0.060	0.052
	Electric	Gas	0.016	0.017	0.017	0.017	0.015
	Gas	Electric	0.044	0.045	0.045	0.046	0.040
	Gas	Gas	0.003	0.003	0.003	0.003	0.003
All $\leq$ 2.5 ft^3	Electric	Electric	0.108	0.110	0.110	0.113	0.099
	Electric	Gas	0.029	0.030	0.030	0.031	0.027
	Gas	Electric	0.085	0.086	0.086	0.089	0.078
	Gas	Gas	0.006	0.006	0.006	0.006	0.005

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is 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.[230]

[230] 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. Accessed 10/07/2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/39. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0019-0047.

Program Tracking Data & 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:

- Number of units installed
- Type of unit (top-loading, front-loading, or compact)
- Fuel type of water heater (gas or electric)
- Fuel type of dryer (gas or electric)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for clothes washers.

Document Revision History

Table 2-265: ENERGY STAR® Clothes Washer 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 Associates, 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	March 2016	Updated winter coincidence factors and winter and summer demand savings tables.

2.5.3 ENERGY STAR® Dishwasher Measure Overview

TRM Measure ID: R-AP-DW

Market Sector: Residential

Measure Category: Appliances

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

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[231] for dishwashers.

[231] DOE minimum efficiency standard for residential dishwashers. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67.

Table 2-266 Federal Standard for Dishwashers

Product Type	Estimated Annual Energy Use (kWh/year)	Water Consumption (gallons/cycle)
Standard (≥ 8 place settings)	≤ 307	≤ 5.0
Compact (< 8 place settings)	≤ 222	≤ 3.5

High-Efficiency Condition

The following table displays the ENERGY STAR® Final Version 6.0 requirements for eligible dishwashers effective January 29, 2016.[232] These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

Table 2-267 ENERGY STAR® Specifications for Dishwashers

Product Type	Estimated 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 2-267.[233] Default values were taken directly from the ENERGY STAR® 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.

$$kWh_{savings} = kWh_{baseline} - kWh_{ES}$$

Equation 103

$$kWh_{baseline} = kWh_{conv,machine} + kWh_{conv,WH}$$

$$kWh_{conv,machine} = RUEC_{conv} \times MCF$$

[232] Available for download at: http://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Residential%20Dishwasher%20Version%206.0%20Final%20Program%20Requirements_0.pdf.

[233] ENERGY STAR® Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

$$kWh_{conv,WH} = RUEC_{conv} \times WHCF$$

Equation 104

$$kWh_{ES} = kWh_{ES,machine} + kWh_{ES,WH}$$

$$kWh_{ES,machine} = RUEC_{ES} \times MCF$$

$$kWh_{ES,WH} = RUEC_{ES} \times WHCF$$

Equation 105

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 2-266)*

$RUEC_{ES}$ = *ENERGY STAR® rated use electricity consumption = 270 kWh/year for standard and 203 kWh/year for compact (Table 2-267)*

MCF = *Machine consumption factor = 44%*

$WHCF$ = *Water heater consumption factor = 56%*

Demand Savings Algorithms

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times CF$$

$$AOH = CPY \times d$$

Equation 106

Where:

AOH = *Annual operating hours*

CF = *Coincidence factor = (Table 2-268)*

CPY = *Cycles per year = 215*

$d \quad = \quad \textit{Average wash cycle duration} = 2.1\ \textit{hours}$[234]

Table 2-268: ENERGY STAR® Dishwasher Coincidence Factors[235]

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 2-269: ENERGY STAR® Dishwasher Energy Savings

ENERGY STAR® Dishwasher – EnergySavings (kWh)		
Product Type	Electric Water Heating	Gas Water Heating
Standard	37	16
Compact	19	8

Deemed Summer Demand Savings Table

Table 2-270: ENERGY STAR® Dishwasher Summer Peak Demand Savings (kW)

ENERGY STAR® Dishwasher – Summer Demand Savings (kW)						
Dishwasher Type	Water Heating Fuel	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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

234 Average of Consumer Reports Cycle Times for Dishwashers. http://www.consumerreports.org/cro/appliances/kitchen-appliances/dishwashers/dishwasher-ratings/ratings-overview.htm.

235 See Volume 1, Appendix B.

Deemed Winter Demand Savings Tables

Table 271: ENERGY STAR® Dishwasher Winter Peak Demand Savings (kW)

ENERGY STAR® Dishwasher – Winter Demand Savings (kW)						
Dishwasher Type	Water Heating Fuel	Climate Zone 1	Climate Zone 2	Climate Zone 3	Climate Zone 4	Climate Zone 5
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

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is 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.[236]

Program Tracking Data & 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:

- Number of units installed
- Type of dishwasher (standard or compact)
- Fuel type of water heater (gas or electric)

[236] 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. Accessed 10/07/2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/67. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0060-0007.

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for dishwashers.

Document Revision History

Table 2-272: ENERGY STAR® Dishwasher 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 Associates, 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® specifications incorporated into 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 measure. Consolidated table formats.
v3.1	March 2016	Updated summer and winter coincidence factors and demand savings tables.

2.5.4 ENERGY STAR® Refrigerator Measure Overview

TRM Measure ID: R-AP-RF

Market Sector: Residential

Measure Category: Appliances

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Replace-on-Burnout, New Construction, Early Retirement

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations

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

Utilities should refer to the January 2015 memo, "Considerations for early replacement of residential equipment,"[237] when designing programs that permit savings to be claimed for early retirement. To qualify for early retirement, the ENERGY STAR® unit must replace an existing, full-size, working unit with an age of at least six years. To determine the remaining useful life of an existing unit, see Table 2-276. 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.

In order 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.

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[237] 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.

Baseline Condition

For new construction or replace-on-burnout, the baseline is the Department of Energy (DOE) minimum efficiency standard[238] for refrigerators, effective September 15, 2014.

For early retirement, the baseline for refrigerators is assumed to be the annual unit energy consumption of the refrigerator being replaced, as reported by the Association of Home Appliance Manufacturers (AHAM) refrigerator database[239] and adjusted for age according to the formula in the Energy and Demand Savings Methodology section of this measure. AHAM energy use data includes the average manufacturer reported annual kWh usage by year of production dating back to the 1970s.

Alternatively, the baseline annual energy usage of the refrigerator 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".[240]

To determine annual kWh of the refrigerator being replaced, use the following formula:

$$\boldsymbol{Annual\ kWh\ Usage} = \frac{\boldsymbol{WH \times 8{,}760}}{\boldsymbol{h \times 1{,}000}}$$

Equation 107

Where:

WH	=	$Watt\text{-}hours\ metered\ during\ a\ time\ period$
h	=	$Measurement\ time\ period\ (hours)$
$8{,}760$	=	$Hours\ in\ a\ year$
$1{,}000\ Watt\text{-}hours$	=	$1\ kWh$

High-Efficiency Condition

Table 2-273 displays the ENERGY STAR® requirements for eligible refrigerators, which went into effect September 15, 2014. These values are subject to updates in ENERGY STAR® specifications; energy efficiency service providers are expected to comply with the latest ENERGY STAR® requirements.

238 DOE minimum efficiency standard for residential refrigerators and freezers. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43.

239 AHAM Refrigerator Database. http://rfdirectory.aham.org/AdvancedSearch.aspx.

240 Alex Moore, D&R International, Ltd. "Incorporating Refrigerator Replacement into the Weatherization Assistance Program" Information Tool Kit." Department of Energy. November 19, 2001. http://www.waptac.org/data/files/Website_Docs/technical_tools/toolkit07.pdf.

Table 2-273: ENERGY STAR® Specifications for Refrigerators

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% more energy efficient than the minimum federal standard (see Table 2-274)

Configuration Codes (for Table 2-274):

BF: Bottom Freezer
SD: Refrigerator Only – Single Door
SR: Refrigerator/Freezer – Single Door
SS: Side-by-Side
TF: Top Freezer

TTD: Through the Door (Ice Maker)

A: Automatic Defrost
M: Manual Defrost
P: Partial Automatic Defrost

AV = Adjusted Volume = Fresh Volume + 1.63 x Freezer Volume (ft^3)

Table 2-274: Formulas to Calculate the ENERGY STAR® Criteria for each Refrigerator Product Category by Adjusted Volume[241]

Product Number	Product Class	Baseline Energy Usage Federal Standard as of Sept 15, 2014 (kWh/year)[242]	Average ENERGY STAR® Energy Usage (kWh/year)[243]	Configuration(s)	Ice (Y/N)	Defrost
1, 2	Refrigerator-freezers—manual or partial automatic defrost	7.99 × AV + 225.0	7.19 × AV + 202.5	SS, TF, BF, SR	Y, N	M, P
1A	Refrigerator-only—manual defrost	6.79 × AV + 193.6	6.11 × AV + 174.2	SD	Y, N	M
3	Refrigerator freezers—automatic defrost with top-mounted freezer without an automatic icemaker	8.07 × AV + 233.7	7.26 × AV + 210.3	TF	N	A
3-BI	Built-in refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic icemaker	9.15 × AV + 264.9	8.24 × AV + 238.4	TF	N	A
3I	Refrigerator-freezers—automatic defrost with top-mounted freezer with an automatic ice maker without TTD ice service	8.07 × AV + 317.7	7.26 × AV + 294.3	TF	N	A
3I-BI	Built-in refrigerator-freezers—automatic defrost with top-mounted freezer without an automatic ice maker with TTD ice service	9.15 × AV + 348.9	8.24 × AV + 322.4	TF	N	A
3A	Refrigerator-only—automatic defrost	7.07 × AV + 201.6	6.36 × AV + 181.4	SD	Y, N	A

[241] Available for download at http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf. Select product classes excluded.

[242] http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.

[243] Approximately 10% more efficient than baseline, as specified in the ENERGY STAR® Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

Product Number	Product Class	Baseline Energy Usage Federal Standard as of Sept 15, 2014 (kWh/year)[242]	Average ENERGY STAR® Energy Usage (kWh/year)[243]	Configuration(s)	Ice (Y/N)	Defrost
Product Number	**Product Class**	**Baseline Energy Usage Federal Standard as of Sept 15, 2014 (kWh/year)[244]**	**Average ENERGY STAR® Energy Usage (kWh/year)[245]**	**Configuration(s)**	**Ice (Y/N)**	**Defrost**
3A-BI	Built-in refrigerator-only—automatic defrost	8.02 × AV + 228.5	7.22 × AV + 205.7	SD	Y, N	A
4	Refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker	8.51 × AV + 297.8	7.66 × AV + 268.0	SS	N	A
4-BI	Built-in refrigerator-freezers—automatic defrost with side-mounted freezer without an automatic icemaker	10.22 × AV + 357.4	9.20 × AV + 321.7	SS	N	A
4I	Refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without TTD ice service	8.51 × AV + 381.8	7.66 × AV + 352.0	SS	N	A
4I-BI	Built-in refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker without TTD ice service	10.22 × AV + 441.4	9.20 × AV + 405.7	SS	N	A
5	Refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	8.85 × AV + 317.0	7.97 × AV + 285.3	BF	N	A
5-BI	Built-in refrigerator-freezers—automatic defrost with bottom-mounted freezer without an automatic icemaker	9.40 × AV + 336.9	8.46 × AV + 303.2	BF	N	A

[244] http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.
[245] Approximately 10% more efficient than baseline, as specified in the ENERGY STAR® Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

Product Number	Product Class	Baseline Energy Usage Federal Standard as of Sept 15, 2014 (kWh/year)[242]	Average ENERGY STAR® Energy Usage (kWh/year)[243]	Configuration(s)	Ice (Y/N)	Defrost
5I	Refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without TTD ice service	8.85 × AV + 401.0	7.97 × AV + 369.3	BF	N	A
Product Number	**Product Class**	**Baseline Energy Usage Federal Standard as of Sept 15, 2014 (kWh/year)[246]**	**Average ENERGY STAR® Energy Usage (kWh/year)[247]**	**Configuration(s)**	**Ice (Y/N)**	**Defrost**
5I-BI	Built-in refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker without TTD ice service	9.40 × AV + 420.9	8.46 × AV + 387.2	BF	N	A
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	BF	Y	A
5A-BI	Built-in refrigerator-freezers—automatic defrost with bottom-mounted freezer with an automatic icemaker with TTD ice service	9.83 × AV + 499.9	8.85 × AV + 458.3	BF	Y	A
6	Refrigerator-freezers—automatic defrost with top-mounted freezer with TTD ice service	8.40 × AV + 385.4	7.56 × AV + 355.3	TF	Y	A
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	SS	Y	A
7-BI	Built-in refrigerator-freezers—automatic defrost with side-mounted freezer with an automatic icemaker with TTD ice service	10.25 × AV + 502.6	9.23 × AV + 460.7	SS	Y	A

[246] http://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf.
[247] Approximately 10% more efficient than baseline, as specified in the ENERGY STAR® Appliance Savings Calculator (updated September 2015). http://www.energystar.gov/sites/default/files/asset/document/appliance_calculator.xlsx.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

New Construction or Replace-on-Burnout

Energy Savings Algorithms

$$\boldsymbol{kWh_{savings} = kWh_{baseline} - kWh_{ES}}$$

Equation 108

Where:

$kWh_{baseline}$ = *Federal standard baseline energy usage (see Table 2-274)*

kWh_{ES} = *ENERGY STAR average energy usage (see Table 2-274)*

Demand Savings Algorithms

$$\boldsymbol{kW_{savings} = \frac{kWh_{savings}}{8,760\ hrs} \times LSAF}$$

Equation 109

Where:

$LSAF$ = *Load Shape Adjustment Factor (see Table 2-275)*

Table 2-275: ENERGY STAR® Refrigerator Load Shape Adjustment Factors[248]

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 (16 – RUL)**

[248] See Volume 1, Appendix B.

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 Volume 3, Appendix D of this document.

Where:

RUL = *Remaining Useful Life (see Table 2-276)*

EUL = *Estimated Useful Life = 16 years*

Table 2-276: Remaining Useful Life (RUL) of Replaced Refrigerator

Age of Replaced Refrigerator (years)	RUL (years)	Age of Replaced Refrigerator (years)	RUL (years)
6	10.3	14	6.3
7	9.5	15	6.0
8	8.9	16	5.0
9	8.3	17	4.0
10	7.8	18	3.0
11	7.4	19	2.0
12	7.0	20	1.0
13	6.6	21[249,250]	0.0

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 **2**-**8**.

[249] RULs are capped at the 75th percentile of equipment age, 21 years, as determined based on DOE survival curves (see
Figure **2**-**8**). Systems older than 21 years should use the ROB baseline. See the January 2015 memo, "Considerations for early replacement of residential equipment," for further detail.

[250] 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.

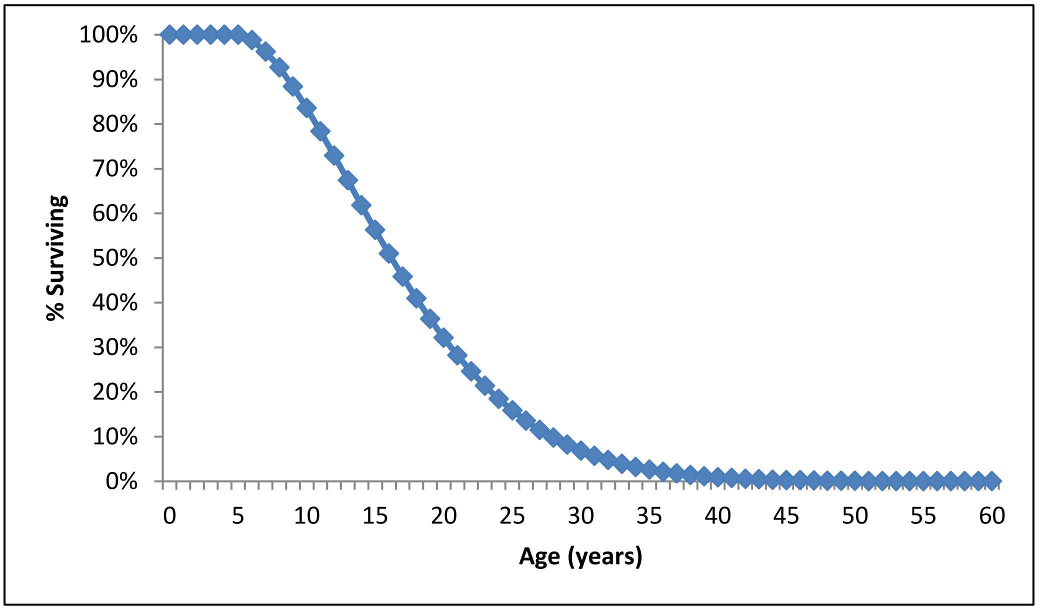


Figure 2-8: **Survival Function for ENERGY STAR® Refrigerators**[251]

The method for estimating the remaining useful life (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 2-8. 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 % surviving value is 56%. Half of 56% is 28%. The age corresponding to 28% on the chart is 21 years. Therefore, the RUL of the refrigerator being replaced is (21 – 15) = 6 years.

Energy Savings Algorithms

For the RUL time period:

$$kWh_{savings,ER} = kWh_{manf} - kWh_{ES}$$

Equation 110

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

[251] 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.

$$kWh_{savings,ROB} = kWh_{baseline} - kWh_{ES}$$

Equation 111

Where:

kWh_{manf} = *Annual unit energy consumption from the Association of Home Appliance Manufacturers (AHAM) refrigerator database*[252] *(or from metering)*

$kWh_{baseline}$ = *Federal standard baseline energy usage (see Table 2-274)*

kWh_{ES} = *ENERGY STAR® average energy usage (see Table 2-274)*

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:

$$kW_{savings,ER} = \frac{kWh_{savings,ER}}{8,760\ hrs} \times LSAF$$

Equation 112

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

$$kW_{savings,ROB} = \frac{kWh_{savings,ROB}}{8,760\ hrs} \times LSAF$$

Equation 113

Where:

$LSAF$ = *Load Shape Adjustment Factor (Table 2-275)*

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 Volume 3, Appendix D of this document.

Where:

RUL = *Remaining Useful Life (see Table 2-276)*

EUL = *Estimated Useful Life = 16 years*[253]

[252] AHAM Refrigerator Database. http://rfdirectory.aham.org/AdvancedSearch.aspx.

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

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is 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.[254]

Program Tracking Data & 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:

- Number of units installed
- The project type of the installation (New Construction, Replace-on-Burnout, or Early Retirement)
- Installed refrigerator model number

[253] 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: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

[254] Final Rule: Standards, Federal Register, 76 FR 57516 (Sept. 15, 2011) and associated Technical Support Document. Accessed 10/10/2014. http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/43. Download TSD at: http://www.regulations.gov/#!documentDetail;D=EERE-2008-BT-STD-0012-0128.

- Product class (see Table 2-274)
- Refrigerator volume
- Freezer volume
- Retired refrigerator model number (Early Retirement only)
- Retired refrigerator annual energy usage (Early Retirement only)
- Age of retired refrigerator (Early Retirement only)
- Recommended: internal temperature(s) in retired refrigerator and, if present, freezer (Early Retirement only)
- Recommended: customer responses to survey questionnaire for early retirement eligibility determination (Early Retirement only)

References and Efficiency Standards

Petitions and Rulings

This section is not applicable.

Relevant Standards and Reference Sources

- The applicable version of the ENERGY STAR® specifications and requirements for refrigerators.

Document Revision History

Table 2-277: ENERGY STAR® Refrigerator 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 Associates, 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 EM&V team’s memo, “Considerations for early replacement of residential equipment.” Remaining useful lifetimes updated. LSAF updated to align with new peak demand methodology.
v3.1	11/05/2015	TRM v3.1 update. Correction to legacy LSAF. Revision to align with ENERGY STAR® calculator and specification.
v3.1	March 2016	Updated summer and winter coincidence factors.

2.6 RESIDENTIAL: RENEWABLE ENERGY SYSTEMS

2.6.1 Solar Photovoltaic (PV) Measure Overview

TRM Measure ID: R-RN-PV

Market Sector: Residential

Measure Category: Renewables

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit, New Construction

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Calculations or Simulation Software

Savings Methodology: Algorithms, Model-Calculator (PVWatts™)

Measure Description

This section summarizes the savings calculations of the Solar Photovoltaic Standard Offer, Market Transformation, and Pilot programs. The primary objective of these programs is to achieve cost-effective reduction in energy savings and peak demand savings. Participation in the Solar Photovoltaic program involves the installation of a solar photovoltaic system. There are two primary methods used to estimate savings. The deemed method uses deemed algorithms, and the M&V method uses a simulation tool: the National Renewable Energy Laboratory's (NREL) PVWatts™.

Eligibility Criteria

Only photovoltaic systems that result in net reductions of the customer's purchased energy and peak demand qualify for these deemed savings estimates.

The installation must also meet the following requirements in order to be eligible for these deemed savings values:

- The system shall be installed by a licensed electrical contractor or, in the case of a residential installation by the homeowner, with the approval of the electrical inspector in accordance with the National Electric Code (NEC 690, "Solar Photovoltaic Systems") or local building codes.
- If the system is utility interactive the inverter shall be listed by national testing laboratory (see, for example, UL 1741, "Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems") and meet the requirements of the Institute of Electrical and

Electronics Engineers (IEEE) Standard 929-2000 “Recommended Practice for Utility Interface of Photovoltaic (PV) Systems.”

- The estimated annual energy generation from the PV system shall not exceed the customer’s annual energy consumption.
- **Standard Installation:** The array azimuth shall be within +/- 20 degrees of south; the tilt angle shall be between 0 (horizontal) and latitude + 15 degrees to use the deemed savings factors.
- **Non-Standard Installation:** PUCT Docket No. 40885 allows for alternative means for estimating deemed savings for solar PV systems for non-standard installations, allowing residential customers around the state access to utility incentives for systems installed on roofs – or portions of roofs – that are not within 20 degrees of south, or for which the tilt angle must exceed 15 degrees from horizontal due to site specific considerations. The proposed alternative would also facilitate the installation of single-axis or two-axis tracking systems. For those solar PV installations that do not conform to the installation standards of the existing deemed savings, the deemed demand and energy savings should be established by modeling the performance of the system using PVWatts™ Version 1.

Each utility may have additional program eligibility requirements, which are listed here. These requirements are provided for reference purposes only, and are not listed in any PUCT-approved petition. Therefore, these utility-specific eligibility requirements may be subject to change.

- **American Electric Power and El Paso Electric:** The estimated annual electrical energy output of a solar electric system, as modeled by National Renewable Energy Laboratory’s (NREL) PVWatts™[255] and considering an appropriate factor for shading, must be at least 80% of the estimated annual energy output for an optimally-sited, un-shaded system of the same DC capacity.

Baseline Condition

PV system not currently installed (typical), or production capacity of an existing system is less than any utility requirements, so that additional panels can be added.

High-Efficiency Condition

PV systems must meet the eligibility criteria shown above to be eligible for incentives.

Energy and Demand Savings Methodology

Depending on whether a solar PV system qualifies as a “standard” or “non-standard” installation, separate savings methodologies may be used to calculate savings as outlined in the following sections. Non-standard systems are those installed on roofs – or portions of roofs – that are not

[255] Optimally-sited system is determined by selecting an appropriate location, entering system capacity in kWdc, and accepting default parameters for tilt (latitude tilt), orientation (due south), and derating factor (0.77) into the PVWatts calculator.

within 20 degrees of south, or for which the tilt angle must exceed 15 degrees from horizontal due to site-specific considerations.

Savings Algorithms and Input Variables

Standard Installation

The following formula calculates the energy savings for solar electric photovoltaic energy systems based on the rated watts DC_{STC}.

$$\boldsymbol{Deemed\ Energy\ Savings\ (kWh) = 1.60 \times Watts\ DC_{STC}\ installed}$$

Equation 114

Non-Standard Installation

PUCT Docket No. 40885 allows for alternative means for estimating deemed savings for solar PV systems for non-standard installations, permitting both residential and commercial customers around the state access to utility incentives for systems installed on roofs – or portions of roofs – that are not within 20 degrees of south, or for which the tilt angle must exceed 15 degrees from horizontal due to site specific considerations. The proposed alternative would also facilitate the installation of single-axis or two-axis tracking systems.

For those solar PV installations that do not conform to the installation standards of the existing deemed savings, the deemed demand and energy savings be established by modeling the performance of the system using PVWatts™ Version 1.[256]

Summer Demand Savings Methodology

The following formula calculates the demand savings for solar electric photovoltaic energy systems based on the rated watts DC_{STC}.

$$\boldsymbol{Deemed\ Demand\ Savings\ (kW) = 0.83 \times kW\ DC_{STC}\ installed}$$

Equation 115

Winter Demand Savings Methodology

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

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.

[256] A. P. Dobos. PVWatts Version 1 Technical Reference. National Renewable Energy Laboratory. NREL/TP-6A20-60272. October 2013. http://www.nrel.gov/docs/fy14osti/60272.pdf. PVWatts™ v.1 calculator available at: http://rredc.nrel.gov/solar/calculators/pvwatts/version1/.

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

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

For non-standard installation PV systems, PVWatts™ should be used to model the performance of the system and to estimate energy and demand savings.

Measure Life and Lifetime Savings

The estimated useful life (EUL) of photovoltaic system is established at 30.0 years.

This value is consistent with the Frontier Associates' engineering estimate based on manufacturers' warranties.

Program Tracking Data & Evaluation Requirements

The following information will be required to be collected to determine the project eligibility.

- Project location (city)
- DC rating for the system
- Standard or non-standard system
- Savings approach type: deemed algorithm or PVWatts™
- System latitude
- System tilt
- System azimuth

References and Efficiency Standards

Petitions and Rulings

- Docket No. 40885. 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 Revise Deemed Savings Values for Commercial HVAC and Solar Photovoltaic Measures. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

- National Electric Code (NEC) 690, "Solar Photovoltaic Systems" or local building codes.
- Institute of Electrical and Electronics Engineers (IEEE) Standard 929-2000 "Recommended Practice for Utility Interface of Photovoltaic (PV) Systems." http://standards.ieee.org/findstds/standard/929-2000.html.
- A. P. Dobos. PVWatts Version 1 Technical Reference. National Renewable Energy Laboratory. NREL/TP-6A20-60272. October 2013. http://www.nrel.gov/docs/fy14osti/60272.pdf. PVWattsTM v.1 calculator available at: http://rredc.nrel.gov/solar/calculators/pvwatts/version1/.

Document Revision History

Table 2-278: Residential Solar Electric (Photovoltaic) Energy Systems 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 structure.
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.

2.7 RESIDENTIAL: LOAD MANAGEMENT

2.7.1 Direct Load Control of Outdoor Compressor Units Measure Overview

TRM Measure ID: R-LM-OC

Market Sector: Residential

Measure Category: Load Management

Applicable Building Types: Single-family

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

Savings Methodology: Engineering Estimates and M&V

Measure Description

These deemed savings values provide a benchmark for estimating the annual summer peak demand savings associated with the curtailment of residential air conditioning energy usage during periods of high demand via direct load control switches or certain programmable communicating thermostats installed to control the outdoor compressor units of split unitary HVAC systems in detached single-family homes in CenterPoint Houston's service territory. The deemed savings values are on a per-home basis, predicated on basic considerations related to the design and implementation of a residential demand response program.

For calculation of savings using a measurement and verification approach, see Volume 4, Section 2.5.1 of this document.

Eligibility Criteria

The home must be an occupied, single-family detached home that participates in a residential demand response program offered by CenterPoint Houston in which a direct load control switch or programmable communicating thermostat is installed to control the electrical supply to all outdoor units (compressors) of the unitary split central air conditioning systems installed at a home

Baseline Condition

This section is not applicable.

High-Efficiency Condition

This section is not applicable.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

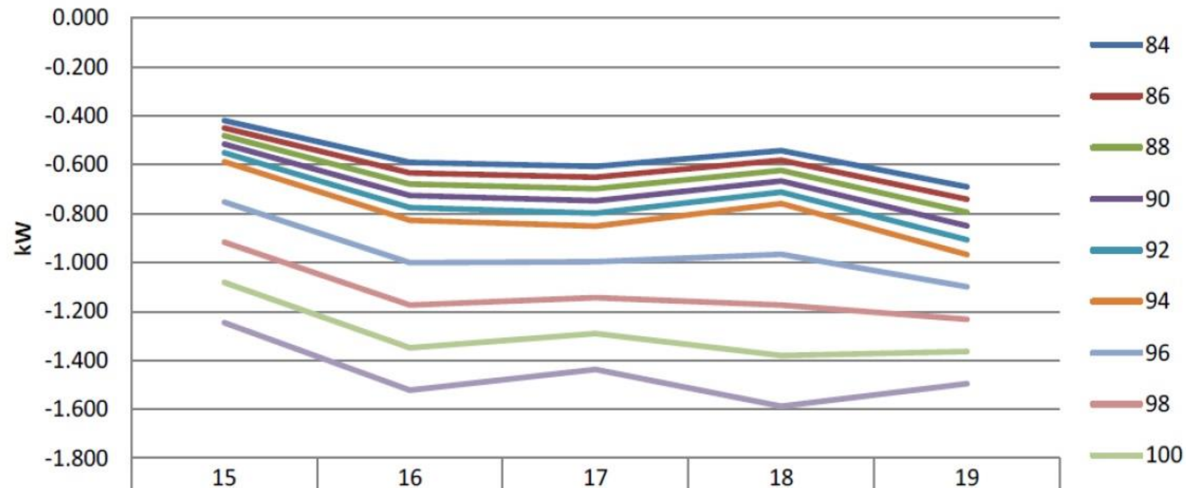
CenterPoint Houston undertook a multi-year research project evaluating the potential for a residential demand response program allowing residential customers in single-family, detached homes to provide summer peak demand savings by participating in load curtailment events with remotely-controllable, major electric energy end use equipment in their homes.

The 2011 pilot involved installation of 74 direct load control (DLC) switches on outdoor compressor units at the homes of test group participants in the CenterPoint Smart Partners program. Measurement and verification was performed using data from 30 homes (in which 35 switches were installed) randomly selected from among the participants.

The 2012 pilot involved installation of 1,379 DLC switches at 1,026 homes in the CenterPoint Houston service territory. A total of 314 customers were randomly selected for this M&V study. Sub metering devices were installed on 458 air conditioner compressors and 18 pool pumps at these 314 premises. Participating homes were self-selected from among the customers of two Retail Electric Providers who agreed to participate in the program.

Load control events were called during the summers of 2011 and 2012. Events were two to four hours in duration (though only 3 and 4 hour events were included in the analysis presented herein), and began at either 2 p.m. or 3 p.m. (ending at either 6 p.m. or 7 p.m.; no three-hour events were begun at 2 p.m. to avoid “bounce back” in the peak hour, which frequently occurs between 5 p.m. and 6 p.m.). The general criterion for events was a daily high temperature above 94 degrees, but events were called with a range of temperatures occurring across the duration of events. Furthermore, operating conditions affecting residential demand for cooling vary across these hours (on average, occupancy is lower earlier in the afternoon and demand for cooling is further lowered for those homes employing afternoon setups via programmable thermostats until the evening program is engaged). As such, estimates of hourly load shed for HVAC compressors were developed by hour and by temperature.

Hourly compressor load shed estimates were developed by the implementing contractor using regression analysis on hourly loads estimated from on/off runtime monitoring of the controlled compressor units. They are reproduced in Figure 2-9 which shows load reduction between 2 p.m. and 7 p.m. (the values on the horizontal axis are the hour ending values, so 15 represents 15:00, or the hour from 2:00–3:00 p.m.). The load reduction in any single hour ranges from 0.42 kW at 84 degrees in the 2 p.m. hour to just under 1.6 kW at 102 degrees in the 6 p.m. hour.



	15	16	17	18	19
84	-0.419	-0.590	-0.607	-0.542	-0.691
86	-0.450	-0.633	-0.652	-0.582	-0.741
88	-0.482	-0.679	-0.698	-0.623	-0.794
90	-0.515	-0.726	-0.747	-0.666	-0.849
92	-0.551	-0.775	-0.798	-0.712	-0.907
94	-0.587	-0.827	-0.851	-0.759	-0.968
96	-0.752	-1.001	-0.997	-0.966	-1.100
98	-0.917	-1.175	-1.144	-1.174	-1.232
100	-1.082	-1.348	-1.290	-1.381	-1.364
102	-1.247	-1.522	-1.437	-1.588	-1.496

Figure 2-9: Primary Load Reductions (kW/Household), DLC Switch on Residential HVAC Compressor Unit

Development of the proposed deemed savings value based on this information takes into account two factors: (1) the expected design of the measure for which the proposed deemed savings value will be used, and (2) the weather conditions that can be expected in a summer peak demand period, when CenterPoint Houston will want to deploy the residential demand response to maximize capacity. Specifically, the proposed deemed savings values were developed based on the following parameters:

- Curtailment events will be four hours in duration, lasting either from 2 p.m. to 6 p.m. or 3 p.m. to 7 p.m., and will only be called on weekdays.
- Cycling will be accomplished by deploying a 50 percent cycling strategy (taken as a percentage of time) or an equivalent strategy.
- Participating customers will be asked to provide demand response services for up to 40 total hours per summer peak demand period (10 events, based on the above four hours per event).
- Curtailment events will be initiated on days when system demand is expected to be at its highest, which, in turn, will generally correlate with high temperatures.

Given these program considerations, an analysis of typical meteorological year data for CenterPoint Houston's service territory was undertaken, using Typical Meteorological Year (TMY3) data for Houston's Bush Intercontinental Airport. In a Typical Meteorological Year, there are twenty days with high temperatures of 96 degrees or above. Given that 2 of every 7 days are likely to be weekends, approximately 14 of these 20 days would be weekdays, on which events could be initiated. As such, it is reasonable to expect that the ten events called each summer peak demand season will occur on days for which conditions in these twenty peak days are representative. Using the average temperature in each hour between 2PM and 7 PM for those twenty days, typical load reductions for each hour can be constructed from the data provided in Figure 2-9.

Table 2-279: Typical Hourly Load Reductions, Compressor Units on Residential HVAC Systems

Hour	Temperature (°F)	Typical Load Reduction (kW)
2 p.m.–3 p.m.	97.1	0.84
3 p.m.–4 p.m.	97.2	1.00
4 p.m.–5 p.m.	95.1	0.93
5 p.m.–6 p.m.	92.5	0.72
6 p.m.–7 p.m.	89.1	0.82
Average Hourly Load Reduction		**0.86**

Assuming an even distribution of events that run from 2 p.m. to 6 p.m. and events that run from 3 p.m. to 7 p.m., an average hourly load reduction of 0.86 kW per home is estimated.

Programmable communicating thermostats may receive the same deemed savings so long as they follow the same parameters outlined above.

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

Occupied, single-family detached homes that participate in a residential demand response program offered by CenterPoint Houston in which a direct load control switch or programmable communicating thermostat is installed to control the electrical supply to all outdoor units (compressors) of the unitary split central air conditioning systems installed at a home are granted a deemed savings value of 0.86 kW per home per summer peak demand period.

Table 2-280: Direct Load Control of Outdoor Compressor Units Summer Peak Demand Savings

DLC for Outdoor Compressor Units
Summer Peak Savings (kW)
0.86

Deemed Winter Demand Savings Tables

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The measure life for the residential demand response measure for which these deemed savings values are granted is one year.

Program Tracking Data & Evaluation Requirements

No primary inputs or contextual data must be specified or tracked by the program database to inform the evaluation and apply the savings properly, beyond evidence of participation.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 41413. Petition of CenterPoint Energy Houston Electric, LLC to Establish Deemed Savings Values for Residential Demand Response with Direct Load Control Switches Installed on Outdoor Compressor Units. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-281: Residential Direct Load Control of Outdoor Compressor Units 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. Modified to allow for thermostat-regulated direct load control. 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. Added reference to M&V Protocols volume for alternative savings calculation methodology.

2.7.2 Direct Load Control of Swimming Pool Pump Motors Measure Overview

TRM Measure ID: R-LM-SP

Market Sector: Residential

Measure Category: Load Management

Applicable Building Types: Single-family

Fuels Affected: Electricity

Decision/Action Type(s): Retrofit

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

Savings Methodology: Engineering Estimates and M&V

Measure Description

These deemed savings values provide a benchmark for estimating the annual summer peak demand savings associated with the curtailment of swimming pool filtration system energy usage during periods of high demand via direct load control switches or certain programmable communicating thermostats installed to control the electrical supplies to pool pump motors in detached single-family homes in CenterPoint Houston's service territory. The deemed savings values are on a per-home basis, predicated on basic considerations related to the design and implementation of a residential demand response program.

For calculation of savings using a measurement and verification approach, see Volume 4, Section 2.5.1 of this document.

Eligibility Criteria

Pool pump motors must be installed in an occupied, single-family detached home that participates in a residential demand response program offered by CenterPoint Houston in which a direct load control switch or programmable communicating thermostat is installed to control the electrical supply to the motor(s) driving the pump(s) of a swimming pool filtration system.

Baseline Condition

This section is not applicable.

High-Efficiency Condition

This section is not applicable.

Energy and Demand Savings Methodology

Savings Algorithms and Input Variables

CenterPoint Houston undertook a multi-year research project evaluating the potential for a residential demand response program allowing residential customers in single-family, detached homes to provide summer peak demand savings by participating in load curtailment events with remotely-controllable, major electric energy end use equipment in their homes.

The 2011 pilot involved installation of 74 direct load control (DLC) switches on outdoor compressor units at the homes of test group participants in the CenterPoint Smart Partners program. Measurement and verification was performed using data from 30 homes (in which 35 switches were installed) randomly selected from among the participants.

The 2012 pilot involved installation of 1,379 DLC switches at 1,026 homes in the CenterPoint Houston service territory. A total of 314 customers were randomly selected for this M&V study. Sub metering devices were installed on 458 air conditioner compressors and 18 pool pumps at these 314 premises. Participating homes were self-selected from among the customers of two Retail Electric Providers who agreed to participate in the program.

Load control events were called during the summers of 2011 and 2012. Events were two to four hours in duration (though only 3 and 4 hour events were included in the analysis presented herein), and began at either 2 p.m. or 3 p.m. (ending at either 6 p.m. or 7 p.m.; no three-hour events were begun at 2 p.m. to avoid “bounce back” in the peak hour, which frequently occurs between 5 and 6 p.m.). The general criterion for events was a daily high temperature above 94 degrees, but events were called with a range of temperatures occurring across the duration of events. Furthermore, operating conditions affecting residential demand for cooling vary across these hours (on average, occupancy is lower earlier in the afternoon and demand for cooling is further lowered for those homes employing afternoon setups via programmable thermostats until the evening program is engaged). As such, estimates of hourly load shed for HVAC compressors were developed by hour and by temperature.

Development of the proposed deemed savings value based on this information takes into account two factors: (1) the expected design of the measure for which the proposed deemed savings value will be used, and (2) the weather conditions that can be expected in a summer peak demand period, when CenterPoint Houston will want to deploy the residential demand response to maximize capacity. Specifically, the proposed deemed savings values were developed based on the following parameters:

- Curtailment events will be four hours in duration, lasting either from 2 p.m. to 6 p.m. or 3 p.m. to 7 p.m., and will only be called on weekdays.
- Cycling will be accomplished by deploying a 100 percent cycling strategy (taken as a percentage of time) or an equivalent strategy.
- Participating customers will be asked to provide demand response services for up to 40 total hours per summer peak demand period (10 events, based on the above four hours per event).
- Curtailment events will be initiated on days when system demand is expected to be at its highest, which, in turn, will generally correlate with high temperatures.

Given these program considerations, an analysis of typical meteorological year data for CenterPoint Houston's service territory was undertaken, using Typical Meteorological Year (TMY3) data for Houston's Bush Intercontinental Airport. In a Typical Meteorological Year, there are twenty days with high temperatures of 96 degrees or above. Given that 2 of every 7 days are likely to be weekends, approximately 14 of these 20 days would be weekdays, on which events could be initiated. As such, it is reasonable to expect that the ten events called each summer peak demand season will occur on days for which conditions in these twenty peak days are representative.

The variables of interest in estimating pool pump demand savings are the typical energy draw of swimming pool pumps, and their aggregated load shape.

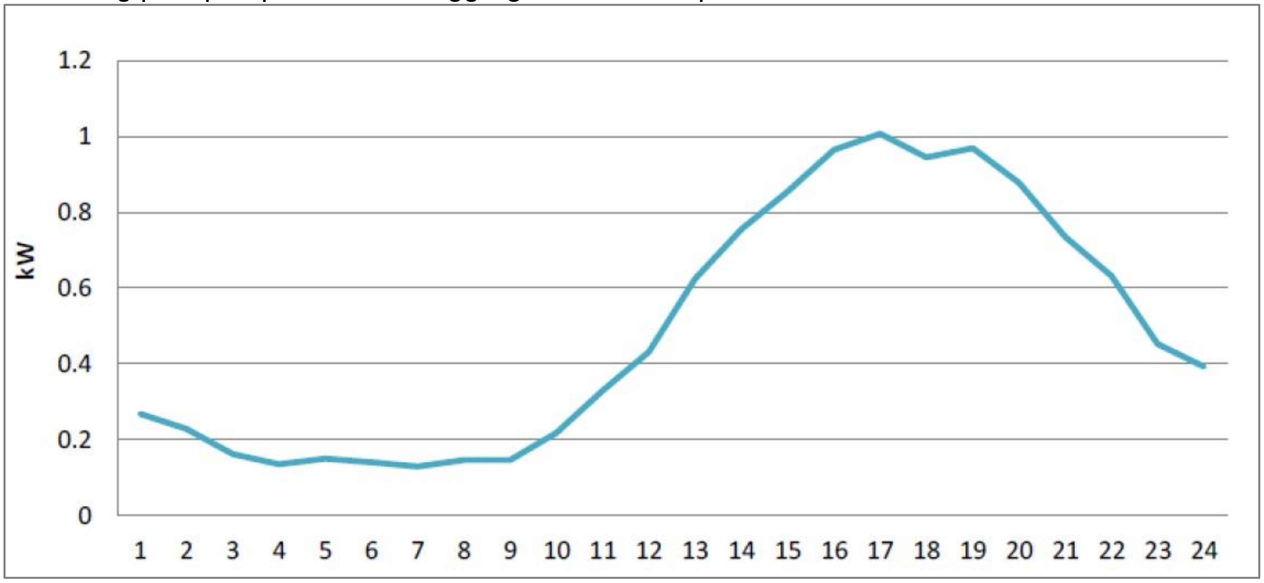


Figure 2-10 presents the observed load shape from on-off monitoring and nameplate data collection for pool pumps observed in the 2012 pilot in Houston.

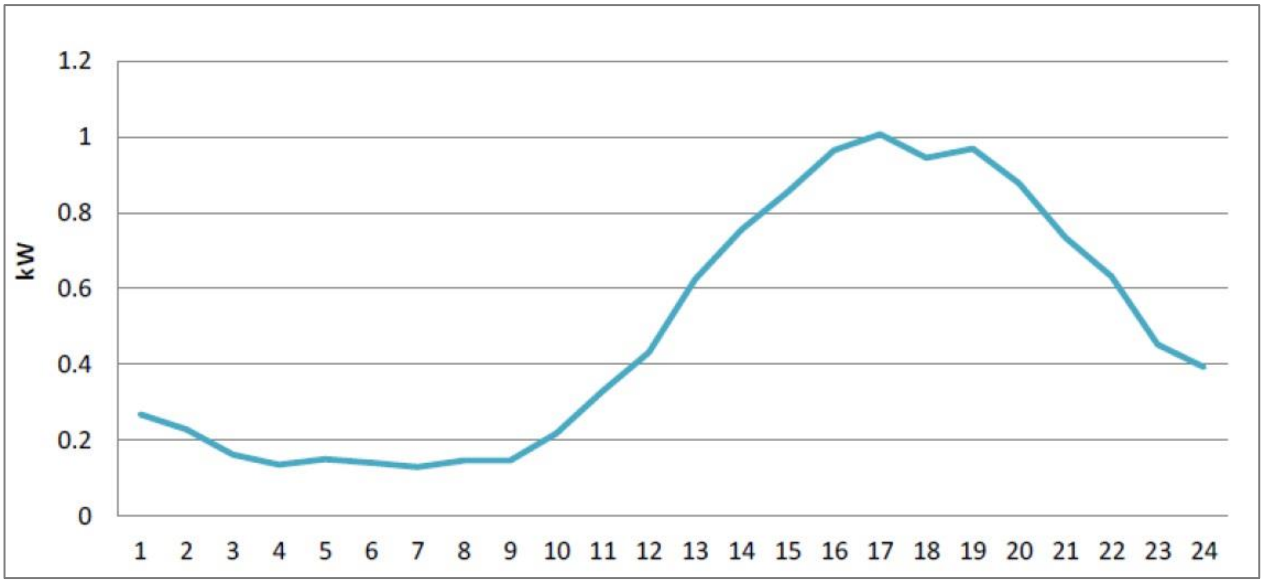


Figure 2-10: Average Hourly Pool Pump Demand

On average, the observed demand pattern is consistent with pumping systems that draw 1.5 kW for 8 hours per day; however, the curve provides relatively high coincidence, with average demand of 0.95 kW for the five hours between 2 p.m. and 7 p.m. during which the 4-hour events are likely to be called. As such, the proposed deemed demand savings for swimming pool pumps is 0.95 kW.

Programmable communicating thermostats may receive the same deemed savings so long as they follow the same parameters outlined above.

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

Occupied, single-family detached homes that participate in a residential demand response program offered by CenterPoint Houston in which a direct load control switch or programmable communicating thermostat is installed to control the electrical supply to the motor(s) driving the pump(s) of a swimming pool filtration system are granted a deemed savings value of 0.95 kW per home per summer peak demand period.

Table 2-282: Direct Load Control of Swimming Pool Pump Motors Summer Peak Demand Savings

DLC for Pool Pump Motors
Summer Peak Savings (kW)
0.95

Deemed Winter Demand Savings Tables

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on winter peak demand savings and methodology.

Claimed Peak Demand Savings

Refer to Volume 1, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

Measure Life and Lifetime Savings

The measure life for the residential demand response measure for which these deemed savings values are granted is one year.

Program Tracking Data & Evaluation Requirements

No primary inputs or contextual data must be specified or tracked by the program database to inform the evaluation and apply the savings properly, beyond evidence of participation.

References and Efficiency Standards

Petitions and Rulings

- Docket No. 41413. Petition of CenterPoint Energy Houston Electric, LLC to Establish Deemed Savings Values for Residential Demand Response with Direct Load Control Switches Installed on Outdoor Compressor Units. Public Utility Commission of Texas.

Relevant Standards and Reference Sources

This section is not applicable.

Document Revision History

Table 2-283: Residential Direct Load Control of Swimming Pool Pump Motors 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. Modified to allow for thermostat-regulated direct load control. 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. Added reference to M&V Protocols volume for alternative savings calculation methodology.

2.8 RESIDENTIAL: APPLIANCE RECYCLING

2.8.1 Refrigerator/Freezer Recycling Measure Overview

TRM Measure ID: R-AP-RR

Market Sector: Residential

Measure Category: Appliance Recycling

Applicable Building Types: Single-family, duplex and triplex; Multifamily; Manufactured

Fuels Affected: Electricity

Decision/Action Type(s): Early Retirement

Program Delivery Type(s): Prescriptive

Deemed Savings Type: Deemed Savings Values

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/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, provided that 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 in order to ensure proper disposal in accordance with applicable federal, state, and local regulations.

Baseline Condition

Without program intervention, the recycled refrigerator or freezer would have remained operable on the electrical grid. As a result, the baseline condition for early retirement programs is the status quo (continued operation) and the basis for estimating energy savings is the annual energy consumption of the refrigerator or freezer being retired (as specified in the “Energy and Demand Savings Methodology” section).

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

Savings Algorithms and Input Variables

Energy Savings

Energy savings are calculated as follows:

$$\begin{aligned} \boldsymbol{kWh_{savings}} &= \boldsymbol{kWh_{existing} \times ISAF \times PUF} \\ &= \boldsymbol{1,308 \times 0.942 \times 0.915} \\ &= \boldsymbol{1,128\ kWh} \end{aligned}$$

Equation 116

Where:

$kWh_{existing}$ = *Average annual energy consumption*[257] = *1,308 kWh*

$ISAF$ = *In Situ Adjustment Factor*[258] = *0.942*

PUF = *Part Use Factor*[259] = *0.915*

[257] The Cadmus Group, Inc. "Residential Retrofit High Impact Measure Evaluation Report". Prepared for California Public Utilities Commission Energy Division. February 8, 2010. Average of DOE-Based Full-Year Unit Energy Consumption (weighted by representative utility survey participation).

[258] Ibid. 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.

[259] 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).

Demand Savings

Summer peak demand savings are calculated as follows:

$$kW_{savings} = \frac{kWh_{savings}}{AOH} \times LSAF$$

Equation 117

Where:

AOH = $Annual\ Operating\ Hours = 8{,}760\ hours$

$LSAF$ = $Load\ Shape\ Adjustment\ Factor\ (Table\ 2\text{-}284)$

Table 2-284: Load Shape Adjustment Factors[260]

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

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, Appendix B: Peak Demand Reduction Documentation for further details on peak demand savings and methodology.

Additional Calculators and Tools

This section is not applicable.

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[260] See Volume 1, Appendix B.

Measure Life and Lifetime Savings

Based on the KEMA Residential Refrigerator Recycling Ninth Year Retention Study,[261] the Estimated Useful Life of Refrigerator Recycling is 8 years, representing the assumed remaining useful life of the retired unit.

Program Tracking Data & 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:

- Number of refrigerators/freezers replaced
- Age of removed unit
- Size (in cubic feet)
- Configuration (top freezer, bottom freezer, side-by-side, or single-door)

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

Not applicable.

Document Revision History

Table 2-285: Residential 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. LSAF updated to align with new peak demand methodology.
v3.1	11/05/2015	TRM v3.1 update. No revision.
v3.1	March 2016	Updated summer and winter coincidence factors.

[261] KEMA, Inc. "Residential Refrigerator Recycling Ninth Year Retention Study." Prepared for Southern California Edison Company. July 22, 2004.