



# Technical Reference Manual

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State of Pennsylvania

**Act 129**

Energy Efficiency and Conservation Program

&

**Act 213**

Alternative Energy Portfolio Standards

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## Table of Contents

<b>1</b>	<b>INTRODUCTION</b>	<b>1</b>
1.1	Purpose	1
1.2	Definitions	51
1.3	General Framework	73
1.4	Algorithms	73
1.5	Data and Input Values	84
1.6	Baseline Estimates	85
1.7	Resource Savings in Current and Future Program Years	95
1.8	Prospective Application of the TRM	95
1.9	Electric Resource Savings	95
1.10	Post Implementation Review	106
1.11	Adjustments to Energy and Resource Savings	116
1.12	Calculation of the Value of Resource Savings	127
1.13	Transmission and Distribution System Losses	138
1.14	Measure Lives	138
1.15	Custom Measures	138
1.16	Impact of Weather	149
1.17	Measure Applicability Based on Sector	1640
1.18	Algorithms for Energy Efficient Measures	1640
<b>2</b>	<b>RESIDENTIAL MEASURES</b>	<b>1711</b>
2.1	Electric HVAC	1842
2.2	Electric Clothes Dryer with Moisture Sensor	2749
2.3	Efficient Electric Water Heaters	21224
2.4	Electroluminescent Nightlight	3325
2.5	Furnace Whistle	3527
2.6	Heat Pump Water Heaters	4131
2.7	Home Audit Conservation Kits	4636
2.8	LED Nightlight	4939
2.9	Low Flow Faucet Aerators	5141
2.10	Low Flow Showerheads	5745
2.11	Programmable Thermostat	6649
2.12	Room AC (RAC) Retirement	6952
2.13	Smart Strip Plug Outlets	7558
2.14	Solar Water Heaters	7860
2.15	Electric Water Heater Pipe Insulation	8464
2.16	Residential Whole House Fans	8767
2.17	Ductless Mini Split Heat Pumps	8969
2.18	Fuel Switching: Domestic Hot Water Electric to Gas	9575
2.19	Fuel Switching: Heat Pump Water Heater to Gas Water Heater	10179
2.20	Fuel Switching: Electric Heat to Gas Heat	10885
2.21	Ceiling / Attic and Wall Insulation	11588
2.22	Refrigerator / Freezer Recycling with and without Replacement	12193
2.23	Residential New Construction	131404
2.24	ENERGY STAR Refrigerators	136406
2.25	ENERGY STAR Freezers	142411

2.26	ENERGY STAR Clothes Washers .....	145114
2.27	ENERGY STAR Dishwashers .....	151120
2.28	ENERGY STAR Dehumidifiers .....	154123
2.29	ENERGY STAR Room Air Conditioners .....	157126
2.30	ENERGY STAR Lighting .....	162130
2.31	ENERGY STAR Windows .....	170136
2.32	ENERGY STAR Audit .....	172138
2.33	Home Performance with ENERGY STAR .....	173139
2.34	ENERGY STAR Televisions .....	177143
2.35	ENERGY STAR Office Equipment .....	181147
2.36	ENERGY STAR LEDs .....	185151
2.37	Residential Occupancy Sensors .....	193155
2.38	Holiday Lights .....	194156
2.39	Low Income Lighting (FirstEnergy) .....	197159
2.40	Water Heater Tank Wrap .....	200162
2.41	Pool Pump Load Shifting .....	203165
2.42	High Efficiency Two Speed Pool Pump .....	206168
2.43	Variable Speed Pool Pumps (with Load Shifting Option) .....	208170
<b>3</b>	<b>COMMERCIAL AND INDUSTRIAL MEASURES .....</b>	<b>226175</b>
3.1	Baselines and Code Changes .....	226175
3.2	Lighting Equipment Improvements .....	227176
3.3	Premium Efficiency Motors .....	249195
3.4	Variable Frequency Drive (VFD) Improvements .....	256202
3.5	Variable Frequency Drive (VFD) Improvement for Industrial Air Compressors .....	261207
3.6	HVAC Systems .....	263209
3.7	Electric Chillers .....	270216
3.8	Anti-Sweat Heater Controls .....	274220
3.9	High Efficiency Refrigeration/Freezer Cases .....	278224
3.10	High Efficiency Evaporator Fan Motors for Reach In Refrigerated Cases .....	281227
3.11	High Efficiency Evaporator Fan Motors for Walk in Refrigerated Cases .....	287233
3.12	ENERGY STAR Office Equipment .....	293239
3.13	Smart Strip Plug Outlets .....	298244
3.14	Beverage Machine Controls .....	300246
3.15	High Efficiency Ice Machines .....	302248
3.16	Wall and Ceiling Insulation .....	305251
3.17	Strip Curtains for Walk In Freezers and Coolers .....	312258
3.18	Water Source and Geothermal Heat Pumps .....	320266
3.19	Ductless Mini Split Heat Pumps – Commercial < 5.4 tons .....	329275
3.20	ENERGY STAR Electric Steam Cooker .....	336282
3.21	Refrigeration – Night Covers for Display Cases .....	340286
3.22	Office Equipment – Network Power Management Enabling .....	342288
3.23	Refrigeration – Auto Closers .....	345291
3.24	Refrigeration – Door Gaskets for Walk-in Coolers and Freezers .....	347293
3.25	Refrigeration – Suction Pipes Insulation .....	350296
3.26	Refrigeration – Evaporator Fan Controllers .....	354298
3.27	ENERGY STAR Clothes Washer .....	357301
3.28	Electric Resistance Water Heaters .....	365308

3.29	Heat Pump Water Heaters .....	371313
3.30	LED Channel Signage.....	379320
3.31	Low Flow Pre Rinse Sprayers for Retrofit Programs .....	382322
3.32	Low Flow Pre Rinse Sprayers for Time of Sale / Retail Programs .....	387327
3.33	Small C/I HVAC Refrigerant Charge Correction .....	392333
3.34	Refrigeration – Special Doors with Low or No Anti-Sweat Heat for Low Temp Case .....	397337
3.35	ENERGY STAR Room Air Conditioner .....	400340
<b>4</b>	<b>APPENDICES .....</b>	<b>403342</b>
4.1	Appendix A: Measure Lives.....	403342
4.2	Appendix B: Relationship between Program Savings and Evaluation Savings.....	465346
4.3	Appendix C: Lighting Audit and Design Tool.....	466347
4.4	Appendix D: Motor & VFD Audit and Design Tool.....	467349
4.5	Appendix E: Lighting Audit and Design Tool for New Construction Projects.....	468350
4.6	Appendix F: Eligibility Requirements for Solid State Lighting Products in Commercial and Industrial Applications .....	469351
4.7	Appendix G: Zip Code Mapping .....	472354
<b>1</b>	<b>INTRODUCTION .....</b>	<b>111</b>
1.1	Purpose .....	141
1.2	Using the TRM .....	212
1.3	Definitions .....	515
1.4	General Framework.....	747
1.5	Algorithms .....	747
1.6	Data and Input Values.....	818
1.7	Baseline Estimates.....	818
1.8	Resource Savings in Current and Future Program Years .....	919
1.9	Prospective Application of the TRM .....	919
1.10	Electric Resource Savings .....	919
1.11	Post-Implementation Review .....	1020
1.12	Adjustments to Energy and Resource Savings.....	1120
1.13	Calculation of the Value of Resource Savings.....	1222
1.14	Transmission and Distribution System Losses .....	1322
1.15	Measure Lives .....	1322
1.16	Custom Measures .....	1323
1.17	Impact of Weather .....	1424
1.18	Measure Applicability Based on Sector.....	1525
1.19	Algorithms for Energy Efficient Measures .....	1625
<b>2</b>	<b>RESIDENTIAL MEASURES .....</b>	<b>1726</b>
2.1	Electric HVAC.....	1827
2.2	Electric Clothes Dryer with Moisture Sensor.....	2735
2.3	Efficient Electric Water Heaters .....	2937
2.4	Electroluminescent Nightlight.....	3341
2.5	Furnace Whistle .....	3543
2.6	Heat Pump Water Heaters .....	4148
2.7	LED Nightlight .....	4653
2.8	Low Flow Faucet Aerators.....	5155
2.9	Low Flow Showerheads .....	5760

2.10	Programmable Thermostat.....	66
2.11	Room AC (RAC) Retirement.....	69
2.12	Smart Strip Plug Outlets.....	75
2.13	Solar Water Heaters.....	78
2.14	Electric Water Heater Pipe Insulation.....	8483
2.15	Residential Whole House Fans.....	8786
2.16	Ductless Mini-Split Heat Pumps.....	8988
2.17	Fuel Switching: Domestic Hot Water Electric to Gas, Oil, or Propane.....	9594
2.18	Fuel Switching: Heat Pump Water Heater to Gas, Oil or Propane Water Heater...	10099
2.19	Fuel Switching: Electric Heat to Gas/Propane/Oil Heat.....	107495
2.20	Ceiling / Attic and Wall Insulation.....	115444
2.21	Refrigerator / Freezer Recycling with and without Replacement.....	121446
2.22	Residential New Construction.....	131423
2.23	ENERGY STAR Refrigerators.....	136428
2.24	ENERGY STAR Freezers.....	142433
2.25	ENERGY STAR Clothes Washers.....	145436
2.26	ENERGY STAR Dishwashers.....	151444
2.27	ENERGY STAR Dehumidifiers.....	154444
2.28	ENERGY STAR Room Air Conditioners.....	157447
2.29	ENERGY STAR Lighting.....	162450
2.30	ENERGY STAR Windows.....	170458
2.31	ENERGY STAR Audit.....	172460
2.32	Home Performance with ENERGY STAR.....	173464
2.33	ENERGY STAR Televisions.....	177465
2.34	ENERGY STAR Office Equipment.....	181469
2.35	ENERGY STAR LEDs.....	185473
2.36	Residential Occupancy Sensors.....	193478
2.37	Holiday Lights.....	194479
2.38	Water Heater Tank Wrap.....	197482
2.39	Pool Pump Load Shifting.....	203485
2.40	Variable Speed Pool Pumps (with Load Shifting Option).....	206488
2.41	Duct Insulation and Sealing.....	212492
2.42	Water Heater Temperature Setback.....	218497
2.43	ENERGY STAR Water Coolers.....	222204
<b>3</b>	<b>COMMERCIAL AND INDUSTRIAL MEASURES.....</b>	<b>226204</b>
3.1	Baselines and Code Changes.....	226204
3.2	Lighting Equipment Improvements.....	227205
3.3	Premium Efficiency Motors.....	249226
3.4	Variable Frequency Drive (VFD) Improvements.....	256233
3.5	Variable Frequency Drive (VFD) Improvement for Industrial Air Compressors....	261236
3.6	HVAC Systems.....	263238
3.7	Electric Chillers.....	270244
3.8	Anti-Sweat Heater Controls.....	274248
3.9	High-Efficiency Refrigeration/Freezer Cases.....	278252
3.10	High-Efficiency Evaporator Fan Motors for Reach-In Refrigerated Cases.....	281255
3.11	High-Efficiency Evaporator Fan Motors for Walk-in Refrigerated Cases.....	287261
3.12	ENERGY STAR Office Equipment.....	293267

3.13	Smart Strip Plug Outlets.....	298272
3.14	Beverage Machine Controls.....	300274
3.15	High-Efficiency Ice Machines.....	302276
3.16	Wall and Ceiling Insulation.....	305279
3.17	Strip Curtains for Walk-In Freezers and Coolers.....	312286
3.18	Water Source and Geothermal Heat Pumps.....	320294
3.19	Ductless Mini-Split Heat Pumps – Commercial < 5.4 tons.....	329302
3.20	ENERGY STAR Electric Steam Cooker.....	336309
3.21	Refrigeration – Night Covers for Display Cases.....	340313
3.22	Office Equipment – Network Power Management Enabling.....	342315
3.23	Refrigeration – Auto Closers.....	345318
3.24	Refrigeration – Door Gaskets for Walk-in and Reach-in Coolers and Freezers.....	347320
3.25	Refrigeration – Suction Pipes Insulation for Walk-in Coolers and Freezers.....	351323
3.26	Refrigeration – Evaporator Fan Controllers.....	354326
3.27	ENERGY STAR Clothes Washer.....	357329
3.28	Electric Resistance Water Heaters.....	365336
3.29	Heat Pump Water Heaters.....	371341
3.30	LED Channel Signage.....	379349
3.31	Low Flow Pre-Rinse Sprayers for Retrofit Programs.....	382352
3.32	Low Flow Pre-Rinse Sprayers for Time of Sale / Retail Programs.....	387357
3.33	Small C/I HVAC Refrigerant Charge Correction.....	392362
3.34	Refrigeration – Special Doors with Low or No Anti-Sweat Heat for Low Temp Case.....	397366
3.35	ENERGY STAR Room Air Conditioner.....	400369
3.36	Refrigeration – Floating Head Pressure Controls.....	407371
3.37	Variable Speed Refrigeration Compressor.....	411375
3.38	Fuel Switching: Domestic Hot Water Electric to Gas / Oil / Propane.....	413377
3.39	Fuel Switching: Heat Pump Water Heaters to Gas / Oil / Propane.....	419383
3.40	Fuel Switching: Commercial Electric Heat to Natural gas / Propane / Oil Heat.....	427391
<b>4</b>	<b>AGRICULTURAL MEASURES.....</b>	<b>433397</b>
4.1	Automatic Milker Takeoffs.....	434398
4.2	Dairy Scroll Compressors.....	437401
4.3	High Efficiency Ventilation Fans with and without Thermostats.....	440404
4.4	Heat Reclaimers.....	445409
4.5	High Volume Low Speed Fans.....	448412
4.6	Livestock Waterer.....	451415
4.7	Variable Speed Drive (VSD) Controller on Dairy Vacuum Pumps.....	453417
4.8	Low Pressure Irrigation System.....	456420
<b>5</b>	<b>APPENDICES.....</b>	<b>460424</b>
5.1	Appendix A: Measure Lives.....	460424
5.2	Appendix B: Relationship between Program Savings and Evaluation Savings.....	465429
5.3	Appendix C: Lighting Audit and Design Tool.....	466430
5.4	Appendix D: Motor & VFD Audit and Design Tool.....	467431
5.5	Appendix E: Lighting Audit and Design Tool for New Construction Projects.....	468432
5.6	Appendix F: Eligibility Requirements for Solid State Lighting Products in Commercial and Industrial Applications.....	469433
5.7	Appendix G: Zip Code Mapping.....	472436





## List of Tables

Table 1-1: Periods for Energy Savings and Coincident Peak Demand Savings.....	106
Table 1-2: California CZ Mapping Table.....	169
Table 2-1: Residential Electric HVAC – References.....	2245
Table 2-2: Efficient Electric Water Heater Calculation Assumptions.....	22023
Table 2-3: Energy Savings and Demand Reductions.....	22123
Table 2-4: Electroluminescent Nightlight – References.....	3426
Table 2-5: Furnace Whistle – References.....	3627
Table 2-6: EFLH for various cities in Pennsylvania (TRM Data).....	3728
Table 2-7: Assumptions and Results of Deemed Savings Calculations (Pittsburgh, PA).....	3729
Table 2-8: Assumptions and Results of Deemed Savings Calculations (Philadelphia, PA).....	3729
Table 2-9: Assumptions and Results of Deemed Savings Calculations (Harrisburg, PA).....	3829
Table 2-10: Assumptions and Results of Deemed Savings Calculations (Erie, PA).....	3829
Table 2-11: Assumptions and Results of Deemed Savings Calculations (Allentown, PA).....	3830
Table 2-12: Assumptions and Results of Deemed Savings Calculations (Scranton, PA).....	3930
Table 2-13: Assumptions and Results of Deemed Savings Calculations (Williamsport, PA).....	3930
Table 2-14: Heat Pump Water Heater Calculation Assumptions.....	4333
Table 2-15: Energy Savings and Demand Reductions.....	4535
Table 2-16: Home Audit Conversion Kit Calculation Assumptions.....	4737
Table 2-17: LED Nightlight – References.....	5040
Table 2-18: Low Flow Faucet Aerator Calculation Assumptions.....	5343
Table 2-19: Residential Electric HVAC Calculation Assumptions.....	6750
Table 2-20: Room AC Retirement Calculation Assumptions.....	7154
Table 2-21: RAC Retirement Only EFLH and Energy Savings by City.....	7255
Table 2-22: Preliminary Results from ComEd RAC Recycling Evaluation.....	7457
Table 2-23: Smart Strip Plug Outlet Calculation Assumptions.....	7650
Table 2-24: Solar Water Heater Calculation Assumptions.....	8062
Table 2-25: Whole House Fan Deemed Energy Savings by PA City.....	8868
Table 2-26: DHP – Values and References.....	9174
Table 2-27: DHP – Heating Zones.....	9373
Table 2-28: Calculation Assumptions for Fuel Switching, Domestic Hot Water Electric to Gas.....	9777
Table 2-29: Energy Savings and Demand Reductions for Fuel Switching, Domestic Hot Water Electric to Gas.....	9978
Table 2-30: Gas Consumption for Fuel Switching, Domestic Hot Water Electric to Gas.....	9978
Table 2-31: Calculation Assumptions for Heat Pump Water Heater to Gas Water Heater.....	10384
Table 2-32: Energy Savings and Demand Reductions for Heat Pump Water Heater to Gas Water Heater.....	10683
Table 2-33: Gas Consumption for Heat Pump Water Heater to Gas Water Heater.....	10683
Table 2-34: Default values for algorithm terms, Fuel Switching, Electric Heat to Gas Heat.....	11087
Table 2-35: Default values for algorithm terms, Ceiling/Attic and Wall Insulation.....	11790
Table 2-36: EFLH, CDD and HDD by City.....	11992
Table 2-37: Refrigerator Per Unit “Deemed” Energy Consumption Calculation Using Regression Model and Program Values (Program values obtained from PY3 data from the seven Act 129-EDGs).....	12495

Table 2-38: Freezer Per Unit “Deemed” Energy Consumption Calculation Using Regression Model and Program Values (Program values obtained from PY3 data from the seven Act 129 EDCs).....	12596
Table 2-39: Refrigerator Per Unit “Net” Energy Consumption Calculation Using Equation #2 (adjusts for units that are removed but then replaced).....	12697
Table 2-40: Freezer Per Unit “Net” Energy Consumption Calculation Using Equation #2 (adjusts for units that are removed but then replaced).....	12798
Table 2-41: Residential New Construction – References .....	133403
Table 2-42: Baseline Insulation and Fenestration Requirements by Component (Equivalent U-Factors).....	134404
Table 2-43: Energy Star Homes – User Defined Reference Home .....	134404
Table 2-44: Federal Standard and ENERGY STAR Refrigerators Maximum Annual Energy Consumption if Configuration and Volume Known.....	137407
Table 2-45: Default Savings Values for ENERGY STAR Refrigerators.....	138408
Table 2-46: ENERGY STAR Most Efficient Annual Energy Usage if Configuration and Volume Known.....	139409
Table 2-47: Default Savings Values for ENERGY STAR Most Efficient Refrigerators .....	139409
Table 2-48: Federal Refrigerator Standards Effective as of the 2015 TRM.....	140440
Table 2-49: Federal Standard and ENERGY STAR Freezers Maximum Annual Energy Consumption if Configuration and Volume Known.....	143442
Table 2-50: Default Savings Values for ENERGY STAR Freezers.....	144443
Table 2-51: Federal Freezer Standards Effective as of the 2015 TRM.....	144443
Table 2-52: ENERGY STAR Clothes Washers – References .....	147446
Table 2-53: Default Clothes Washer Savings .....	149448
Table 2-54: Future Federal Standards for Clothes Washers .....	150449
Table 2-55: Federal Standard and ENERGY STAR v 5.0 Residential Dishwasher Standard .....	152421
Table 2-56: ENERGY STAR Dishwashers – References .....	152421
Table 2-57: Default Dishwasher Hot Water Fuel Mix .....	153422
Table 2-58: Default Dishwasher Energy and Demand Savings .....	153422
Table 2-59: Dehumidifier Minimum Federal Efficiency and ENERGY STAR Standards .....	155124
Table 2-60: Dehumidifier Default Energy Savings .....	156124
Table 2-61: RAC Federal Minimum Efficiency and ENERGY STAR Standards .....	158127
Table 2-62: Casement-only and Casement Slider RAC Federal Minimum Efficiency and ENERGY STAR Standards .....	158127
Table 2-63: Reverse Cycle RAC Federal Minimum Efficiency Standards .....	159428
<b>Table 2-64: Deemed EFLH and Default Energy Savings .....</b>	<b>159428</b>
Table 2-65: RAC Federal Minimum Efficiency and ENERGY STAR Version 3.0 Standards (effective 2014 TRM).....	160429
Table 2-66: Casement Only and Casement Slider RAC Federal Minimum Efficiency and ENERGY STAR Version 3.0 Standards (effective 2014 TRM).....	160429
Table 2-67: Reverse Cycle RAC Federal Minimum Efficiency Standards and ENERGY STAR Version 3.0 Standards (effective 2014 TRM).....	161429
Table 2-68: ENERGY STAR Lighting – References .....	164432
Table 2-69: Baseline Wattage by Lumen Output .....	166434
Table 2-70: Default Savings for ENERGY STAR Indoor Fixtures, ENERGY STAR Outdoor Fixtures and ENERGY STAR Torchieres (per fixture).....	169435
Table 2-71: Default Savings for ENERGY STAR Ceiling Fans Light Fixtures (per fixture).....	169435

Table 2-72: ENERGY STAR Windows – References .....	171137
Table 2-73: ENERGY STAR TVs – References .....	177143
Table 2-74: ENERGY STAR TVs Version 5.3 maximum power consumption .....	178144
Table 2-75: TV power consumption .....	179145
Table 2-76: Deemed energy savings for ENERGY STAR Version 5.3 and ENERGY STAR Most Efficient TVs .....	180145
Table 2-77: Deemed coincident demand savings for ENERGY STAR Version 5.3 and ENERGY STAR Most Efficient TVs .....	180146
Table 2-78: ENERGY STAR Office Equipment – References .....	183149
Table 2-79: ENERGY STAR Office Equipment Energy and Demand Savings Values .....	184150
Table 2-80: General Service Lamps .....	186151
Table 2-81: Reflector Lamps .....	187152
Table 2-82: Residential LED Variables .....	188153
Table 2-83: Residential Occupancy Sensors Calculations Assumptions .....	193155
Table 2-84: Holiday Lights Assumptions .....	195157
Table 2-85: Low Income Lighting Calculations Assumptions .....	198160
Table 2-86: Energy Savings and Demand Reductions .....	199161
Table 2-87: Water Heater Tank Wrap – Default Values .....	201163
Table 2-88: Deemed savings by water heater capacity .....	202164
Table 2-89: Pool Pump Load Shifting Assumptions .....	204166
Table 2-90: Single Speed Pool Pump Specification .....	205167
Table 2-91: High Efficiency Pool and Motor – Two Speed Pump Calculations Assumptions .....	206168
Table 2-92: Two Speed Pool Pump Deemed Savings Values .....	207169
Table 2-93: Residential VFD Pool Pumps Calculations Assumptions .....	209171
Table 2-94: Single Speed Pool Pump Specification .....	210172
Table 3-1: Lighting Power Densities from ASHRAE 90.1-2007 Building Area Method .....	233181
Table 3-2: Lighting Power Densities from ASHRAE 90.1-2007 Space-by-Space Method .....	234182
Table 3-3: Baseline Exterior Lighting Power Densities .....	236184
Table 3-4: Lighting HOU and CF by Building Type or Function .....	238185
Table 3-5: Interactive Factors and Other Lighting Variables .....	241188
Table 3-6: Lighting Controls Assumptions .....	242189
Table 3-7: Savings Control Factors Assumptions .....	244190
Table 3-8: Assumptions for LED Traffic Signals .....	245191
Table 3-9: LED Traffic Signals .....	246192
Table 3-10: Reference Specifications for Above Traffic Signal Wattages .....	247193
Table 3-11: LED Exit Signs .....	248194
Table 3-12: Building Mechanical System Variables for Premium Efficiency Motor Calculations .....	250196
Table 3-13: Baseline Motor Nominal Efficiencies for PY1 and PY2 .....	251197
Table 3-14: Baseline Motor Nominal Efficiencies for PY3 and PY4 .....	252198
Table 3-15: Stipulated Hours of Use for Motors in Commercial Buildings .....	253199
Table 3-16: Variables for VFD Calculations .....	258204
Table 3-17: ESF and DSF for Typical Commercial VFD Installations .....	259205
Table 3-18: Variables for Industrial Air Compressor Calculation .....	262208
Table 3-19: Variables for HVAC Systems .....	265211
Table 3-20: HVAC Baseline Efficiencies .....	266212
Table 3-21: Cooling EFLH for Pennsylvania Cities .....	267213

Table 3-22: Heating EFLH for Pennsylvania Cities™	268214
Table 3-23: Electric Chiller Variables	271217
Table 3-24: Electric Chiller Baseline Efficiencies (IECC 2009)	272218
Table 3-25: Chiller Cooling EFLH by Location™	273219
Table 3-26: Anti-Sweat Heater Controls—Values and References	276222
Table 3-27: Recommended Fully Deemed Impact Estimates	277223
Table 3-28: Refrigeration Cases—References	278224
Table 3-29: Refrigeration Case Efficiencies	279225
Table 3-30: Freezer Case Efficiencies	279225
Table 3-31: Refrigeration Case Savings	279225
Table 3-32: Freezer Case Savings	280226
Table 3-33: Variables for High Efficiency Evaporator Fan Motor	282228
Table 3-34: Variables for HE Evaporator Fan Motor	283229
Table 3-35: Shaded Pole to PSC Deemed Savings	284230
Table 3-36: PSC to ECM Deemed Savings	284230
Table 3-37: Shaded Pole to ECM Deemed Savings	285231
Table 3-38: Default High Efficiency Evaporator Fan Motor Deemed Savings	285231
Table 3-39: Variables for High Efficiency Evaporator Fan Motor	288234
Table 3-40: Variables for HE Evaporator Fan Motor	289235
Table 3-41: PSC to ECM Deemed Savings	290236
Table 3-42: Shaded Pole to ECM Deemed Savings	291237
Table 3-43: Default High Efficiency Evaporator Fan Motor Deemed Savings	291237
Table 3-44: ENERGY STAR Office Equipment—References	295241
Table 3-45: ENERGY STAR Office Equipment Energy and Demand Savings Values	296242
Table 3-46: ENERGY STAR Office Equipment Measure Life	297243
Table 3-47: Smart Strip Calculation Assumptions	298244
Table 3-48: Beverage Machine Controls Energy Savings	301247
Table 3-49: Ice Machine Reference values for algorithm components	303249
Table 3-50: Ice Machine Energy Usage	304250
Table 3-51: Non-Residential Insulation—Values and References	306252
Table 3-52: Ceiling R-Values by Building Type	308254
Table 3-53: Wall R-Values by Building Type	308254
Table 3-54: HVAC Baseline Efficiencies for Non-Residential Buildings	309255
Table 3-55: Cooling EFLH for Key PA Cities	310256
Table 3-56: Deemed Energy Savings and Demand Reductions for Strip Curtains	315261
Table 3-57: Strip Curtain Calculation Assumptions for Supermarkets	316262
Table 3-58: Strip Curtain Calculation Assumptions for Convenience Stores	316262
Table 3-59: Strip Curtain Calculation Assumptions for Restaurant	317263
Table 3-60: Strip Curtain Calculation Assumptions for Refrigerated Warehouse	318264
Table 3-61: Water Source or Geothermal Heat Pump Baseline Assumptions	321267
Table 3-62: Geothermal Heat Pump—Values and References	324270
Table 3-63: Federal Minimum Efficiency Requirements for Motors	326272
Table 3-64: Ground/Water Loop Pump and Circulating Pump Efficiency	326272
Table 3-65: Default Baseline Equipment Efficiencies	327273
Table 3-66: DHP—Values and References	331277
Table 3-67: Cooling EFLH for Pennsylvania Cities™	333279
Table 3-68: Heating EFLH for Pennsylvania Cities™	334280

Table 3-69: Steam Cooker – Values and References.....	337283
Table 3-70: Default Values for Electric Steam Cookers by Number of Pans.....	338284
Table 3-71: Night Covers Calculations Assumptions.....	341287
Table 3-72: Savings Factors.....	341287
Table 3-73: Network Power Controls, Per Unit Summary Table.....	343289
Table 3-74: Refrigeration Auto Closers Calculations Assumptions.....	346292
Table 3-75: Door Gasket Assumptions.....	347293
Table 3-76: Door Gasket Savings per Linear Foot (CZ 4 Allentown, Pittsburgh, Williamstown) .....	348294
Table 3-77: Door Gasket Savings per Linear Foot (CZ 8 Harrisburg).....	348294
Table 3-78: Door Gasket Savings per Linear Foot (CZ 13 Philadelphia).....	349294
Table 3-79: Door Gasket Savings per Linear Foot (CZ 16 Scranton).....	349295
Table 3-80: Door Gasket Savings per Linear Foot (CZ 6 Erie).....	349295
Table 3-81: Insulate Bare Refrigeration Suction Pipes Calculations Assumptions.....	352297
Table 3-82: Insulate Bare Refrigeration Suction Pipes Savings per Linear Foot.....	352297
Table 3-83: Evaporator Fan Controller Calculations Assumptions.....	356300
Table 3-84: Commercial Clothes Washer Calculation Assumptions.....	361304
Table 3-85: Deemed Savings for Top Loading ENERGY STAR Clothes Washer for Laundry in Multifamily Buildings.....	363306
Table 3-86: Deemed Savings for Front Loading ENERGY STAR Clothes Washer for Laundry in Multifamily Buildings.....	363306
Table 3-87: Deemed Savings for Top Loading ENERGY STAR Clothes Washer for Laundromats .....	364307
Table 3-88: Deemed Savings Front Loading ENERGY STAR Clothes Washer for Laundromats .....	364307
Table 3-89: Typical water heating loads.....	366309
Table 3-90: Electric Resistance Water Heater Calculation Assumptions.....	368311
Table 3-91: Energy Savings and Demand Reductions.....	369312
Table 3-92: Typical water heating loads.....	372314
Table 3-93: COP Adjustment Factors.....	374316
Table 3-94: Electric Resistance Water Heater Calculation Assumptions.....	376317
Table 3-95: Energy Savings and Demand Reductions.....	378319
Table 3-96: LED Channel Signage Calculation Assumptions.....	381321
Table 3-97: Low Flow Pre-Rinse Sprayer Calculations Assumptions.....	385325
Table 3-98: Low Flow Pre-Rinse Sprayer Calculations Assumptions.....	390330
Table 3-99: Low Flow Pre-Rinse Sprayer Deemed Savings.....	391331
Table 3-100: Refrigerant Charge Correction Calculations Assumptions.....	394334
Table 3-101: Refrigerant charge correction COP degradation factor (RCF) for various relative charge adjustments for both TXV metered and non-TXV units.....	395335
Table 3-102: Special Doors with Low or No Anti-Sweat Heat for Low Temp Case Calculations Assumptions.....	399339
Table 3-103: Variables for HVAC Systems.....	400340
Table 3-104: Room Air Conditioner Baseline Efficiencies.....	401341
Table 3-105: Cooling EFLH for Pennsylvania Cities.....	401341
Table 1-1: End-Use Categories and Measures in the TRM.....	313
Table 1-2: kWh Savings Thresholds.....	515
Table 1-3: Periods for Energy Savings and Coincident Peak Demand Savings.....	1020

Table 1-4: California CZ Mapping Table .....	1524
Table 2-1: Residential Electric HVAC - References .....	2231
Table 2-2: Alternate Cooling EFLH.....	2433
Table 2-3: Alternate Heating EFLH .....	2433
Table 2-4: Efficient Electric Water Heater Calculation Assumptions.....	3139
Table 2-5: Energy Factors based on Tank Size .....	3139
Table 2-6: Electroluminescent Nightlight - References .....	3442
Table 2-7: Furnace Whistle - References.....	3644
Table 2-8: EFLH for various cities in Pennsylvania (TRM Data).....	3745
Table 2-9: Assumptions and Results of Deemed Savings Calculations (Pittsburgh, PA).....	3745
Table 2-10: Assumptions and Results of Deemed Savings Calculations (Philadelphia, PA) ...	3745
Table 2-11: Assumptions and Results of Deemed Savings Calculations (Harrisburg, PA) .....	3846
Table 2-12: Assumptions and Results of Deemed Savings Calculations (Erie, PA).....	3846
Table 2-13: Assumptions and Results of Deemed Savings Calculations (Allentown, PA) .....	3846
Table 2-14: Assumptions and Results of Deemed Savings Calculations (Scranton, PA).....	3947
Table 2-15: Assumptions and Results of Deemed Savings Calculations (Williamsport, PA) ...	3947
Table 2-16: Heat Pump Water Heater Calculation Assumptions .....	4359
Table 2-17: Energy Factor Based on Tank Size .....	4359
Table 2-18: LED Nightlight - References.....	5054
Table 2-19: Low Flow Faucet Aerator Calculation Assumptions.....	5357
Table 2-20: Low Flow Showerhead Calculation Assumptions .....	5864
Table 2-21: Residential Electric HVAC Calculation Assumptions .....	67
Table 2-22: Room AC Retirement Calculation Assumptions .....	71
Table 2-23: RAC Retirement-Only EFLH and Energy Savings by City.....	72
Table 2-24: Preliminary Results from ComEd RAC Recycling Evaluation.....	74
Table 2-25: Smart Strip Plug Outlet Calculation Assumptions.....	76
Table 2-26: Solar Water Heater Calculation Assumptions .....	80
Table 2-27: Energy Factors Based on Tank Size.....	81
Table 2-28: Whole House Fan Deemed Energy Savings by PA City.....	8887
Table 2-29: DHP – Values and References .....	9190
Table 2-30: DHP – Heating Zones .....	9392
Table 2-31: Calculation Assumptions for Fuel Switching, Domestic Hot Water Electric to Gas	9796
Table 2-32: Energy Factors based on Tank Size .....	9897
Table 2-33: Energy Savings and Demand Reductions for Fuel Switching, Domestic Hot Water Electric to Fossil Fuel .....	9998
Table 2-34: Fuel Consumption for Fuel Switching, Domestic Hot Water Electric to Fossil Fuel	9998
Table 2-35: Calculation Assumptions for Heat Pump Water Heater to Fossil Fuel Water Heaters .....	103404
Table 2-36: Energy Savings and Demand Reductions for Heat Pump Water Heater to Fossil Fuel Water Heater .....	106403
Table 2-37: Gas, Oil, Propane Consumption for Heat Pump Water Heater to Gas Water Heater .....	106404
Table 2-38: Default values for algorithm terms, Fuel Switching, Electric Heat to Gas Heat .	110407
Table 2-39: Alternate Heating EFLH for Air Source Heat Pumps .....	112409
Table 2-40: Alternate Heating EFLH for Electric Furnaces .....	112409
Table 2-41: Alternate Heating EFLH for Electric Baseboard Heating .....	112409
Table 2-42: Alternate Heating EFLH for Fossil Fuel Furnaces .....	113440

Table 2-43: Alternate Heating EFLH for Fossil Fuel Boilers .....	113410
Table 2-44: Default values for algorithm terms, Ceiling/Attic and Wall Insulation.....	117413
Table 2-45: EFLH, CDD and HDD by City .....	119415
Table 2-46: Deemed Savings values for Residential Refrigerator Recycling Without Replacement With a New Refrigerator .....	124419
Table 2-47: Deemed Savings values for Residential Freezer Recycling Without Replacement With a New Freezer.....	125419
Table 2-48: Deemed Savings values for Residential Refrigerator Recycling With Replacement With a New Refrigerator .....	126420
Table 2-49: Deemed Savings values for Residential Freezer Recycling With Replacement With a New Freezer .....	127420
Table 2-50: Residential New Construction – References .....	133425
Table 2-51: Baseline Insulation and Fenestration Requirements by Component (Equivalent U- Factors).....	134426
Table 2-52: Energy Star Homes - User Defined Reference Home .....	134426
Table 2-53: Federal Standard and ENERGY STAR Refrigerators Maximum Annual Energy Consumption if Configuration and Volume Known.....	137429
Table 2-54: Default Savings Values for ENERGY STAR Refrigerators .....	138430
Table 2-55: ENERGY STAR Most Efficient Annual Energy Usage if Configuration and Volume Known.....	139431
Table 2-56: Default Savings Values for ENERGY STAR Most Efficient Refrigerators .....	139431
Table 2-57: Federal Refrigerator Standards Effective as of the 2015 TRM.....	140432
Table 2-58: Federal Standard and ENERGY STAR Freezers Maximum Annual Energy Consumption if Configuration and Volume Known.....	143434
Table 2-59: Default Savings Values for ENERGY STAR Freezers.....	144434
Table 2-60: Federal Freezer Standards Effective as of the 2015 TRM.....	144435
Table 2-61: ENERGY STAR Clothes Washers - References .....	147438
Table 2-62: Default Clothes Washer Savings .....	149439
Table 2-63: Future Federal Standards for Clothes Washers .....	150440
Table 2-64: Federal Standard and ENERGY STAR v 5.0 Residential Dishwasher Standard	152442
Table 2-65: ENERGY STAR Dishwashers - References .....	152442
Table 2-66: Default Dishwasher Energy and Demand Savings .....	153443
Table 2-67: Dehumidifier Minimum Federal Efficiency and ENERGY STAR Standards .....	155445
Table 2-68: Dehumidifier Default Energy Savings .....	156445
Table 2-69: RAC Federal Minimum Efficiency and ENERGY STAR Version 3.0 Standards	160448
Table 2-70: Casement-Only and Casement-Slider RAC Federal Minimum Efficiency and ENERGY STAR Version 3.0 Standards (effective 2014 TRM) .....	160448
Table 2-71: Reverse-Cycle RAC Federal Minimum Efficiency Standards and ENERGY STAR Version 3.0 Standards (effective 2014 TRM) .....	161449
Table 2-72: Deemed EFLH and Default Energy Savings' .....	161449
Table 2-73: ENERGY STAR Lighting - References .....	164452
Table 2-74: Baseline Wattage by Lumen Output for General Service Lamps (GSL).....	166454
Table 2-75. Default Baseline Wattage for Reflector Bulbs.....	167455
Table 2-76. Energy and Demand HVAC Interactive Effects by EDC .....	168456
Table 2-77: Default Savings for ENERGY STAR Indoor Fixtures, ENERGY STAR Outdoor Fixtures and ENERGY STAR Torchieres (per fixture) .....	169456
Table 2-78: Default Savings for ENERGY STAR Ceiling Fans Light Fixtures (per fixture)...	169457



Table 2-79: ENERGY STAR Windows - References .....	171159
Table 2-80: ENERGY STAR TVs - References .....	177165
Table 2-81: TV power consumption.....	179167
Table 2-82: Deemed energy savings for ENERGY STAR Version 5.3 and ENERGY STAR Most Efficient TVs.....	180167
Table 2-83: Deemed coincident demand savings for ENERGY STAR Version 5.3 and ENERGY STAR Most Efficient TVs.....	180168
Table 2-84: ENERGY STAR Office Equipment - References .....	183171
Table 2-85: ENERGY STAR Office Equipment Energy and Demand Savings Values.....	184172
Table 2-86: Residential LED Variables .....	188174
Table 2-87: Baseline Wattage by Lumen Output for General Service Lamps (GSL).....	189175
Table 2-88: Default Baseline Wattage for Reflector Bulbs.....	190176
Table 2-89: Energy and Demand HVAC Interactive Effects by EDC.....	191177
Table 2-90: Residential Occupancy Sensors Calculations Assumptions.....	193178
Table 2-91: Holiday Lights Assumptions .....	195180
Table 2-92: Water Heater Tank Wrap – Default Values.....	201183
Table 2-93: Deemed savings by water heater capacity .....	202184
Table 2-94: Pool Pump Load Shifting Assumptions.....	204186
Table 2-95: Single Speed Pool Pump Specification.....	205187
Table 2-96: Residential VFD Pool Pumps Calculations Assumptions .....	209189
Table 2-97: Single Speed Pool Pump Specification.....	210190
Table 2-98: Duct Sealing – Values and References .....	214194
Table 2-99: Efficient Electric Water Heater Calculation Assumptions.....	220199
Table 2-100: Energy Savings and Demand Reductions .....	221200
Table 2-101: ENERGY STAR Water Coolers – References.....	222201
Table 3-1: Lighting Power Densities from ASHRAE 90.1-2007 Building Area Method.....	233211
Table 3-2: Lighting Power Densities from ASHRAE 90.1-2007 Space-by-Space Method .....	234212
Table 3-3: Baseline Exterior Lighting Power Densities .....	236214
Table 3-4: Savings Adjustment Factors and Adjusted EULs for HPT8 Measures .....	237215
Table 3-5: Savings Adjustment Factors and Adjusted EULs for T5 Measures .....	238216
Table 3-6: Lighting HOU and CF by Building Type or Function.....	238216
Table 3-7: Interactive Factors and Other Lighting Variables.....	241219
Table 3-8: Lighting Controls Assumptions.....	242220
Table 3-9: Savings Control Factors Assumptions .....	244221
Table 3-10: Assumptions for LED Traffic Signals.....	245222
Table 3-11: LED Traffic Signals.....	246223
Table 3-12: Reference Specifications for Above Traffic Signal Wattages.....	247224
Table 3-13: LED Exit Signs .....	248225
Table 3-14: Building Mechanical System Variables for Premium Efficiency Motor Calculations .....	250227
Table 3-15: Baseline Motor Nominal Efficiencies for PY1 and PY2.....	251228
Table 3-16: Baseline Motor Nominal Efficiencies for PY3 and PY4.....	252229
Table 3-17: Stipulated Hours of Use for Motors in Commercial Buildings .....	253230
Table 3-18: Variables for VFD Calculations .....	258234
Table 3-19: ESF and DSF for Typical Commercial VFD Installations' .....	259234
Table 3-20: Variables for Industrial Air Compressor Calculation .....	262237
Table 3-21: Variables for HVAC Systems .....	265240



Table 3-22: HVAC Baseline Efficiencies .....	266241
Table 3-23: Cooling EFLH for Pennsylvania Cities' .....	267242
Table 3-24: Heating EFLH for Pennsylvania Cities' .....	268243
Table 3-25: Electric Chiller Variables .....	271245
Table 3-26: Electric Chiller Baseline Efficiencies (IECC 2009) .....	272246
Table 3-27: Chiller Cooling EFLH by Location' .....	273247
Table 3-28: Anti-Sweat Heater Controls – Values and References .....	276250
Table 3-29: Recommended Fully Deemed Impact Estimates .....	277251
Table 3-30: Refrigeration Cases - References .....	278252
Table 3-31: Refrigeration Case Efficiencies .....	279253
Table 3-32: Freezer Case Efficiencies .....	279253
Table 3-33: Refrigeration Case Savings .....	279253
Table 3-34: Freezer Case Savings .....	280254
Table 3-35: Variables for High-Efficiency Evaporator Fan Motor .....	282256
Table 3-36: Variables for HE Evaporator Fan Motor .....	283257
Table 3-37: Shaded Pole to PSC Deemed Savings .....	284258
Table 3-38: PSC to ECM Deemed Savings .....	284258
Table 3-39: Shaded Pole to ECM Deemed Savings .....	285259
Table 3-40: Default High-Efficiency Evaporator Fan Motor Deemed Savings .....	285259
Table 3-41: Variables for High-Efficiency Evaporator Fan Motor .....	288262
Table 3-42: Variables for HE Evaporator Fan Motor .....	289263
Table 3-43: PSC to ECM Deemed Savings .....	290264
Table 3-44: Shaded Pole to ECM Deemed Savings .....	291265
Table 3-45: Default High-Efficiency Evaporator Fan Motor Deemed Savings .....	291265
Table 3-46: ENERGY STAR Office Equipment - References .....	295269
Table 3-47: ENERGY STAR Office Equipment Energy and Demand Savings Values .....	296270
Table 3-48: ENERGY STAR Office Equipment Measure Life .....	297271
Table 3-49: Smart Strip Calculation Assumptions .....	298272
Table 3-50: Beverage Machine Controls Energy Savings .....	301275
Table 3-51: Ice Machine Reference values for algorithm components .....	303277
Table 3-52: Ice Machine Energy Usage .....	304278
Table 3-53: Non-Residential Insulation – Values and References .....	306280
Table 3-54: Ceiling R-Values by Building Type .....	308282
Table 3-55: Wall R-Values by Building Type .....	308282
Table 3-56: HVAC Baseline Efficiencies for Non-Residential Buildings .....	309283
Table 3-57: Cooling EFLH for Key PA Cities .....	310284
Table 3-58: Deemed Energy Savings and Demand Reductions for Strip Curtains .....	315289
Table 3-59: Strip Curtain Calculation Assumptions for Supermarkets .....	316290
Table 3-60: Strip Curtain Calculation Assumptions for Convenience Stores .....	316290
Table 3-61: Strip Curtain Calculation Assumptions for Restaurant .....	317291
Table 3-62: Strip Curtain Calculation Assumptions for Refrigerated Warehouse .....	318292
Table 3-63: Water Source or Geothermal Heat Pump Baseline Assumptions .....	321295
Table 3-64: Geothermal Heat Pump– Values and References .....	324298
Table 3-65: Federal Minimum Efficiency Requirements for Motors .....	326300
Table 3-66: Ground/Water Loop Pump and Circulating Pump Efficiency .....	326300
Table 3-67: Default Baseline Equipment Efficiencies .....	327301
Table 3-68: DHP – Values and References .....	331304

Table 3-69: Cooling EFLH for Pennsylvania Cities'	333306
Table 3-70: Heating EFLH for Pennsylvania Cities'	334307
Table 3-71: Steam Cooker - Values and References	337310
Table 3-72: Default Values for Electric Steam Cookers by Number of Pans	338311
Table 3-73: Night Covers Calculations Assumptions	341314
Table 3-74: Savings Factors	341314
Table 3-75: Network Power Controls, Per Unit Summary Table	343316
Table 3-76: Refrigeration Auto Closers Calculations Assumptions	346319
Table 3-77: Door Gasket Assumptions	347320
Table 3-78: Door Gasket Savings per Linear Foot for Walk-in Coolers and Freezers (CZ 4 Pittsburgh, Scranton)	348321
Table 3-79: Door Gasket Savings per Linear Foot for Walk-in Coolers and Freezers (CZ 15 Allentown, Harrisburg, Philadelphia, Williamstown)	348321
Table 3-80: Door Gasket Savings per Linear Foot for Walk-in Coolers and Freezers (CZ 9 Erie)	349321
Table 3-81: Door Gasket Savings per Linear Foot for Reach-in Coolers and Freezers (CZ 4 Pittsburgh, Scranton)	349322
Table 3-82: Door Gasket Savings per Linear Foot for Reach-in Coolers and Freezers (CZ 15 Allentown, Harrisburg, Philadelphia, Williamstown)	349322
Table 3-83: Door Gasket Savings per Linear Foot for Reach-in Coolers and Freezers (CZ 9 Erie)	350322
Table 3-84: Insulate Bare Refrigeration Suction Pipes Calculations Assumptions	352324
Table 3-85: Insulate Bare Refrigeration Suction Pipes Savings per Linear Foot for Walk-in Coolers and Freezers of Restaurants and Grocery Stores	352324
Table 3-86: Evaporator Fan Controller Calculations Assumptions	356328
Table 3-87: Commercial Clothes Washer Calculation Assumptions	361332
Table 3-88: Deemed Savings for Top Loading ENERGY STAR Clothes Washer for Laundry in Multifamily Buildings	363334
Table 3-89: Deemed Savings for Front Loading ENERGY STAR Clothes Washer for Laundry in Multifamily Buildings	363334
Table 3-90: Deemed Savings for Top Loading ENERGY STAR Clothes Washer for Laundromats	364335
Table 3-91: Deemed Savings Front Loading ENERGY STAR Clothes Washer for Laundromats	364335
Table 3-92: Typical water heating loads	366337
Table 3-93: Electric Resistance Water Heater Calculation Assumptions	368339
Table 3-94: Energy Factors based on Tank Size	369339
Table 3-95: Energy Savings and Demand Reductions	369340
Table 3-96: Typical water heating loads	372342
Table 3-97: COP Adjustment Factors	374344
Table 3-98: Electric Resistance Water Heater Calculation Assumptions	376346
Table 3-99: Energy Factor Based on Tank Size	377346
Table 3-100: Energy Savings and Demand Reductions	378347
Table 3-101: LED Channel Signage Calculation Assumptions	381350
Table 3-102: Power demand of baseline (neon and argon-mercury) and energy-efficient (LED) signs	381351
Table 3-103: Low Flow Pre-Rinse Sprayer Calculations Assumptions	385355

Table 3-104: Low Flow Pre-Rinse Sprayer Calculations Assumptions ..... 390360

Table 3-105: Low Flow Pre-Rinse Sprayer Deemed Savings ..... 391361

Table 3-106: Refrigerant Charge Correction Calculations Assumptions ..... 394363

Table 3-107: Refrigerant charge correction COP degradation factor (RCF) for various relative charge adjustments for both TXV metered and non-TXV units ..... 395364

Table 3-108: Special Doors with Low or No Anti-Sweat Heat for Low Temp Case Calculations Assumptions ..... 399368

Table 3-109: Variables for HVAC Systems ..... 400369

Table 3-110: Room Air Conditioner Baseline Efficiencies ..... 401370

Table 3-111: Cooling EFLH for Pennsylvania Cities ..... 401370

Table 3-112: Floating Head Pressure Controls – Values and References ..... 408372

Table 3-113: Annual Savings kWh/HP by Location ..... 409373

Table 3-114: Default Condenser Type Annual Savings kWh/HP by Location ..... 409373

Table 3-115: VSD Compressor – Values and References ..... 412376

Table 3-116: Typical water heating loads ..... 414378

Table 3-117: Commercial Water Heater Fuel Switch Calculation Assumptions ..... 416380

Table 3-118: Water Heating Fuel Switch Energy Savings and Demand Reductions ..... 417381

Table 3-119: Typical water heating loads ..... 420384

Table 3-120: COP Adjustment Factors ..... 423387

Table 3-121: Heat Pump Water Heater Fuel Switch Calculation Assumptions ..... 424388

Table 3-122: Energy Savings and Demand Reductions ..... 425389

Table 3-123: Variables for HVAC Systems ..... 429393

Table 3-124: HVAC Baseline Efficiencies ..... 430394

Table 3-125: Heating EFLH for Pennsylvania Cities' ..... 431395

Table 4-1: Variables for Automatic Milker Takeoffs ..... 435399

Table 4-2: Variables for Dairy Scroll Compressors ..... 438402

Table 4-3: Variables for Ventilation Fans ..... 442406

Table 4-4: Default values for standard and high efficiency ventilation fans for dairy and swine facilities ..... 443407

Table 4-5: Default Hours for Ventilation Fans by Facility Type by Location (No Thermostat) ..... 443407

Table 4-6: Default Hours Reduced by Thermostats by Facility Type and Location ..... 444408

Table 4-7: Variables for Heat Reclaimers ..... 446410

Table 4-8: Variables for HVLS Fans ..... 449413

Table 4-9: Default Values for Conventional and HVLS Fan Wattages ..... 449413

Table 4-10: Default Hours by Location for Dairy/Poultry/Swine Applications ..... 449413

Table 4-11: Variables for Livestock Waterers ..... 452416

Table 4-12: Variables for VSD Controller on Dairy Vacuum Pump ..... 455419

Table 4-13: Variables for Low Pressure Irrigation Systems ..... 458422

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# 1 INTRODUCTION

The Technical Reference Manual (TRM) was developed to measure the resource savings from standard energy efficiency measures. The savings' algorithms use measured and customer data as input values in industry-accepted algorithms. The data and input values for the algorithms come from Alternative Energy Portfolio Standards (AEPS) application forms<sup>1</sup>, EDC program application forms, industry accepted standard values (e.g. ENERGY STAR standards), or data gathered by Electric Distribution Companies (EDCs). The standard input values are based on the best available measured or industry data.

Some electric input values were derived from a review of literature from various industry organizations, equipment manufacturers, and suppliers. These input values are updated to reflect changes in code, federal standards and recent program evaluations.

## 1.1 Purpose

The TRM was developed for the purpose of estimating annual electric energy savings and coincident peak demand savings for a selection of energy efficient technologies and measures. The TRM provides guidance to the Administrator responsible for awarding Alternative Energy Credits (AECs). The revised TRM serves a dual purpose of being used to determine compliance with the AEPS Act, 73 P.S. §§ 1648.1-1648.8, and the energy efficiency and conservation requirements of Act 129 of 2008, 66 Pa.C.S. § 2806.1. The TRM will continue to be updated on an annual basis to reflect the addition of technologies and measures as needed to remain relevant and useful.

Resource savings to be measured include electric energy (kWh) and electric capacity (kW) savings. The algorithms in this document focus on the determination of the per unit savings for the energy efficiency ~~and demand response~~ measures. The algorithms and methodologies set forth in this document must be used to determine EDC reported gross savings and evaluation measurement and verification (EM&V) verified savings, ~~unless an alternative measurement approach or custom measure protocols is submitted and approved for use.~~

For an Act 129 program, EDCs may, as an alternative to using the energy and demand savings values for standard measures contained in the TRM, use alternative methods to calculate *ex ante* savings and/or ask their evaluation contractor to use a custom method to verify *ex post* savings. The EDCs, however, must track savings estimated from the TRM protocols and alternative methods and report both sets of values in the quarterly and/or annual EDC reports. The EDCs must justify the deviation from the TRM *ex ante* and *ex post* protocols in the quarterly and/or annual reports in which they report the deviations. EDCs should be aware that use of a custom method as an alternative to the approved TRM protocol increases the risk that the PA PUC may challenge their reported savings. The alternative measurement methods are subject to review and approval by the Commission to ensure their accuracy after the reports are filed to the Commission.

<sup>1</sup> Note: Information in the TRM specifically relating to the AEPS Act is shaded in gray.

## **1.2 Using the TRM**

This section provides a consistent framework for EDC Implementation Conservation Service Providers (ICSPs) to estimate *ex ante* (claimed) savings and for EDC evaluation contractors to estimate *ex post* (verified) savings for Act 129 Energy Efficiency & Conservation (EE&C) programs.

### **1.2.1 Measure Categories**

The TRM categorizes all prescriptive measures into two categories: deemed measures and partially deemed measures. Methods used to estimate *ex ante* and/or *ex post* savings differ for deemed measures and partially deemed measures.

- **Deemed measure protocols** have specified “deemed energy and demand savings values”<sup>2</sup>; no additional measurement or calculation is required to determine deemed savings. These protocols also may contain an algorithm with “stipulated variables”<sup>3</sup> to provide transparency into deemed savings values and to facilitate the updating of deemed savings values in future TRMs. Stipulated variables should not be adjusted using customer-specific or program-specific information for calculating *ex ante* and/or *ex post* savings.
- **Partially deemed measure protocols** have algorithms with stipulated<sup>4</sup> and “open variables”<sup>5</sup>, that require measurement of certain parameters to calculate the energy and demand savings. Customer-specific or program-specific information is used for each open variable, resulting in multiple savings values for the same measure. Some open variables may have a default value to use when the open variable cannot be collected. Only variables specifically identified as open variables may be adjusted using customer-specific or program-specific information.

Note that **Custom measures**<sup>6</sup> are considered too complex or unique to be included in the list of standard measures provided in the TRM and so are outside the scope of this TRM. Custom measures are determined through a custom-measure-specific process, which is described in Section 1.16 in this TRM.

### **1.2.2 Customer and Program Specific Data**

The EDCs and their contractors (ICSPs and ECs) are encouraged to collect and apply customer-specific or program-specific data in the *ex ante* and/or *ex post* savings calculations for as many open variables as possible to reflect most accurate savings values. Site-specific data or

2 A stipulated value for a variable refers to a single input value to an algorithm, while a deemed savings estimate is the result of calculating the end result of all of the stipulated values in the savings algorithm.

3 A stipulated value for a variable refers to a single input value to an algorithm.

4 Ibid

5 Open variables are listed with a “default value” and an option for “EDC Data Gathering” in the TRM. When a measure indicates that an input to a prescriptive saving algorithm may take on a range of values, an average value is also provided in many cases. This value is considered the default input to the algorithm, and should be used when customer-specific information is not available.

6 This TRM does not provide calculations or algorithms for custom measures since the category covers a wide range of equipment, approaches, and measures. Where custom measures are discussed, the TRM requires site specific equipment, operating schedules, baseline and installed efficiencies, and calculation methodologies to estimate energy and demand savings.

information should be used for measures with important variations in one or more input values (e.g. delta watts, efficiency level, equipment capacity, operating hours). Customer-specific data comes directly from the measure application form or application process and/or EDC data gathering, such as, facility staff interviews, posted schedules, building monitoring systems (BMS), panel data, or metered data. In addition, standard input values for stipulated variables and default values for some open variables provided in this TRM are to be based on evaluations completed in Pennsylvania or best available measured or industry data, available from other jurisdictions or industry associations. The EDCs may use default values for open variables in the TRM if customer-specific or program-specific information is unreliable or the EDCs cannot obtain the information.

Values for exact variables that should be determined using customer-specific information are clearly described in the measure protocols in this TRM. This methodology will provide the EDCs with more flexibility to use customer-specific data, when available obtained from their application process and evaluations to improve the accuracy and reliability of savings.

### **1.2.3 End-use Categories & Thresholds for Using Default Values**

The determination of when to use default values for open variables provided in the TRM in the *ex ante* and/or *ex post* savings calculations is a function of the savings impact and uncertainty associated with the measure. The default values are appropriate for low-impact and low-uncertainty measures such as lighting retrofits in a small business facility. In contrast, customer-specific values are appropriate for high-impact and high-uncertainty measures, such as HVAC or lighting retrofits in universities or hospitals that have diverse facilities, and where those types of projects represent a significant share of program savings for a year.

The TRM puts all measures<sup>7</sup> into various end-use categories<sup>8</sup> (e.g. lighting, HVAC, motors & VFDs). The kWh savings thresholds are established at the end-use category level used to determine whether customer-specific information is necessary for estimating *ex ante* and/or *ex post* savings. If a project involves multiple measures/technology types that fall under the same end-use category, the savings for all those measures/technology types should be grouped together to determine if the project falls below or above a particular threshold<sup>9</sup>. **Table 1-1** lists all the end-use categories and the sections for measures within a particular end-use category.

Table 1-1: End-Use Categories and Measures in the TRM<sup>10</sup>

<b><u>End-Use Categories</u></b>	<b><u>List of Measures (Sections)</u></b>
<b><u>Residential Market Sector</u></b>	
<u>Lighting</u>	<u>2.4, 2.7, 2.29, 2.35, 2.36, 2.37</u>
<u>HVAC</u>	<u>2.1, 2.5, 2.10, 2.11, 2.15, 2.16, 2.19, 2.22, 2.28</u>
<u>Hot Water</u>	<u>2.3, 2.8, 2.9, 2.13, 2.14, 2.17, 2.18, 2.42</u>
<u>Appliances</u>	<u>2.2, 2.21, 2.23, 2.24, 2.25, 2.26, 2.27, 2.33,</u>

<sup>7</sup> A measure is defined as an efficient technology or procedure that results in energy savings as compared to the baseline efficiency.

<sup>8</sup> An end-use category describes the categories of equipment that provide a service to an individual or building.

<sup>9</sup> For example, linear fluorescent lighting, CFL lighting and LED lighting are individual measures within the Lighting end-use category.

<sup>10</sup> Please note that this is not an exhaustive list of end-uses and that others may be included in future TRM updates.

	<a href="#">2.43</a>
<a href="#">Building Shell</a>	<a href="#">2.2, 2.22, 2.30, 2.41</a>
<a href="#">Office Equipment</a>	<a href="#">2.12, 2.34</a>
<a href="#">Agricultural Equipment</a>	<a href="#">4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8</a>
<a href="#">Miscellaneous</a>	<a href="#">2.31, 2.32, 2.39, 2.40</a>
<b><a href="#">Commercial &amp; Industrial Market Sector</a></b>	
<a href="#">Lighting</a>	<a href="#">3.2, 3.30</a>
<a href="#">HVAC</a>	<a href="#">3.6, 3.7, 3.18, 3.19, 3.33, 3.35, 3.40</a>
<a href="#">Motors &amp; VFDs</a>	<a href="#">3.3, 3.4, 3.5</a>
<a href="#">Hot Water</a>	<a href="#">3.28, 3.29, 3.31, 3.32, 3.38, 3.39</a>
<a href="#">Refrigeration</a>	<a href="#">3.8, 3.9, 3.10, 3.11, 3.17, 3.21, 3.23, 3.24, 3.25, 3.26, 3.34, 3.36, 3.37</a>
<a href="#">Appliances</a>	<a href="#">3.27</a>
<a href="#">Food Service Equipment</a>	<a href="#">3.14, 3.15, 3.20</a>
<a href="#">Building Shell</a>	<a href="#">3.16</a>
<a href="#">Office Equipment</a>	<a href="#">3.12, 3.13, 3.22</a>
<a href="#">Agricultural Equipment</a>	<a href="#">4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8</a>

[Table 1-2](#) shows the kWh thresholds<sup>11</sup> for various end-use categories. For projects with savings of established kWh thresholds or higher, the EDCs are required to collect site-specific information for open variables used in the calculation of energy and demand savings. If savings for individual end-use categories within projects fall below the threshold, the EDCs may gather customer-specific data, or may use the default stipulated value for each open variable. The thresholds below are subject to review and adjustment by the EDC ECs in coordination with SWE to minimize the uncertainty of estimates. End-use metering is the preferred method of data collection for projects above the threshold, but trend data from BMS or panel data are acceptable substitutes. The EDCs are encouraged to meter projects with savings below the thresholds that have high uncertainty but are not required i.e. where data is unknown, variable, or difficult to verify. Exact conditions of “high uncertainty” are to be determined by the EDCs to appropriately manage variance. Metering completed by the ICSP may be leveraged by the evaluation contractor, subject to a reasonableness review<sup>12</sup>. This approach is intended to determine values for key variables and verify savings at a high level of rigor for projects that account for majority of the programs expected savings.

<sup>11</sup> These end-use specific thresholds were developed by the SWE based on review of methods used by other jurisdictions. In addition, the SWE also performed a sensitivity analyses using different thresholds based on all the energy efficiency projects (partially deemed/non-custom) implemented in Phase I (PY1 through PY4) of Act 129 Programs among all the EDCs.

<sup>12</sup> EDC evaluation contractors must verify the project-specific M&V data (including pre and post metering results) obtained by the CSPs, as practicable, for projects in the evaluation sample. If the evaluation contractor determines that data collected by the CSPs are not reasonably valid, then the evaluator must perform measurements consistent with IPMVP options to collect post-retrofit information for projects that have estimated savings above a threshold kWh/year level. The SWE reserves the right to audit and review claimed and verified impacts of any project selected in the evaluation sample.



Table 1-2: kWh Savings Thresholds

<u>End-Use Category</u>	<u>Expected kWh Savings Threshold<sup>13</sup></u>
C&I Lighting	>= 500,000 kWh
C&I HVAC	>= 250,000 kWh
C&I Motors & VFDs	>= 250,000 kWh
C&I Building Shell	>= 250,000 kWh

#### **1.2.4 Applicability of the TRM for estimating Ex Ante (Claimed) savings**

For replacements and retrofits, the applicable date for determining which TRM version to use to estimate EDC claimed savings is the “in-service date” (ISD) or “commercial date of operation” (CDO) – the date at which the measure is “installed and commercially operable,”<sup>14</sup> and when savings actually start to occur. This is analogous to when a commercial customer’s meter “sees” the savings under expected and designed-for operation. For most projects, this is obvious. For projects with commissioning, the CDO occurs after the commissioning is completed. For incented measures that have been installed, but are not being used because there is no occupant, or will not be used until another, unrelated installation/project is completed; the equipment is not “commercially operable.” For these projects, the CDO is the date at which the customer begins using the incented equipment, not the date at which the equipment is energized. For new construction, the appropriate TRM must be based on the date when the building/construction permit was issued (or the date construction starts if no permit is required) because that aligns with codes and standards that define the baseline. Savings begin to accrue at the project’s ISD.

#### **1.21.3 Definitions**

The TRM is designed for use with both the AEPS Act and Act 129; however, it contains words and terms that apply only to the AEPS or only to Act 129. The following definitions are provided to identify words and terms that are specific for implementation of the AEPS:

- Administrator/Program Administrator (PA) – The Credit Administrator of the AEPS program that receives and processes, and approves AEPS Credit applications.
- AEPS application forms – application forms submitted to qualify and register alternative energy facilities for alternative energy credits.
- Application worksheets – part of the AEPS application forms.
- Alternative Energy Credits (AECs) – A tradable instrument used to establish, verify, and measure compliance with the AEPS. One credit is earned for each 1000kWh of electricity generated (or saved from energy efficiency or conservation measures) at a qualified alternative energy facility.

13 In situations where an ICSP meters a project because the expected kWh savings are above the established threshold and then realizes that the actual savings are below the threshold, metered results should be used for reporting claimed and verified savings.

14 Pennsylvania Public Utility Commission Act 129 Phase II Order, Docket Number: M-2012-2289411 and M-2008-2069887, Adopted August 2, 2012, language in Section K.1.b.

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- EDC Estimated Savings – EDC estimated savings for projects and programs of projects which are enrolled in a program, but not yet completed and/or measured and verified (M&Ved). The savings estimates may or may not follow a TRM or CMP method. The savings calculations/estimates may or may not follow algorithms prescribed by the TRM or Custom Measure Protocols (CMP) and are based on non-verified, estimated or stipulated values.
- EDC Reported Gross Savings – Also known as “EDC Claimed Savings”. EDC estimated savings for projects and programs of projects which are completed and/or M&Ved. The estimates follow a TRM or CMP method. The savings calculations/estimates follow algorithms prescribed by the TRM or CMP and are based non-verified, estimated, stipulated, EDC gathered or measured values of key variables.
- Natural Equipment ReplacementRetrofit on Burnout (ROB) Measure – The replacement of equipment that has failed or is at the end of its service life with a model that is more efficient than required by the codes and standards in effect at the time of replacement, or is more efficient than standard practice if there are no applicable codes or standards. The baseline used for calculating energy savings for natural equipment replacementretrofit on burnout measures is the applicable code, standard or standard practice. The incremental cost for natural equipment replacementretrofit on burnout measures is the difference between the cost of baseline and more efficient equipment. Examples of projects which fit in this category include replacement due to existing equipment failure, as well as replacement of equipment which may still be in functional condition, but which is operationally obsolete due to industry advances and is no longer cost effective to keep.
- New Construction Measure – The substitution of efficient equipment for standard baseline equipment which the customer does not yet own. The baseline used for calculating energy savings is the construction of a new building or installation of new equipment that complies with applicable code, standard and standard practice in place at the time of construction/installation. The incremental cost for a new construction measure is the difference between the cost of the baseline and more efficient equipment. Examples of projects which fit in this category include installation of a new production line, construction of a new building, or an addition to an existing facility.
- Realization Rate – The ratio of “Verified Savings” to “EDC Reported Gross Savings”.
- Retrofit Measure (Early Replacement Measure) – The replacement of existing equipment, which is functioning as intended and is not operationally obsolete, with a more efficient model primarily for purposes of increased efficiency. Retrofit measures have a dual baseline: for the estimated remaining useful life of the existing equipment the baseline is the existing equipment; afterwards the baseline is the applicable code, standard and standard practice expected to be in place at the time the unit would have been naturally replaced. If there are no known or expected changes to the baseline standards, the standard in effect at the time of retrofit is to be used. The incremental cost is the full cost of equipment replacement. In practice in order to avoid the uncertainty surrounding the determination of “remaining useful life” early replacement measure savings and costs sometimes follow natural equipment replacement baseline and incremental cost definitions. Examples of projects which fit in this category include upgrade of an existing production line to gain efficiency, upgrade of an existing, but functional lighting or HVAC system that is not part of a renovation/remodeling project, replacement of an operational chiller, or installation of a supplemental measure such as adding a Variable Frequency Drive (VFD) to an existing constant speed motor.

- **Substantial Renovation Measure** – The substitution of efficient equipment for standard baseline equipment during the course of a major renovation project which removes existing, but operationally functional equipment. The baseline used for calculating energy savings is the installation of new equipment that complies with applicable code, standard and standard practice in place at the time of the substantial renovation. The incremental cost for a substantial renovation measure is the difference between the cost of the baseline and more efficient equipment. Examples include renovation of a plant which replaces an existing production line with a production line for a different product, substantial renovation of an existing building interior, replacement of an existing standard HVAC system with a ground source heat pump system.
- **Verified Savings** – Evaluator estimated savings for projects and programs of projects which are completed and for which the impact evaluation and EM&V activities are completed. The estimates follow a TRM or CMP method. The savings calculations/estimates follow algorithms prescribed by the TRM or CMP and are based on verified values of stipulated variables, EDC or evaluator gathered data, or measured key variables.

~~For the Act 129 program, EDCs may, as an alternative to using the energy savings' values for standard measures contained in the TRM, submit a custom measure protocol with alternative measurement methods to support different energy savings' values. The alternative measurement methods are subject to review and approval by the Commission to ensure their accuracy.~~

#### 1.31.4 General Framework

In general, energy and demand savings will be estimated using TRM stipulated values, measured values, customer data and information from the AEPS application forms, worksheets and field tools.

Three systems will work together to ensure accurate data on a given measure:

The application form that the customer or customer's agent submits with basic information.

Application worksheets and field tools with more detailed, site-specific data, input values and calculations.

Algorithms that rely on standard or site-specific input values based on measured data. Parts or all of the algorithms may ultimately be implemented within the tracking system, application forms and worksheets and field tools.

#### 1.41.5 Algorithms

The algorithms that have been developed to calculate the energy and or demand savings are typically driven by a change in efficiency level between the energy efficient measure and the baseline level of efficiency. The following are the basic algorithms.

$$\Delta kW = kW_{base} - kW_{ee}$$

$$\Delta kW_{peak} = \Delta kW \times CF$$

$$\Delta kWh = \Delta kW \times EFLH$$

Where:

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$\Delta kW$	= Demand Savings
$\Delta kW_{peak}$	= Coincident Peak Demand Savings
$\Delta kWh$	= Annual Energy Savings
$kW_{base}$	= Connected load kW of baseline case.
$kW_{ee}$	= Connected load kW of energy efficient case.
EFLH	= Equivalent Full Load Hours of operation for the installed measure.
CF	= Demand Coincidence Factor, defined as the fraction of the total technology demand that is coincident with the utility system summer peak, as defined by Act 129.

Other resource savings will be calculated as appropriate.

Specific algorithms for each of the measures may incorporate additional factors to reflect specific conditions associated with a measure. This may include factors to account for coincidence of multiple installations or interaction between different measures.

#### 4.51.6 Data and Input Values

The input values and algorithms are based on the best available and applicable data. The input values for the algorithms come from the [AEPS application forms](#), EDC data gathering, or from standard values based on measured or industry data.

Many input values, including site-specific data, come directly from the [AEPS application forms](#), EDC data gathering, worksheets and field tools. Site-specific data on the [AEPS application forms](#) and EDC data gathering are used for measures with important variations in one or more input values (e.g., delta watts, efficiency level, capacity, etc.).

Standard input values are based on the best available measured or industry data, including metered data, measured data from other state evaluations (applied prospectively), field data, and standards from industry associations. The standard values for most commercial and industrial measures are supported by end-use metering for key parameters for a sample of facilities and circuits.

For the standard input assumptions for which metered or measured data were not available, the input values (e.g., delta watts, delta efficiency, equipment capacity, operating hours, coincidence factors) were assumed based on best available industry data or standards. These input values were based on a review of literature from various industry organizations, equipment manufacturers and suppliers.

#### 4.61.7 Baseline Estimates

[The savings methods and assumptions can differ substantially based on the program delivery mechanism for each measure type. Within each of the measure protocols in the TRM, there is a](#)

definition for the measure's baseline efficiency, a critical input into the savings calculations. For most measures there will be at least two baselines that are most commonly used:

- One for market-driven choices -- often called "lost opportunity" and either replacing equipment that has failed (retrofit on burnout) or new installations (new construction)
- One for discretionary installations -- often called early replacement

For all new construction and replacement of non-working equipment, the (NC) and retrofit on burnout (ROB) scenarios, the baseline may be a jurisdictional code, a national standard, or the prevailing level of efficiency in the marketplace. The  $\Delta kW$  and  $\Delta kWh$  values savings calculations are based on standard efficiency equipment versus new high-efficiency equipment. For all early replacement measures (EREP) scenarios, the  $\Delta kW$  and  $\Delta kWh$  values are based on baseline may be the existing equipment versus new high-efficiency equipment efficiency, but at some point the  $\Delta kW$  and  $\Delta kWh$  savings calculations must incorporate changes to the baseline for new installations, e.g. code or market changes. This approach encourages residential and business consumers to replace working inefficient equipment and appliances with new high-efficiency products rather than taking no action to upgrade or only replacing them with new standard-efficiency products. The baseline estimates used in the TRM are documented in baseline studies or other market information. Baselines will be updated to reflect changing codes, practices and market transformation effects, and will be handled in future versions of the TRM by describing the choice of and reasoning behind a shifting baseline assumption.

#### **4.71.8 Resource Savings in Current and Future Program Years**

AECS and energy efficiency and demand response reduction savings will apply in equal annual amounts corresponding to either PJM planning years or calendar years beginning with the year deemed appropriate by the Administrator, and lasting for the approved life of the measure for AEPS Credits. Energy efficiency and demand response savings associated with Act 129 can claim savings for up to fifteen years. For Act 129 requirements, annual savings may be claimed starting in the month of the in-service date for the measure.

#### **4.81.9 Prospective Application of the TRM**

The TRM will be applied prospectively. The input values are from the AEPS application forms, EDC program application forms, EDC data gathering and standard input values (based on measured data including metered data and evaluation results). The TRM will be updated annually based on new information and available data and then applied prospectively for future program years. Updates will not alter the number of AEPS Credits, once awarded, by the Administrator, nor will it alter any energy savings or demand reductions already in service and within measure life. Any newly approved measure, whether in the TRM or approved as an interim protocol, may be applied retrospectively consistent with the EDC's approved plan. If any errors are discovered in the TRM or clarifications are required, those corrections or clarifications should be applied to the associated measure calculations for the current program year, if applicable.

#### **4.91.10 Electric Resource Savings**

Algorithms have been developed to determine the annual electric energy and electric coincident peak demand savings.

Annual electric energy savings are calculated and then allocated separately by season (summer and winter) and time of day (on-peak and off-peak). Summer coincident peak demand savings are calculated using a demand savings algorithm for each measure that includes a coincidence factor. ~~Application of this coincidence factor converts the demand savings of the measure, which may not occur at time of system peak window, to demand savings that is expected to occur during the top 100 hours. This coincidence factor applies to the top 100 hours as defined in the Implementation Order as long as the EE&C measure class is operable during the summer peak hours.~~

Table 1-~~313~~: Periods for Energy Savings and Coincident Peak Demand Savings

Period	Energy Savings	Coincident Peak Demand Savings
Summer	May through September	June through <del>September</del> August (excluding weekends and holidays)
Winter	October through April	N/A
Peak	8:00 a.m. to 8:00 p.m. Mon.-Fri.	<del>122:00</del> p.m. to <del>86:00</del> p.m.
Off-Peak	8:00 p.m. to 8:00 a.m. Mon.-Fri., 12 a.m. to 12 a.m. Sat/Sun & holidays	N/A

The time periods for energy savings and coincident peak demand savings were chosen to best fit the Act 129 requirement, which reflects the seasonal avoided cost patterns for electric energy and capacity that were used for the energy efficiency program cost effectiveness purposes. For energy, the summer period May through September was selected based on the pattern of avoided costs for energy at the PJM level. In order to keep the complexity of the process for calculating energy savings' benefits to a reasonable level by using two time periods, the knee periods for spring and fall were split approximately evenly between the summer and winter periods.

~~For capacity, the summer period June through September was selected to match the period of time required to measure the 100 highest hours of demand. This period also correlates with the highest avoided costs' time period for capacity. The experience in PJM has been that nearly all of the 100 highest hours of an EDC's peak demand occur during these four months. Coincidence factors are used to determine the impact of energy efficiency measures on peak demand. For capacity, the definition of summer peak is adopted from PJM which is applied statewide in this TRM. Only the summer peak period is defined for the purpose of this TRM. The coincident summer peak period is defined as the period between the hour ending 15:00 Eastern Prevailing Time (EPT) and the hour ending 18:00 EPT during all days from June 1 through August 31, inclusive, that is not a weekend or federal holiday<sup>15</sup>.~~

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#### 4.401.11 Post-Implementation Review

The Administrator will review AEPS application forms and tracking systems for all measures and conduct field inspections on a sample of installations. For some programs and projects (e.g.,

<sup>15</sup> PJM Manual 18B for Energy Efficiency Measurement & Verification

custom, large process, large and complex comprehensive design), post-installation review and on-site verification of a sample of AEPS application forms and installations will be used to ensure the reliability of site-specific savings' estimates.

#### **4.41.12 Adjustments to Energy and Resource Savings**

##### **4.41.12.1 Coincidence with Electric System Peak**

Coincidence factors are used to reflect the portion of the connected load savings or generation that is coincident with the top 100 hours system peak period.

##### **4.41.12.2 Measure Retention and Persistence of Savings**

The combined effect of measure retention and persistence is the ability of installed measures to maintain the initial level of energy savings or generation over the measure life. ~~Measure retention and persistence effects were accounted for in the metered data that were based on C&I installations over an eight year period. As a result, some algorithms incorporate retention and persistence effects in the other input values. For other measures, if~~ the measure is subject to a reduction in savings or generation over time, the reduction in retention or persistence is accounted for using factors in the calculation of resource savings (e.g., in-service rates for residential lighting measures).

It is important to note that the Commission's Phase II Implementation Order, dated August 2, 2012, provides clarification on the accumulation and reporting of savings from Act 129 programs in Phase II. This order states on page 26 that "Savings reduction targets can be considered cumulative in two different ways - at the end of a phase and among phases. The Act 129 programs are cumulative at the end of a phase such that the savings at the end of a phase must show that the total savings from measures installed during the phase are equal to or greater than the established reduction target. Therefore, if any measures are installed whose useful life expires before the end of the phase, another measure must be installed or implemented during that phase which replenishes the savings from the expired measure." This means that reported savings for Phase II must take into account the useful life of measures. For example, savings for a measure with a useful life of two years installed in the first program year of Phase II cannot be counted towards the established reduction target unless another measure is installed or implemented to replenish the savings from the expired measures.

It is also important to note that the 2008 Pennsylvania Act 129 legislation states that the Total Resource Cost test shall be used to determine program cost effectiveness, and defines the TRC test as "A STANDARD TEST THAT IS MET IF, OVER THE EFFECTIVE LIFE OF EACH PLAN NOT TO EXCEED 15 YEARS, THE NET PRESENT VALUE OF THE AVOIDED MONETARY COST OF SUPPLYING ELECTRICITY IS GREATER THAN THE NET PRESENT VALUE OF THE MONETARY COST OF ENERGY EFFICIENCY CONSERVATION MEASURES." Thus when TRC ratios are calculated for Act 129 programs, the life for any measure cannot be longer than 15 years.

##### **4.41.31.12.3 Interactive Measure Energy Savings**

Interaction of energy savings is accounted for specific measures as appropriate. For all other measures, interaction of energy savings is zero.

For Residential New Construction, the interaction of energy savings is accounted for in the home energy rating tool that compares the efficient building to the baseline or reference building and calculates savings.

For Commercial and Industrial (C&I) lighting, the energy savings is increased by an amount specified in the algorithm to account for HVAC interaction: depending on the presence of air conditioning.

For C&I custom measures, interaction is accounted for in the site-specific analysis where relevant.

#### **4.11.41.12.4 Verified Gross Adjustments**

Evaluation activities at a basic level consist of verification of the installation and operation of measures. In many cases, the number of widgets found on-site may differ from the number stated on the application, which represents the number of widgets paid for by the program. When the number of widgets found on-site is less than what is stated on the application, the savings will be adjusted by a realization rate. For example, if an application states 100 widgets but an on-site inspection only finds 85, the realization rate applied is 85% (assuming no other discrepancies). On-site widget counts within 5% of the application numbers can be considered to be within reasonable error without requiring realization rate adjustment.

On the other hand, if the number of widgets found on-site is more than what is stated on the application, the savings will be capped at the application findings. For example, if an application states 100 widgets but an on-site inspection finds 120, the realization rate applied is 100% (assuming no other discrepancies).

#### **4.121.13 Calculation of the Value of Resource Savings**

The calculation of the value of the resources saved is not part of the TRM. The TRM is limited to the determination of the per unit resource savings in physical terms at the customer meter.

In order to calculate the value of the energy savings for reporting cost-benefit analyses and other purposes, the energy savings are determined at the customer level and then increased by the amount of the transmission and distribution losses to reflect the energy savings at the system level. The energy savings at the system level are then multiplied by the appropriate avoided costs to calculate the value of the benefits.

*System Savings* = *(Savings at Customer) X (T&D Loss Factor)*

*Value of Resource Savings* = *(System Savings) X (System Avoided Costs) + (Value of Other Resource Savings)*

~~The value of the benefits for a particular measure will also include other resource savings where appropriate. Maintenance savings will be estimated in annual dollars levelized over the life of the measure. The details of this methodology are subject to change by the 2011 TRC Order.~~



Please refer to the 2013 TRC Order<sup>16</sup> for a more detailed discussion of other resource savings.

### 4.431.14 Transmission and Distribution System Losses

The TRM calculates the energy savings at the customer meter level. The electric energy consumption reduction compliance targets for Phase II of Act 129 are established at the retail level i.e. based on forecasts of sales. The energy savings must be reported to the Commission at the customer meter level, which is used to determine if EDCs have met their statutory targets for Phase II. For the purpose of calculating cost-effectiveness of Act 129 programs, the value of both energy and demand savings shall be calculated at the system level. The TRM calculates the energy savings at the customer meter level. These savings need to be increased by the amount of transmission and distribution system losses in order to determine the energy savings at the system level, which is required for value of resource calculations. The electric line loss factor factors multiplied by the savings calculated from the algorithms will result in savings at the system level.

The EDC specific electric loss factor line loss factors filed in its Commission approved EE&C Plans, or other official reports filed with the Commission should be applied to gross up energy savings at from the customer meter is 1.11 for both energy and demand<sup>17</sup>. The electric level to the system level. The EDCs are allowed to use alternate loss factor was developed to be applicable to statewide programs. Therefore, average factors calculated to reflect system losses at the margin based on PJM data were utilized. This reflects a mix of different losses that occur related to delivery at different voltage levels. peaking conditions when available to gross up demand savings to the system level. The 1.11 factor used Commissions encourages the use of the most recent and accurate values for line loss factors for both energy and capacity is a weighted average loss factor. These electric loss factors reflect losses at the margin demand known to the EDCs, regardless of what was filed in the original Phase II EE&C Plans.

### 4.441.15 Measure Lives

Measure lives are provided in Appendix A for informational purposes and for use in other applications such as reporting lifetime savings or in benefit cost studies that span more than one year. For the purpose of calculating the Total Resource Cost (TRC) Test for Act 129, measures cannot claim savings for more than 15 years.

In general, avoided cost savings for programs where measures replace units before the end of their useful life are measured from the efficient unit versus the replaced unit for the remaining life of the existing unit, then from the efficient unit versus a new standard unit for the remaining efficient measure's life. Specific guidance will be provided through the 20142013 TRC Order.

### 4.451.16 Custom Measures

Custom measures are considered too complex or unique to be included in the list of standard measures provided in the TRM. Also included are measures that may involve metered data, but

<sup>16</sup> See 2012 PA Total Resource Cost (TRC) Test; 2009 PA Total Resource Cost Test Final Order, at Docket Nos. M-2012-2300653 and M-2009-2108601, (2013 TRC Test Final Order), entered August 30, 2012.  
<sup>17</sup> The 1.11 factor is to be used for the AEPS portfolio and is not binding for the purpose of cost-effectiveness calculations or coincident peak demand savings calculations for Act 129.

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require additional assumptions to arrive at a 'typical' level of savings as opposed to an exact measurement. ~~To quantify savings for custom measures, a custom measure protocol must be followed. While TRM measures are reviewed and approved by the PA PUC through the TRM update process, custom measures do not undergo the same approval process. The EDCs are not required to submit savings protocols for C&I custom measures to the Commission or the SWE for each measure/technology type prior to implementing the custom measure. The Commission recommends that these protocols be established in general conformity to the International Performance Measurement and Verification Protocol (IPMVP)<sup>18</sup> or Federal Energy Management Program<sup>19</sup> M&V Guidelines. All evaluation sampled custom projects require a Site-Specific Measurement and Verification Plan (SSMVP) developed by the EDC evaluator which must be available for SWE review. During Phase I of Act 129, the TWG developed custom measure protocols (CMPs) for calculating the energy and demand savings for several custom measures. CMPs approved during Phase I are considered available for use in Phase II by EDCs<sup>20</sup>.~~ The qualification for and availability of AEPS Credits and energy efficiency and demand response savings are determined on a case-by-case basis. \_

~~In addition, certain mass market programs in the residential sector are a subset of custom measures. These programs offer measures, or groups of measures, which are not included in the TRM. As with the C&I CMPs, during Phase I of Act 129, the TWG developed mass market protocols ("MMPs") for calculating the energy and demand savings associated with residential behavioral modification and low-income weatherization programs. MMPs approved during Phase I are considered available for use in Phase II by the EDCs.~~

An AEPS application must be submitted, containing adequate documentation fully describing the energy efficiency measures installed or proposed and an explanation of how the installed facilities qualify for AECs. The AEPS application must include a proposed evaluation plan by which the Administrator may evaluate the effectiveness of the energy efficiency measures provided by the installed facilities. All assumptions should be identified, explained and supported by documentation, where possible. The applicant may propose incorporating tracking and evaluation measures using existing data streams currently in use provided that they permit the Administrator to evaluate the program using the reported data.

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To the extent possible, the energy efficiency measures identified in the AEPS application should be verified by the meter readings submitted to the Administrator.

For further discussion, please see [Appendix B: Relationship between Program Savings and Evaluation Savings](#)~~Appendix B: Relationship between Program Savings and Evaluation Savings.~~

#### 4.461.17 Impact of Weather

To account for weather differences within Pennsylvania, ~~the~~ Equivalent Full Load Hours (ELFH) for C&I HVAC measures are calculated based on the degree day scaling methodology. ~~The EFLH values reported in the 2012 Connecticut Program Savings Documentation were taken~~adjusted

<sup>18</sup> [http://www.evo-world.org/index.php?option=com\\_content&task=view&id=272&Itemid=279](http://www.evo-world.org/index.php?option=com_content&task=view&id=272&Itemid=279)

<sup>19</sup> [www1.eere.energy.gov/femp/pdfs/mv\\_guidelines.pdf](http://www1.eere.energy.gov/femp/pdfs/mv_guidelines.pdf)

<sup>20</sup> If the CMPs use a top 100 hours approach for calculating peak demand savings, the protocol must be revised to address the new peak demand window definition prior to use.

using full load hours (FLH) from the US Department of Energy's ENERGY STAR Calculator<sup>21</sup> that provides ELFH. Degree day scaling ratios were calculated using heating degree day and cooling degree day values for seven Pennsylvania cities: Allentown, Erie, Harrisburg, Philadelphia, Pittsburgh, Scranton, and Williamsport. -These reference cities provide a representative sample of the various climate and utility regions in Pennsylvania.

In addition, several protocols in this TRM rely on the work and analysis completed in California, where savings values are adjusted for climate. These measures include Refrigeration – Auto Closers (Section 3.23), Refrigeration – Door Gaskets for Walk-in Coolers and Freezers (Section 3.24), and Refrigeration – Suction Pipes Insulation (Section 3.25). There are sixteen California climate zones and seven Pennsylvania cities. Each of the seven reference cities are mapped to a California climate zone as shown in Table 1-4: California CZ Mapping TableTable 1-4 based on comparable number of cooling degree hours and average wet bulb temperatures. Section 3.23, 3.24 and 3.25 will follow this mapping table.

Table 1-4: California CZ Mapping Table

<u>Reference City</u>	<u>California Climate Zone</u>
<u>Allentown</u>	<u>15</u>
<u>Erie</u>	<u>9</u>
<u>Harrisburg</u>	<u>15</u>
<u>Philadelphia</u>	<u>15</u>
<u>Pittsburgh</u>	<u>4</u>
<u>Scranton</u>	<u>4</u>
<u>Williamsport</u>	<u>15</u>

Furthermore, all the Pennsylvania zip codes are mapped to a reference city and as shown in Appendix G: Zip Code MappingAppendix G: Zip Code Mapping. In general, zip codes were mapped to the closest reference city because the majority of the state resides in ASHRAE climate zone 5. However, Philadelphia and a small area southwest of Harrisburg are assigned to ASHRAE climate zone 4. Therefore, any zip code in ASHRAE climate zone 4 were manually assigned to Philadelphia, regardless of distance.

In addition, several protocols rely on the work and analysis completed in California, where savings values are adjusted for climate. There are sixteen California climate zones. Each of the seven reference cities are mapped to a California climate zone as shown in Table 1-2: California CZ Mapping Table based on comparable number of cooling degree days and average dry bulb temperatures. Any weather dependent protocol using California based models will follow this mapping table.

<sup>21</sup> [http://www.energystar.gov/ia/business/bulk\\_purchasing/bpsavings\\_calc/ASHP\\_Sav\\_Calc.xls](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/ASHP_Sav_Calc.xls)

Table 1-2: California-CZ Mapping Table

Reference-City	California-Climate-Zone
Allentown	4
Erie	6
Harrisburg	8
Philadelphia	13
Pittsburgh	4
Scranton	16
Williamsport	4

#### 4.171.18 Measure Applicability Based on Sector

Protocols for the residential sector quantify savings for measures typically found in residential areas under residential meters. Likewise, protocols for the C&I sector quantify savings for measures typically found in C&I areas under C&I meters. However, there is some overlap where measure type, usage and the sector do not match.

Protocols in the residential and C&I sections describe measure savings based on the *application* or *usage characteristics* of the measure rather than how the measure is *metered*. For example, if a measure is found in a residential environment but is metered under a commercial meter, the residential sector protocol is used. On the other hand, if a measure is found in a commercial environment but is metered under a residential meter, the commercial sector protocol is used. This is particularly relevant for residential appliances that frequently appear in small commercial spaces (commercial protocol) and residential appliances that are used in residential settings but are under commercial meters (multi-family residences). In addition, air sealing, duct sealing and ceiling/attic and wall insulation protocols and standards for residential measures should be used to estimate savings for apartment units in two to four units multifamily complexes whereas air sealing and insulation protocols and standards for C&I measures should be applied for Common areas in multifamily complexes with more than four units.

#### 4.181.19 Algorithms for Energy Efficient Measures

The following sections present measure-specific algorithms. Section 2 addresses residential sector measures and Section 3 addresses commercial and industrial sector measures. Section 4 addresses agricultural measures for both residential and commercial and industrial market sectors.

~~Section 4 addresses demand response measures for both residential and commercial and industrial measures.~~

## **2 RESIDENTIAL MEASURES**

The following section of the TRM contains savings protocols for residential measures.

## 2.1 Electric HVAC

The method for determining residential high-efficiency cooling and heating equipment energy impact savings is based on algorithms that determine a central air conditioner or heat pump's cooling/heating energy use and peak demand contribution. Input data is based both on fixed assumptions and data supplied from the high efficiency equipment **AEPS application form** or EDC data gathering.

The algorithms applicable for this program measure the energy savings directly related to the more efficient hardware installation.

Larger commercial air conditioning and heat pump applications are dealt with in Section 3.6.

### 2.1.1 Algorithms

#### Central A/C and Air Source Heat Pump (ASHP) (High Efficiency Equipment Only)

This algorithm is used for the installation of new high efficiency A/C and ASHP equipment.

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{cool} = CAPY_{cool}/1000 \times (1/SEER_b - 1/SEER_e) \times EFLH_{cool}$$

$$\Delta kWh_{heat} \text{ (ASHP Only)} = CAPY_{heat}/1000 \times (1/HSPF_b - 1/HSPF_e) \times EFLH_{heat}$$

$$\Delta kW_{peak} = CAPY_{cool}/1000 \times (1/EER_b - 1/EER_e) \times CF$$

#### Central A/C (Proper Sizing<sup>22</sup>)

$$\Delta kWh = (CAPY_{cool}/(SEER_q \times 1000)) \times EFLH_{cool} \times PSF$$

$$\Delta kW_{peak} = ((CAPY_{cool}/(EER_q \times 1000)) \times CF) \times PSF$$

#### Central A/C and ASHP (Maintenance)

This algorithm is used for measures providing services to maintain, service or tune-up central A/C and ASHP units.

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{cool} = ((CAPY_{cool}/(1000 \times SEER_m)) \times EFLH_{cool}) \times MF_{cool}$$

$$\Delta kWh_{heat} \text{ (ASHP Only)} = ((CAPY_{heat}/(1000 \times HSPF_m)) \times EFLH_{heat}) \times MF_{heat}$$

$$\Delta kW_{peak} = ((CAPY_{cool}/(1000 \times EER_m)) \times CF) \times MF_{cool}$$

#### Central A/C and ASHP (Duct Sealing)

This algorithm is used for measures that improve duct systems by reducing air leakage.

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

<sup>22</sup> Proper sizing requires Manual J calculations, following of ENERGY STAR QI procedures, or similar calculations.

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$$\Delta kWh_{cool} = (CAPY_{cool}/(1000 \times SEER_e)) \times EFLH_{cool} \times DuctSF$$

$$\Delta kWh_{heat} \text{ (ASHP Only)} = (CAPY_{heat}/(1000 \times HSPF_e)) \times EFLH_{heat} \times DuctSF$$

$$\Delta kW_{peak} = ((CAPY_{cool}/(1000 \times EER_e)) \times CF) \times DuctSF$$

#### Ground Source Heat Pumps (GSHP)

This algorithm is used for the installation of new GSHP units. For GSHP systems over 65,000 BTUh, see commercial algorithm stated in Section 3.6.1.

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\underline{COP_{sys}} = COP_g \times GSHPDF$$

$$\underline{EER_{sys}} = EER_g \times GSHPDF$$

$$\Delta kWh_{cool} = CAPY_{cool}/1000 \times (1/SEER_b - (1/(\underline{EER_g} \underline{EER_{sys}} \times GSER))) \times EFLH_{cool}$$

$$\Delta kWh_{heat} = CAPY_{heat}/1000 \times (1/HSPF_b - (1/(\underline{COP_g} \underline{COP_{sys}} \times GSOP))) \times EFLH_{heat}$$

$$\Delta kW = CAPY_{cool}/1000 \times (1/EER_b - (1/(\underline{EER_g} \underline{EER_{sys}} \times GSPK))) \times CF$$

#### GSHP Desuperheater

This algorithm is used for the installation of a desuperheater for a GSHP unit.

$$\underline{\Delta kWh} = \underline{EDSH}$$

$$\underline{\Delta kWh} = \frac{\left\{ EFDSH \times \left( \frac{1}{EF_{Base}} \right) \times \left( HW \times 365 \times 8.3 \frac{lb}{gal} \times (T_{hot} - T_{cold}) \right) \right\}}{3413 \frac{Btu}{kWh}}$$

$$\underline{\Delta kWh} = 576 kWh$$

$$\Delta kW = \underline{PDSHEDSH} \times \underline{Energy\ to\ Demand\ Factor}$$

#### Furnace High Efficiency Fan

This algorithm is used for the installation of new high efficiency furnace fans.

$$\Delta kWh_{heat} = HFS$$

$$\Delta kWh_{cool} = CFS$$

$$\Delta kW_{peak} = PDFS$$

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### 2.1.2 Definition of Terms

$CAPY_{cool}$	= The cooling capacity (output in Btuh) of the central air conditioner or heat pump being installed. This data is obtained from the AEPS Application Form based on the model number or from EDC data gathering.
$CAPY_{heat}$	= The heating capacity (output in Btuh) of the central air conditioner or heat pump being installed. This data is obtained from the AEPS Application Form based on the model number or from EDC data gathering.
$SEER_b$	= Seasonal Energy Efficiency Ratio of the Baseline Unit.
$SEER_e$	= Seasonal Energy Efficiency Ratio of the qualifying unit being installed. This data is obtained from the AEPS Application Form or EDC's data gathering based on the model number.
$SEER_m$	= Seasonal Energy Efficiency Ratio of the Unit receiving maintenance.
$EER_b$	= Energy Efficiency Ratio of the Baseline Unit.
$EER_e$	= Energy Efficiency Ratio of the unit being installed. This data is obtained from the AEPS Application Form or EDC data gathering based on the model number.
$EER_g$	= EER of the ground source heat pump being installed. Note that EERs of GSHPs are measured differently than EERs of air source heat pumps (focusing on entering water temperatures rather than ambient air temperatures). The equivalent SEER of a GSHP can be estimated by multiplying $EER_g$ by 1.02.
$EER_{sys}$	= Ground Source Heat Pump effective system EER.
$GSER$	= Factor used to determine the SEER of a GSHP based on its $EER_g$ .
$EFLH_{cool}$	= Equivalent Full Load Hours of operation during the cooling season for the average unit.
$EFLH_{heat}$	= Equivalent Full Load Hours of operation during the heating season for the average unit.
$PSF$	= Proper Sizing Factor or the assumed saving due to proper sizing and proper installation.
$MF_{cool}$	= Maintenance Factor or assumed savings due to completing recommended maintenance on installed cooling equipment.

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$MF_{heat}$	= Maintenance Factor or assumed savings due to completing recommended maintenance on installed heating equipment.
DuctSF	= Duct Sealing Factor or the assumed savings due to proper sealing of all cooling ducts.
CF	= Demand Coincidence Factor (See Section 1.4)
$HSPF_b$	= Heating Seasonal Performance Factor of the Baseline Unit.
$HSPF_e$	= Heating Seasonal Performance Factor of the unit being installed. This data is obtained from the <u>AEPS Application Form</u> or EDC's data gathering.
$HSPF_m$	= Heating Seasonal Performance Factor of the unit receiving maintenance.
$COP_g$	= Coefficient of Performance. This is a measure of the efficiency of a heat pump.
<u><math>GSHPDF</math></u>	<u>= Ground Source Heat Pump De-rate Factor</u>
<u><math>COP_{sys}</math></u>	<u>= Ground Source Heat Pump effective system COP.</u>
GSOP	= Factor to determine the HSPF of a GSHP based on its $COP_g$ .
GSPK	= Factor to convert $EER_g$ to the equivalent EER of an air conditioner to enable comparisons to the baseline unit.
<u><math>EFDSH</math></u>	<u>= Energy Factor per desuperheater.</u>
<u><math>EF_{base}</math></u>	<u>= Energy Factor of Electric Water Heater</u>
<u>HW</u>	<u>= Daily Hot Water Use</u>
<u><math>T_h</math></u>	<u>= Hot Water Temperature</u>
<u><math>T_c</math></u>	<u>= Cold Water Temperature</u>
$EDSH$	= <u>Assumed Fixed</u> savings per desuperheater. <sup>23</sup>
$PDSH$	= Assumed peak-demand savings per desuperheater.
HSF	= Assumed heating season savings per furnace high efficiency fan
CFS	= Assumed cooling season savings per furnace high efficiency fan

23 GSHP desuperheaters are generally small, auxiliary heat exchangers that uses superheated gases from the GSHP's compressor to heat water. This hot water then circulates through a pipe to the home's storage water heater tank.

*PDFS* = Assumed peak-demand savings per furnace high efficiency fan

*1000* = Conversion from watts to kilowatts.

Table 2-1: Residential Electric HVAC - References

Component	Type	Value	Sources
CAPY <sub>cool</sub> CAPY <sub>heat</sub>	Variable	EDC Data Gathering	AEPS Application; EDC Data Gathering
SEER <sub>b</sub>	Fixed	Replace on Burnout: 13 SEER	1
	Variable	Early Retirement: <a href="#">Default 10 SEER or EDC Data Gathering</a>	13; EDC Data Gathering
SEER <sub>e</sub>	Variable	EDC Data Gathering	AEPS Application; EDC Data Gathering
SEER <sub>m</sub>	<a href="#">FixedVariable</a>	<a href="#">49Default 10 SEER or EDC Data Gathering</a>	<a href="#">4313; EDC Data Gathering</a>
EER <sub>b</sub>	Fixed	Replace on Burnout: 11.3	2
	Variable	Early Retirement: <a href="#">Default 8.69 EER or EDC Data Gathering</a>	14; EDC Data Gathering
EER <sub>e</sub>	Fixed	(11.3/13) X SEER <sub>e</sub>	2
EER <sub>g</sub>	Variable	EDC Data Gathering	AEPS Application; EDC's Data Gathering
<a href="#">EER<sub>sys</sub></a>	<a href="#">Variable</a>	<a href="#">Calculated</a>	<a href="#">Calculated</a>
EER <sub>m</sub>	<a href="#">FixedVariable</a>	<a href="#">8-69Default 8.69 SEER or EDC Data Gathering</a>	<a href="#">1414; EDC Data Gathering</a>
GSER	Fixed	1.02	3
EFLH <sub>cool</sub>	Default	Allentown Cooling = 487 Hours Erie Cooling = 389 Hours Harrisburg Cooling = 551 Hours Philadelphia Cooling = 591 Hours Pittsburgh Cooling = 432 Hours Scranton Cooling = 417 Hours Williamsport Cooling = 422 Hours	4
	Optional	An EDC can <a href="#">either use the Alternate EFLH Table or estimate it's own EFLH based on customer billing data analysis.</a>	<a href="#">Alternate EFLH Table (See Section 02-1.3);</a> EDC Data Gathering
EFLH <sub>heat</sub>	Default	Allentown Heating = 1,193 Hours Erie Heating = 1,349 Hours Harrisburg Heating = 1,103 Hours Philadelphia Heating = 1,060 Hours Pittsburgh Heating = 1,209 Hours	4

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		Scranton Heating = 1,296 Hours Williamsport Heating = 1,251 Hours	
	Optional	An EDC can <a href="#">either use the Alternate EFLH Table or estimate its own EFLH</a> based on customer billing data analysis.	<a href="#">Alternate EFLH Table (See Section 02-1.3);</a> EDC Data Gathering
PSF	Fixed	5%	5
MF <sub>cool</sub>	Fixed	<del>40</del> 5%	15
MF <sub>heat</sub>	Fixed	<del>40</del> 5%	15
<del>DuctSF</del>	<del>Fixed</del>	<del>48</del> %	<del>12</del>
CF	Fixed	70%	6
HSPF <sub>b</sub>	Fixed	Replace on Burnout: 7.7	7
	Variable	Early Retirement: EDC Data Gathering	EDC Data Gathering
HSPF <sub>e</sub>	Variable	EDC Data Gathering	AEPS Application; EDC's Data Gathering
HSPF <sub>m</sub>	Fixed	6.8	13
COP <sub>g</sub>	Variable	EDC Data Gathering	AEPS Application; EDC's Data Gathering
<a href="#">GSHPDR</a>	<a href="#">Fixed</a>	<a href="#">0.885</a>	<a href="#">19</a> <a href="#">(Engineering Estimate - See 2.1.4)</a>
<a href="#">COP<sub>sys</sub></a>	<a href="#">Variable</a>	<a href="#">Calculated</a>	<a href="#">Calculated</a>
GSOP	Fixed	3.413	8
GSPK	Fixed	0.8416	9
<a href="#">EFDSh</a>	<a href="#">Fixed</a>	<a href="#">17</a> %	<a href="#">10_11</a>
EDSH	Fixed	<del>4842576</del> kWh	<del>40</del> <a href="#">Calculated</a>
<a href="#">EF<sub>base</sub></a>	<a href="#">Fixed</a>	<a href="#">0.904</a>	<a href="#">Table 2-4</a>
<a href="#">HW</a>	<a href="#">Fixed</a>	<a href="#">50</a>	<a href="#">Table 2-4</a>
<a href="#">T<sub>hot</sub></a>	<a href="#">Fixed</a>	<a href="#">124</a>	<a href="#">Table 2-4</a>
<a href="#">T<sub>cold</sub></a>	<a href="#">Fixed</a>	<a href="#">55</a>	<a href="#">Table 2-4</a>
<a href="#">Energy To Demand Factor</a>	<a href="#">Fixed</a>	<a href="#">0.00009172</a>	<a href="#">Table 2-4</a>
PDSH	Fixed	<del>0.3405</del> kW	<del>44</del> <a href="#">Calculated</a>
HFS	Fixed	311 kWh	16
CFS	Fixed	135 kWh	17
PDFS	Fixed	0.114 kW	18

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### 2.1.3 Alternate Equivalent Full Load Hour (EFLH) Tables

Table 2-2 and Table 2-3 below show cooling EFLH and heating EFLH, respectively, by city and for each EDC's housing demographics. EFLH values are only shown for cities that are close to customers in each EDC's service territory. In order to determine the most appropriate EFLH value to use for a project, first select the appropriate EDC, then, from that column, pick the closest city to the project location. The value shown in that cell will be the EFLH value to use for the project.

Table 2-2: Alternate Cooling EFLH

	PPL	Penelec	Met Ed	West Penn	Duquesne	Penn Power	PECO
Allentown	431	528	453	N/A	N/A	N/A	523
Erie	N/A	418	N/A	413	N/A	397	N/A
Harrisburg	487	N/A	506	580	N/A	N/A	N/A
Philadelphia	N/A	N/A	536	N/A	N/A	N/A	651
Pittsburgh	N/A	468	N/A	458	417	448	N/A
Scranton	376	454	N/A	N/A	N/A	N/A	N/A
Williamsport	N/A	N/A	N/A	447	N/A	N/A	N/A

Field Code Changed

Table 2-3: Alternate Heating EFLH

	PPL	Penelec	Met Ed	West Penn	Duquesne	Penn Power	PECO
Allentown	1112	1057	1122	N/A	N/A	N/A	1320
Erie	N/A	1204	N/A	1317	N/A	1376	N/A
Harrisburg	1028	N/A	1035	1077	N/A	N/A	N/A
Philadelphia	N/A	N/A	1001	N/A	N/A	N/A	1165
Pittsburgh	N/A	1068	N/A	1175	1274	1234	N/A
Scranton	1203	1151	N/A	N/A	N/A	N/A	N/A
Williamsport	N/A	N/A	N/A	1218	N/A	N/A	N/A

Field Code Changed

### 2.1.4 System Performance of Ground Source Heat Pumps

Ground Source heat pump nameplate AHRI ratings do not include auxiliary pumping energy for ground loop water distribution. Based on McQuay heat pump design guidelines, it is estimated that approximately a 1/3 HP pump would be required to be paired with a 2.5 ton Ground Source Heat Pump (assuming 3 GPM/ton design flow and 200 ft./ton of 1-inch tubing). At 7.5 GPM, a 1/3 HP pump would consume approximately 0.23 kW (7.5 GPM @ 30 ft. head). Assuming a 2 kW load for the heat pump itself, this would amount to a roughly 11.5% increase in system energy. The system COP de-rate factor would then be 0.885.

#### Sources:

1. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
2. Average EER for SEER 13 units.
3. VEIC estimate. Extrapolation of manufacturer data.

4. Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models assume 50% oversizing of air conditioners<sup>24</sup> and 40% oversizing of heat pumps.<sup>25</sup>
5. Northeast Energy Efficiency Partnerships, Inc., “Strategies to Increase Residential HVAC Efficiency in the Northeast”, (February 2006): Appendix C Benefits of HVAC Contractor Training: Field Research Results 03-STAC-01, page 46.
6. Based on an analysis of six different utilities by Proctor Engineering.
7. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
8. Engineering calculation, HSPF/COP=3.413.
9. VEIC Estimate. Extrapolation of manufacturer data.
- ~~10. VEIC estimate, based on PEPSCO assumptions.~~
- ~~11. VEIC estimate, based on PEPSCO assumptions.~~
10. “Residential Ground Source Heat Pumps with Integrated Domestic Hot Water Generation: Performance Results from Long-Term Monitoring”, U.S. Department of Energy, November 2012.
11. Desuperheater Study, New England Electric System, 1998 42 U.S.C.A 6295(i) (West Supp. 2011) and 10 C.F.R. 430.32 (x) (2011).
12. Northeast Energy Efficiency Partnerships, Inc., “Benefits of HVAC Contractor Training”, (February 2006): Appendix C Benefits of HVAC Contractor Training: Field Research Results 03-STAC-01.
13. Minimum Federal Standards for new Central Air Conditioners and Air Source Heat Pumps between 1990 and 2006 based on VEIC estimates.
14. The same EER to SEER ratio used for SEER 13 units applied to SEER 10 units.  $EER_m = (11.3/13) * 10$ .
- ~~15. VEIC estimate. Conservatively assumes less savings than for QIV because of the retrofit context.~~
15. 2013 Illinois Statewide TRM (Central Air Conditioning in Wisconsin, Energy Center of Wisconsin, May 2008)
16. Scott Pigg (Energy Center of Wisconsin), “Electricity Use by New Furnaces: A Wisconsin Field Study”, Technical Report 230-1, October 2003, page 20. The average heating-mode savings of 400 kWh multiplied by the ratio of average heating degree days in PA compared to Madison, WI (5568/7172).
17. Ibid, page 34. The average cooling-mode savings of 88 kWh multiplied by the ratio of average EFLH in PA compared to Madison, WI (749/487).

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24 Neme, Proctor, Nadal, “National Energy Savings Potential From Addressing Residential HVAC Installation Problems. ACEEE, February 1, 1999. Confirmed also by *Central Air Conditioning in Wisconsin, a compilation of recent field research*. Energy Center of Wisconsin. May 2008, emended December 15, 2010

25 ACCA, “Verifying ACCA Manual S Procedures,” <http://www.acca.org/Files/?id=67>.

18. Ibid, page 34. The average kW savings of 0.1625 multiplied by the coincidence factor from Table 2-1.
19. [McQuay Application Guide 31-008, Geothermal Heat Pump Design Manual, 2002.](#)

## 2.2 Electric Clothes Dryer with Moisture Sensor

Measure Name	Electric Clothes Dryer with Moisture Sensor
Target Sector	Residential Establishments
Measure Unit	Clothes Dryer
Unit Energy Savings	136 kWh
Unit Peak Demand Reduction	0.047 kW
Measure Life	<del>4</del> 13 years

Clothes dryers with drum moisture sensors and associated moisture-sensing controls achieve energy savings over clothes dryers that do not have moisture sensors.

### 2.2.1 Eligibility

This measure requires the purchase of an electric clothes dryer with a drum moisture sensor and associated moisture-sensing controls. ENERGY STAR currently does not rate or certify electric clothes dryers.

The TRM does not provide energy and demand savings for electric clothes dryers. The following sections detail how this measure's energy and demand savings were determined.

### 2.2.2 Algorithms

#### Energy Savings

The annual energy savings of this measure was determined to be **136 kWh**. This value was based on the difference between the annual estimated consumption of a standard unit without a moisture sensor as compared to a standard unit with a moisture sensor. This calculation is shown below:

$$\Delta kWh = 905 - 769 = 136 kWh$$

The annual consumption of a standard unit without a moisture sensor (905 kWh) was based on 2008 estimates from Natural Resources Canada.<sup>26</sup>

The annual consumption of a standard unit with a moisture sensor (769 kWh) was based on estimates from EPRI<sup>27</sup> and the Consumer Energy Center<sup>28</sup> that units equipped with moisture sensors (and energy efficient motors, EPRI) are about 15% more efficient than units without.

$$\Delta kWh = 905 - (905 * 0.15) = 769 kWh$$

#### Demand Savings

The demand savings of this measure was determined to be 0.346 kW. This value was based on the estimated energy savings divided by the estimated of annual hours of use. The estimated of

<sup>26</sup> Natural Resources Canada Report.pdf

<sup>27</sup> EPRI Electric Clothes Dryer Report.pdf

<sup>28</sup> Natural Living Guide.pdf

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annual hours of use was based on 392<sup>29</sup> loads per year with a 1 hour dry cycle. This calculation is shown below:

$$\Delta kW = 136 / 392 = 0.346 \text{ kW}$$

The demand coincidence factor of this measure was determined to be **0.136**. This value was based on the assumption that 5 of 7 loads are run on peak days, 5 of 7 days the peak can occur on, 1.07 loads per day (7.5 per week, Reference #4), 45 minutes loads, and 3 available daily peak hours. This calculation is shown below:

$$CF = (5/7) * (5/7) * (1.07) * (0.75) * (1/3) = 0.136$$

The resulting demand savings based on this coincidence factor was determined to be **0.047 kW**. This calculation is shown below:

$$\Delta kW_{peak} = 0.346 * 0.136 = 0.047 \text{ kW}$$

The assumptions used to determine this measure's net demand value are listed below:

*On-peak Annual Hours of Operation Assumption =*  
66.2% (May 2009 TRM)

*Summer Annual Hours of Operation Assumption =*  
37.3% (May 2009 TRM)

### 2.2.3 Measure Life

~~We Based on information developed by the National Association of Homebuilders and ENERGY STAR, we have assumed the measure life to be that of an electric clothes washer. The Database for Energy Efficiency Resources estimates the measure life of clothes washers at 14 dryer to be 13 years.<sup>30</sup>~~

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### 2.2.4 Evaluation Protocol

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

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<sup>29</sup> Energy Star Clothes Washer Calculator Assumptions.pdf

<sup>5</sup> NAHB, *Study of Life Expectancy of Home Components*, Feb. 2007, p. 7.

<sup>6</sup> ENERGY STAR Market & Industry Scoping Report – Residential Clothes Dryers, Nov. 2011, p. 4.

<sup>30</sup> DEER EUL values, updated October 10, 2008



## 2.3 Efficient Electric Water Heaters

Measure Name	Efficient Electric Water Heaters
Target Sector	Residential Establishments
Measure Unit	Water Heater
Unit Energy Savings	89 kWh for 0.93 Varies with Energy Factor 122 kWh for 0.94 Energy Factor 155 kWh for 0.95 Energy Factor of New Unit
Unit Peak Demand Reduction	0.0082 kW for 0.93 Varies with Energy Factor 0.0112 kW for 0.94 Energy Factor 0.0142 kW for 0.95 Energy Factor of New Unit
Measure Life	14 years

Efficient electric water heaters utilize superior insulation to achieve energy factors of 0.93 or above. Standard electric water heaters have energy factors of 0.904.

### 2.3.1 Eligibility

This protocol documents the energy savings attributed to electric water heaters with Energy Factor of 0.93 or greater. The target sector primarily consists of single-family residences.

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### 2.3.2 Algorithms

The energy savings calculation utilizes average performance data for available residential efficient and standard water heaters and typical water usage for residential homes. The energy savings are obtained through the following formula:

$$\Delta kWh = \frac{\left\{ \left( \frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}} \right) \times \left( HW \times 365 \times 8.3 \frac{lb}{gal} \times (T_{hot} - T_{cold}) \right) \right\}}{3413 \frac{Btu}{kWh}}$$

Demand savings result from reduced hours of operation of the heating element, rather than a reduced connected load. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = EnergyToDemandFactor \times Energy Savings$$

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average Usage_{Summer WD Noon-8}}{Annual Energy Usage}$$

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The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM<sup>31</sup>. The factor is constructed as follows:

- 1) Obtain the average kW, as monitored for 82 water heaters in PJM territory<sup>32</sup>, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, 183 spring/fall days) to obtain annual energy usage.
- 2) Obtain the average kW during noon to 8 PM on summer days from the same data.
- 3) The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study<sup>33</sup>.
- 4) The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor*.

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted in [Figure 2-1](#) below.

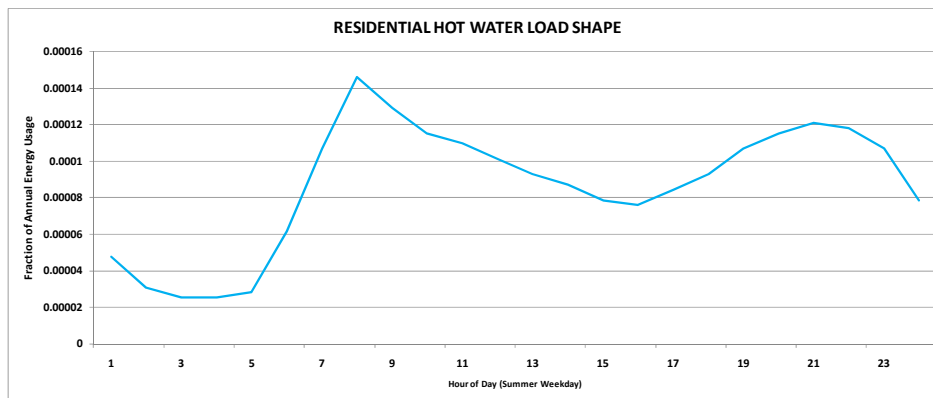


Figure 2-1: Load shapes for hot water in residential buildings taken from a PJM study.

31 Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>

32 The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled "Mean", in tables 14, 15, and 16 in pages 5-31 and 5-32

33 The 5<sup>th</sup> column, labeled "Mean" of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer *weekday* usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher on weekends than on weekdays.

### 2.3.3 Definition of Terms

The parameters in the above equation are listed in [Table 2-4](#) ~~Table 2-24~~ below.

Table 2-~~4~~24: Efficient Electric Water Heater Calculation Assumptions

Component	Type	Values	Source
EF <sub>base</sub> , Energy Factor of baseline water heater	Fixed	<del>See Table 2-5</del> <del>0.904</del>	1
EF <sub>proposed</sub> , Energy Factor of proposed efficient water heater	Variable	<del>&gt;=0.93</del> <u>0.93</u> (default) or EDC Data Gathering	Program Design; EDC Data Gathering
HW, Hot water used per day in gallons	Fixed	50 gallon/day	2
T <sub>hot</sub> , Temperature of hot water	Fixed	<del>120</del> <u>123</u> °F	<del>3</del> <u>3</u>
T <sub>cold</sub> , Temperature of cold water supply	Fixed	55 °F	4
Energy To Demand Factor	Fixed	0.00009172	1-4

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### 2.3.4 Energy Factors based on Tank Size

Federal Standards for Energy Factors are equal to 0.97 -0.00132 x Rated Storage in Gallons. The following table shows the Energy Factors for various tank sizes.

Table 2-5: Energy Factors based on Tank Size

Tank Size (gallons)	Energy Factor
<u>40</u>	<u>0.9172</u>
<u>50</u>	<u>0.9040</u>
<u>65</u>	<u>0.8842</u>
<u>80</u>	<u>0.8644</u>
<u>120</u>	<u>0.8116</u>

#### Sources:

1. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is 0.904. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE-2006-BT-STD-0129, p. 30
2. ~~Residential Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters", Federal Register / Vol. 63, No. 90, pp. 26005-26006.~~
3. ~~Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.~~
4. 2. Consumption Survey, EIA, 2009.2012 SWE Residential Baseline Study Mid-Atlantic TRM, footnote #24

### 2.3.42.3.5 Deemed Savings

The deemed savings Savings for the installation of efficient electric water heaters with various Energy Factors are listed are calculated using the formula below:

Table 2.3: Energy Savings and Demand Reductions

Energy Factor	Energy Savings (kWh)	Demand Reduction (kW)
0.95	154	-0.0142
0.94	122	0.0112
0.93	89	0.0082

$$\Delta kWh = (2,671.58 - \frac{2,449.87}{EF_{Proposed}})$$

$$\Delta kW_{peak} = \Delta kWh \times 0.00009172$$

### 2.3.52.3.6 Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, an electric water heater's lifespan is **14 years**<sup>34</sup>.

### 2.3.62.3.7 Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

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<sup>34</sup> DEER values, updated October 10, 2008  
[http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

## 2.4 Electroluminescent Nightlight

Measure Name	Electroluminescent Nightlight
Target Sector	Residential Establishments
Measure Unit	Nightlight
Unit Energy Savings	26 kWh
Unit Peak Demand Reduction	0 kW
Measure Life	8 years

Savings from installation of plug-in electroluminescent nightlights are based on a straightforward algorithm that calculates the difference between existing and new wattage and the average daily hours of usage for the lighting unit being replaced. An “installation” rate is used to modify the savings based upon the outcome of participant surveys, which will inform the calculation. Demand savings is assumed to be zero for this measure.

### 2.4.1 Algorithms

The general form of the equation for the electroluminescent nightlight energy savings algorithm is:

$$\Delta kWh = ((W_{inc} * h_{inc}) - (W_{NL} * h_{NL})) * 365 / 1000 * ISR_{NL}$$

$$\Delta kW_{peak} = 0 \text{ (assumed)}$$

$$\text{Deemed Energy Savings} = ((7*12) - (0.03*24)) * 365 / 1000 * 0.84 = 25.53 \text{ kWh}$$

(Rounded to 26 kWh)

### 2.4.2 Definition of Terms

$W_{NL}$  = Watts per electroluminescent nightlight

$W_{inc}$  = Watts per incandescent nightlight

$h_{NL}$  = Average hours of use per day per electroluminescent nightlight

$h_{inc}$  = Average hours of use per day per incandescent nightlight

$ISR_{NL}$  = In-service rate per electroluminescent nightlight, to be revised through surveys

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Table 2-646: Electroluminescent Nightlight - References

Component	Type	Value	Sources
W <sub>NL</sub>	VariableFixed	0.03_or EDC Data Gathering	1
W <sub>inc</sub>	Fixed	7	2
h <sub>NL</sub>	Fixed	24	3
h <sub>inc</sub>	Fixed	12	2
ISR <sub>NL</sub>	Variable	0.84See ISR for CFLs	PA CFL ISR value
Measure Life (EUL)	Fixed	8	4

**Sources:**

1. Limelite Equipment Specification. Personal Communication, Ralph Ruffin, EI Products, 512-357-2776/ ralph@limelite.com.
2. Southern California Edison Company, “LED, Electroluminescent & Fluorescent Night Lights”, Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2 & p. 3.
3. As these nightlights are plugged in without a switch, the assumption is they will operate 24 hours per day.
4. Southern California Edison Company, “LED, Electroluminescent & Fluorescent Night Lights”, Work Paper WPSCRELG0029 Rev. 1, February 2009, p. 2 & p. 3.

## 2.5 Furnace Whistle

Measure Name	Furnace Whistle
Target Sector	Residential Establishments
Measure Unit	Furnace whistle (promote regular filter change-out)
Unit Energy Savings	Varies
Unit Peak Demand Reduction	<u>Varies</u> 0 kW
Measure Life	15 years

Savings estimates are based on reduced furnace blower fan motor power requirements for winter and summer use of the blower fan motor. This furnace whistle measure applies to central forced-air furnaces, central AC and heat pump systems. Each table in this protocol (2 through 6) presents the annual kWh savings for each major urban center in Pennsylvania based on their respective estimated full load hours (EFLH). Where homes do not have A/C or heat pump systems for cooling, only the annual heating savings will apply.

### 2.5.1 Algorithms

$$\Delta kWh = \Delta kWh_{heating} + \Delta kWh_{cooling}$$

$$\Delta kWh_{heating} = MkW \times EFLH_{heating} \times EI \times ISR$$

$$\Delta kWh_{cooling} = MkW \times EFLH_{cooling} \times EI \times ISR$$

$$\Delta kW_{peak} = 0 = \Delta kWh_{cooling} / EFLH_{cooling} \times CF$$

### 2.5.2 Definition of Terms

*MkW* = Average motor full load electric demand (kW)

*EFLH* = Estimated Full Load Hours (Heating and Cooling) for the EDC region.

*EI* = Efficiency Improvement

*ISR* = In-service Rate

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Table 2-757: Furnace Whistle - References

Component	Type	Value	Sources
MkW	Fixed	0.5 kW	1, 2
EFLH	Fixed	Variable. See <a href="#">Table 2-8: EFLH for various cities in Pennsylvania (TRM Data)</a> <del>Table 2-6: EFLH for various cities in Pennsylvania (TRM Data)</del> <del>Table 2-8</del>	TRM <a href="#">Table 2-1: Residential Electric HVAC - References</a> <del>Table 2-4: Residential Electric HVAC - References</del> <del>Table 2-1</del>
EI	Fixed	15%	3
ISR	Fixed	0.474	4
CF	<a href="#">Fixed</a>	<a href="#">70%</a>	<a href="#">TRM Table 2-1</a>
Measure EUL	Fixed	15	15

**Sources:**

1. The Sheltair Group HIGH EFFICIENCY FURNACE BLOWER MOTORS MARKET BASELINE ASSESSMENT provided BC Hydro cites Wisconsin Department of Energy [2003] analysis of electricity use from furnaces (see Blower Motor Furnace Study). The Blower Motor Study Table 17 (page 38) shows 505 Watts for PSC motors in space heat mode; last sentence of the second paragraph on page 38 states: ". . . multi-speed and single speed furnaces motors drew between 400 and 800 Watts, with 500 being the average value." Submitted to: Fred Liebich BC Hydro Tel. 604 453-6558 Email: fred.liebich@bchydro.com, March 31, 2004.
2. FSEC, "Furnace Blower Electricity: National and Regional Savings Potential", page 98 - Figure 1 (assumptions provided in Table 2, page 97) for a blower motor applied in prototypical 3-Ton HVAC for both PSC and BPM motors, at external static pressure of 0.8 in. w.g., blower motor Watt requirement is 452 Watts.
3. US DOE Office of Energy Efficiency and Renewable Energy - "Energy Savers" publication - "Clogged air filters will reduce system efficiency by 30% or more." Savings estimates assume the 30% quoted is the worst case and typical households will be at the median or 15% that is assumed to be the efficiency improvement when furnace filters are kept clean.
4. The In Service Rate is taken from an SCE Evaluation of 2000-2001 Schools Programs, by Ridge & Associates 8-31-2001, Table 5-19 Installation rates, Air Filter Alarm 47.4%.



Table 2-868: EFLH for various cities in Pennsylvania (TRM Data)

City	Cooling load hours	Heating load hours	Total load hours
Allentown	487	1,193	1,681
Erie	389	1,349	1,739
Harrisburg	551	1,103	1,654
Philadelphia	591	1,060	1,651
Pittsburgh	432	1,209	1,641
Scranton	417	1,296	1,713
Williamsport	422	1,251	1,673

The following table presents the assumptions and the results of the deemed savings calculations for each EDC.

Table 2-979: Assumptions and Results of Deemed Savings Calculations (Pittsburgh, PA)

	Blower Motor kW	Pittsburgh EFLH	Clean Annual kWh	Dirty Annual kWh	Furnace Whistle Savings	ISR	Estimated Savings (kWh)
Heating	0.5	1,209	604	695	91	0.474	43
Cooling	0.5	432	216	248	32	0.474	15
Total		1,641	820	944	123		58

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$$\Delta kW_{\text{peak}} = 0.024 \text{ kW}$$

Table 2-10810: Assumptions and Results of Deemed Savings Calculations (Philadelphia, PA)

	Blower Motor kW	Philadelphia EFLH	Clean Annual kWh	Dirty Annual kWh	Furnace Whistle Savings	ISR	Estimated Savings (kWh)
Heating	0.5	1,060	530	609	79	0.474	38
Cooling	0.5	591	296	340	44	0.474	21
Total		1,651	826	949	124		59

$$\Delta kW_{\text{peak}} = 0.025 \text{ kW}$$

Table 2-~~11911~~: Assumptions and Results of Deemed Savings Calculations (Harrisburg, PA)

	Blower Motor kW	Harrisburg EFLH	Clean Annual kWh	Dirty Annual kWh	Furnace Whistle Savings	ISR	Estimated Savings (kWh)
Heating	0.5	1,103	552	634	83	0.474	39
Cooling	0.5	551	276	317	41	0.474	20
Total		1,654	827	951	124		59

$$\Delta kW_{\text{peak}} = 0.025 \text{ kW}$$

Table 2-~~121012~~: Assumptions and Results of Deemed Savings Calculations (Erie, PA)

	Blower Motor kW	Erie EFLH	Clean Annual kWh	Dirty Annual kWh	Furnace Whistle Savings	ISR	Estimated Savings (kWh)
Heating	0.5	1,349	675	776	101	0.474	48
Cooling	0.5	389	195	224	29	0.474	14
Total		1,739	869	1,000	130		62

$$\Delta kW_{\text{peak}} = 0.025 \text{ kW}$$

Table 2-~~131113~~: Assumptions and Results of Deemed Savings Calculations (Allentown, PA)

	Blower Motor kW	Allentown EFLH	Clean Annual kWh	Dirty Annual kWh	Furnace Whistle Savings	ISR	Estimated Savings (kWh)
Heating	0.5	1,193	597	686	89	0.474	42
Cooling	0.5	487	244	280	37	0.474	17
Total		1,681	840	966	126		60

$$\Delta kW_{\text{peak}} = 0.024 \text{ kW}$$

Table 2-~~1412~~14: Assumptions and Results of Deemed Savings Calculations (Scranton, PA)

	Blower Motor kW	Scranton EFLH	Clean Annual kWh	Dirty Annual kWh	Furnace Whistle Savings	ISR	Estimated Savings (kWh)
Heating	0.5	1,296	648	745	97	0.474	46
Cooling	0.5	417	208	240	31	0.474	15
Total		1,713	857	985	129		61

$$\Delta kW_{\text{peak}} = 0.025 \text{ kW}$$

Table 2-~~1513~~15: Assumptions and Results of Deemed Savings Calculations (Williamsport, PA)

	Blower Motor kW	Williamsport EFLH	Clean Annual kWh	Dirty Annual kWh	Furnace Whistle Savings	ISR	Estimated Savings (kWh)
Heating	0.5	1,251	625	719	94	0.474	44
Cooling	0.5	422	211	243	32	0.474	15
Total		1,673	836	962	125		59

$\Delta kW_{peak} = 0.025 \text{ kW}$

## 2.6 Heat Pump Water Heaters

Measure Name	Heat Pump Water Heaters
Target Sector	Residential Establishments
Measure Unit	Water Heater
Unit Energy Savings	1,698,774 kWh for 2.3 Energy Factor 1,474,542 kWh for 2.0 Energy Factor
Unit Peak Demand Reduction	0.156162 kW for 2.3 Energy Factor 0.135 kW 141kW for 2.0 Energy Factor
Measure Life	14 years

Heat Pump Water Heaters take heat from the surrounding air and transfer it to the water in the tank, unlike conventional water heaters, which use either gas (or sometimes other fuels) burners or electric resistance heating coils to heat the water.

### 2.6.1 Eligibility

This protocol documents the energy savings attributed to heat pump water heaters with Energy Factors of 2.0 to 2.3. The target sector primarily consists of single-family residences.

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### 2.6.2 Algorithms

The energy savings calculation utilizes average performance data for available residential heat pump and standard electric resistance water heaters and typical water usage for residential homes. The energy savings are obtained through the following formula:

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$$\Delta kWh = \frac{\left( \left( \frac{1}{EF_{Base}} - \left( \frac{1}{EF_{Proposed}} \times \frac{1}{F_{Adjust}} \right) \right) \times HW \times 365 \times 8.3 \frac{lb}{gal} \times (T_{hot} - T_{cold}) \right)}{3413 \frac{Btu}{kWh}} \left( \left( \frac{1}{EF_{Base}} - \left( \frac{1}{EF_{Proposed}} \times \frac{1}{F_{Deratest}} \right) \right) \times HW \right) \times 3413 \frac{Btu}{kWh}$$

For heat pump water heaters, demand savings result primarily from a reduced connected load. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = EnergyToDemandFactor \times Energy Savings$$

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average Usage_{Summer WD Noon-8}}{Annual Energy Usage}$$

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM<sup>35</sup>. The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory<sup>36</sup>, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, and 183 spring/fall days) to obtain annual energy usage.
2. Obtain the average kW during noon to 8 PM on summer days from the same data.
3. The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study<sup>37</sup>.
4. The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor*.

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted for three business types in ~~Figure 2-2~~ ~~Figure 2-2~~ below.

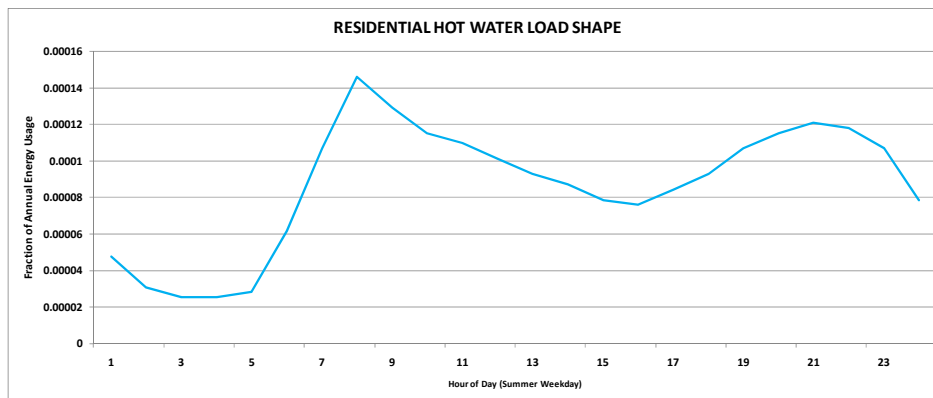


Figure 2-2: Load shapes for hot water in residential buildings taken from a PJM study.

35 Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~media/committees-groups/working-groups/irwg/20070301/20070301-pjm-deemed-savings-report.ashx>

36 The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled "Mean", in tables 14, 15, and 16 in pages 5-31 and 5-32

37 The 5th column, labeled "Mean" of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher on weekends than on weekdays

### 2.6.3 Definition of Terms

The parameters in the above equation are listed in [Table 2-16](#)~~Table 2-14~~~~16~~.

Table 2-~~16~~~~14~~~~16~~: Heat Pump Water Heater Calculation Assumptions

Component	Type	Values	Source
EFbase , Energy Factor of baseline water heater	Fixed	<del>0.904</del> <del>See Table</del> <del>2-17</del>	4
EFproposed, Energy Factor of proposed efficient water heater	Variable	<del>&gt;=2.0</del> <del>or EDC</del> <del>Data Gathering</del>	Program Design, <del>EDC Data</del> <del>Gathering</del>
HW , Hot water used per day in gallons	Fixed	50 gallon/day	5
Thot , Temperature of hot water	Fixed	<del>120-123</del> °F	6
Tcold , Temperature of cold water supply	Fixed	55 °F	7
FDerate, COP De-rating factor	Fixed	0.84	8, and discussion below
EnergyToDemandFactor	Fixed	0.00009172	1-4

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### 2.6.4 Energy Factors based on Tank Size

#### Federal Standards ~~Sources:~~

~~Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs~~ Energy Factors are equal to  $0.97 - 0.00132 \times \text{Rated Storage}$  in PJM Region Gallons. The following table shows the Energy Factors for various tank sizes.

Table 2-17: Energy Factor Based on Tank Size

Tank Size (gallons)	Energy Factor
<del>40</del>	<del>0.9172</del>
<del>50</del>	<del>0.9040</del>
<del>65</del>	<del>0.8842</del>
<del>80</del>	<del>0.8644</del>
<del>120</del>	<del>0.8116</del>

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#### Sources:

1. [Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region](http://www.pjm.com/~media/committees-groups/working-groups/Inwg/20070301/20070301-pjm-deemed-savings-report.ashx). The report can be accessed online:  
<http://www.pjm.com/~media/committees-groups/working-groups/Inwg/20070301/20070301-pjm-deemed-savings-report.ashx>

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<http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>

2. The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled “Mean”, in tables 14, 15, and 16 in pages 5-31 and 5-32
3. The 5th column, labeled “Mean” of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher on the weekends than on weekdays.
4. Federal Standards are  $0.97 - 0.00132 \times \text{Rated Storage in Gallons}$ . For a 50-gallon tank this is approximately 0.90. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: EE–2006–BT–STD–0129, p. 30

~~5. “Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters”, Federal Register / Vol. 63, No. 90, p. 26005-26006”~~

~~5. Residential Energy Consumption Survey, EIA, 2009.~~

~~6.1. 2012 SWE Residential Baseline Study Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.~~

~~7.6. Mid-Atlantic TRM, footnote #24~~

~~8.7. The performance curve is adapted from Table 1 in~~

~~<http://wescorhvac.com/HPWH%20design%20details.htm#Single-stage%20HPWHs>~~

~~The performance curve depends on other factors, such as hot water set point. Our adjustment factor of 0.84 is a first order approximation based on the information available in literature.~~

#### **2.6.42.6.5 Heat Pump Water Heater Energy Factor**

The Energy Factors are determined from a DOE testing procedure that is carried out at 56 °F wet bulb temperature. However, the average wet bulb temperature in PA is closer to 45 °F<sup>38</sup>. The heat pump performance is temperature dependent. The plot below shows relative coefficient of performance (COP) compared to the COP at rated conditions<sup>39</sup>. According to the linear regression shown on the plot, the COP of a heat pump water heater at 45 °F is 0.84 of the COP at nominal rating conditions. As such, a de-rating factor of 0.84 is applied to the nominal Energy Factor of the Heat Pump water heaters.

38 Based on TMY2 weather files from DOE2.com for Erie, Harrisburg, Pittsburgh, Wilkes-Barre, And Williamsport, the average annual wetbulb temperature is  $45 \pm 1.3$  °F. The wetbulb temperature in garages or attics, where the heat pumps are likely to be installed, are likely to be two or three degrees higher, but for simplicity, 45 °F is assumed to be the annual average wetbulb temperature.

39 The performance curve is adapted from Table 1 in <http://wescorhvac.com/HPWH%20design%20details.htm#Single-stage%20HPWHs>

The performance curve depends on other factors, such as hot water set point. Our adjustment factor of 0.84 is a first order approximation based on the information available in literature.

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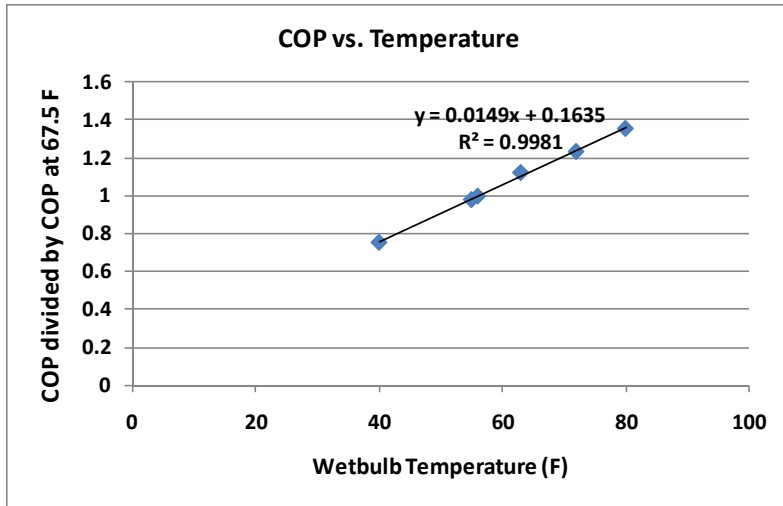


Figure 2-3: Dependence of COP on outdoor wet-bulb temperature.

**2.6-52.6.6 Deemed Savings**

~~The deemed savings Savings for the installation of heat pump efficient electric water heaters with various Energy Factors are listed calculated using the formula below.~~

$$\Delta kWh = (2,671.61 - \frac{2,916.51}{EF_{Proposed}})$$

Table 2-15: Energy Savings and Demand Reductions

Energy Factor	Energy Savings (kWh)	Demand Reduction (kW)
2.3-	1,698	0.156
2.0-	1,474	0.135

$$\Delta kW_{peak} = \Delta kWh \times 0.00009172$$

**2.6-62.6.7 Measure Life**

According to an October 2008 report for the CA Database for Energy Efficiency Resources, an electric water heater's lifespan is **14 years**<sup>40</sup>.

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40 DEER values, updated October 10, 2008  
[http://www.deerresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deerresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

## 2.7 Home Audit Conservation Kits

Measure Name	Home Audit Conservation Kits
Target Sector	Residential Establishments
Measure Unit	One Energy Conservation Kit
Unit Energy Savings	Variable based on ISR
Unit Peak Demand Reduction	Variable based on ISR
Measure Life	8.1 years

Energy Conservation kits consisting of four CFLs, four faucet aerators, two smart power strips and two LED night lights are sent to participants of the Home Energy Audit programs. This document quantifies the energy savings associated with the energy conservation kits.

### 2.7.1 Eligibility

The conservation kits are sent to residential customers only.

### 2.7.2 Algorithms

The following algorithms are adopted from the Pennsylvania Public Utilities Commission's Technical Reference Manual (TRM). The demand term has been modified to include the installation rate, which was inadvertently omitted in the TRM.

$$\begin{aligned} \Delta kWh &= N_{CFL} \times ((CFL_{watts} \times (CFL_{hours} \times 365)) / 1000) \times ISR_{CFL} \\ &+ N_{Aerator} \times Savings_{Aerator} \times ISR_{Aerator} \\ &+ N_{SmartStrip} \times Savings_{SmartStrip} \times ISR_{SmartStrip} \\ &+ N_{NiteLite} \times Savings_{NiteLite} \times ISR_{NiteLite} \end{aligned}$$

$$\begin{aligned} \Delta kW_{peak} &= N_{CFL} \times (CFL_{watts} / 1000) \times CF \times ISR_{CFL} \\ &+ N_{Aerator} \times DemandReduction_{Aerator} \times ISR_{Aerator} \\ &+ N_{SmartStrip} \times DemandReduction_{SmartStrip} \times ISR_{SmartStrip} \\ &+ N_{NiteLite} \times DemandReduction_{NiteLite} \times ISR_{NiteLite} \end{aligned}$$

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### 2.7.3 Definition of Terms

The parameters in the above equations are listed in Table 2-16.

Table 2-16: Home Audit Conversion Kit Calculation Assumptions

Component	Value	Source
$N_{CFL}$ : Number of CFLs per kit	4	Program design <sup>41</sup>
$CFL_{Watts}$ : Difference between supplanted and efficient luminaire wattage (W) <sup>42</sup>	40 (2013 TRM) 27.3 (2014 TRM)	Program Design
$ISR_{\text{CFL}}$ : In-Service Rate or Percentage of units rebated that actually get used	variable	EDC Data-Gathering SWE Data-Gathering
$CFL_{hours}$ : hours of operation per day	2.8	PA TRM Table 2-68
$CF_{\text{CFL}}$ : CFL Summer Demand Coincidence Factor	0.05	PA TRM Table 2-68
$N_{Aerator}$ : Number of faucet aerators per kit	4	Program design
$N_{SmartStrip}$ : Number of Smart Strips per kit	2	Program design
$Savings_{Aerator}$ (kWh)	48	PA TRM – Section 2.9
$DemandReduction_{Aerator}$ (kW)	0.0044	PA TRM – Section 2.9
$ISR_{Aerator}$	variable	EDC Data-Gathering <sup>43</sup>
$Savings_{SmartStrip}$ (kWh)	184	PA TRM – Section 2.9
$DemandReduction_{SmartStrip}$ (kW)	0.013	PA TRM – Section 2.9
$ISR_{SmartStrip}$	variable	EDC Data-Gathering
$Savings_{NiteLite}$ (kWh)	26.3	PA Interim TRM <sup>44</sup>
$DemandReduction_{NiteLite}$ (kW)	0	PA Interim TRM
$ISR_{NiteLite}$	variable	EDC Data-Gathering
$N_{NiteLite}$	2	Program Design

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<sup>41</sup> Four 23-W CFLs are sent out. We assume that one replaces a 100W lamp while the remaining CFLs replace 60W lamps.

<sup>42</sup> Adjusts for EISA 2007. 100-watt incandescent baseline is 72 watts as of 2013 TRM and 60-watt incandescent baseline is 43 watts as of 2014 TRM. Reference Section 2.30 for further information on EISA 2007.

<sup>43</sup> The ISR calculation for aerators is averaged from observations of a binary variable that takes on value 1 if the aerator is installed and the home has electric water heating, 0 otherwise.

<sup>44</sup> The savings for night lights are 22.07 kWh in the PA TRM, p. 24. However, these savings are the product of 26.3 kWh and an ISR of 0.84. Since the ISR for the conservation kit items are determined by data gathering during the impact evaluation, the savings for night lights herein are cast as  $26.3 \times ISR$ , with ISR as a program-specific empirically-determined variable.

#### **2.7.4 — Partially Deemed Savings**

The deemed energy and demand savings per kit are dependent on the measured ISRs for the individual kit components.

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#### **2.7.5 — Measure Life**

The measure life for CFLs is **6.4 years** according to ENERGY STAR<sup>45</sup>. The measure life of the Smart Strips are **5 years**, and the measure life of the faucet aerators are **12 years**. The weighted (by energy savings) average life of the energy conservation kit is **8.4 years**.

#### **2.7.6 — Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings. The fraction of cases where a given measure has supplanted the baseline equipment constitutes the ISR for the measure.

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<sup>45</sup>Energy Star Appliances, Energy Star Lighting, and several Residential Electric HVAC measures lives updated February 2008. U.S. Environmental Protection Agency and U.S. Department of Energy, Energy Star. <<http://www.energystar.gov/>>.

### 2.8.2.7 LED Nightlight

Measure Name	LED Nightlight
Target Sector	Residential Establishments
Measure Unit	LED Nightlight
Unit Energy Savings	22 kWh
Unit Peak Demand Reduction	0 kW
Measure Life	8 years

Savings from installation of LED nightlights are based on a straightforward algorithm that calculates the difference between existing and new wattage and the average daily hours of usage for the lighting unit being replaced. An “installation” rate is used to modify the savings based upon the outcome of participant surveys, which will inform the calculation. Demand savings is assumed to be zero for this measure.

#### 2.8.2.7.1 Algorithms

Assumes a 1 Watt LED nightlight replaces a 7 Watt incandescent nightlight. The nightlight is assumed to operate 12 hours per day, 365 days per year; estimated useful life is 8 years (manufacturer cites 11 years 100,000 hours). Savings are calculated using the following algorithm:

$$\Delta kWh = ((Watts_{base} - Watts_{NL}) \times (NL_{hours} \times 365)) / 1000 \times ISR$$

$$\Delta kW_{peak} = 0 \text{ (assumed)}$$

#### 2.8.2.7.2 Definition of Terms

$Watts_{base}$  = Wattage of baseline nightlight

$Watts_{NL}$  = Wattage of LED nightlight

$NL_{hours}$  = Average hours of use per day per Nightlight

$ISR$  = In-service rate

(The EDC EM&V contractors will reconcile the ISR through survey activities)

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Table 2-181718: LED Nightlight - References

Component	Type	Value	Sources
Watts <sub>base</sub>	Variable	Default = 7 Watts; EDC Data Gathering	EDC Data Gathering
Watts <sub>NL</sub>	Variable	DataDefault= 1 Watt; EDCData Gathering	EDC Data Gathering
NL <sub>hours</sub>	Fixed	12	1
ISR	Fixed	0.84See ISR for CFLs	PA CFL ISR value
EUL	Fixed	8 years	1

**Sources:**

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

**2.8.32.7.3 Deemed Savings**

The default energy savings is based on a delta watts assumption (Watts<sub>base</sub> – Watts<sub>EE</sub>) of 6 watts.

$$\Delta kWh = ((6 \times (12 \times 365))/1000) \times 0.84 = 22.07 kWh \text{ (rounded to } 22kWh)$$

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### 2.9.2.8 Low Flow Faucet Aerators

<b>Measure Name</b>	<b>Low Flow Faucet Aerators</b>
<b>Target Sector</b>	Residential <a href="#">Establishments</a>
<b>Measure Unit</b>	Aerator
<b>Unit Energy Savings</b>	<a href="#">4827.4</a> kWh <sup>46</sup>
<b>Unit Peak Demand Reduction</b>	<a href="#">0.00440025</a> kW
<b>Measure Life</b>	12 years

Installation of low-flow faucet aerators is an inexpensive and lasting approach for water conservation. These efficient aerators reduce water consumption and consequently reduce hot water usage and save energy associated with heating the water. This protocol presents the assumptions, analysis and savings from replacing standard flow aerators with low-flow aerators in kitchens and bathrooms.

The low-flow kitchen and bathroom aerators will save on the electric energy usage due to the reduced demand of hot water. The maximum flow rate of qualifying kitchen and bathroom aerators is 1.5 gallons per minute.

This protocol documents the energy savings attributable to efficient low flow aerators in residential applications. The savings claimed for this measure are attainable in homes with standard resistive water heaters. Homes with non-electric water heaters do not qualify for this measure.

#### 2.9.12.8.1 Algorithms

The energy savings and demand reduction are obtained through the following calculations:

$$\Delta kWh = ISR \times ELEC \times [(F_B - F_P) \times T_{Person-Day} \times N_{Persons} \times 365 \times \Delta T_L \times U_H \times U_E \times DF/RE] / (F/home)$$

$$\Delta kW_{peak} = ISR \times Energy Impact \times F_{ED}$$

The Energy to Demand Factor,  $F_{ED}$ , is defined below:

$$EnergyToDemandFactor = AverageUsage_{SummerWDNoon-8PM} / AnnualEnergyUsage$$

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand

<sup>46</sup> Segmenting by housing type using results of the 2012 PA baseline study produced savings estimates for single-family and multifamily that were within 0.5 kWh of statewide estimates. Therefore, a single, statewide estimate is used.

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response study for PJM<sup>47</sup>. The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted for three business types in Figure 2-4 below.

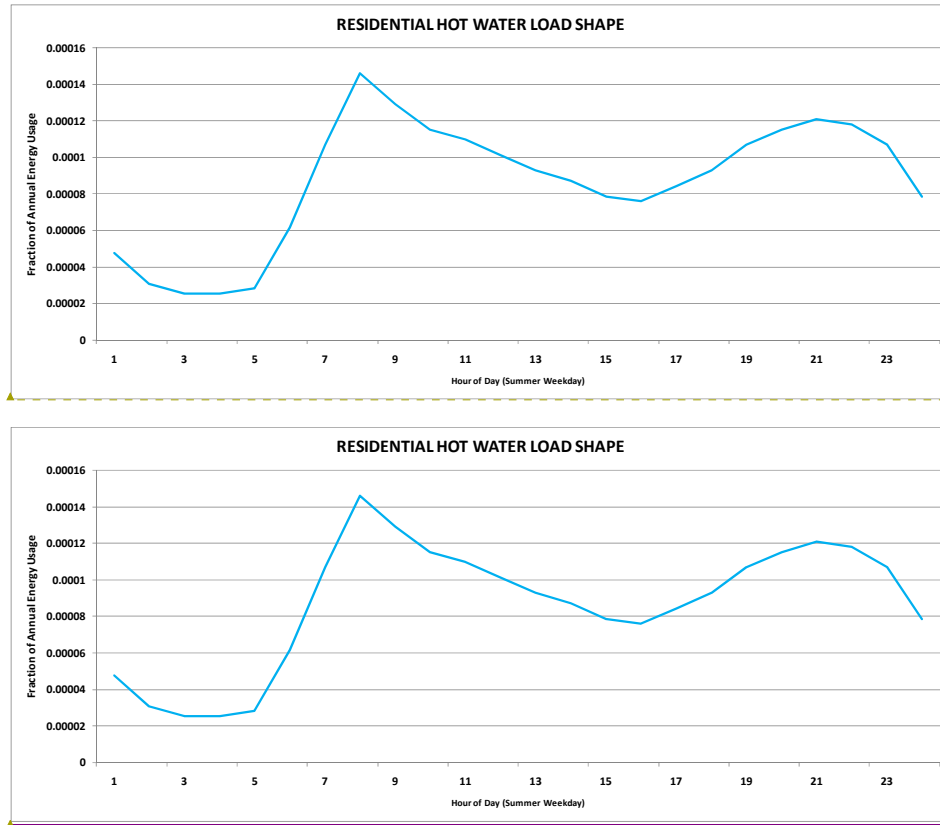


Figure 2-4: Load shapes for hot water in residential buildings taken from a PJM study.

### 2.9.22.8.2 Definition of Terms

The parameters in the above equation are defined in [Table 2-18](#); [Table 2-19](#).

47 Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx> The summer load shapes are taken from tables 14, 15, and 16 in pages 5-31 and 5-32, and table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The factor is constructed as follows: 1) Obtain the average kW, as monitored for 82 water heaters in PJM territory, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, 183 spring/fall days) to obtain annual energy usage. 2) Obtain the average kW during noon to 8 PM on summer days from the same data. 3) The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study. 4) The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor*.

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Table 2-~~1918~~19: Low Flow Faucet Aerator Calculation Assumptions

Parameter	Description	Type	Value	Source
F <sub>B</sub>	Average Baseline Flow Rate of aerator (GPM)	Fixed	1.2	21
F <sub>P</sub>	Average Post Measure Flow Rate of Sprayer (GPM)	Fixed	0.94	21
T <sub>Person-Day</sub>	Average time of hot water usage per person per day (minutes)	Fixed	-9.85 Kitchen=4.5 Bathroom=1.6 Unknown=6.1	52
N <sub>Per</sub>	Average number of persons per household	Variable	Default SF=2.7 Default MF=1.8 Default unknown=2.6 Or EDC Data Gathering	3
ΔT	Average temperature differential between outgoing mixed faucet water and supply water (°F)	Fixed	35	4
U <sub>H</sub>	Unit Conversion: 8.33BTU/(Gallons-°F)	Fixed	8.33	Convention
U <sub>E</sub>	Unit Conversion: 1 kWh/3413 BTU	Fixed	1/3413	Convention
Eff <sub>RE</sub>	Recovery efficiency of electric water heater	Fixed	0.98	65
F <sub>ED</sub>	Energy To Demand Factor	Fixed	0.00009172	16
F/home	Average number of faucets in the home	Fixed	Kitchen=1.0 Bathroom=2.8 Unknown=3.58	37
DF	Percentage of water flowing down drain	Fixed	Kitchen=75% Bathroom=90% Unknown=79.5%	58
ISR	In Service Rate	Variable	Variable	EDC Data Gathering

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ELEC	Percentage of homes with electric water heat	Variable	Default=43% Or EDC Data Gathering	9
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**Sources:**

1. [Illinois TRM Effective June 1, 2013. Maximum rated flowrates of 2.2 gpm and 1.5 gpm are not an accurate measurement of actual average flowrates over a period of time because of throttling. These flowrates represent an average flow consumed over a period of time and take occupant behavior \(not always using maximum flow rates\) into account. Based on results from various studies.48495051](#)
2. [Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. If aerator location is known, use the corresponding kitchen/bathroom value. If unknown, use 6.1 min/person/day as the average length of use value, which is the total for the household: kitchen \(4.5 min/person/day\) + bathroom \(1.6 min/person/day\) = 6.1 min/person/day.](#)
3. [Table 4-8, section 4.2.4. GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2012. For The Pennsylvania Public Utility Commission.](#)
- 4-4. [Illinois TRM effective June 1, 2013. Based on a 90F mixed faucet temperature and a 55F supply temperature.](#)
- 2-5. [Mid Atlantic TRM Version 2.0 \(updated July 2011\) and Ohio TRM updated August 2010.](#)

[Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region.](#)

**Sources:**

- 3-6. ~~[Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region.](#)~~ The report can be accessed online: <http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>. The summer load shapes are taken from tables 14, 15, and 16 in pages 5-31 and 5-32, and table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The factor is constructed as follows: 1) Obtain the average kW, as monitored for 82 water heaters in PJM territory, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, and 183 spring/fall days) to obtain annual energy usage. 2) Obtain the average kW during noon to 8 PM on summer days from the same data. 3) The average noon to 8 PM demand is converted to average weekday noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study. 4) The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the EnergyToDemandFactor.

[48 2000, Mayer, Peter, William DeOreo, and David Lewis. Seattle Home Water Conservation Study. December 2000.v](#)  
[49 2003, Mayer, Peter, William DeOreo. Residential Indoor Water Conservation Study. Aquacraft, Inc. Water Engineering and Management. Prepared for East Bay Municipal Utility District and the US EPA. July 2003](#)  
[50 2011, DeOreo, William. Analysis of Water Use in New Single Family Homes. By Aquacraft. For Salt Lake City Corporation and US EPA. July 20, 2011.](#)  
[51 2008, Schultdt, Marc, and Debra Tachibana. Energy related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings.](#)

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4. ~~Illinois TRM Effective June 1, 2012. Maximum rated flowrates of 2.2 gpm and 1.5 gpm are not an accurate measurement of actual average flowrates over a period of time because of throttling. These flowrates represent an average flow consumed over a period of time and take occupant behavior (not always using maximum flow rates) into account. Based on results from various studies.~~
- 5.7. Table 4-68, section 4.6.3. GDS Associates, Inc. Pennsylvania 2012 Statewide Residential Baseline End-Use Saturation Study, 2012. For The Pennsylvania Public Utility Commission.
- 6.8. ~~Illinois TRM effective June 1, 2012. Based on a 90F mixed faucet temperature and a 55F supply temperature.~~
7. ~~Illinois TRM Effective June 1, 2012. Based on various studies with flow rates that ranged from 6.74 min/person/day to 13.4 min/person/day.~~
- 8.9. ~~Mid Atlantic TRM Version 2.0 (updated July 2011) and Ohio TRM updated August 2010.~~
10. Illinois TRM Effective June 1, 2013. Faucet usages are at times dictated by volume, only usage of the sort that would go straight down the drain will provide savings. Due to the lack of a metering study that has determined this specific factor, the Illinois Technical Advisory Group has deemed these values to be 75% for the kitchen and 90% for the bathroom. If the aerator location is unknown an average of 79.5% should be used which is based on the assumption that 70% of household water runs through the kitchen faucet and 30% through the bathroom  $(0.7*0.75)+(0.3*0.9)=0.795$ .
11. Table 4-61, Section 4.6.1 GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2012. For The Pennsylvania Public Utility Commission. This study finds that only 43% of households statewide have an electric water heater. As such, if the proportion of households with electric water heaters is unknown, deemed savings should only be applied to 43% of the study group.

For example, a direct installed (ISR=1) kitchen low flow faucet aerator in a single family electric DHW home:

$$\begin{aligned} \Delta \text{kWh} &= 1.0 * 1.0 * (((1.2 - 0.94) * 4.5 * 2.7 * 365 * 35 * 8.33 * (1/3413) * .75 / \\ & \quad .98) / 1) \\ &= 75.4 \text{ kWh} \end{aligned}$$

For example, a direct installed (ISR=1) low flow faucet aerator in unknown faucet in an unknown family type electric DHW home:

$$\begin{aligned} \Delta \text{kWh} &= 1.0 * 1.0 * (((1.2 - 0.94) * 6.1 * 2.6 * 365 * 35 * 8.33 * (1/3413) * .795 \\ & \quad / .98) / 3.8) \\ &= 27.4 \text{ kWh per faucet} \end{aligned}$$

### **2.9.32.8.3 Deemed Savings**

The deemed energy savings for the installation of a low flow aerator compared to a standard aerator is **ISR × 4827.4 kWh/year** with a demand reduction of **ISR × 0.00440025 kW**, with ISR determined through data collection.

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### **2.9.42.8.4 Measure Life**

The measure life is 12 years, according to California's Database of Energy Efficiency Resources (DEER).

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### **2.9.52.8.5 Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings. EDC Data Gathering

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## 2.10.2.9 Low Flow Showerheads

Measure Name	Low Flow Showerheads
Target Sector	Residential Establishments
Measure Unit	Water Heater
Unit Energy Savings	Partially Deemed. <a href="#">See Section 2.10.4.</a>
Unit Peak Demand Reduction	Partially Deemed. <a href="#">See Section 2.10.4.</a>
Measure Life	9 years

This measure relates to the installation of a low flow (generally 1.5 GPM) showerhead in bathrooms in homes with electric water heater. The baseline is a standard showerhead using 2.5 GPM.

### 2.10.12.9.1 Eligibility

This protocol documents the energy savings attributable to replacing a standard showerhead with an energy efficient low flow showerhead for electric water heaters. The target sector primarily consists of residential residences.

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### 2.10.22.9.2 Algorithms

The annual energy savings are obtained through the following formula:

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$$\Delta kWh = \frac{ISR * ELEC * (((GPM_{base} - GPM_{low}) / GPM_{base}) * \frac{peopleN_{Persons}}{gals/day} * \frac{days/year}{showers365}) * (TEMP_{ft} - TEMP_{in}) / RE * U_H * U_E / (S/home)}{1}$$

$$\Delta kW_{peak} = \Delta kWh * EnergyToDemandFactor$$

**2.10.32.9.3 Definition of Terms**Table 2-20: Low Flow Showerhead Calculation Assumptions

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<u>Parameter</u>	<u>Description</u>	<u>Type</u>	<u>Value</u>	<u>Source</u>
<u>GPM<sub>Base</sub></u>	<u>Gallons per minute of baseline showerhead</u>	<u>Fixed</u>	<u>2.5</u>	<u>1</u>
<u>GPM<sub>Low</sub></u>	<u>Gallons per minute of low flow showerhead</u>	<u>Variable</u>	<u>Default value = 1.5 or EDC Data Gathering</u>	<u>2</u>
<u>People</u>	<u>Average number of persons per household</u>	<u>Variable</u>	<u>Default SF=2.7 Default MF=1.8 Default unknown=2.6 Or EDC Data Gathering</u>	<u>3</u>
<u>gals/day</u>	<u>Average gallons of hot water used for showering per person per day</u>	<u>Fixed</u>	<u>11.7</u>	<u>4</u>
<u>days/year</u>	<u>Number of days per year</u>	<u>Fixed</u>	<u>365</u>	
<u>Showers</u>	<u>Average number of showers in the home</u>	<u>Variable</u>	<u>Default SF=1.7 (89.6% of homes) Default MF=1.3 (10.4% of homes) Default unknown = 1.6 Or EDC Data Gathering</u>	<u>5</u>
<u>TEMP<sub>t</sub></u>	<u>Assumed temperature of water used by showerhead</u>	<u>Fixed</u>	<u>101° F</u>	<u>6</u>
<u>TEMP<sub>in</sub></u>	<u>Assumed temperature of water entering house</u>	<u>Fixed</u>	<u>55° F</u>	<u>6.7</u>
<u>U<sub>H</sub></u>	<u>Unit Conversion: 8.33BTU/(Gallons-°F)</u>	<u>Fixed</u>	<u>8.33</u>	<u>Convention</u>
<u>U<sub>E</sub></u>	<u>Unit Conversion: 1 kWh/3413 BTU</u>	<u>Fixed</u>	<u>1/3413</u>	<u>Convention</u>
<u>RE</u>	<u>Recovery efficiency of electric water heater</u>	<u>Fixed</u>	<u>0.98</u>	<u>8</u>
<u>F<sub>ED</sub></u>	<u>Energy To Demand Factor</u>	<u>Fixed</u>	<u>0.00009172</u>	<u>9</u>
<u>SR</u>	<u>In Service Rate</u>	<u>Variable</u>	<u>Variable</u>	<u>EDC Data Gathering</u>
<u>ELEC</u>	<u>Percentage of homes with electric water heat</u>	<u>Variable</u>	<u>Default=43% Or EDC Data Gathering</u>	<u>10</u>

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<u>Sources:</u>	$GPM_{base}$	=Gallons per minute of baseline showerhead = 2.5 GPM <sup>52</sup>
	$GPM_{low}$	=Gallons per minute of low flow showerhead
	people	=Average number of people per household <sup>53</sup> =
		Single Family = 2.7 (89.57% of homes)
		Multifamily = 1.8 (10.43% of homes)
	gals/day	=Average gallons of hot water used for showering per person per day = 11.654
	days/year	=Number of days per year = 365
	showers	=Average number of showers in the home <sup>55</sup> =
		Single Family = 1.7 (89.57% of homes)
		Multifamily = 1.3 (10.43% of homes)
	$TEMP_{ft}$	=Assumed temperature of water used by faucet = 105° F <sup>56</sup>
	$TEMP_{in}$	=Assumed temperature of water entering house = 55° F <sup>57</sup>
	RE	=Recovery efficiency of electric hot water heater = 0.9858
	$U_H$	=Unit Conversion = 8.33 BTU/(Gallons °F)
	$U_E$	=Unit Conversion: 1 kWh / 3413 BTU

1. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Uses the federal minimum GPM allowed as the baseline for the replaced showerheads, corresponding to 2.5 GPM.

52 The Energy Policy Act of 1992 established the maximum flow rate for showerheads at 2.5 gallons per minute (GPM).

53 PA 2012 Residential Baseline Study.

54 The most commonly quoted value for the amount of hot water used for showering per person per day is 11.6 GPD. See the U.S. Environmental Protection Agency's "water sense" documents:

[http://www.epa.gov/watersense/docs/home\\_suppstat508.pdf](http://www.epa.gov/watersense/docs/home_suppstat508.pdf)

55 PA 2012 Residential Baseline Study.

56 Mid Atlantic TRM Version 2.0, Ohio TRM updated August 2010, Illinois TRM effective June 2012.

57 A good approximation of annual average water main temperature is the average annual ambient air temperature. Average water main temperature = 55° F based on:

[http://wf.ncdc.noaa.gov/img/documentlibrary/clim81supp3/tempnormal\\_hires.jpg](http://wf.ncdc.noaa.gov/img/documentlibrary/clim81supp3/tempnormal_hires.jpg)

58 Mid Atlantic TRM Version 2.0 (updated July 2011) and Ohio TRM updated August 2010.

2. Illinois TRM Effective June 1, 2013. Allows for varying flow rate of the low-flow showerhead, most notably values of 2.0 GPM, 1.75 GPM and 1.5 GPM. Custom or actual values are also allowed for.
3. Table 4-8, section 4.2.4. GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2012. For The Pennsylvania Public Utility Commission.
4. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Based upon a metering study, this report concludes that the average shower length is 7.8 minutes and the average number of showers per day per person is 0.6. Using the showerhead flow rate of 2.5 GPM, the resulting calculation for gallons per day is as follows: 7.8 min \* 2.5 gallons/min \* 0.6 showers per day per person = 11.7 gallons per day per person.
5. Table 4-69, section 4.6.3. GDS Associates, Inc. Pennsylvania Statewide Residential End-Use Saturation Study, 2012. For The Pennsylvania Public Utility Commission.
6. Cadmus and Opinion Dynamics Evaluation Team. Showerhead and Faucet Aerator Meter Study. For Michigan Evaluation Working Group. June 2013. Temperature sensors provided the mixed water temperature readings resulting in an average of 101°F. Inlet water temperatures were measured and a weighted average based upon city populations was used to calculate the value of 55°F.
7. A good approximation of annual average water main temperature is the average annual ambient air temperature. Average water main temperature = 55° F based on: [http://wf.ncdc.noaa.gov/img/documentlibrary/clim81supp3/tempnormal\\_hires.jpg](http://wf.ncdc.noaa.gov/img/documentlibrary/clim81supp3/tempnormal_hires.jpg)
8. Mid Atlantic TRM Version 2.0 (updated July 2011) and Ohio TRM updated August 2010.
9. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>. The summer load shapes are taken from tables 14, 15, and 16 in pages 5-31 and 5-32, and table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The factor is constructed as follows: 1) Obtain the average kW, as monitored for 82 water heaters in PJM territory, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, and 183 spring/fall days) to obtain annual energy usage. 2) Obtain the average kW during noon to 8 PM on summer days from the same data. 3) The average noon to 8 PM demand is converted to average weekday noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study. 4) The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the EnergyToDemandFactor.
10. Table 4-61, Section 4.6.1 of the 2012 Pennsylvania Statewide Residential End-Use and Saturation Study. This study finds that only 43% of households statewide have an electric water heater. As such, if the proportion of households with electric water heaters is unknown, deemed savings should only be applied to 43% of the study group.



For example, a direct-installed (ISR=1) 1.5 GPM low flow showerhead in a single family electric DHW home where the number of showers is not known:

$$\Delta kWh = 1.0 * 1.0 * \left( \frac{((2.5 - 1.5) / 2.5) * 2.7 * 11.7 * 365}{(1/3413) / 0.98} \right) * (101-55) * 8.33 * 1.7$$

$$310.8 = kWh$$

For example, a direct-installed (ISR=1) 1.5 GPM low flow showerhead in an unknown family type home with electric DHW where the number of showers is not known:

$$\Delta kWh = 1.0 * 1.0 * \left( \frac{((2.5 - 1.5) / 2.5) * 2.6 * 11.7 * 365}{(1/3413) / 0.98} \right) * (101-55) * 8.33 * 1.6$$

$$318.0 = kWh$$

*EnergyToDemandFactor=Summer peak coincidence factor for measure = 0.0000917259*

$\Delta kWh$  =Annual kWh savings

$\Delta kW$  =Summer peak kW savings

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage. The Energy to Demand Factor is defined as:

$$\text{EnergyToDemandFactor} = \frac{\text{Average Usage}_{\text{Summer WD Noon-8}}}{\text{Annual Energy Usage}}$$

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM60. The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, and 183 spring/fall days) to obtain annual energy usage.
2. Obtain the average kW during noon to 8 PM on summer days from the same data.
3. The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study,

59 Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>  
60 Op. cit.

4. The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the Energy to Demand Factor, or Coincidence Factor.

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted in Figure 2-5 below.

Field Code Changed

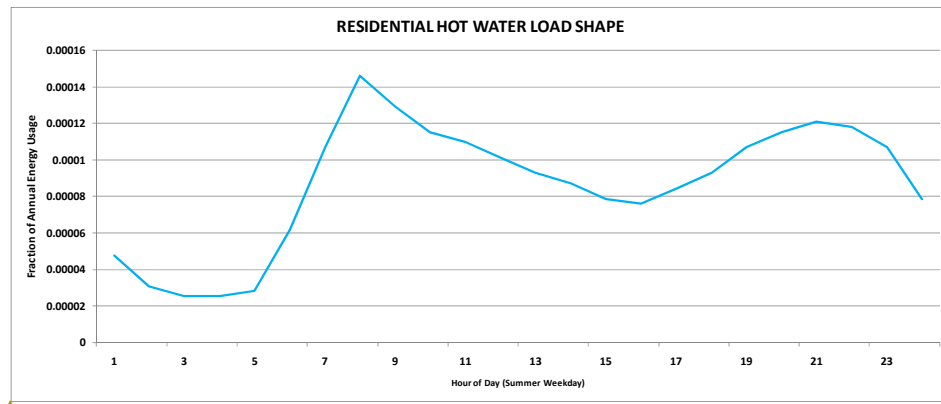
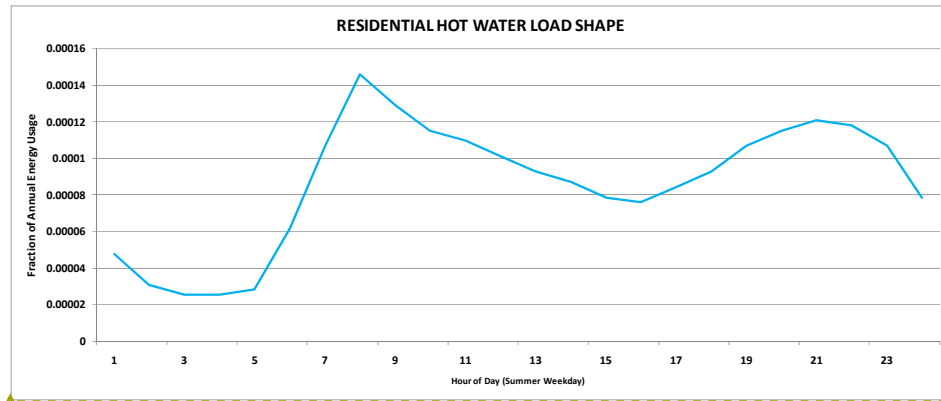


Figure 2-5: Load shapes for hot water in residential buildings taken from a PJM study.

**2.10.42.9.4 Deemed Savings**

Housing Type	Low Flow Rate (gpm)	Unit Energy Savings (kWh)	Unit Demand Savings (kW)
Single Family	2.0	467155	0.01540142
	1.75	254233	0.02300214
	1.5	335311	0.03070285
Multifamily	2.0	146135	0.01340124
	1.75	219203	0.02040186
	1.5	292271	0.02680249
Statewide	2.0	466159	0.01520146
	1.75	249239	0.02280219
	1.5	334318	0.03040292

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**2.10.52.9.5 Measure Life**

According to the Efficiency Vermont Technical Reference User Manual (TRM), the expected measure life is **9 years**<sup>61</sup>.

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**2.10.62.9.6 Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installation coupled with ~~assignment of stipulated energy savings~~[EDC Data Gathering](#).

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<sup>61</sup> Efficiency Vermont, Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions, TRM User Manual No. 2008-53, 07/18/08.

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**2.412.10 Programmable Thermostat**

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Measure Name	Programmable Thermostat
Target Sector	Residential Establishments
Measure Unit	Programmable Thermostat
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	11

Programmable thermostats are used to control heating and/or cooling loads in residential buildings by modifying the temperature set-points during specified unoccupied and nighttime hours. These units are expected to replace a manual thermostat and the savings assume an existing ducted HVAC system with electric resistance heating and DX cooling. A standard programmable thermostat installed on a heat pump can have negative energy consequences. However, the option exists to input higher efficiency levels if coupled with a newer unit. The EDCs will strive to educate the customers to use manufacturer default setback and setup settings.

**2.41.12.10.1 Algorithms**

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$$\Delta kWh = \Delta kWh_{COOL} + \Delta kWh_{HEAT}$$

$$\Delta kWh_{COOL} = CAP_{COOL}/1000 \times (1/(SEER \times Eff_{duct})) \times EFLH_{COOL} \times ESF_{COOL}$$

$$\Delta kWh_{HEAT} = CAP_{HEAT}/1000 \times (1/(HSPF \times Eff_{duct})) \times EFLH_{HEAT} \times ESF_{HEAT}$$

$$\Delta kW_{peak} = 0$$

**2.41.22.10.2 Definition of Terms**

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$CAP_{COOL}$  = Capacity of the air conditioning unit in BTUh, based on nameplate capacity.

$CAP_{HEAT}$  = Nominal heating capacity of the electric furnace in BTUh

$Eff_{duct}$  = Duct system efficiency

$SEER$  = Seasonal energy efficiency ratio of the cooling unit.

$HSPF$  = Heating seasonal performance factor of the heating unit.

$ESF_{COOL,HEAT}$  = Energy savings factor for cooling and heating, respectively

$EFLH_{COOL, HEAT}$  = Equivalent full load hours

Table 2-214921: Residential Electric HVAC Calculation Assumptions

Component	Type	Value	Sources
CAP <sub>COOL</sub>	Variable	Nameplate data	EDC Data Gathering
		Default: 36,000 BTUh	1
CAP <sub>HEAT</sub>	Variable	Nameplate Data	EDC Data Gathering
		Default: 36,000 BTUh	1
SEER	Variable	Nameplate data	EDC Data Gathering
		Default: 10 SEER	2
HSPF	Variable	Nameplate data	EDC Data Gathering
		Default: 3.413 HSPF (equivalent to electric furnace COP of 1)	2
Eff <sub>duct</sub>	Fixed	0.8	3
ESF <sub>COOL</sub>	Fixed	2%	4
ESF <sub>HEAT</sub>	Fixed	3.6%	5
EFLH <sub>COOL</sub>	Default	Allentown Cooling = 487 Hours Erie Cooling = 389 Hours Harrisburg Cooling = 551 Hours Philadelphia Cooling = 591 Hours Pittsburgh Cooling = 432 Hours Scranton Cooling = 417 Hours Williamsport Cooling = 422 Hours	6
	Optional	An EDC can estimate it's own EFLH based on customer billing data analysis.	EDC Data Gathering
EFLH <sub>HEAT</sub>	Default	Allentown Heating = 1,193 Hours Erie Heating = 1,349 Hours Harrisburg Heating = 1,103 Hours Philadelphia Heating = 1,060 Hours Pittsburgh Heating = 1,209 Hours Scranton Heating = 1,296 Hours Williamsport Heating = 1,251 Hours	6
	Optional	An EDC can estimate it's own EFLH based on customer billing data analysis.	EDC Data Gathering
Measure Life (EUL)	Fixed	11	7

**Sources:**

1. Average size of residential air conditioner or furnace.

2. Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006.
3. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, September 1, 2009.
4. DEER 2005 cooling savings for climate zone 16, assumes a variety of thermostat usage patterns.
5. “Programmable Thermostats. Report to KeySpan Energy Delivery on Energy Savings and Cost Effectiveness”, GDS Associates, Marietta, GA. 2002. 3.6% factor includes 56% realization rate.
6. Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models assume 50% oversizing of air conditioners<sup>62</sup> and 40% oversizing of heat pumps.<sup>63</sup>
7. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, September 1, 2009, based on DEER.

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62 Neme, Proctor, Nadal, “National Energy Savings Potential From Addressing Residential HVAC Installation Problems. ACEEE, February 1, 1999. Confirmed also by *Central Air Conditioning in Wisconsin, a compilation of recent field research*. Energy Center of Wisconsin. May 2008, emended December 15, 2010

63 ACCA, “Verifying ACCA Manual S Procedures,” <http://www.acca.org/Files/?id=67>.



### 2.12.11 Room AC (RAC) Retirement

Measure Name	Room A/C Retirement
Target Sector	Residential Establishments
Measure Unit	Room A/C
Unit Energy Savings	<i>Varies</i>
Unit Peak Demand Reduction	<i>Varies</i>
Measure Life	4

This measure is defined as retirement and recycling without replacement of an *operable* but older and inefficient room AC (RAC) unit that would not have otherwise been recycled. The assumption is that these units will be permanently removed from the grid rather than handed down or sold for use in another location by another EDC customer, and furthermore that they would not have been recycled without this program. This measure is quite different from other energy-efficiency measures in that the energy/demand savings is not the difference between a pre- and post-configuration, but is instead the result of complete elimination of the existing RAC. Furthermore, the savings are *not* attributable to the customer that owned the RAC, but instead are attributed to a *hypothetical user of the equipment had it not been recycled*. Energy and demand savings is the estimated energy consumption of the retired unit over its remaining useful life (RUL).

#### 2.12.11.1 Algorithms

Although this is a fully deemed approach, any of these values can and should be evaluated and used to improve the savings estimates for this measure in subsequent TRM revisions.

##### Retirement-Only

All EDC programs are currently operated under this scenario. For this approach, impacts are based only on the existing unit, and savings apply *only for the remaining useful life (RUL) of the unit*.

$$\Delta kWh = EFLH_{RAC} * (CAPY/1000) * (1/EER_{RetRAC})$$

$$\Delta kW_{peak} = (CAPY/1000) * (1/EER_{RetRAC}) * CF_{RAC}$$

##### Replacement and Recycling

It is not apparent that any EDCs are currently implementing the program in this manner, but the algorithms are included here for completeness. For this approach, the ENERGY STAR upgrade measure would have to be combined with recycling via a turn-in event at a retail appliance store, where the old RAC is turned in at the same time that a new one is purchased. Unlike the retirement-only measure, the savings here are attributed to the customer that owns the retired RAC, and are based on the old unit and original unit being of the same size and configuration. In this case, two savings calculations would be needed. One would be applied over the remaining life of the recycled unit, and another would be used for the rest of the effective useful life, as explained below.

For the remaining useful life (RUL) of the existing RAC: The baseline value is the EER of the retired unit.

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$$\Delta kWh = EFLH_{RAC} * (CAPY/1000) * (1/EER_{RetRAC} - 1/EER_{ES})$$

$$\Delta kW_{peak} = (CAPY/1000) * (1/EER_{RetRAC} - 1/EER_{ES}) * CF_{RAC}$$

**After the RUL for (EUL-RUL) years:** The baseline EER would revert to the minimum Federal appliance standard EER.

$$\Delta kWh = EFLH_{RAC} * (CAPY/1000) * (1/EER_b - 1/EER_{ES})$$

$$\Delta kW_{peak} = (CAPY/1000) * (1/EER_b - 1/EER_{ES}) * CF_{RAC}$$

### 2.12.22.11.2 Definition of Terms

$EFLH_{RAC}$  = The Equivalent Full Load Hours of operation for the installed measure. In actuality, the number of hours and time of operation can vary drastically depending on the RAC location (living room, bedroom, home office, etc.).

#### Correction of ES RAC EFLH Values:

An additional step is required to determine  $EFLH_{RAC}$  values. Normally, the EFLH values from the ENERGY STAR Room AC Calculator would be used directly. However, the current (July 2010) ES Room AC calculator EFLHs are too high because they are the same as those used for the Central AC calculator, whereas RAC full load hours should be much lower than for a CAC system. As such, the ES EFLH values were corrected as follows:

$$EFLH_{RAC} = EFLH_{ES-RAC} * AF$$

#### Where:

$EFLH_{ES-RAC}$  = Full load hours from the ENERGY STAR Room AC Calculator

$AF$  = Adjustment factor for correcting current ES Room AC calculator EFLHs.

Note that when the ENERGY STAR RAC calculator values are eventually corrected in the ES calculator, the corrected  $EFLH_{ES-RAC}$  values can be used directly and this adjustment step can be ignored and/or deleted.

$CAPY$  = Rated cooling capacity (size) of the RAC in Btuh.

$EER_{RetRAC}$  = The Energy Efficiency Ratio of the unit being retired-recycled expressed as kBtuh/kW.

$EER_b$  = The Energy Efficiency Ratio of a RAC that just meets the minimum federal appliance standard efficiency expressed as kBtuh/kW.

$EER_{ES}$  = The Energy Efficiency Ratio for an ENERGY STAR RAC expressed as kBtuh/kW.

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$CF_{RAC}$  = Demand Coincidence Factor (See Section 1.4), which is 0.58 from the 2010 PA TRM for the “ENERGY STAR Room Air Conditioner” measure.

1000 = Conversion factor, convert capacity from Btuh to kBtuh (1000 Btuh/kBtuh)

Table 2-~~22~~2022: Room AC Retirement Calculation Assumptions

Component	Type	Value	Sources
EFLH <sub>RAC</sub>	Varies	Table 2-21: RAC Retirement Only EFLH and Energy Savings by City; “Corrected Hours” Table 2-23	1
EFLH <sub>ES-RAC</sub>	Varies	Table 2-21: RAC Retirement Only EFLH and Energy Savings by City; “Original Hours” Table 2-23	1
AF	Fixed	0.31	2
CAPY (RAC capacity, Btuh)	VariableFixed	Default :10,000; or EDC Data Gathering	3
EER <sub>RetRAC</sub>	VariableFixed	9.07Default: 9.07; or EDC Data Gathering	4
EER <sub>b</sub> (for a 10,000 Btuh unit)	Fixed	9.8	5
EER <sub>ES</sub> (for a 10,000 Btuh unit)	VariableFixed	10.8Default: 10.8; or EDC Data Gathering	5
CF <sub>RAC</sub>	Fixed	0.58	6
RAC Time Period Allocation Factors	Fixed	65.1%, 34.9%, 0.0%, 0.0%	6
Measure Life (EUL)	Fixed	4	See source notes

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Table 2-232423: RAC Retirement-Only EFLH and Energy Savings by City<sup>64</sup>

City	Original Hours (EFLH <sub>ES-RAC</sub> )	Corrected Hours (EFLH <sub>RAC</sub> )	Energy Impact (kWh)	Demand Impact (kW)
Allentown	784	243	268	0.6395
Erie	482	149	164	
Harrisburg	929	288	318	
Philadelphia	1032	320	353	
Pittsburgh	737	228	251	
Scranton	621	193	213	
Williamsport	659	204	225	

**Sources:**

1. Full load hours for Pennsylvania cities from the ENERGY STAR Room AC Calculator<sup>65</sup> spreadsheet, Assumptions tab. Note that the EFLH values currently used in the ES Room AC calculator are incorrect and too high because they are the same as those used for the Central AC calculator, but should be much less.
  - a. For reference, EIA-RECS for the Northeast, Middle Atlantic region shows the per-household energy use for an RAC = 577 kWh and an average of 2.04 units per home, so the adjusted RAC use = 283 kWh per unit. This more closely aligns with the energy consumption for room AC using the adjusted EFLH values than without adjustment.
2. Mid Atlantic TRM Version 1.0. April 28, 2010 Draft. Prepared by Vermont Energy Investment Corporation. An adjustment to the ES RAC EFLHs of 31% was used for the “Window A/C” measure. The average ratio of EFLH for Room AC provided in RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008<sup>66</sup> to FLH for Central Cooling for the same location (provided by AHRI: <[http://www.energystar.gov/ia/business/bulk\\_purchasing/bpsavings\\_calc/Calc\\_CAC.xls](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls)> is 31%. This factor was applied to the EFLH for Central Cooling provided for PA cities and averaged to come up with the assumption for EFLH for Room AC.”

64

**Table 2-23**

**Table 2-24** should be used with a master “mapping table” that maps the zip codes for all PA cities to one of the representative cities above. This mapping table would also be used for the TRM ENERGY STAR Room Air Conditioning measure. This table will be developed in the context of the TWG.

65 The Room AC calculator can be found here

[http://www.energystar.gov/ia/business/bulk\\_purchasing/bpsavings\\_calc/CalculatorConsumerRoomAC.xls](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorConsumerRoomAC.xls) and the Central AC calculator is here: [http://www.energystar.gov/ia/business/bulk\\_purchasing/bpsavings\\_calc/Calc\\_CAC.xls](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_CAC.xls).

66 Accessed:

<[http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117\\_RLW\\_CF%20Res%20RAC.pdf](http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)>

3. 10,000 Btuh is the typical size assumption for the ENERGY STAR Room AC Savings calculator. It is also used as the basis for PA TRM ENERGY STAR Room AC measure savings calculations, even though not explicitly stated in the TRM. For example:
  - a. Energy savings for Allentown = 74 kWh and EFLH = 784 hrs:  
 $784 * (10,000/1000) * (1/9.8 - 1/10.8) = 74 \text{ kWh}$ .
  - b. CPUC 2006-2008 EM&V, “Residential Retrofit High Impact Measure Evaluation Report”, prepared for the CPUC Energy Division, February 8, 2010, page 165, Table 147 show average sizes of 9,729 and 10,091 Btuh.
4. Massachusetts TRM, Version 1.0, October 23, 2009, “Room AC Retirement” measure, Page 52-54. Assumes an existing/recycled unit EER=9.07, reference is to weighted 1999 AHAM shipment data. This value should be evaluated and based on the actual distribution of recycled units in PA and revised in later TRMs if necessary. Other references include:
  - a. ENERGY STAR website materials on Turn-In programs, if reverse-engineered indicate an EER of 9.16 is used for savings calculations for a 10 year old RAC. Another statement indicates that units that are at least 10 years old use 20% more energy than a new ES unit which equates to:  $10.8 \text{ EER}/1.2 = 9 \text{ EER}$   
<http://www.energystar.gov/ia/products/recycle/documents/RoomAirConditionerTurn-InAndRecyclingPrograms.pdf>
  - b. “Out With the Old, in With the New: Why Refrigerator and Room Air Conditioner Programs Should Target Replacement to Maximize Energy Savings.” National Resources Defense Council, November 2001. Page 3, Cites a 7.5 EER as typical for a room air conditioner in use in 1990s. However, page 21 indicates an 8.0 EER was typical for a NYSERDA program.
5. ENERGY STAR and Federal Appliance Standard minimum EERs for a 10,000 Btuh unit with louvered sides. [http://www.energystar.gov/index.cfm?c=roomac.pr\\_crit\\_room\\_ac](http://www.energystar.gov/index.cfm?c=roomac.pr_crit_room_ac)
6. PA TRM June 2010, coincident demand factor and Time Period Allocation Factors for ENERGY STAR Room AC.

### **2.12.32.11.3 Measure Life**

*Room Air Conditioner Retirement = 4 years*

From the PA TRM, the EUL for an ENERGY STAR Room Air Conditioner is 10 years, but the TRM does not provide an RUL for RACs. However, as shown in [Table 2-24](#)~~Table 2-2224~~, the results from a recent evaluation of ComEd’s appliance recycling program<sup>67</sup> found a median age of 21 to 25 years for recycled ACs. For a unit this old, the expected life of the savings is likely to be short, so 4 years was chosen as a reasonable assumption based on these references:

---

67 Residential Appliance Recycling Program Year 1 Evaluation Report – Final Report, prepared for Commonwealth Edison by Itron (under contract to Navigant Consulting), November 2009.

1. DEER database, presents several values for EUL/RUL for room AC recycling:
  - [http://www.deeresources.com/deer2008exante/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer2008exante/downloads/EUL_Summary_10-1-08.xls)
    - a. DEER 0607 recommendation: EUL=9, RUL=1/3 of EUL = 3 years. The 1/3 was defined as a “reasonable estimate”, but no basis given.
    - b. 2005 DEER: EUL=15, did not have recycling RUL
    - c. Appliance Magazine and ENERGY STAR calculator: EUL=9 years
    - d. CA IOUs: EUL=15, RUL=5 to 7
2. “Out With the Old, in With the New: Why Refrigerator and Room Air Conditioner Programs Should Target Replacement to Maximize Energy Savings,” National Resources Defense Council, November 2001, page 21, 5 years stated as a credible estimate.
3. From the PA TRM June 2010, if the ratio of refrigerator recycling measure life to ENERGY STAR measure life is applied:  $(8/13) * 10$  years (for RAC) = 6 years for RAC recycling.

Table 2-~~242224~~: Preliminary Results from ComEd RAC Recycling Evaluation

Appliance Type	Age in Years									N
	0 to 5	6 to 10	11 to 15	16 to 20	21 to 25	26 to 30	31 to 35	36 to 40	Over 40	
Room Air Conditioners	0%	5%	7%	18%	37%	18%	5%	6%	5%	—

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**Sources:**

24-1. Navigant Consulting evaluation of ComEd appliance recycling program.

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## 2.132.12 Smart Strip Plug Outlets

Measure Name	Smart Strip Plug Outlets
Target Sector	Residential
Measure Unit	Per Smart Strip
Unit Energy Savings	<p><del>184 kWh</del> <u>48.9 kWh (5-plug, unspecified use or multiple purchased)</u></p> <p><u>58.7 kWh (7-plug, unspecified use or multiple purchased)</u></p> <p><u>62.1 kWh (5-plug, Entertainment Center)</u></p> <p><u>74.5 kWh (7-plug, Entertainment Center)</u></p>
Unit Peak Demand Reduction	<p><del>0.013 kW</del> <u>0.0054 kW (5-plug, unspecified use or multiple purchased)</u></p> <p><u>0.0064 kW (7-plug, unspecified use or multiple purchased)</u></p> <p><u>0.0068 kW (5-plug, Entertainment Center)</u></p> <p><u>0.0082 kW (7-plug, Entertainment Center)</u></p>
Measure Life	<u>54</u> years

Smart Strips are power strips that contain a number of controlled sockets with at least one uncontrolled socket. When the appliance that is plugged into the uncontrolled socket is turned off, the power strips then shuts off the items plugged into the controlled sockets.

### 2.13.1 Eligibility

This protocol documents the energy savings attributed to the installation of smart strip plugs. The most likely area of application is within residential spaces, i.e. single family and multifamily homes. The two areas of usage considered are home ~~computer~~ office systems and home entertainment systems. Power strips used with entertainment systems typically save more energy than power strips used with home office components. It is expected that approximately ~~four~~ three to five items will be plugged into each 5-plug power strip, and that five to six items will be plugged into a 7-plug power strip.

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### 2.13.2 Algorithms

~~The DSMore Michigan Database of Energy Efficiency Measures performed engineering calculations using standard standby equipment wattages for typical computer and TV systems and idle times.~~ The energy savings and demand reduction were obtained through the following calculations using standard standby or low power wattages for typical entertainment center and home office components. If the intended use of the power strip is not specified, or if multiple power strips are purchased, the algorithm for "unspecified use should be applied". If it is known that the power strip is intended to be used for an entertainment center, the "entertainment center" algorithm should be applied:

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$$\Delta kWh_{unspecified\ use} = \frac{(kW_{comp} \times Hr_{comp}) + (kW_{TV} \times Hr_{TV})}{2} \times 365 = 184\ kWh \quad 48.9\ kWh$$

(5-plug): 58.7 kWh (7-plug)

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$$\Delta kWh_{entertainment\ center} = kW_{TV} \times Hr_{TV} \times 365 = 62.1\ kWh \quad (5-plug); \quad 74.5\ kWh \quad (7-plug)$$

$$\Delta kW_{peak\ unspecified\ use} = \frac{CF \times (kW_{comp} + kW_{TV})}{2} = 0.0130054\ kW$$

(5-plug): 0.0064 kW (7-plug)

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$$\Delta kW_{peak\ entertainment\ center} = CF \times kW_{TV} = 0.0068\ kW \quad (5-plug); \quad 0.0082\ kW \quad (7-plug)$$

**2.13.3 Definition of Terms**

The parameters in the above equation are listed in [Table 2-23](#), [Table 2-25](#), [Table 2-25](#).

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Table 2-25: Smart Strip Plug Outlet Calculation Assumptions

Parameter	Component	Type	Value	Source
kW <sub>comp</sub>	Idle kW of computer system	Fixed	0.02040049 (5-plug) 0.00588 (7-plug)	1,2,4
Hr <sub>comp</sub>	Daily hours of computer idle time	Fixed	20	1
kW <sub>TV</sub>	Idle kW of TV system	Fixed	0.03200085 (5-plug) 0.0102 (7-plug)	1,4
Hr <sub>TV</sub>	Daily hours of TV idle time	Fixed	4920	1
CF	Coincidence Factor	Fixed	0.5080	43

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**Sources:**

1. "Electricity Savings Opportunities for Home Electronics and Other Plug-In Devices in Minnesota Homes", Energy Center of Wisconsin, May 2010.
2. "Smart Plug Strips", ECOS, July 2009.
3. Efficiency Vermont coincidence factor for smart strip measure – in the absence of empirical evaluation data, this was based on the assumptions of the typical run pattern for televisions and computers in homes.
4. "Advanced Power Strip Research Report", NYSERDA, August 2011.

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**2.13.4 Deemed Savings**

22. DSMore MI-DB

**2.13.5 Deemed Savings**

$$\Delta kWh = 18448.9\ kWh \quad (5-plug\ power\ strip,\ unspecified\ use\ or\ multiple\ purchased)$$

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58.7 kWh (7-plug power strip, unspecified use or multiple purchased)

62.1 kWh (5-plug power strip, entertainment center)

74.5 kWh (7-plug power strip, entertainment center)

$\Delta kW_{peak}$  = 0.0130054 kW (5-plug power strip, unspecified use or multiple purchase)

0.0064 kW (7-plug power strip, unspecified use, or multiple purchased)

0.0068 kW (5-plug power strip, entertainment center)

0.0082 kW (7 plug power strip, entertainment center)

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**2.13.62.13.5 Measure Life**

To ensure consistency with the annual savings calculation procedure used in the DSMore MI database, the measure life of **5 years** is taken from DSMore.

4 years<sup>68</sup>

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**2.13.72.13.6 Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

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<sup>68</sup> "Smart Strip Electrical Savings and Usability", David Rogers, Power Smart Engineering, October 2008.

### 2.14.22.13.1 Solar Water Heaters

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Measure Name	Solar Water Heaters
Target Sector	Residential Establishments
Measure Unit	Water Heater
Default Unit Energy Savings	1.623698 kWh
Default Unit Peak Demand Reduction	0.293306 kW
Measure Life	15 years

Solar water heaters utilize solar energy to heat water, which reduces electricity required to heat water.

#### 2.14.12.13.1 Eligibility

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This protocol documents the energy savings attributed to solar water in PA. The target sector primarily consists of single-family residences.

#### 2.14.22.13.2 Algorithms

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The energy savings calculation utilizes average performance data for available residential solar and standard water heaters and typical water usage for residential homes. The energy savings are obtained through the following formula:

$$\Delta kWh = \frac{\left\{ \left( \frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}} \right) \times \left( HW \times 365 \times 8.3 \frac{lb}{gal} \times (T_{hot} - T_{cold}) \right) \right\}}{3413 \frac{Btu}{kWh}}$$

The energy factor used in the above equation represents an average energy factor of market available solar water heaters<sup>69</sup>. The demand reduction is taken as the annual energy *usage* of the baseline water heater multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage. Note that this is a different formulation than the demand savings calculations for other water heaters. This modification of the formula reflects the fact that a solar water heater's capacity is subject to seasonal variation, and that during the peak summer season (top 100 hours), the water heater is expected to fully supply all domestic hot water needs.

$$\Delta kWh_{peak} = EnergyToDemandFactor \times BaseEnergy Usage$$

The Energy to Demand Factor is defined below:

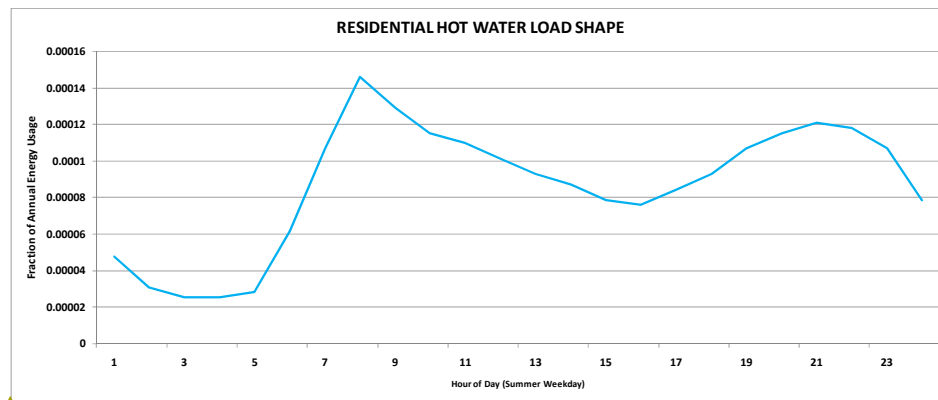
$$EnergyToDemandFactor = \frac{Average Usage_{Summer WD Noon-8}}{Annual Energy Usage}$$

69 We have taken the average energy factor for all solar water heaters with collector areas of 50 ft<sup>2</sup> or smaller from <http://www.solar-rating.org/ratings/ratings.htm>. As a cross check, we have calculated that the total available solar energy in PA for the same set of solar collectors is about twice as much as the savings claimed herein – that is, there is sufficient solar capacity to actualize an average energy factor of 1.84.

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM<sup>70</sup>. The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory<sup>71</sup>, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, and 183 spring/fall days) to obtain annual energy usage.
2. Obtain the average kW during noon to 8 PM on summer days from the same data. Noon to 8 PM is used because most of the top 100 hours (over 80%) occur during noon and 8 PM<sup>72</sup>.
3. The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study<sup>73</sup>.
4. The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor*.

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted for three business types in [Figure 2-6](#)



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70 Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>

71 The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled "Mean", in tables 14, 15, and 16 in pages 5-31 and 5-32

72 On the other hand, the band would have to expanded to at least 12 hours to capture all 100 hours.

73 The 5th column, labeled "Mean" of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher on weekends than on weekdays.

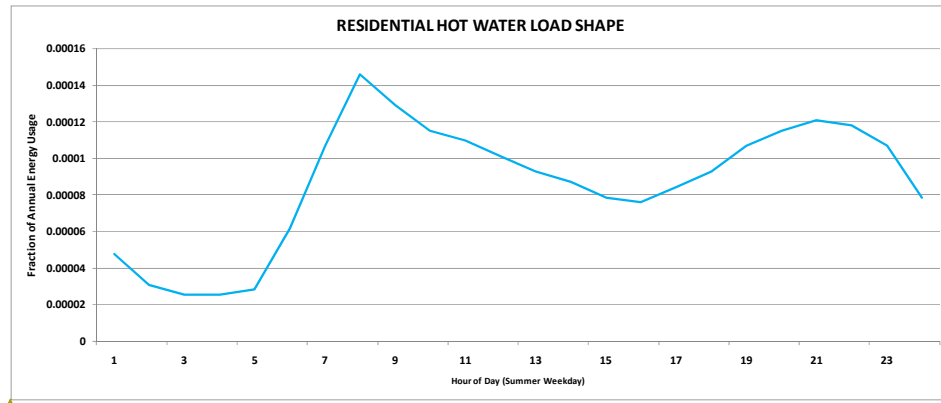


Figure 2-6: Load shapes for hot water in residential buildings taken from a PJM study.

**2.14.32.13.3 Definition of Terms**

The parameters in the above equation are listed in [Table 2-26](#)[Table 2-24](#)[Table 2-26](#)[Table 2-26](#).

Table 2-26: Solar Water Heater Calculation Assumptions

Component	Type	Values	Source
EF <sub>base</sub> , Energy Factor of baseline electric heater	Fixed Variable	0.904 <a href="#">See Table 2-27</a>	6
		Default: .904 (50 gallon)	6
EF <sub>proposed</sub> , Year-round average Energy Factor of proposed solar water heater	Fixed Variable	1.84 <a href="#">EDC Data Gathering</a>	4 <a href="#">EDC Data Gathering</a>
		Default: 1.84	1
HW, Hot water used per day in gallons	Fixed	50 gallon/day	7
T <sub>hot</sub> , Temperature of hot water	Fixed	120 F	8
T <sub>cold</sub> , Temperature of cold water supply	Fixed	55 F	9
Default Baseline Energy Usage (kWh)	Calculated	3,194	
EnergyToDemandFactor: Ratio of average Noon to 8 PM usage during summer peak to annual energy usage	Fixed	0.00009172	2-5

**2.13.4 Energy Factors based on Tank Size**

*Federal standards for Energy Factors (EF) are equal to 0.97 – (.00132 x Rated Storage in Gallons). The following table shows the Energy Factors for various tank sizes:*

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**Table 2-27: Energy Factors Based on Tank Size**

<u>Tank Size (gallons)</u>	<u>Energy Factor</u>
<u>40</u>	<u>0.9172</u>
<u>50</u>	<u>0.9040</u>
<u>65</u>	<u>0.8842</u>
<u>80</u>	<u>0.8644</u>
<u>120</u>	<u>0.8116</u>

**Sources:**

1. The average energy factor for all solar water heaters with collector areas of 50 ft<sup>2</sup> or smaller is from <http://www.solar-rating.org/ratings/ratings.htm>. As a cross check, we have calculated that the total available solar energy in PA for the same set of solar collectors is about twice as much as the savings claimed herein – that is, there is sufficient solar capacity to actualize an average energy factor of 1.84.
2. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>
3. The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled “Mean”, in tables 14,15, and 16 in pages 5-31 and 5-32
4. On the other hand, the band would have to be expanded to at least 12 hours to capture all 100 hours.
5. The 5th column, labeled “Mean” of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher is the weekends than on weekdays.
6. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank, this is approximately 0.90. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: EE–2006–BT–STD–0129, p. 30
7. “Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters”, Federal Register / Vol. 63, No. 90, pp. 26005-26006.
8. [Pennsylvania Statewide Residential End-Use and Saturation Study. 2012.](#)
- 8.1. ~~Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.~~
9. Mid-Atlantic TRM, footnote #24

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#### ~~2.14.4~~ **Deemed Savings**

#### **2.13.5 Deemed Savings (based on default values)**

$$\Delta kWh = 1,623,698 kWh$$

$$\Delta kW_{peak} = 0.293,306 kW$$

#### ~~2.14.52.13.6~~ **Measure Life**

The expected useful life is 1574 years, according to ENERGY STAR<sup>75</sup>.

#### ~~2.14.62.13.7~~ **Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

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<sup>74</sup> The actual measure life for the Solar Water Heater measure is 20 years according to ENERGY STAR, but is reduced to 15 years per Act 129.

<sup>75</sup> [http://www.energystar.gov/index.cfm?c=solar\\_wheat.pr\\_savings\\_benefits](http://www.energystar.gov/index.cfm?c=solar_wheat.pr_savings_benefits)

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## 2.15.2.14 Electric Water Heater Pipe Insulation

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Measure Name	Electric Water Heater Pipe Insulation
Target Sector	Residential Establishments
Measure Unit	Water Heater
Unit Energy Savings	<del>96 kWh</del> Default: 9.6 kWh per foot of installed insulation
Unit Peak Demand Reduction	<del>0.0088 kW</del> 0.0088 kW per foot of installed insulation
Measure Life	13 years

This measure relates to the installation of foam insulation and reducing the water heating set point from 3-4 degrees Fahrenheit on 10 feet of exposed pipe in unconditioned space, ¾" thick. The baseline for this measure is a standard efficiency electric water heater (EF=0.904) with an annual energy usage of 3,191 kWh.<sup>76</sup>

### 2.15.12.14.1 Eligibility

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This protocol documents the energy savings for an electric water heater attributable to insulating 10 feet of exposed pipe in unconditioned space, ¾" thick. The target sector primarily consists of residential residences.

### 2.15.22.14.2 Algorithms

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The annual energy savings are assumed to be 3% of the annual energy use of an electric water heater (3,191 kWh), or 96 kWh based on 10 feet of insulation. This estimate is based on a recent report prepared by the ACEEE for the State of Pennsylvania.<sup>77</sup> On a per foot basis, this is equivalent to 9.6 kWh.

$$\Delta kWh = 96.6 \text{ kWh} \text{ per foot of installed insulation}$$

The summer coincident peak kW savings are calculated as follows:

$$\Delta kW_{peak} = \Delta kWh * EnergyToDemandFactor$$

### 2.15.32.14.3 Definition of Terms

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$$\Delta kWh = \text{Annual kWh savings} = 96.6 \text{ kWh per } 10 \text{ ft-foot of installed insulation}$$

$$EnergyToDemandFactor = \text{Summer peak coincidence factor for measure} = 0.00009172^{78}$$

<sup>76</sup> See Section 2.3 for assumptions used to calculate annual energy usage.

<sup>77</sup> American Council for an Energy-Efficient Economy, Summit Blue Consulting, Vermont Energy Investment Corporation, ICF International, and Synapse Energy Economics, Potential for Energy Efficiency, Demand Response, and Onsite Solar Energy in Pennsylvania, Report Number E093, April 2009, p. 117.

<sup>78</sup> Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>



$$\Delta kW_{peak} = \text{Summer peak kW savings} = \underline{0.0088 \text{ kW}} \cdot \underline{0.0088 \text{ kW per foot of installed insulation}}$$

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage. The Energy to Demand Factor is defined as:

$$\text{EnergyToDemandFactor} = \frac{\text{Average Usage}_{\text{Summer WD Noon-8}}}{\text{Annual Energy Usage}}$$

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM<sup>79</sup>. The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, and 183 spring/fall days) to obtain annual energy usage.
2. Obtain the average kW during noon to 8 PM on summer days from the same data.
3. The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study,
4. The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the Energy to Demand Factor, or Coincidence Factor.

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted in [Figure 2-7](#).

<sup>79</sup> Op. cit.

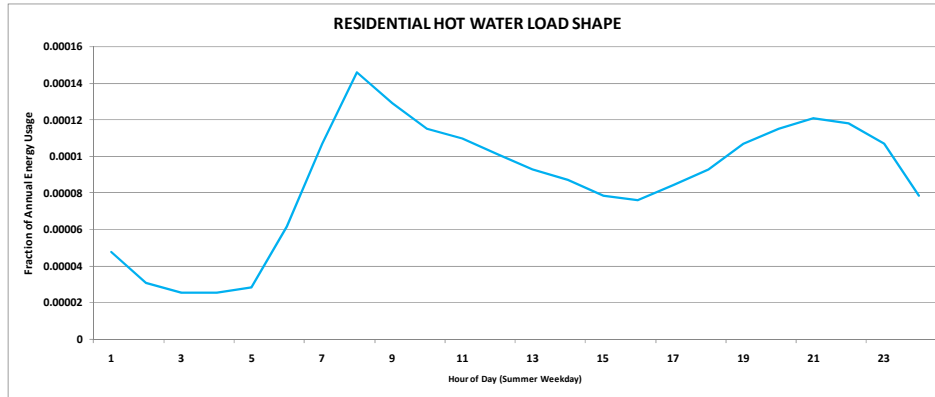


Figure 2-7: Load shapes for hot water in residential buildings taken from a PJM study.

#### 2.15.42.14.4 Measure Life

According to the Efficiency Vermont Technical Reference User Manual (TRM), the expected measure life is **13 years**<sup>80</sup>.

#### 2.15.52.14.5 Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

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<sup>80</sup> Efficiency Vermont, Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions, TRM User Manual No. 2008-53, 07/18/08.

### 2.462.15 Residential Whole House Fans

Measure Name	Whole House Fans
Target Sector	Residential Establishments
Measure Unit	Whole House Fan
Unit Energy Savings	Varies by location (187 kWh/yr to 232 kWh/yr)
Unit Peak Demand Reduction	0 kW
Measure Life	15 years

This measure applies to the installation of a whole house fan. The use of a whole house fan will offset existing central air conditioning loads. Whole house fans operate when the outside temperature is less than the inside temperature, and serve to cool the house by drawing cool air in through open windows and expelling warmer air through attic vents.

The baseline is taken to be an existing home with central air conditioning (CAC) and without a whole house fan.

The retrofit condition for this measure is the installation of a new whole house fan.

#### 2.46.12.15.1 Algorithms

The energy savings for this measure result from reduced air conditioning operation. While running, whole house fans can consume up to 90% less power than typical residential central air conditioning units.<sup>81</sup> Energy savings for this measure are based on whole house fan energy savings values reported by the energy modeling software, REM/Rate<sup>82</sup>.

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#### 2.46.22.15.2 Model Assumptions

- The savings are reported on a "per house" basis with a modeled baseline cooling provided by a SEER 10 Split A/C unit.
- Savings derived from a comparison between a naturally ventilated home and a home with a whole-house fan.
- 2181 square-foot single-family detached home built over unconditioned basement.<sup>83</sup>

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<sup>81</sup> *Whole House Fan, Technology Fact Sheet*, (March 1999), Department of Energy Building Technologies Program, DOE/GO-10099-745, accessed October 2010

[http://www.energysavers.gov/your\\_home/space\\_heating\\_cooling/related.cfm/mytopic=12357](http://www.energysavers.gov/your_home/space_heating_cooling/related.cfm/mytopic=12357)

<sup>82</sup> Architectural Energy Corporation, REM/Rate v12.85.

<sup>83</sup> EIA (2005), Table HC1.1.3: "Housing Unit Characteristics by Average Floorspace",

[http://www.eia.doe.gov/emeu/recs/recs2005/hc2005\\_tables/hcfloorspace/pdf/tablehc1.1.3.pdf](http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/hcfloorspace/pdf/tablehc1.1.3.pdf) Used Single Family Detached "Heated" value for Mid-Atlantic region as representative of the living space cooled by a 10 SEER Split A/C unit. The floorspace recorded for "Cooling" is likely to be affected by Room A/C use.

Table 2-282528: Whole House Fan Deemed Energy Savings by PA City

City	Annual Energy Savings (kWh/house)
Allentown	204
Erie	200
Harrisburg	232
Philadelphia	229
Pittsburgh	199
Scranton	187
Williamsport	191

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This measure assumes no demand savings as whole house fans are generally only used during milder weather (spring/fall and overnight). Peak 100 hours typically occur during very warm periods when a whole house fan is not likely being used.

**2.16.32.15.3 Measure Life**

Measure life = 20 years<sup>84</sup> (15 year maximum for PA TRM)

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<sup>84</sup> DEER EUL Summary, Database for Energy Efficient Resources, accessed October 2010, [http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

### 2.17.2.16 Ductless Mini-Split Heat Pumps

Measure Name	Ductless Heat Pumps
Target Sector	Residential Establishments
Measure Unit	Ductless Heat Pumps
Unit Energy Savings	Variable based on efficiency of systems
Unit Peak Demand Reduction	Variable based on efficiency of systems
Measure Life	15 years

ENERGY STAR ductless “mini-split” heat pumps utilize high efficiency SEER/EER and HSPF energy performance factors of 14.5/12 and 8.2, respectively, or greater. This technology typically converts an electric resistance heated home into an efficient single or multi-zonal ductless heat pump system. Homeowners have choice to install an ENERGY STAR qualified model or a standard efficiency model.

#### 2.17.12.16.1 Eligibility

This protocol documents the energy savings attributed to ductless mini-split heat pumps with energy efficiency performance of 14.5/12 SEER/EER and 8.2 HSPF or greater with inverter technology.<sup>85</sup> The baseline heating system could be an existing electric resistance heating, a lower-efficiency ductless heat pump system, a ducted heat pump, electric furnace, or a non-electric fuel-based system. The baseline cooling system can be a standard efficiency heat pump system, central air conditioning system, or room air conditioner. In addition, this could be installed in new construction or an addition. For new construction or addition applications, the baseline assumption is a standard-efficiency ductless unit. The DHP systems could be installed as the primary heating or cooling system for the house or as a secondary heating or cooling system for a single room.

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#### 2.17.22.16.2 Algorithms

The savings depend on three main factors: baseline condition, usage (primary or secondary heating system), and the capacity of the indoor unit.

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The algorithm is separated into two calculations: single zone and multi-zone ductless heat pumps. The savings algorithm is as follows:

##### Single Zone:

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{heat} = CAPY_{heat}/1000 \times (1/HSPF_b - 1/HSPF_e) \times EFLH_{heat} \times LF$$

$$\Delta kWh_{cool} = CAPY_{cool}/1000 \times (1/SEER_b - 1/SEER_e) \times EFLH_{cool} \times LF$$

<sup>85</sup> The measure energy efficiency performance is based on ENERGY STAR minimum specification requirements as specified in ARHI and CEE directory for ductless mini-split heat pumps. Ductless heat pumps fit these criteria and can easily exceed SEER levels of 16 or greater.

$$\Delta kW_{peak} = CAPY_{cool}/1000 \times (1/EER_b - 1/EER_e) \times CF$$

**Multi-Zone:**

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\begin{aligned} \Delta kWh_{heat} &= [CAPY_{heat}/1000 \times (1/HSPF_b - 1/HSPF_e) \times EFLH_{heat} \times LF]_{ZONE1} \\ &+ [CAPY_{heat}/1000 \times (1/HSPF_b - 1/HSPF_e) \times EFLH_{heat} \times LF]_{ZONE2} \\ &+ [CAPY_{heat}/1000 \times (1/HSPF_b - 1/HSPF_e) \times EFLH_{heat} \times LF]_{ZONE n} \end{aligned}$$

$$\begin{aligned} \Delta kWh_{cool} &= [CAPY_{cool}/1000 \times (1/SEER_b - 1/SEER_e) \times EFLH_{cool} \times LF]_{ZONE1} \\ &+ [CAPY_{cool}/1000 \times (1/SEER_b - 1/SEER_e) \times EFLH_{cool} \times LF]_{ZONE2} \\ &+ [CAPY_{cool}/1000 \times (1/SEER_b - 1/SEER_e) \times EFLH_{cool} \times LF]_{ZONE n} \end{aligned}$$

$$\begin{aligned} \Delta kW_{peak} &= [CAPY_{cool}/1000 \times (1/EER_b - 1/EER_e) \times CF]_{ZONE1} + \\ &[CAPY_{cool}/1000 \times (1/EER_b - 1/EER_e) \times CF]_{ZONE2} + \\ &[CAPY_{cool}/1000 \times (1/EER_b - 1/EER_e) \times CF]_{ZONE n} \end{aligned}$$

**2.17.32.16.3 Definition of Terms**

$CAPY_{cool, heat}$	= The cooling or heating (at 47° F) capacity of the indoor unit, given in BTUH as appropriate for the calculation
$EFLH_{cool, heat}$	= Equivalent Full Load Hours – If the unit is installed as the primary heating or cooling system, as defined in Table 2-27, the EFLH will use the EFLH primary hours listed in Table 2-26. If the unit is installed as a secondary heating or cooling system, the EFLH will use the EFLH secondary hours listed in Table 2-26.
$HSPF_b$	= Heating efficiency of baseline unit
$HSPF_e$	= Efficiency of the installed DHP
$SEER_b$	= Cooling efficiency of baseline unit
$SEER_e$	= Efficiency of the installed DHP
$EER_b$	= The Energy Efficiency Ratio of the baseline unit
$EER_e$	= The Energy Efficiency Ratio of the efficient unit
$LF$	= Load factor

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Table 2-292629: DHP – Values and References

Component	Type	Values	Sources
CAPY <sub>cool</sub> CAPY <sub>heat</sub>	Variable	EDC Data Gathering	AEPS Application; EDC Data Gathering
EFLH primary	Fixed	Allentown Cooling = 487 Hours Allentown Heating = 1,193 Hours Erie Cooling = 389 Hours Erie Heating = 1,349 Hours Harrisburg Cooling = 551 Hours Harrisburg Heating = 1,103 Hours Philadelphia Cooling = 591 Hours Philadelphia Heating = 1,060 Hours Pittsburgh Cooling = 432 Hours Pittsburgh Heating = 1,209 Hours Scranton Cooling = 417 Hours Scranton Heating = 1,296 Hours Williamsport Cooling = 422 Hours Williamsport Heating = 1,251 Hours	1
	Optional	An EDC can estimate it's own EFLH based on customer billing data analysis.	EDC Data Gathering
EFLH secondary	Fixed	Allentown Cooling = 243 Hours Allentown Heating = 800 Hours Erie Cooling = 149 Hours Erie Heating = 994 Hours Harrisburg Cooling = 288 Hours Harrisburg Heating = 782 Hours Philadelphia Cooling = 320 Hours Philadelphia Heating = 712 Hours Pittsburgh Cooling = 228 Hours Pittsburgh Heating = 848 Hours Scranton Cooling = 193 Hours Scranton Heating = 925 Hours Williamsport Cooling = 204 Hours Williamsport Heating = 875 hours	2, 3
HSPF <sub>b</sub>	Fixed	Standard DHP: 7.7 Electric resistance: 3.413 ASHP: 7.7 Electric furnace: 3.242 No existing or non-electric heating: use standard DHP: 7.7	4, 6

Component	Type	Values	Sources
SEER <sub>b</sub>	Fixed	DHP, ASHP, or central AC: 13 Room AC: 11 No existing cooling for primary space: use DHP, ASHP, or central AC: 13 No existing cooling for secondary space: use Room AC: 11	5, 6, 7
HSPF <sub>e</sub>	Variable	Based on nameplate information. Should be at least ENERGY STAR.	AEPS Application; EDC Data Gathering
SEER <sub>e</sub>	Variable	Based on nameplate information. Should be at least ENERGY STAR.	AEPS Application; EDC Data Gathering
CF	Fixed	70%	8
EER <sub>b</sub>	Fixed	= (11.3/13) X SEER <sub>b</sub> for DHP or central AC = 9.8 room AC	5,9
EER <sub>e</sub>	Variable	= (11.3/13) X SEER <sub>e</sub> Based on nameplate information. Should be at least ENERGY STAR.	AEPS Application; EDC Data Gathering
LF	Fixed	25%	10

#### Sources:

1. Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models assume 50% oversizing of air conditioners<sup>86</sup> and 40% oversizing of heat pumps.<sup>87</sup>
2. Secondary cooling load hours based on room air conditioner “corrected” EFLH work paper that adjusted the central cooling hours to room AC cooling hours; see Section 2.12 Room AC Retirement measure.
3. Secondary heating hours based on a ratio of HDD base 68 and base 60 deg F. The ratio is used to reflect the heating requirement for secondary spaces is less than primary space as the thermostat set point in these spaces is generally lowered during unoccupied time periods.
4. COP = 3.413 HSPF for electric resistance heating. Electric furnace efficiency typically varies from 0.95 to 1.00 and thereby assumed a COP 0.95 = 3.242.
5. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.

<sup>86</sup> Neme, Proctor, Nadal, “National Energy Savings Potential From Addressing Residential HVAC Installation Problems. ACEEE, February 1, 1999. Confirmed also by *Central Air Conditioning in Wisconsin, a compilation of recent field research*. Energy Center of Wisconsin. May 2008, emended December 15, 2010

<sup>87</sup> ACCA, “Verifying ACCA Manual S Procedures,” <http://www.acca.org/Files/?id=67>.



6. Air-Conditioning, Heating, and Refrigeration Institute (AHRI); the directory of the available ductless mini-split heat pumps and corresponding efficiencies (lowest efficiency currently available). Accessed 8/16/2010.
7. SEER based on average EER of 9.8 for room AC unit. From Pennsylvania's Technical Reference Manual.
8. Based on an analysis of six different utilities by Proctor Engineering. From Pennsylvania's Technical Reference Manual.
9. Average EER for SEER 13 unit. From Pennsylvania's Technical Reference Manual.
10. The load factor is used to account for inverter-based DHP units operating at partial loads. The value was chosen to align savings with what is seen in other jurisdictions, based on personal communication with Bruce Manclark, Delta-T, Inc., who is working with Northwest Energy Efficiency Alliance (NEEA) on the Northwest DHP Project <<http://www.nwductless.com/>>, and the results found in the "Ductless Mini Pilot Study" by KEMA, Inc., June 2009. This adjustment is required to account for partial load conditions and because the EFLH used are based on central ducted systems which may overestimate actual usage for baseboard systems.

#### **2.17.42.16.4 Definition of Heating Zone**

Definition of primary and secondary heating systems depends primarily on the location where the source heat is provided in the household, and shown in [Table 2-30Table 2-2730](#).

Table 2-~~30~~~~2730~~: DHP – Heating Zones

Component	Definition
Primary Heating Zone	Living room Dining room House hallway Kitchen areas Family Room Recreation Room
Secondary Heating Zone	Bedroom Bathroom Basement Storage Room Office/Study Laundry/Mudroom Sunroom/Seasonal Room

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#### **2.17.52.16.5 Measure Life**

According to an October 2008 report for the CA Database for Energy Efficiency Resources, a heat pump's lifespan is **15 years**.<sup>88</sup>

<sup>88</sup> DEER values, updated October 10, 2008. Various sources range from 12 to 20 years, DEER represented a reasonable mid-range. [http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

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**2.17.62.16.6 Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings. A sample of pre- and post-metering is recommended to verify heating and cooling savings.

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### 2.18.17 Fuel Switching: Domestic Hot Water Electric to Gas, Oil, or Propane

Measure Name	Fuel Switching: DHW Electric to Gas
Target Sector	Residential
Measure Unit	Water Heater
Unit Energy Savings	3,494,338 kWh
Unit Peak Demand Reduction	0.293,306 kW
Gas Consumption, Fossil Fuel Consumption Increase	46.58 Gas: 15.38 MMBtu Propane: 15.38 MMBtu Oil: 20.04 MMBtu
Measure Life	Gas: 13 years Propane: 13 years Oil: 8 years

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Natural gas, propane and oil water heaters generally offer the customer lower costs compared to standard electric water heaters. Additionally, they typically see an overall energy savings when looking at the source energy of the electric unit versus the gas-fossil fuel-fired unit. Standard-Federal standard electric water heaters have energy factors of 0.904 for a 50 gal unit and a federal standard efficiency gas and propane-fired water heater have an energy factor of 0.59467 for a 40gal unit and 0.514 for an oil-fired 40 gal unit<sup>89</sup>.

#### 2.18.12.17.1 Eligibility

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#### 2.18.2 Eligibility

This protocol documents the energy savings attributed to converting from a standard electric water heater with Energy Factor of 0.904 or greater to a standard ENERGY STAR natural gas or propane water heater with Energy Factor of 0.59467 or greater, and 0.514 for oil water heater. The target sector primarily consists of single-family residences.

#### 2.18.32.17.2 Algorithms

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The energy savings calculation utilizes average performance data for available residential standard electric and natural gas fossil fuel-fired water heaters and typical water usage for residential homes. Because there is little electric energy associated with a natural gas fossil fuel-fired water heater, the energy savings are the full energy utilization of the electric water heater. The energy savings are obtained through the following formula:

$$\Delta kWh = \left\{ \left( \frac{1}{EF_{Elec,bl}} \right) \times \left( HW \times 365 \times \frac{days}{yr} \times 1 \frac{BTU}{lb-F} \times 8.3 \frac{lb}{gal} \times (T_{hot} - T_{cold}) \right) \right\} \frac{Btu}{kWh}$$

<sup>89</sup> RECS 2009 data indicate that the most common size is 31 to 49 gal. An average of 40 gal unit is considered for this protocol. <http://www.eia.gov/consumption/residential/data/2009/>.

Although there is a significant electric savings, there is an associated increase in natural gas/fossil fuel energy consumption. While this gas/fossil fuel consumption does not count against PA Act 129 energy savings, it is expected to be used in the program TRC test. The increased natural gas-energy/fossil fuel usage is obtained through the following formula:

$$\text{GasFuel Consumption (MMBtu)} = \frac{\left\{ \left( \frac{1}{EF_{NG,inst}} \right) \times \left( HW \times 365 \times 8.3 \frac{\text{lb}}{\text{gal}} \times (T_{hot} - T_{cold}) \right) \right\}}{1,000,000 \frac{\text{Btu}}{\text{MMBtu}}} \left\{ \left( \frac{1}{EF_{fuel,inst}} \right) \times \left( HW \times 365 \frac{\text{days}}{\text{yr}} \times 1 \frac{\text{BTU}}{\text{lb} - F} \times 8.3 \frac{\text{lb}}{\text{gal}} \times (T_{hot} - T_{cold}) \right) \right\} / 1,000,000 \frac{\text{Btu}}{\text{MMBtu}}$$

Demand savings result from the removal of the connected load of the electric water heater. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = \text{EnergyToDemandFactor} \times \text{Energy Savings}$$

The Energy to Demand Factor is defined below:

$$\text{EnergyToDemandFactor} = \frac{\text{Average Usage}_{\text{Summer WD Noon-8}}}{\text{Annual Energy Usage}}$$

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM<sup>90</sup>. The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory<sup>91</sup>, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, and 183 spring/fall days) to obtain annual energy usage.
2. Obtain the average kW during noon to 8 PM on summer days from the same data.
3. The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study<sup>92</sup>.
4. The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor*.

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted in [Figure 2-8](#).

90 Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>

91 The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled "Mean", in tables 14,15, and 16 in pages 5-31 and 5-32

92 The 5th column, labeled "Mean" of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher is the weekends than on weekdays.

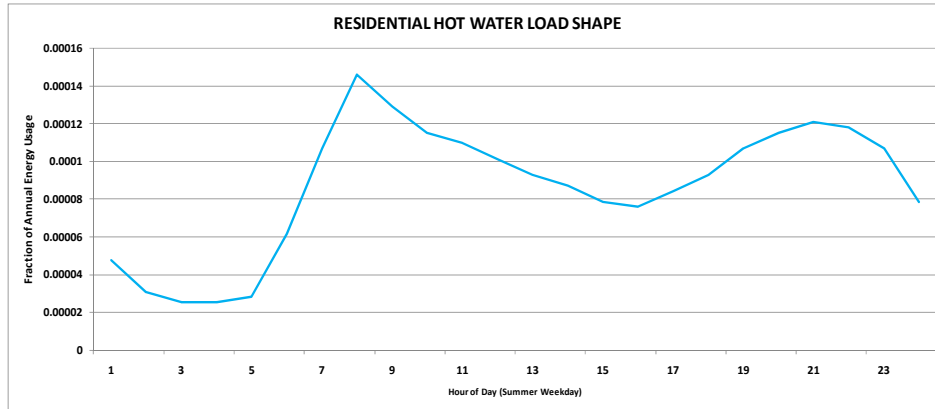


Figure 2-8: Load shapes for hot water in residential buildings taken from a PJM.

**2.18.42.17.3 Definition of Terms**

The parameters in the above equation are listed in [Table 2-31](#)[Table 2-2831](#) below.

Table 2-~~31~~~~2831~~: Calculation Assumptions for Fuel Switching, Domestic Hot Water Electric to Gas

Component	Type	Values	Source
EF <sub>elect,bl</sub> , Energy Factor of baseline water heater	Fixed/Variable	0.904 or EDC Data Gathering	4
EF <sub>NG,inst</sub> , Energy Factor of installed natural gas water heater*	Variable	>=0.59467	5
EF <sub>Propane,inst</sub> , Energy Factor of installed propane water heater*	Variable	>=0.67	5
EF <sub>Oil,inst</sub> , Energy Factor of installed oil water heater*	Variable	>=0.514	6
HW, Hot water used per day in gallons	Fixed	50 gallon/day	67
T <sub>hot</sub> , Temperature of hot water	Fixed	120-123 °F	7
T <sub>cold</sub> , Temperature of cold water supply	Fixed	55 °F	8
EnergyToDemandFactor	Fixed	0.00009172	1-3

\* For tankless water heaters, the EF should be at least 0.82

**2.17.4 Energy Factors based on Tank Size**

Federal Standards for Energy Facotrs are equal to 0.97 -0.00132 x Rated Storage in Gallons. The following table shows the Energy Factors for various tank sizes.

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**Table 2-32: Energy Factors based on Tank Size**

<u>Tank Size (gallons)</u>	<u>Energy Factor</u>
<u>40</u>	<u>0.9172</u>
<u>50</u>	<u>0.9040</u>
<u>65</u>	<u>0.8842</u>
<u>80</u>	<u>0.8644</u>
<u>120</u>	<u>0.8116</u>

**Sources:**

1. Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online:  
<http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>
2. The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled "Mean", in tables 14, 15, and 16 in pages 5-31 and 5-32
3. The 5th column, labeled "Mean" of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher on the weekends than on weekdays.
4. Federal Standards are  $0.97 - 0.00132 \times \text{Rated Storage in Gallons}$ . For a 50-gallon tank this is 0.904. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE-2006-BT-STD-0129, p. 30
5. [Commission Order<sup>93</sup> requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the EnergyStar standard for Gas Storage Water Heaters beginning September 1, 2010. From Residential Water Heaters Key Product Criteria.](#)  
[http://www.energystar.gov/index.cfm?c=water\\_heat.pr\\_crit\\_water\\_heaters](http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters) Accessed June 2013
5. Federal Standards are  $0.67 - 0.0019 \times \text{Rated Storage in Gallons}$ : [for oil-fired storage water heater](#). For a 40-gallon tank this is [0.594514](#). "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE-2006-BT-STD-0129, p. 30
6. [307](#). "Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters", Federal Register / Vol. 63, No. 90, p. 26005-26006.

<sup>93</sup> See page 42 of the 2013 TRC Test Final Order

7-8. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.

8-7. [Pennsylvania Statewide Residential End-Use and Saturation Study, 2012, page 42.9.](#)  
Mid-Atlantic TRM, footnote #24

**2.18.52.17.5 Deemed Savings**

The deemed savings for the installation of a natural gas/[propane/oil](#) water heater in place of a standard electric water heater are listed in [Table 2-33](#)~~Table 2-2933~~ below.

Table 2-~~332933~~33: Energy Savings and Demand Reductions for Fuel Switching, Domestic Hot Water Electric to [GasFossil Fuel](#)

Electric unit Energy Factor	Energy Savings (kWh)	Demand Reduction (kW)
0.904	<a href="#">3,4943338</a>	<a href="#">0.293306</a>

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The deemed [gasfossil fuel](#) consumption for the installation of a standard efficiency natural gas/[propane/oil](#) water heater in place of a standard electric water heater is listed in [Table 2-34](#)~~Table 2-3034~~ below.

Table 2-~~343034~~34: [GasFuel](#) Consumption for Fuel Switching, Domestic Hot Water Electric to [GasFossil Fuel](#)

<a href="#">Fuel Type</a>	<a href="#">Gas unit Energy Factor</a>	<a href="#">GasFossil Fuel Consumption (MMBtu)</a>
<a href="#">Gas</a>	<a href="#">0.59467</a>	<a href="#">16.581537</a>
<a href="#">Propane</a>	<a href="#">0.67</a>	<a href="#">15.37</a>
<a href="#">Oil</a>	<a href="#">0.514</a>	<a href="#">20.04</a>

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Note that 1 MMBtu of propane is equivalent to 10.87 gals of propane, and 1 MMBtu of oil is equivalent to 7.19 gals of oil<sup>94</sup>.

**2.17.6 Measure Life**

According to an October 2008 report for the CA Database for Energy Efficiency Resources, gas and propane water heaters' lifespans are **13 years**. An oil water heater's lifespan is 8 years.<sup>95</sup>

**2.18.62.17.7 Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

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94 [http://www.energystar.gov/ia/business/industry/industry\\_challenge/QuickConverter.xls](http://www.energystar.gov/ia/business/industry/industry_challenge/QuickConverter.xls)  
95 DEER values, updated October 10, 2008:  
[http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

**2.18.7 Measure Life**

~~According to an October 2008 report for the CA Database for Energy Efficiency Resources, a gas water heater's lifespan is 13 years<sup>96</sup>.~~

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**2.18.8 Evaluation Protocols**

~~The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.~~

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<sup>96</sup> DEER values, updated October 10, 2008:-  
[http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)



### 2.19.2.18 Fuel Switching: Heat Pump Water Heater to Gas, Oil or Propane Water Heater

Measure Name	Fuel Switching: Heat Pump Water Heater to Gas Water Heater
Target Sector	Residential
Measure Unit	Water Heater
Unit Energy Savings	1,717kWh (for EF = 2.0)
Unit Peak Demand Reduction	0.157 kW
Gas Consumption Increase	16.58 MMBtu
Measure Life	13 years
Unit Energy Savings	1,793 kWh (for EF = 2.0)
Unit Peak Demand Reduction	0.164 kW
Gas, Fossil Fuel Consumption Increase	Gas: 15.38 MMBtu Propane: 15.38 MMBtu Oil: 20.04 MMBtu
Measure Life	Gas: 13 years Propane: 13 years Oil: 8 years

Natural gas ~~water, propane and oil~~water heaters reduce electric energy and demand compared to heat pump water heaters. Standard heat pump water heaters have energy factors of 2.0 and ~~a federal standard efficiency~~ENERGY STAR gas ~~and propane water heater has~~heaters have an energy factor of 0.59467 for a 40gal unit, ~~and 0.514 for an oil-fired 40 gal unit.~~

#### 2.19.12.18.1 Eligibility

#### 2.19.2 Eligibility

This protocol documents the energy savings attributed to converting from a standard heat pump water heater with Energy Factor of 2.0 or greater to ~~a standard~~an ENERGY STAR natural gas ~~or propane~~ water heater with Energy Factor of 0.59467 or greater ~~and 0.514 for an oil water heater.~~ The target sector primarily consists of single-family residences.

#### 2.19.32.18.2 Algorithms

The energy savings calculation utilizes average performance data for available residential standard heat pump water heaters and ~~natural gas~~fossil fuel-fired water heaters and typical water usage for residential homes. Because there is little electric energy associated with a ~~natural gas~~fossil fuel-fired water heater, the energy savings are the full energy utilization of the heat pump water heater. The energy savings are obtained through the following formula:

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$$\Delta kWh = \frac{\left\{ \left( \frac{1}{EF_{HP,bl} \times F_{Derate}} \right) \times \left( HW \times 365 \times 8.3 \frac{lb}{gal} \times (T_{hot} - T_{cold}) \right) \right\}}{3413 \frac{Btu}{kWh}}$$

Although there is a significant electric savings, there is an associated increase in **natural gas energy fossil fuel energy** consumption. While this **gas fossil fuel** consumption does not count against PA Act 129 energy savings, it is expected to be used in the program TRC test. The increased **natural gas energy fossil fuel energy** is obtained through the following formula:

$$\text{Gas Fossil Fuel Consumption (MMBtu)} = \frac{\left\{ \left( \frac{1}{EF_{NG,inst}} \right) \times \left( HW \times 365 \times 8.3 \frac{lb}{gal} \times (T_{hot} - T_{cold}) \right) \right\}}{1,000,000 \frac{Btu}{MMBtu}}$$

Demand savings result from the removal of the connected load of the heat pump water heater. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage.

$$\text{Demand Savings} = \text{EnergyToDemandFactor} \times \text{Energy Savings}$$

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The Energy to Demand Factor is defined below:

$$\text{EnergyToDemandFactor} = \frac{\text{Average Usage}_{\text{Summer WD Noon-8}}}{\text{Annual Energy Usage}}$$

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM<sup>97</sup>. The factor is constructed as follows:

1. Obtain the average kW, as monitored for 82 water heaters in PJM territory<sup>98</sup>, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, and 183 spring/fall days) to obtain annual energy usage.
2. Obtain the average kW during noon to 8 PM on summer days from the same data.
3. The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study<sup>99</sup>.
4. The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor*.

97 Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>

98 The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled "Mean", in tables 14, 15, and 16 in pages 5-31 and 5-32

99 The 5th column, labeled "Mean" of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher on weekends than on weekdays.

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted in Figure 2-9.

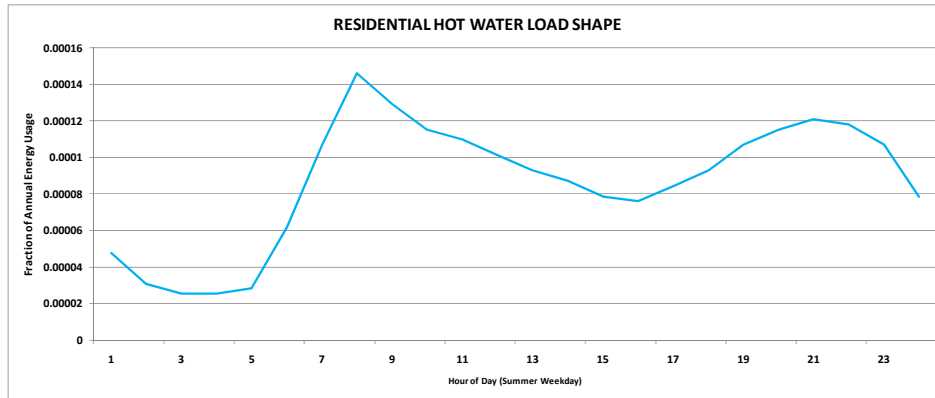


Figure 2-9: Load shapes for hot water in residential buildings taken from a PJM.

**2.19.42.18.3 Definition of Terms**

The parameters in the above equation are listed in [Table 2-35Table 2-3135](#).

Table 2-~~353135~~: Calculation Assumptions for Heat Pump Water Heater to ~~GasFossil Fuel Water HeaterHeaters~~

Component	Type	Values	Source
EF <sub>HP,bl</sub> , Energy Factor of baseline heat pump water heater	FixedVariable	Default ≥ 2.0_ or EDC Data Gathering	4
EF <sub>NG,inst</sub> , Energy Factor of installed natural gas water heater	Variable	≥ 0.59467	5
EF <sub>Propane,inst</sub> , Energy Factor of installed propane water heater	Variable	≥ 0.67	5
EF <sub>Oil,inst</sub> , Energy Factor of installed oil water heater	Variable	≥ 0.514	6
HW, Hot water used per day in gallons	Fixed	50 gallon/day	6
T <sub>hot</sub> , Temperature of hot water	Fixed	120123 °F	7
T <sub>cold</sub> , Temperature of cold water supply	Fixed	55 °F	8
F <sub>Derate</sub> , COP De-rating factor	Fixed	0.84	9, and discussion below
EnergyToDemandFactor	Fixed	0.00009172	1-3

**Sources:**

[23-1](#). Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online:

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<http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>

- 24.2. The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled “Mean”, in tables 14,15, and 16 in pages 5-31 and 5-32
- 25.3. The 5th column, labeled “Mean” of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer weekday usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher is the weekends than on weekdays.
- 26.4. Heat pump water heater efficiencies have not been set in a Federal Standard. However, the Federal Standard for water heaters does refer to a baseline efficiency for heat pump water heaters as EF = 2.0 “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: **EE-2006-BT-STD-0129**.
- 27.5. Federal Commission Order<sup>100</sup> requires fuel switching to ENERGY STAR measures, not standard efficiency measures. The Energy Factor has therefore been updated to reflect the EnergyStar standard for Gas Storage Water Heaters beginning September 1, 2010. From Residential Water Heaters Key Product Criteria. [http://www.energystar.gov/index.cfm?c=water\\_heat.pr\\_crit\\_water\\_heaters](http://www.energystar.gov/index.cfm?c=water_heat.pr_crit_water_heaters) Accessed June 2013 ederal Standards are 0.67 -0.0019 x Rated Storage in Gallons. ederal Standards are 0.67 -0.0019 x Rated Storage in Gallons. For a 40-gallon tank this is 0.594. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: **EE-2006-BT-STD-0129**, p. 30
- 28.6. “Energy Conservation Program for Consumer Products: Test Procedure for Water Heaters”, **Federal Register** / Vol. 63, No. 90, p. 26005-26006.
7. Pennsylvania Statewide Residential End-Use and Saturation Study, 2012, page 42.
29. ~~Many states have plumbing codes that limit shower and bathtub water temperature to 120°F.~~
- 30.8. Mid-Atlantic TRM, footnote #24

Based on TMY2 weather files from DOE2.com for Erie, Harrisburg, Pittsburgh, Wilkes-Barre, And Williamsport, the average annual wet bulb temperature is  $45 \pm 1.3$  °F. The wet bulb temperature in garages or attics, where the heat pumps are likely to be installed, are likely to be two or three degrees higher, but for simplicity, 45 °F is assumed to be the annual average wet bulb temperature.

<sup>100</sup> [See page 42 of the 2013 TRC Test Final Order.](#)

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#### 2.19.52.18.4 Heat Pump Water Heater Energy Factor

The Energy Factors are determined from a DOE testing procedure that is carried out at 56 °F wet bulb temperature. However, the average wet bulb temperature in PA is closer to 45 °F<sup>101</sup>. The heat pump performance is temperature dependent. The plot in Figure 2-10 shows relative coefficient of performance (COP) compared to the COP at rated conditions<sup>102</sup>. According to the linear regression shown on the plot, the COP of a heat pump water heater at 45 °F is 0.84 of the COP at nominal rating conditions. As such, a de-rating factor of 0.84 is applied to the nominal Energy Factor of the Heat Pump water heaters.

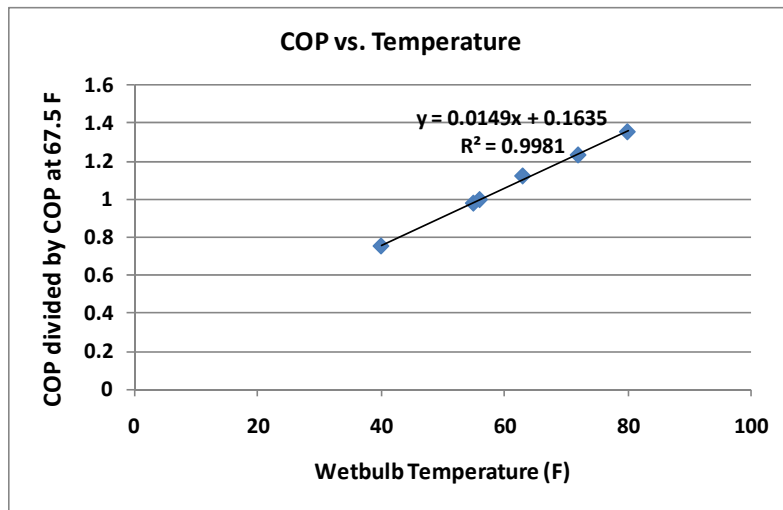


Figure 2-10: Dependence of COP on Outdoor Wet-Bulb Temperature

#### 2.19.62.18.5 Deemed Savings

The deemed savings for the installation of a [natural gas fossil fuel-fired](#) water heater in place of a standard heat pump water heater are listed in [Table 2-36](#) [Table 2-3236](#) below.

<sup>101</sup> Based on TMY2 weather files from DOE2.com for Erie, Harrisburg, Pittsburgh, Wilkes-Barre, And Williamsport, the average annual wetbulb temperature is  $45 \pm 1.3$  °F. The wetbulb temperature in garages or attics, where the heat pumps are likely to be installed, are likely to be two or three degrees higher, but for simplicity, 45 °F is assumed to be the annual average wetbulb temperature.

<sup>102</sup> The performance curve is adapted from Table 1 in <http://wescorhvac.com/HPWH%20design%20details.htm#Single-stage%20HPWHs>

The performance curve depends on other factors, such as hot water set point. Our adjustment factor of 0.84 is a first order approximation based on the information available in literature.

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Table 2-363236: Energy Savings and Demand Reductions for Heat Pump Water Heater to Gas Fossil Fuel Water Heater

Heat Pump unit Energy Factor	Energy Savings (kWh)	Demand Reduction (kW)
2.0	1,747,796	0-157,164

The deemed gas consumption for the installation of a standard efficiency ENERGY STAR natural gas water, propane or oil water heater in place of a standard heat pump water heater is listed in Table 2-373337 below.

Table 2-373337: Gas, Oil, Propane Consumption for Heat Pump Water Heater to Gas Water Heater

Fuel Type	Gas-unit Energy Factor	Gas Consumption (MMBtu)
Gas	0.59467	16.5815.37
Propane	0.67	15.37
Oil	0.514	20.04

2.19.72.18.6 Measure Life

2.19.8 According to an October 2008 report for the CA Database for Energy Efficiency Resources, Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, a gas and propane water heaters' lifespan are 13 years<sup>103</sup>. An oil water heater's lifespan is 13 years<sup>104</sup>.

2.19.92.18.7 Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

103 DEER values, updated October 10, 2008  
[http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)  
 104 DEER values, updated October 10, 2008  
[http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)  
[http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

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**2.19.10 Evaluation Protocols**

~~The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.~~

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## 2.202.19 Fuel Switching: Electric Heat to Gas/Propane/Oil Heat

This protocol documents the energy savings attributed to converting from an existing electric heating system to a new natural gas, propane, or oil furnace or boiler in a residential home. The target sector primarily consists of single-family residences.

The baseline for this measure is an existing residential home with an electric primary heating source. The heating source can be electric baseboards, electric furnace, or electric air source heat pump.

The retrofit condition for this measure is the installation of a new standard efficiency natural gas, propane, or oil furnace- or boiler.

### 2.20.12.19.1 Algorithms

The energy savings are the full energy consumption of the electric heating source minus the energy consumption of the gasfossil fuel furnace blower motor. The energy savings are obtained through the following formulas:

#### Heating savings with electric baseboards or electric furnace (assumes 100% efficiency):

Energy Impact:

$$\Delta kWh_{elec\ heat} = \frac{CAPY_{elec\ heat} \times EFLH_{heat}}{3412 \frac{Btu}{kWh}} - \frac{CAPY_{elec\ heat} \times EFLH_{elec\ furnace}}{3412 \frac{Btu}{kWh}} - \frac{HP_{motor} \times \left(746 \frac{W}{HP}\right) \times EFLH_{heatelec\ furnace}}{\eta_{motor} \times 1000 \frac{W}{kW}}$$

#### Heating savings with electric air source heat pump:

Energy Impact:

$$\Delta kWh_{ASHP\ heat} = \frac{CAPY_{ASHP\ heat} \times EFLH_{heat}}{HSPF_{ASHP} \times 1000 \frac{W}{kW}} - \frac{HP_{motor} \times \left(746 \frac{W}{HP}\right) \times EFLH_{heat}}{\eta_{motor} \times 1000 \frac{W}{kW}}$$

For boilers, the annual pump energy consumption is negligible (<50 kWh per year) and not included in this calculation.<sup>105</sup>

There are no peak demand savings as it is a heating only measure.

Although there is a significant electric savings, there is also an associated increase in natural gas energy consumption. While this gas consumption does not count against PA Act 129 energy savings, it is expected to be used in the program TRC test. The increased natural gasfossil fuel energy is obtained through the following formulas:

<sup>105</sup> Pump motors are typically 1/25 HP. With 1,000 hour runtime and 80% assumed efficiency, this translates to 37 kWh.

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**Gas consumption with natural gas furnace:**

$$\text{Gas Consumption (MMBtu)} = \frac{\text{CAPY}_{\text{Gas heat}} \times \text{EFLH}_{\text{heat}}}{\text{AFUE}_{\text{Gas heat}} \times 1,000,000 \frac{\text{Btu}}{\text{MMBtu}}} + \frac{\text{CAPY}_{\text{Fuel Heat}} \times \text{EFLH}_{\text{fuel furnace}}}{\text{AFUE}_{\text{Fuel heat}} \times 1,000,000 \frac{\text{Btu}}{\text{MMBtu}}}$$

**2-20-22.19.2 Definition of Terms**

$\text{CAPY}_{\text{elec heat}}$  = Total heating capacity of existing electric baseboards or electric furnace (BtuH)

$\text{CAPY}_{\text{ASHP heat}}$  = Total heating capacity of existing electric ASHP (BtuH)

$\text{CAPY}_{\text{Gas}} \text{CAPY}_{\text{fuel heat}}$  = Total heating capacity of new natural gas furnace (BtuH)

$\text{EFLH}_{\text{heat}} \text{EFLH}_{\text{ASHP}}$  = Equivalent Full Load Heating hours for Air Source Heat Pumps

$\text{EFLH}_{\text{elec furnace}}$  = Equivalent Full Load Heating hours for Electric Forced Air Furnaces

$\text{EFLH}_{\text{elec bb}}$  = Equivalent Full Load Heating hours for Electric Baseboard systems

$\text{EFLH}_{\text{fuel furnace}}$  = Equivalent Full Load Heating hours for Fossil Fuel Furnace systems

$\text{HSPF}_{\text{ASHP}}$  = Heating Seasonal Performance Factor for existing heat pump (Btu/W•hr)

$\text{AFUE}_{\text{Gas}} \text{AFUE}_{\text{fuel heat}}$  = Annual Fuel Utilization Efficiency for the new gas furnace (%)

$\text{HP}_{\text{motor}}$  = Gas furnace blower motor horsepower (hp)

$\eta_{\text{motor}}$  = Efficiency of furnace blower motor

The default values for each term are shown in [Table 2-38](#)~~Table 2-34~~[38](#).

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Table 2-383438: Default values for algorithm terms, Fuel Switching, Electric Heat to Gas Heat

Term	Type	Value	Source
CAPY <sub>elec heat</sub>	Variable	Nameplate	EDC Data Gathering
CAPY <sub>ASHP heat</sub>	Variable	Nameplate	EDC Data Gathering
CAPY <sub>Gas</sub> CAPY <sub>fuel heat</sub>	Variable	Nameplate	EDC Data Gathering
EFLH <sub>heat</sub> EFLH <sub>ASHP</sub>	Default	Allentown = 1,193 Erie = 1,349 Harrisburg = 1,103 Philadelphia = 1,060 Pittsburgh = 1,209 Scranton = 1,296 Williamsport = 1,251	20122014 PA TRM <a href="#">Table 2-1</a> , <a href="#">Table 2-1</a> , in Electric HVAC section
	Optional	An EDC can <a href="#">either use the Alternate EFLH Table</a> or estimate it's own EFLH based on customer billing data analysis.	<a href="#">Alternate EFLH Table (See Section 2.19.3)</a> or EDC Data Gathering
EFLH <sub>elec furnace</sub>	Default	<a href="#">Allentown = 1,000</a> <a href="#">Erie = 1,075</a> <a href="#">Harrisburg = 947</a> <a href="#">Philadelphia = 934</a> <a href="#">Pittsburgh = 964</a> <a href="#">Scranton = 1,034</a> <a href="#">Williamsport = 1,011</a>	1
	Optional	An EDC can <a href="#">either use the Alternate EFLH Table</a> or estimate it's own EFLH based on customer billing data analysis.	<a href="#">Alternate EFLH Table (See Section 2.19.3)</a> or EDC Data Gathering
EFLH <sub>elec bb</sub>	Default	<a href="#">Allentown = 1,321</a> <a href="#">Erie = 1,396</a> <a href="#">Harrisburg = 1,265</a> <a href="#">Philadelphia = 1,236</a> <a href="#">Pittsburgh = 1,273</a> <a href="#">Scranton = 1,357</a> <a href="#">Williamsport = 1,354</a>	1
	Optional	An EDC can <a href="#">either use the Alternate EFLH Table</a> or estimate it's own EFLH based on customer billing data analysis.	<a href="#">Alternate EFLH Table (See Section 2.19.3)</a> or EDC Data Gathering

<u>EFLH<sub>fuel_furnace</sub></u>	<u>Default</u>	<u>Allentown = 1,022</u> <u>Erie = 1,098</u> <u>Harrisburg = 969</u> <u>Philadelphia = 955</u> <u>Pittsburgh = 985</u> <u>Scranton = 1,056</u> <u>Williamsport = 1,033</u>	<u>1</u>
	<u>Optional</u>	<u>An EDC can either use the Alternate EFLH Table or estimate it's own EFLH based on customer billing data analysis.</u>	<u>Alternate EFLH Table (See Section 2.19.3) or EDC Data Gathering</u>
<u>EFLH<sub>fuel_boiler</sub></u>	<u>Default</u>	<u>Allentown = 1,334</u> <u>Erie = 1,411</u> <u>Harrisburg = 1,279</u> <u>Philadelphia = 1,249</u> <u>Pittsburgh = 1,283</u> <u>Scranton = 1,371</u> <u>Williamsport = 1,354</u>	<u>1</u>
	<u>Optional</u>	<u>An EDC can either use the Alternate EFLH Table or estimate it's own EFLH based on customer billing data analysis.</u>	<u>Alternate EFLH Table (See Section 2.19.3) or EDC Data Gathering</u>
HSPF <sub>A SHP</sub>	Variable	Default = 7.7	2010 PA TRM <del>Table 2-4</del> <u>Table 2-1</u>
		Nameplate	EDC Data Gathering
<u>AFUE<sub>Gas</sub></u> <u>AFUE<sub>fuel heat</sub></u>	Variable	Default = 90% <u>(natural gas/propane furnace)</u> <u>80% (natural gas/propane steam boiler)</u> <u>82% (natural gas/propane hot water boiler)</u> <u>85% (oil furnace)</u> <u>82% (oil steam boiler)</u> <u>84% (oil hot water boiler)</u>	NAECA Code Effective May 1, 2013106
		Nameplate	EDC Data Gathering

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106 Energy Conservation Program: Energy Conservation Standards for Residential Furnaces and Residential Central Air Conditioners and Heat Pumps. Federal Register, Vol. 76, No. 123, Monday, June 27, 2011. 10 CFR Part 430.

HP <sub>motor</sub>	Variable	Default = ½ hp	Average blower motor capacity for gas furnace (typical range = ¼ hp to ¾ hp)
		Nameplate	EDC Data Gathering
η <sub>motor</sub>	Variable	Default = 0.50	Typical efficiency of ½ hp blower motor
		Nameplate	EDC Data Gathering

### 2.19.3 Alternate Equivalent Full Load Hour (EFLH) Tables

Table 2-39 through Table 2-43Table 2-43Table 2-43 below, show heating EFLH by city and for each EDC's housing demographics. In order to determine the most appropriate EFLH value to use for a project, first select the type of electric heating equipment being replaced, then the appropriate EDC. Next, from the column, pick the closest city to the project location. The value shown in that cell will be the EFLH value to use for the project.

Table 2-39: Alternate Heating EFLH for Air Source Heat Pumps

	<u>PPL</u>	<u>Penelec</u>	<u>Met Ed</u>	<u>West Penn</u>	<u>Duquesne</u>	<u>Penn Power</u>	<u>PECO</u>
Allentown	1112	1057	1122	1165	1265	1226	1320
Erie	1255	1204	1273	1317	1420	1376	1494
Harrisburg	1028	974	1035	1077	1174	1138	1219
Philadelphia	986	940	1001	1039	1134	1098	1165
Pittsburgh	1124	1068	1133	1175	1274	1234	1347
Scranton	1203	1151	1218	1261	1365	1321	1445
Williamsport	1161	1110	1175	1218	1320	1278	1392

Table 2-40: Alternate Heating EFLH for Electric Furnaces

	<u>PPL</u>	<u>Penelec</u>	<u>Met Ed</u>	<u>West Penn</u>	<u>Duquesne</u>	<u>Penn Power</u>	<u>PECO</u>
Allentown	914	890	952	991	1079	1037	1100
Erie	986	964	1027	1064	1150	1108	1183
Harrisburg	866	837	900	940	1027	986	1041
Philadelphia	854	827	893	931	1018	976	1021
Pittsburgh	882	854	914	950	1033	994	1068
Scranton	945	922	983	1020	1107	1064	1144
Williamsport	924	902	961	998	1085	1043	1118

Table 2-41: Alternate Heating EFLH for Electric Baseboard Heating

	<u>PPL</u>	<u>Penelec</u>	<u>Met Ed</u>	<u>West Penn</u>	<u>Duquesne</u>	<u>Penn Power</u>	<u>PECO</u>
Allentown	1355	1204	1280	1334	1351	1355	1326
Erie	1432	1287	1360	1408	1426	1430	1395
Harrisburg	1300	1144	1224	1280	1298	1299	1271
Philadelphia	1272	1115	1194	1247	1268	1269	1242
Pittsburgh	1301	1158	1230	1281	1297	1431	1277
Scranton	1389	1245	1317	1369	1385	1385	1366
Williamsport	1373	1230	1303	1351	1371	1371	1394

**Table 2-42: Alternate Heating EFLH for Fossil Fuel Furnaces**

	<u>PPL</u>	<u>Penelec</u>	<u>Met Ed</u>	<u>West Penn</u>	<u>Duquesne</u>	<u>Penn Power</u>	<u>PECO</u>
<u>Allentown</u>	934	919	985	1023	1116	1071	1106
<u>Erie</u>	1007	995	1060	1098	1188	1144	1190
<u>Harrisburg</u>	887	865	931	973	1064	1018	1048
<u>Philadelphia</u>	873	855	922	962	1055	1007	1027
<u>Pittsburgh</u>	900	882	945	982	1067	1024	1075
<u>Scranton</u>	965	951	1016	1053	1144	1099	1149
<u>Williamsport</u>	944	931	993	1031	1121	1078	1124

**Table 2-43: Alternate Heating EFLH for Fossil Fuel Boilers**

	<u>PPL</u>	<u>Penelec</u>	<u>Met Ed</u>	<u>West Penn</u>	<u>Duquesne</u>	<u>Penn Power</u>	<u>PECO</u>
<u>Allentown</u>	1366	1214	1289	1346	1363	1364	1347
<u>Erie</u>	1445	1299	1370	1422	1440	1440	1417
<u>Harrisburg</u>	1312	1155	1234	1290	1308	1309	1291
<u>Philadelphia</u>	1281	1125	1205	1261	1278	1280	1260
<u>Pittsburgh</u>	1315	1169	1240	1294	1311	1311	1292
<u>Scranton</u>	1400	1256	1330	1378	1399	1397	1386
<u>Williamsport</u>	1384	1238	1313	1365	1382	1383	1364

**2.20.32.19.4 Measure Life**Measure life = 20 years<sup>107</sup>**Sources:**

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<sup>107</sup> PA 2010 TRM Appendix A: Measure Lives. Note that PA Act 129 savings can be claimed for no more than 15 years.

1. Based on REM/Rate modeling using models from the PA 2012 Potential Study. EFLH calculated from kWh consumption for cooling and heating. Models 40% oversizing of heat systems.

## 2.242.20 Ceiling / Attic and Wall Insulation

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This measure applies to installation/retrofit of new or additional insulation in a ceiling/attic, or walls of existing residential homes or apartment units in multifamily complexes with a primary electric heating and/or cooling source. The installation must achieve a finished ceiling/attic insulation rating of R-38 or higher, and/or must add wall insulation of at least an R-6 or greater rating.

The baseline for this measure is an existing residential home with a ceiling/attic insulation R-value less than or equal to R-30, and wall insulation R-value less than or equal to R-11, with an electric primary heating source and/or cooling source.

### 2.21.1 Algorithms

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The savings values are based on the following algorithms.

#### Cooling savings with central A/C:

$$\Delta kWh_{CAC} = \frac{CDD \times 24 \frac{hr}{day} \times DUA}{SEER_{CAC} \times 1000 \frac{W}{kW}} \times \left[ A_{roof} \left( \frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}} \right) + A_{wall} \left( \frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}} \right) \right] \times AHF$$

$$\times A_{roof} \left( \frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}} \right) + A_{wall} \left( \frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}} \right)$$

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$$\Delta kW_{peak-CAC} = \frac{\Delta kWh_{CAC}}{EFLH_{cool}} \times CF_{CAC}$$

#### Cooling savings with room A/C:

$$\Delta kWh_{RAC} = \frac{CDD \times 24 \frac{hr}{day} \times DUA \times F_{room-A/C}}{EER_{RAC} \times 1000 \frac{W}{kW}} \times \left[ A_{roof} \left( \frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}} \right) + A_{wall} \left( \frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}} \right) \right] \times AHF$$

$$\times A_{roof} \left( \frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}} \right) + A_{wall} \left( \frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}} \right)$$

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$$\Delta kW_{peak-RAC} = \frac{\Delta kWh_{RAC}}{EFLH_{cool RAC}} \times CF_{RAC}$$

#### Cooling savings with electric air-to-air heat pump:

$$\Delta kWh_{ASHP cool} = \frac{CDD \times 24 \frac{hr}{day} \times DUA}{SEER_{ASHP} \times 1000 \frac{W}{kW}} \times \left[ A_{roof} \left( \frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}} \right) + A_{wall} \left( \frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}} \right) \right] \times AHF$$

$$\times A_{roof} \left( \frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}} \right) + A_{wall} \left( \frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}} \right)$$

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$$\Delta kW_{peak-ASHP cool} = \frac{\Delta kWh_{ASHP cool}}{EFLH_{cool}} \times CF_{ASHP}$$

#### Heating savings with electric air-to-air heat pump:

$$\Delta kWh_{ASHP heat} = \frac{HDD \times 24 \frac{hr}{day}}{HSPF_{ASHP} \times 1000 \frac{W}{kW}} \times \left[ A_{roof} \left( \frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}} \right) + A_{wall} \left( \frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}} \right) \right]$$

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$$\Delta kW_{peak-ASHP \text{ heat}} = 0$$

**Heating savings with electric baseboard or electric**

$$\Delta kWh_{elec \text{ heat}} = \frac{HDD \times 24 \frac{hr}{day}}{3412 \frac{Btu}{kWh}} \times \left[ A_{roof} \left( \frac{1}{R_{roof,bl}} - \frac{1}{R_{roof,ee}} \right) + A_{wall} \left( \frac{1}{R_{wall,bl}} - \frac{1}{R_{wall,ee}} \right) \right]$$

$$\Delta kW_{peak-elec \text{ heat}} = 0$$

**2.21.2 Definition of Terms**

**CDD** = Cooling Degree Days (Degrees F \* Days)

**HDD** = Heating Degree Days (Degrees F \* Days)

**DUA** = Discretionary Use Adjustment to account for the fact that people do not always operate their air conditioning system when the outside temperature is greater than 65F.

**AHF** = Attic Heating Factor increases cooling load to home due to attic temperatures being warmer than ambient outdoor air temperature on sunny days.

**A<sub>roof</sub>** = Area of the ceiling/attic with upgraded insulation (ft<sup>2</sup>)

**A<sub>wall</sub>** = Area of the wall with upgraded insulation (ft<sup>2</sup>)

**R<sub>roof,bl</sub>** = Assembly R-value of ceiling/attic before retrofit (ft<sup>2</sup>\*°F\*hr/Btu)

**R<sub>roof,ee</sub>** = Assembly R-value of ceiling/attic after retrofit (ft<sup>2</sup>\*°F\*hr/Btu)

**R<sub>wall,bl</sub>** = Assembly R-value of wall before retrofit (ft<sup>2</sup>\*°F\*hr/Btu)

**R<sub>wall,ee</sub>** = Assembly R-value of wall after retrofit (ft<sup>2</sup>\*°F\*hr/Btu)

**SEER<sub>CAC</sub>** = Seasonal Energy Efficiency Ratio of existing home central air conditioner (Btu/W\*hr)

**EEER<sub>RAC</sub>** = Average Energy Efficiency Ratio of existing room air conditioner (Btu/W\*hr)

**SEER<sub>ASHP</sub>** = Seasonal Energy Efficiency Ratio of existing home air source heat pump (Btu/W\*hr)

**HSPF<sub>ASHP</sub>** = Heating Seasonal Performance Factor for existing home heat pump (Btu/W\*hr)

**CF<sub>CAC</sub>** = Demand Coincidence Factor (See Section 1.4) for central AC systems

**CF<sub>RAC</sub>** = Demand Coincidence Factor (See Section 1.4) for Room AC systems

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$CF_{ASHP}$	= Demand Coincidence Factor (See Section 1.4) for ASHP systems
$EFLH_{cool}$	= Equivalent Full Load Cooling hours for Central AC and ASHP
$EFLH_{cool RAC}$	= Equivalent Full Load Cooling hours for Room AC
$F_{Room AC}$	= Adjustment factor to relate insulated area to area served by Room AC units

The default values for each term are shown in [Table 2-35](#), [Table 2-44](#) [Table 2-43](#). The default values for heating and cooling days and hours are given in [Table 2-44](#) [Table 2-36](#) [43](#).

Field Code Changed

Table 2-~~44~~<sup>35</sup>~~44~~: Default values for algorithm terms, Ceiling/Attic and Wall Insulation

Term	Type	Value	Source
$A_{roof}$	Variable	Varies	EDC Data Gathering
$A_{wall}$	Variable	Varies	EDC Data Gathering
DUA	Fixed	0.75	OH TRM <sup>108</sup>
AHF	Fixed	1.056	13.14
$R_{roof,bl}^{109}$	Variable	5	Un-insulated attic
		16	4.5" (R-13) of existing attic insulation
		22	6" (R-19) of existing attic insulation
		30	10" (R-30) of existing attic insulation
$R_{roof,ee}^{110}$	Variable	38	Retrofit to R-38 total attic insulation
		49	Retrofit to R-49 total attic insulation
$R_{wall,bl}^{111}$	Variable	Default = 35.0	15 Assumes existing, un-insulated wall with 2x4 studs @ 16" o.c., w/ wood/vinyl siding
		Existing Assembly R-value	EDC Data Gathering
$R_{wall,ee}^{112}$	Variable	Default = 9.0	Assumes adding R-6 per DOE recommendations <sup>113</sup>

108 "State of Ohio Energy Efficiency Technical Reference Manual," prepared for the Public Utilities Commission of Ohio by Vermont Energy Investment Corporation. August 6, 2010.

109 Used eQuest 3.64 to derive roof assembly R-values. When insulation is added between the joists as in most insulation up to R-30 (10"), the assembly R-value is based on a parallel heat transfer calculation of the insulation and joists, rather than a series heat transfer.

110 Generally as insulation is added beyond R-30 (10"), the insulation has cleared the joists and the R-value of the insulation above the joists can be added as a series heat transfer rather than a parallel heat transfer condition. Therefore, above R-30 insulation levels, the additional R-value can be added directly to the assembly value of R-30 insulation.

111 Used eQuest 6.64 to derive wall assembly R-values.

112 Used eQuest 6.64 to derive wall assembly R-values. It is coincidence that adding R-6 to a 2x4 stud wall essentially yields R-9 assembly value even though this was done using a parallel heat transfer calculation. This was due to rounding. The defaults are based on conservative assumptions of wall construction.

Term	Type	Value	Source
		Retrofit Assembly R-value	EDC Data Gathering
SEER <sub>CAC</sub>	Variable	Default for equipment installed before 1/23/2006 = 10 Default for equipment installed after 1/23/2006 = 13	Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006 ASHRAE 90.1-2007
		Nameplate	EDC Data Gathering
$\overline{EER}_{RAC}$	Variable	Default = 9.8	DOE Federal Test Procedure 10 CFR 430, Appendix F (Used in ES Calculator for baseline)
		Nameplate	EDC Data Gathering
SEER <sub>ASHP</sub>	Variable	Default for equipment installed before 1/23/2006 = 10 Default for equipment installed after 1/23/2006 = 13	Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006 ASHRAE 90.1-2007
		Nameplate	EDC Data Gathering
HSPF <sub>ASHP</sub>	Variable	Default for equipment installed before 1/23/2006 = 6.8 Default for equipment installed after 1/23/2006 = 7.7	Minimum Federal Standard for new Central Air Conditioners/Heat Pumps between 1990 and 2006 ASHRAE 90.1-2007
		Nameplate	EDC Data Gathering
CF <sub>CAC</sub>	Fixed	0.70	<a href="#">Table 2-1</a> , <a href="#">Table 2-1</a>
CF <sub>RAC</sub>	Fixed	0.58	See Section 2.29
CF <sub>ASHP</sub>	Fixed	0.70	<a href="#">Table 2-1</a> , <a href="#">Table 2-1</a>
F <sub>Room,AC</sub>	Fixed	0.38	Calculated <sup>114</sup>

113 DOE recommendation on ENERGY STAR website for adding wall insulation to existing homes in Zones 5-8. Insulation may be loose fill in stud cavities or board insulation beneath siding.

[http://www.energystar.gov/index.cfm?c=home\\_sealing.hm\\_improvement\\_insulation\\_table](http://www.energystar.gov/index.cfm?c=home_sealing.hm_improvement_insulation_table)

114 From PECO baseline study, average home size = 2323 ft<sup>2</sup>, average number of room AC units per home = 2.1. Average Room AC capacity = 10,000 BtuH per ENERGY STAR Room AC Calculator, which serves 425 ft<sup>2</sup> (average between 400 and 450 ft<sup>2</sup> for 10,000 BtuH unit per ENERGY STAR Room AC sizing chart).  $F_{Room,AC} = (425 \text{ ft}^2 * 2.1)/(2323 \text{ ft}^2) = 0.38$

Table 2-453645: EFLH, CDD and HDD by City

City	EFLH <sub>cool</sub> (Hours) <sup>115</sup>	EFLH <sub>cool RAC</sub> (Hours) <sup>116</sup>	CDD (Base 65) <sup>117</sup>	HDD (Base 65) <sup>118</sup>
Allentown	487	243	787	5830
Erie	389	149	620	6243
Harrisburg	551	288	955	5201
Philadelphia	591	320	1235	4759
Pittsburgh	432	228	726	5829
Scranton	417	193	611	6234
Williamsport	422	204	709	6063

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**2.21.3 Measure Life**

Measure life = 25 years<sup>119</sup>.

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<sup>115</sup> PA TRM Table 2-1.

<sup>116</sup> PA TRM Section 2.12 Room AC Retirement

<sup>117</sup> Climatology of the United States No. 81. Monthly Station Normals of Temperature, Precipitation, and Heating and Cooling Degree Days 1971-2000, 36 Pennsylvania. NOAA. <http://cdo.ncdc.noaa.gov/climatenormals/clim81/PAnorm.pdf>

<sup>118</sup> Ibid.

<sup>119</sup> *Massachusetts Statewide Technical Reference Manual for Estimating Savings from Energy Efficiency Measures*, Version 1.0, accessed August 2010 at <http://www.ma-eeac.org/docs/091023-MA-TRMdraft.pdf>. Note that PA Act 129 savings can be claimed for no more than 15 years.

<sup>13</sup> "Improving Attic Thermal Performance", Home Energy, November 2004.

<sup>14</sup> NOAA Climatic Data for Pennsylvania cities- Cloudiness (mean number of days Sunny, Partly Cloudy, and Cloudy). <http://ols.nndc.noaa.gov/pls/olstore/plsql/olstore.prodspecific?prodnum=C00095-PUB-A0001>.

<sup>15</sup> 2013 Illinois Statewide TRM - An estimate based on review of Madison Gas and Electric, Exterior Wall Insulation, R-value for no insulation in walls, and NREL's Building Energy Simulation Test for Existing Homes (BESTEST-EX).

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#### **2.21.4 Attic Heating Effect on Cooling Loads**

On sunny days, attic temperatures can be 20%-35% higher than ambient outdoor air temperatures during the 7 hours between 9 AM and 4 PM and 6%-8% higher for the 4 hours from 7 AM to 9 AM and 4 PM to 6 PM.<sup>13</sup> The remaining 13 hours of the day there was no significant difference seen between attic temperature and outdoor air temperature; this results in an average hourly temperature difference between the attic and outdoor air of approximately +9% over the course of a 24 hour period, but only on sunny days. According to NOAA climatic data for Pennsylvania cities (Allentown, Erie, Harrisburg, Philadelphia, and Pittsburgh) for June through August, it is sunny or partly cloudy an average of 62% of the days.<sup>14</sup> It is assumed that there is an attic heating effect on both sunny and partly cloudy days, but not on cloudy days; therefore, an appropriate attic heating factor would be 1.056 based on the fact that the average hourly difference between attic temperature and outdoor air temperature is approximately +5.6% (9% x 62%).

### 2.22.21 Refrigerator / Freezer Recycling with and without Replacement

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Measure Name	Refrigerator/Freezer Recycling and Replacement
Target Sector	Residential Establishments
Measure Unit	Refrigerator or Freezer
Deemed Unit Annual Energy Savings- Refrigerators	1026 kWh (no replacement) 622 kWh (Replace with ENERGY STAR Unit) 506 kWh (Replace with non-ENERGY STAR Unit) <i>Varies by EDC</i>
Deemed Unit Peak Demand Reduction- Refrigerators	0.116 kW (no replacement) 0.066 kW (Replace with ENERGY STAR Unit) 0.052 kW (Replace with non-ENERGY STAR Unit) <i>Varies by EDC</i>
Deemed Unit Annual Energy Savings- Freezers	1170 kWh (no replacement) 753 kWh (Replace with ENERGY STAR Unit) 667 kWh (Replace with non-ENERGY STAR Unit) <i>Varies by EDC</i>
Deemed Unit Peak Demand Reduction- Freezers	0.145 kW (no replacement) 0.093 kW (Replace with ENERGY STAR Unit) 0.083 kW (Replace with non-ENERGY STAR Unit) <i>Varies by EDC</i>
Measure Life (no replacement)	8 years <sup>120</sup>
Measure Life (with replacement)	7 years (see measure life discussion below)

This measure is (1) the retirement of a refrigerator or freezer with no replacement or (2) the recycling and replacement before end of life of an existing refrigerator or freezer with a new refrigerator or freezer. This protocol quantifies savings where the replacement refrigerator or freezer is ENERGY STAR and non-ENERGY STAR qualified. This protocol applies to both residential and non-residential sectors, as refrigerator and freezer usage and energy usage are assumed to be independent of customer rate class<sup>121</sup>. The deemed savings value is based on regression analysis of metered data on kWh consumption from other States. The deemed savings values for this measure can be applied to refrigerator and freezer retirements or early replacements meeting the following criteria:

- Existing, working refrigerator or freezer 10-30 cubic feet in size (savings do not apply if unit is not working)
- Unit is a primary or secondary unit

#### 2.22.12.21.1 Algorithms

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Equation 1:

<sup>120</sup> Vermont Energy Investment Corporation (VEIC) for NEEP, Mid Atlantic TRM Version 2.0. July 2011. Pg.36.

<sup>121</sup> For example, non-residential rate class usage cases include residential dwellings that are master-metered, usage in offices or any other applications that involve typical refrigerator usage.

$$DEEMED\_kWhsaved\ Per\ Unit = EXISTING\_UEC * PART\_USE$$

Equation 2:

$$NET\_kWhsaved\ Per\ Unit = DEEMED\ kWhsaved\ Per\ Unit - (REPLACEMENTUEC * PART\_USE)$$

### 2.22.22.21.2 Definition of Terms

<i>DEEMED_kWhsaved</i>	= Annual electricity savings measured in kilowatt hours.
<i>EXISTING_UEC</i>	= The average annual unit energy consumption of participating refrigerators. The PY3 value is 1059 for refrigerators and 1188 for freezers.
<i>PART_USE</i>	= The portion of the year the average refrigerator or freezer would likely have operated if not recycled through the program. For PY3, the average refrigerator was plugged in 96.9% of the year and the average freezer was plugged in 98.5% of the year.
<i>REPLACEMENTUEC</i>	= The annual unit energy consumption of the average replacement unit. This comes from the Energy Star calculator and is equal to 417 kWh for a new Energy Star refrigerator, and 537 for a new non Energy Star refrigerator. It is equal to 423 kWh for a new Energy Star freezer, and 510 for a new non Energy Star freezer.

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### 2.22.32.21.3 Deemed Savings Calculations

For removed refrigerators, the annual Unit Energy Consumption (UEC) is based upon a regression ~~analysis~~ analyses of data from ~~452~~ refrigerators metered and recycled through five utilities. The UEC for removed refrigerators was calculated specifically for each utility using data collected from each utility's Program Year Four Appliance Removal programs. Therefore, each UEC represents the average ages, sizes, etc of the fleet of refrigerators removed removed in Program Year Four.

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#### *Existing Refrigerator UEC*

$$\begin{aligned}
 &= 365.25 * (0.582 + 0.027 * (\del{26.617\ years} \text{average age of appliance} \del{27.036}) \\
 &+ 1.055 * (\del{65.8\%} * (\% \text{ of appliances manufactured before 1990}) + 0.067 \\
 &* (\del{17.870} \text{number of cubic feet}) - 1.977 * (\del{9.25\%} \% \text{ of single door units}) \\
 &+ 1.071 * (\del{16.1\%} * (\% \text{ of side-by-side}) + 0.605 * (\del{22.6\%} \\
 &* (\% \text{ of primary usage}) + 0.02 * (\del{3.347} \text{unconditioned space CDDs}) - 0.045 \\
 &* (\del{10.791} \text{unconditioned HDDs})) = 1059\ kWh
 \end{aligned}$$

Source for refrigerator UEC equation: US DOE Uniform Method Project, Savings Protocol for Refrigerator Retirement, April 2013

**No Replacement:**

$$DEEMED\_kWhsaved\ Per\ Unit = EXISTING\_UEC * PART\_USE = 1026\ kWh$$

#### Replacement with Energy Star Unit:

$$NET\_kWhsaved\ Per\ Unit = DEEMED\ kWhsaved\ Per\ Unit - (REPLACEMENTUEC * PART\_USE) = 622\ kWh$$

#### Replacement with non-Energy Star Unit:

$$NET\_kWhsaved\ Per\ Unit = DEEMED\ kWhsaved\ Per\ Unit - (REPLACEMENTUEC * PART\_USE) = 506\ kWh$$

Existing Freezer UEC

$$= 365.25\ days$$

$$\begin{aligned} & * (-2.297 + 0.067 * [31.300\ years\ old] + 0.401 \\ & * [81.8\% \ units\ manufactured\ pre - 1993] + 0.150 * [16.030\ cubic\ feet] + 0.854 \\ & * [35\% \ units\ that\ are\ chest\ freezers] + 0.1046 * [4.010\ CDDs]) (-2.297 + 0.067 \\ & * [average\ age\ of\ appliance] + 0.401 \\ & * [8\% \ of\ appliances\ manufactured\ pre - 1993] + 0.150 \\ & * [average\ number\ of\ cubic\ feet] + 0.854 \\ & * [\% \ of\ appliances\ that\ are\ chest\ freezers] + 0.1046 * [CDDs]) = 1188\ kWh \end{aligned}$$

Source for freezer UEC equation: [Cadmus memo to Michigan Service Commission \(August 2012\) US DOE Uniform Method Project, Savings Protocol for Refrigerator Retirement.122](#)

#### No Replacement:

$$DEEMED\_kWhsaved\ Per\ Unit = EXISTING\_UEC * PART\_USE = 1170\ kWh$$

#### Replacement with Energy Star Unit:

$$NET\_kWhsaved\ Per\ Unit = DEEMED\ kWhsaved\ Per\ Unit - (REPLACEMENTUEC * PART\_USE) = 753\ kWh$$

#### Replacement with non-Energy Star Unit:

$$NET\_kWhsaved\ Per\ Unit = DEEMED\ kWhsaved\ Per\ Unit - (REPLACEMENTUEC * PART\_USE) = 667\ kWh$$

The Commission has computed the [EDC-specific](#) values that are needed for input to the regressions equation based on Act 129 Program Year [34](#) data for removed refrigerators and freezers. Once these input values were determined, they were substituted into the above equation in order to estimate the UEC for removed refrigerators and freezers. [Table 2-37 and Table 2-38 for each EDC. Tab e 2-45](#) below provides the equation inputs needed to calculate the UEC for removed refrigerators and freezers respectively. [Table 2-37 and Table 2-38 below shows the average values for each independent variable based upon the entire fleet of refrigerators and](#)

[122 On page 7-27 of the Uniform Method Protocol, the text states "While differences exist between the evaluation approach for each appliance type \(for example, all stand-alone freezers are secondary units, while refrigerators may be primary or secondary units\), this protocol can also be used to evaluate the savings for freezers."](#)

freezers respectively (for all seven Pennsylvania investor-owned utilities) removed during Act 129 Program Year 3.

Table 2-463746: Deemed Savings values for Residential Refrigerator Per-Unit “Deemed” Energy Consumption Calculation Using Regression Model and Program Values (Program values obtained from PY3 data from the seven Act 129 EDCs) Recycling Without Replacement With a New Refrigerator

Independent Variable	Estimate Coefficient (Daily kWh)	Program Values Based on PY3 data (Average/Proportion)
Intercept	0.582	-
Appliance Age (years)	0.027	26.617
Dummy: Manufactured Pre-1990	1.055	65.75%
Appliance Size (square feet)	0.067	17.87
Dummy: Single Door Configuration	-1.977	9.25%
Dummy: Side-by-Side Configuration	1.071	16.09%
Dummy: Primary Usage Type (in absence of the program)	0.605	22.55%
Proportion of refrigerators in unconditioned space		83.46%
Interaction: Located in Unconditioned Space for GDDs	0.020	4.01
Interaction: Located in Unconditioned Space for HDDs	-0.045	12.93
<b>Estimated UEC (kWh/Year)</b>		<b>1058.825</b>
<b>Part Use Factor Based on Program Year 3 Data</b>		<b>96.9%</b>
<b>Adjusted kWh per year (part use factor times</b>		<b>1026</b>



<b>UEC)</b>							
Variable Name	Duquesne Light	Met Ed	PECO	PennElec	PennPower	PPL	West Penn Power
Age of appliance	32.67	27.96	25.55	22.88	29.06	30.06	30.94
% manufactured pre 1990	68.18%	61.83%	49.86%	61.84%	60.56%	60.43%	64.98%
Appliance size (volume in square feet)	16.03	18.47	18.65	16.11	16.25	18.07	16.57
Dummy: percent that are single-door appliances	12.13%	4.39%	8.12%	8.56%	7.71%	7.03%	8.27%
Dummy: percent that are side by side configuration	12.40%	21.43%	19.89%	10.78%	12.96%	18.31%	13.71%
Dummy: primary usage type (in absence of the program)	18.45%	10.12%	24.74%	17.22%	16.76%	26.01%	14.03%
Located in unconditioned space X CDD	0.98	1.78	2.47	1.07	1.22	0.92	1.20
Located in unconditioned space X HDD	7.90	10.86	9.51	9.93	10.17	9.85	9.42
ESTIMATED UEC Savings (Annual kWh per year) for a removed refrigerator that is not replaced	1068.9	1087.3	1048.5	933.8	1003.9	1107.2	1052.4

Table 2-473847: Freezer Per Unit “\_ Deemed” Energy Consumption Savings Calculation Using Regression Model and Program Values (Program values obtained from PY3 data from the seven Act 129 EDCs)for Residential Freezer Recycling Without Replacement With a New Freezer

Independent Variables	Coefficient	Program Values Based on PY3 data (Average/Proportion)
Intercept	-2.297	-
Age (years)	0.067	31.30
Dummy: Manufactured Pre 1993	0.401	81.82%
Size (cubic feet)	0.15	16.03
Dummy: Chest	0.854	35.01%
CDDs	0.1046	4.01
<b>Estimated UEC (kWh/Year)</b>		<b>1187.5</b>

<b>Part Use Factor Based on Program Year 3 Data</b>		<b>98.5%</b>
<b>Adjusted kWh per year (part use factor times UEC)</b>		<b>1170</b>

Variable Name	Duquesne Light	Met Ed	PECO	PennElec	PennPower	PPL	West Penn Power
Age of appliance	35.51	32.21	29.05	32.88	34.17	32.68	33.21
% manufactured pre 1993	89.41%	87.03%	76.60%	86.94%	88.55%	88.20%	86.85%
Appliance size (volume in square feet)	15.40	15.44	15.59	15.70	15.80	15.65	15.74
Dummy: percent that are chest appliances	27.45%	36.47%	22.70%	34.83%	37.89%	30.14%	33.45%
Located in unconditioned space X CDD	0.78	1.55	1.97	0.88	0.99	0.88	1.08
ESTIMATED UEC Savings (Annual kWh per year) for a removed refrigerator that is not replaced	1120.3	1095.4	983.9	1095.6	1148.7	1074.9	1109.1

When calculating deemed per unit kWh savings for a removed refrigerator or freezer, it is necessary to calculate and apply a “Part-Use” factor. “Part-use” is an appliance recycling-specific adjustment factor used to convert the UEC (determined through the methods detailed above) into an average per-unit deemed savings value. The UEC itself is not equal to the deemed savings value, because: (1) the UEC model yields an estimate of annual consumption, and (2) not all recycled refrigerators and freezers would have operated year-round had they not been decommissioned through the program.

In Program Year 3, the Commission determined that the average removed refrigerator was plugged in and used 96.9% of the year and the average freezer was plugged in and used 98.5% of the year. Thus, the deemed value for the part-use factor is 96.9% (and 98.5%) based on program year 3 data for all EDCs. EDCs may elect to calculate an EDC specific part-use factor. In the event an EDC desires to calculate an EDC specific part-use factor, EDCs should use the following methodology. Using participant surveys, evaluators should determine the amount of time a removed refrigerator is plugged in.

Table 2-39 and Table 2-40 Table 2-48 and Table 2-49 below shows the basis for the calculation of per unit savings for units that are removed but then replaced.

Table 2-48: Deemed Savings values for Residential Refrigerator Per Unit “Net” Energy Consumption Recycling With Replacement With a New Refrigerator Calculation Using Equation #2 (adjusts for units that are removed but then replaced)

Variable	Value
Deemed kWh Saved per unit	4026

Replacement unit energy consumption (UEC for new Energy Star unit)	417
Replacement unit energy consumption (UEC for non-Energy Star unit)	537
Part use factor	96.9%
Refrigerator Per Unit Net savings if replaced with Energy Star unit =	622
Refrigerator Per Unit Net savings if replaced with non-Energy Star unit =	506

Variable Name	Duquesne Light	Met Ed	PECO	PennElec	PennPower	PPL	West Penn Power
Age of appliance	25.97	19.39	22.47	22.54	23.21	30.06	25.50
% manufactured pre 1990	44.70%	30.88%	37.85%	41.57%	41.52%	60.43%	42.54%
Appliance size (volume in square feet)	18.39	20.65	19.57	18.45	18.73	18.07	18.82
Dummy: percent that are single-door appliances	2.62%	0.61%	3.72%	3.01%	2.29%	7.03%	2.25%
Dummy: percent that are side by side configuration	15.44%	35.79%	24.51%	19.83%	18.67%	18.31%	22.15%
Dummy: primary usage type (in absence of the program)	58.73%	88.55%	43.53%	67.13%	62.86%	26.01%	61.83%
Located in unconditioned space X CDD	0.55	0.18	2.40	0.47	0.54	0.92	0.52
Located in unconditioned space X HDD	4.41	1.11	9.25	4.15	4.50	9.85	4.27
ESTIMATED UEC Savings (Annual kWh per year) for a removed refrigerator that is replaced	1193.7	1342.5	1089.5	1186.0	1185.1	1107.2	1229.2
kWh Use of new refrigerator	475.12	475.12	475.12	475.12	475.12	475.12	475.12

Table 2-494049: Deemed Savings values for Residential Freezer Per Unit "Net" Energy Consumption Calculation Using Equation #2 (adjusts for units that are removed but then replaced) Recycling With Replacement With a New Freezer

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Variable	Value	Source
Deemed kWh Saved per unit	4170	Calculation
Replacement unit energy consumption (UEC for new Energy Star unit)	423	Energy Star Calculator

Replacement unit energy consumption- (UEC for new non-Energy Star unit)	540							Energy Star Calculator
Part use factor	98.5%							JACO Appliance Recycling Program Database for PY3
Freezer Per Unit Net savings if replaced with Energy Star unit =	753							Calculation
Freezer Per Unit Net savings if replaced with non Energy Star unit =	667							Calculation
Variable Name	Duquesne Light	Met Ed	PECO	PennElec	PennPower	PPL	West Penn Power	
Age of appliance	31.28	28.20	28.23	29.22	33.21	32.68	31.15	
% manufactured pre 1993	80.90%	86.67%	70.42%	80.60%	91.43%	88.20%	77.95%	
Appliance size (volume in square feet)	16.12	16.67	16.15	16.41	16.29	15.65	16.97	
Dummy: percent that are chest appliances	31.46%	33.33%	14.79%	35.78%	42.86%	30.14%	41.03%	
Located in unconditioned space X CDD	0.87	0.64	2.33	0.69	0.95	0.88	0.72	
ESTIMATED UEC Savings (Annual kWh per year) for a removed refrigerator that is replaced	1059.8	1019.6	974.9	1031.1	1169.8	1074.9	1123.1	
kWh Use of new freezer*	391	391	391	391	391	391	391	

Per unit kW demand savings are based upon annual hours of use of 5,000 and a peak coincidence factor of 62%.

**2.22.42.21.4 Measure Life**

Refrigerator/Freezer Replacement programs: Measure Life = 7 yrs

**Measure Life Rationale**

The 2010 PA TRM specifies a Measure Life of 13 years for refrigerator replacement and 8 years for refrigerator retirement (Appendix A). It is assumed that the TRM listed measure life is either an Effective Useful Life (EUL) or Remaining Useful Life (RUL), as appropriate to the measure. Survey results from a study of the low-income program for SDG&E (2006)<sup>123</sup> found that among the program’s target population, refrigerators are likely to be replaced less frequently than among average customers. Southern California Edison uses an EUL of 18 years for its Low-Income Refrigerator Replacement measure which reflects the less frequent replacement cycle among low-income households. The PA TRM limits measure savings to a maximum of 15 yrs.

123 2004 - 2005 Final Report: A Measurement and Evaluation Study of the 2004-2005 Limited Income Refrigerator Replacement & Lighting Program, Prepared for: San Diego Gas & Electric, July 31, 2006

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Due to the nature of a Refrigerator/Freezer Early Replacement Program, measure savings should be calculated over the life of the ENERGY STAR replacement unit. These savings should be calculated over two periods, the RUL of the existing unit, and the remainder of the measure life beyond the RUL. For the RUL of the existing unit, the energy savings would be equal to the full savings difference between the existing baseline unit and the ENERGY STAR unit, and for the remainder of the measure life the savings would be equal to the difference between a Federal Standard unit and the ENERGY STAR unit. The RUL can be assumed to be 1/3 of the measure EUL.

As an example, Low-Income programs use a measure life of 18 years and an RUL of 6 yrs (1/3\*18). The measure savings for the RUL of 6 yrs would be equal to the full savings. The savings for the remainder of 12 years would reflect savings from normal replacement of an ENERGY STAR refrigerator over a Federal Standard baseline, as defined in the TRM.

*Example Measure savings over lifetime*

$$= 1205 \text{ kWh/yr} * 6 \text{ yrs} + 100 \text{ kWh/yr (ES side mount freezer w/ door ice)} * 12 \text{ yrs} = 8430 \text{ kWh/measure lifetime}$$

For non-Low-Income specific programs, the measure life would be 13 years and an RUL of 4 yrs (1/3\*13). The measure savings for the RUL of 4 yrs would be equal to the full savings. The savings for the remainder of 9 years would reflect savings from normal replacement of an ENERGY STAR refrigerator over a Federal Standard baseline, as defined in the TRM.

*Example Measure savings over lifetime*

$$= 1205 \text{ kWh/yr} * 4 \text{ yrs} + 100 \text{ kWh/yr (ES side mount freezer w/ door ice)} * 9 \text{ yrs} = 5720 \text{ kWh/measure lifetime}$$

To simplify the programs and remove the need to calculate two different savings, a compromise value for measure life of 7 years for both Low-Income specific and non-Low Income specific programs can be used with full savings over this entire period. This provides an equivalent savings as the Low-Income specific dual period methodology for an EUL of 18 yrs and a RUL of 6 yrs.

*Example Measure savings over lifetime*

$$= 1205 \text{ kWh/yr} * 7 \text{ yrs} = 8435 \text{ kWh/measure lifetime}$$

**Sources:**

1. U.S. Department of Energy, draft Uniform Methods Project protocol titled "Refrigerator Recycling Evaluation Protocol", prepared by Doug Bruchs of the Cadmus Group, July 2012
2. Cadmus Memo - August 20, 2012 Technical Memo from the Cadmus Group to the Michigan Evaluation Working Group on the topic of Appliance Recycling Measure Savings Study. This memo summarizes research on the energy savings of recycled refrigerators and freezers conducted by The Cadmus Group, Inc. and Opinion Dynamics (together known as the evaluation team) on behalf Consumers Energy (Consumers) and DTE Energy (DTE). This memo provides an overview of the research conducted and Cadmus' recommendations for deemed per-unit energy and demand savings values for affected measures in the Michigan Energy Measures Database (MEMD).

3. 2009-2010 Pacific Power/Rocky Mountain Power Impact Evaluations - PacifiCorp has impact evaluations for CA, ID, UT, WA, and WY that contain an earlier version of the multi-state Appliance Recycling Program regression models for both refrigerators and freezers. The Statewide Evaluator reviewed the report for the State of Washington, but all states include the same models and are publicly available online. The model coefficients can be found on pages 16 and 17 of the Washington document.  
[http://www.pacificorp.com/content/dam/pacificorp/doc/Energy\\_Sources/Demand\\_Side\\_Management/WA\\_2011\\_SYLR\\_Final\\_Report.pdf](http://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Demand_Side_Management/WA_2011_SYLR_Final_Report.pdf)
4. 2010 Ontario Power Authority Impact Evaluation - This evaluation report contains a regression equation for annual consumption for refrigerators only (the freezer sample was too small). That equation can be found on page 10 of the OPA evaluation report. See  
[http://www.powerauthority.on.ca/sites/default/files/new\\_files/2010/2010%20Residential%20Great%20Refrigerator%20Roundup%20Program%20Evaluation.pdf](http://www.powerauthority.on.ca/sites/default/files/new_files/2010/2010%20Residential%20Great%20Refrigerator%20Roundup%20Program%20Evaluation.pdf)
5. Efficiency Vermont; Technical Reference User Manual (TRM). 2008. TRM User Manual No. 2008-53. Burlington, VT 05401. July 18, 2008.
6. Mid Atlantic TRM Version 2.0. July 2011. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by Northeast Energy Efficiency Partnerships.

## 2.23.2.2 Residential New Construction

### 2.23.12.22.1 Algorithms

#### Insulation Up-Grades, Efficient Windows, Air Sealing, Efficient HVAC Equipment and Duct Sealing (Weather-Sensitive Measures):

Energy and peak demand savings due to improvements in the above measures in Residential New Construction programs will be a direct output of accredited Home Energy Ratings (HERS) software that meets the applicable Mortgage Industry National Home Energy Rating System Standards. REM/Rate124 is cited here as an example of an accredited software which can be used to estimate savings for this program. REM/Rate has a module that compares the energy characteristics of the energy efficient home to the baseline/reference home and calculates savings. For residential new construction, the baseline building thermal envelope and/or system characteristics shall be based on the current state adopted 2009 International Residential Code (IRC 2009).

The energy savings for weather-sensitive measures will be calculated from the software output using the following algorithm:

*Energy savings of the qualified home (kWh)*

$$= (\text{Heating kWh}_b - \text{Heating kWh}_q) + (\text{Cooling kWh}_b - \text{Cooling kWh}_q)$$

The system peak electric demand savings for weather-sensitive measures will be calculated from the software output with the following algorithm, which is based on compliance and certification of the energy efficient home to the EPA's ENERGY STAR for New Homes' program standard:

*Peak demand of the baseline home*

$$= (PL_b \times OF_b) / EER_b$$

*Peak demand of the qualifying home*

$$= (PL_q \times OF_q) / EER_q$$

*Coincident system peak electric demand savings*

$$= (\text{Peak demand of the baseline home} - \text{Peak demand of the qualifying home}) \times CF.$$

#### Hot Water, Lighting, and Appliances (Non-Weather-Sensitive Measures):

Quantification of additional energy and peak demand savings due to the installation of high-efficiency electric water heaters, lighting and other appliances will be based on the algorithms presented for these measures in Section 2 (Residential Measures) of this Manual. Where the TRM algorithms involve deemed savings, e.g. lighting, the savings in the baseline and qualifying homes should be compared to determine the actual savings of the qualifying home above the baseline.

In instances where REM/Rate calculated parameters or model inputs do not match TRM algorithm inputs, additional data collection is necessary to use the TRM algorithms. One such

124 DoE's Building Energy Software Tools Directory ([http://apps1.eere.energy.gov/buildings/tools\\_directory/software](http://apps1.eere.energy.gov/buildings/tools_directory/software)).

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example is lighting. REM/Rate requires an input of percent of lighting fixtures that are energy efficient whereas the TRM requires an exact fixture count. Another example is refrigerators, where REM/Rate requires projected kWh consumed and the TRM deems savings based on the type of refrigerator.

It is also possible to have increases in consumption or coincident peak demand instead of savings for some non-weather sensitive measures. For example, if the amount of efficient lighting in a new home is less than the amount assumed in the baseline (IRC 2009), the home will have higher energy consumption and coincident peak demand for lighting, even though it still qualifies for the program.

### 2.23.22.22.2 Definition of Terms

<i>Heating kWh<sub>b</sub></i>	= Annual heating energy consumption of the baseline home in kWh, from software.
<i>Heating kWh<sub>q</sub></i>	= Annual heating energy consumption of the qualifying home in kWh, from software.
<i>Cooling kWh<sub>b</sub></i>	= Annual cooling energy consumption of the baseline home in kWh, from software.
<i>Cooling kWh<sub>q</sub></i>	= Annual cooling energy consumption of the qualifying home in kWh, from software.
<i>PL<sub>b</sub></i>	= Estimated peak cooling load of the baseline home in kbtuh, from software.

~~*OF<sub>b</sub>* = Over-sizing factor for the HVAC unit in the baseline home.~~

<i>EER<sub>b</sub></i>	= Energy Efficiency Ratio of the baseline unit.
<i>EER<sub>q</sub></i>	= Energy Efficiency Ratio of the qualifying unit.
<i>SEER<sub>b</sub></i>	= Seasonal Energy Efficiency Ratio of the baseline unit.
<i>BLEER</i>	= Factor to convert baseline SEER <sub>b</sub> to EER <sub>b</sub> .
<i>PL<sub>q</sub></i>	= Estimated peak cooling load for the qualifying home constructed, in kbtuh, from software.

~~*OF<sub>q</sub>* = Over-sizing factor for the HVAC unit in the program qualifying home.~~

<i>SEER<sub>q</sub></i>	= SEER associated with the HVAC system in the qualifying home.
<i>CF</i>	= Demand Coincidence Factor (See Section 1.4)

A summary of the input values and their data sources follows:

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Table 2-~~504150~~: Residential New Construction – References

Component	Type	Value	Sources
Heating kWh <sub>b</sub>	Variable	Software Calculated	1
Heating kWh <sub>q</sub>	Variable	Software Calculated	2
Cooling kWh <sub>b</sub>	Variable	Software Calculated	1
Cooling kWh <sub>q</sub>	Variable	Software Calculated	2
PL <sub>b</sub>	Variable	Software Calculated	3
<del>OF<sub>b</sub></del>	<del>Fixed</del>	<del>1.6</del>	<del>4</del>
EER <sub>b</sub>	Variable	EDC Data Gathering or SEER <sub>b</sub> * BLEER	<del>54</del>
EER <sub>q</sub>	Variable	EDC Data Gathering or SEER <sub>q</sub> * BLEER	<del>54</del>
SEER <sub>b</sub>	Fixed	13	<del>65</del>
BLEER	Fixed	(11.3/13)	<del>76</del>
PL <sub>q</sub>	Variable	Software Calculated	<del>87</del>
<del>OF<sub>q</sub></del>	<del>Fixed</del>	<del>1.15</del>	<del>9</del>
SEER <sub>q</sub>	Variable	EDC Data Gathering	<del>108</del>
CF	Fixed	0.70	<del>119</del>

**Sources:**

1. Calculation of annual energy consumption of a baseline home from the home energy rating tool based on the reference home energy characteristics.
2. Calculation of annual energy consumption of an energy efficient home from the home energy rating tool based on the qualifying home energy characteristics
3. Calculation of peak load of baseline home from the home energy rating tool based on the reference home energy characteristics.
- ~~4. PSE&C 1997 Residential New Construction baseline study. 2004 Long Island Power Authority Residential New Construction Baseline Study Values of 155% to 172% over sizing confirms this value.~~
- ~~5.4.~~ If the EER of the unit is know, use the EER. If only the SEER is known, then use SEER \* BLEER to estimate the EER.
- ~~6.5.~~ Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
- ~~7.6.~~ Ratio to calculate EER from SEER based average EER for SEER 13 units.
- ~~8.7.~~ Calculation of peak load of energy efficient home from the home energy rating tool based on the qualifying home energy characteristics.

9. Program guideline for qualifying home.

40.8. SEER of HVAC unit in energy efficient qualifying home.

44.9. Based on an analysis of six different utilities by Proctor Engineering.

The following table lists the building envelope characteristics of the baseline reference home based on IRC 2009 for the three climate zones in Pennsylvania..

Table 2-514251: Baseline Insulation and Fenestration Requirements by Component (Equivalent U-Factors)

Climate Zone	Fenestration U-Factor	Skylight U-Factor	Ceiling U-Factor	Frame Wall U-Factor	Mass Wall U-Factor	Floor U-Factor	Basement Wall U-Factor	Slab R-Value & Depth	Crawl Space Wall U-Factor
4A	0.35	0.60	0.030	0.082	0.141	0.047	0.059	10, 2 ft	0.065
5A	0.35	0.60	0.030	0.060	0.082	0.033	0.059	10, 2 ft	0.065
6A	0.35	0.60	0.026	0.060	0.060	0.033	0.059	10, 4 ft	0.065

**Sources:**

34.1. 2009 International Residential Code Table N1102.1.2. Table N1102.1.2 Equivalent U-Factors presents the R-Value requirements of Table N1102.1.1 in an equivalent U-Factor format. Users may choose to follow Table N1102.1.1 instead. IRC 2009 supersedes this table in case of discrepancy. Additional requirements per Section N1102 of IRC 2009 must be followed even if not listed here.

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Table 2-524352: Energy Star Homes - User Defined Reference Home

Data Point	Value <sup>125</sup>	Source
Air Infiltration Rate	0.30 ACH for windows, skylights, sliding glass doors 0.50 ACH for swinging doors	1
Duct Leakage	12 cfm <sub>25</sub> (12 cubic feet per minute per 100 square feet of conditioned space when tested at 25 pascals)	1
Duct Insulation	Supply ducts in attics shall be insulated to a minimum of R-8. All other ducts insulated to a minimum of R-6.	1
Duct Location	50% in conditioned space, 50% unconditioned space	Program Design
Mechanical Ventilation	None	1
Lighting Systems	Minimum 50% of permanent installed fixtures to be high-efficacy lamps	1
Appliances	Use Default	
Setback Thermostat	Maintain zone temperature down to 55 °F (13 °C) or up to 85 °F (29 °C)	1

<sup>125</sup> Single and multiple family as noted.

Data Point	Value <sup>125</sup>	Source
Temperature Set Points	Heating: 70°F Cooling: 78°F	1
Heating Efficiency		
Furnace	80% AFUE	2
Boiler	80% AFUE	2
Combo Water Heater	76% AFUE (recovery efficiency)	2
Air Source Heat Pump	7.7 HSPF	1
Geothermal Heat Pump	7.7 HSPF	1
PTAC / PTHP	Not differentiated from air source HP	1
Cooling Efficiency		
Central Air Conditioning	13.0 SEER	1
Air Source Heat Pump	13.0 SEER	1
Geothermal Heat Pump	13 SEER (11.2 EER)	1
PTAC / PTHP	Not differentiated from central AC	1
Window Air Conditioners	Not differentiated from central AC	1
Domestic WH Efficiency		
Electric	EF = 0.97 - (0.00132 * gallons)	3
Natural Gas	EF = 0.67 - (0.0019 * gallons)	3
Additional Water Heater Tank Insulation	None	

**Sources:**

1. 2009 International Residential Code (IRC 2009, Sections N1102 – N1104)
2. Federal Register / Vol. 73, No. 145 / Monday, July 28, 2008 / Rules and Regulations, p. 43611-43613, 10 CFR Part 430, “Energy Conservation Program for Consumer Products: Energy Conservation Standards for Residential Furnaces and Boilers.”
3. Federal Register / Vol. 75, No. 73 / Friday, April 16, 2010 / Rules and Regulations, p. 20112-20236, 10 CFR Part 430, “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters; Final Rule.”

### 2.242.23 ENERGY STAR Refrigerators

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Measure Name	Refrigerators
Target Sector	Residential Establishments
Measure Unit	Refrigerator
Unit Energy Savings	Varies by Configuration
Unit Peak Demand Reduction	Varies by Configuration
Measure Life	12 years

This measure is for the purchase and installation of a new refrigerator meeting ENERGY STAR or ENERGY STAR Most Efficient criteria. An ENERGY STAR refrigerator must be at least 20 percent more efficient than the minimum federal government standard. The ENERGY STAR Most Efficient is a new certification that identifies the most efficient products among those that qualify for ENERGY STAR. ENERGY STAR Most Efficient refrigerators must be at least 30 percent more efficient than the minimum federal standard.

#### 2.24.12.23.1 Algorithms

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The general form of the equation for the ENERGY STAR Refrigerator measure savings algorithm is:

$$\text{Total Savings} = \text{Number of Refrigerators} \times \text{Savings per Refrigerator}$$

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of refrigerators. The number of refrigerators will be determined using market assessments and market tracking.

If the volume and configuration of the refrigerator is known, the federal minimum efficiency and ENERGY STAR qualified models' annual energy consumption are determined using [Table](#)

[2-53Table 2-4453](#).

The energy and demand savings are given by the following algorithms:

#### ENERGY STAR Refrigerator

$$\Delta kWh = kWh_{base} - kWh_{EE}$$

$$\Delta kWh_{peak} = (kWh_{base} - kWh_{EE}) / \text{Hours} * CF$$

#### ENERGY STAR Most Efficient Refrigerator

$$\Delta kWh = kWh_{base} - kWh_{ME}$$

$$\Delta kWh_{peak} = (kWh_{base} - kWh_{ME}) / \text{Hours} * CF$$

**2.24.22.23.2 Definition of Terms**

$kWh_{base}$	= Annual energy consumption of baseline unit
$kWh_{EE}$	= Annual energy consumption of ENERGY STAR qualified unit
$kWh_{ME}$	= Annual energy consumption of ENERGY STAR Most Efficient qualified unit
CF	= Demand coincidence factor
Hours	= Hours of operation per year

**Where:**

CF	= 1
Hours	= 8,760 <sup>126</sup>

Refrigerator energy use is characterized by configuration (top freezer, bottom freezer, etc.), volume, whether defrost is manual or automatic and whether there is through-the-door ice. If this information is known, annual energy usage of the ENERGY STAR model and federal standard model can be calculated using [Table 2-53](#) [Table 2-44](#) [53](#). The term "AV" in the equations refers to "Adjusted Volume," which is  $AV = (\text{Fresh Volume}) + 1.63 \times (\text{Freezer Volume})$ . Note, ENERGY STAR algorithms are not given for the categories "bottom mount freezer with through-the-door ice", "refrigerator only-single door without ice" and "refrigerator/freezer- single door." Refer to [Table 2-54](#) [Table 2-45](#) [54](#) for default values for these categories. [Table 2-44](#) [Table 2-53](#) [Table 2-53](#) is also provided for planning purposes to compare to the changing federal standards detailed in [Table 2-57](#) [Table 2-48](#) [57](#).

Table 2-[53](#) [44](#) [53](#): Federal Standard and ENERGY STAR Refrigerators Maximum Annual Energy Consumption if Configuration and Volume Known<sup>127</sup>

Refrigerator Category	Federal Standard Maximim Usage in kWh/year	ENERGY STAR Maximum Energy Usage in kWh/year
<b>Standard Size Models: 7.75 cubic feet or greater</b>		
Manual Defrost and Partial Automatic Defrost	$8.82 \cdot AV + 248.4$	$7.056 \cdot AV + 198.72$
Automatic defrost with top-mounted freezer without through-the-door ice service and all-refrigerators-- automatic defrost	$9.80 \cdot AV + 276$	$7.84 \cdot AV + 220.8$
Automatic defrost with side-mounted freezer without through-the-door ice service	$4.91 \cdot AV + 507.5$	$3.928 \cdot AV + 406$
Automatic defrost with bottom-mounted freezer without through-the-door ice service	$4.60 \cdot AV + 459$	$3.68 \cdot AV + 367.2$
Automatic defrost with top-mounted freezer with through-the-door ice service	$10.20 \cdot AV + 356$	$8.16 \cdot AV + 284.8$

<sup>126</sup> ENERGY STAR Residential Refrigerators Savings Calculator. Accessed [June 18, 2012](#)-[July 2013](#)

<sup>127</sup> ENERGY STAR Refrigerators and Freezers Key Product Criteria.

[http://www.energystar.gov/index.cfm?c=refrig\\_pr\\_crit\\_refrigerators](http://www.energystar.gov/index.cfm?c=refrig_pr_crit_refrigerators) Access [July 2013](#)

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Automatic defrost with side-mounted freezer with through-the-door ice service	10.10*AV+406	8.08*AV+324.8
<b>Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in height</b>		
Compact Refrigerator-Freezer--partial automatic defrost	7.00*AV+398	5.6*AV+318.4
Compact Refrigerator-Freezers--automatic defrost with top-mounted freezer and compact all-refrigerators--automatic defrost	12.70*AV+355	10.16*AV+284
Compact Refrigerator-Freezers--automatic defrost with side-mounted freezer	7.60*AV+501	6.08*AV+400.8
Compact Refrigerator-Freezers--automatic defrost with bottom-mounted freezer	13.10*AV+367	10.48*AV+293.6

The default values for each configuration are given in [Table 2-54](#)[Table 2-4554](#):

Table 2-~~54~~~~554~~: Default Savings Values for ENERGY STAR Refrigerators<sup>128</sup>

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Refrigerator Category	Conventional Unit Energy Usage in kWh/yr <sup>129</sup>	ENERGY STAR Energy Usage in kWh/yr <sup>130</sup>	ΔkWh	ΔkW
Manual Defrost and Partial Automatic Defrost	<u>316311</u>	<u>229230</u>	<u>8780</u>	<u>0.00990092</u>
Top mount freezer without door ice	<u>477475</u>	369	<u>408111</u>	<u>0.01230126</u>
Side mount freezer without door ice	<u>638713</u>	<u>509557</u>	<u>129156</u>	<u>0.01470178</u>
Bottom mount freezer without door ice	<u>569692</u>	<u>448538</u>	<u>121154</u>	<u>0.01380176</u>
Side mount freezer with door ice	<u>713629</u>	<u>557490</u>	<u>156139</u>	<u>0.01780159</u>
Bottom mount freezer with door ice	<u>694569</u>	<u>536447</u>	<u>158122</u>	<u>0.01770139</u>
Refrigerator only - single door without ice	<u>439381</u>	<u>337292</u>	<u>102089</u>	<u>0.01160102</u>
Refrigerator/Freezer – single door	450	348	102	0.0116
<b>Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in height</b>				
Manual Defrost and Partial Automatic Defrost	<u>360362</u>	<u>280276</u>	<u>80086</u>	<u>0.00940098</u>
Top Mount and Refrigerator Only	<u>410417</u>	<u>340306</u>	<u>40111</u>	<u>0.01140126</u>
Bottom mount freezer	<u>454452</u>	362	<u>8990</u>	<u>0.01020103</u>

ENERGY STAR Most Efficient annual energy usage can be calculated using [Table 2-55](#)[Table 2-4655](#).<sup>131</sup> Baseline energy usage can be calculated using [Table 2-53](#)[Table 2-4453](#).

<sup>128</sup> Note configurations not listed do not have any ENERGY STAR qualified models as of August 16, 2012.

<sup>129</sup> ENERGY STAR Residential Refrigerators Qualified Products List. August 16, 2012. July 5, 2013. Average federal standard consumption of all qualifying models by configuration.

<sup>130</sup> Ibid. Average consumption of all ENERGY STAR qualifying models by configuration.

<sup>131</sup> ENERGY STAR Most Efficient 2012 Eligibility Criteria for Recognition Refrigerator-Freezers.

[http://www.energystar.gov/ia/partners/downloads/Ref\\_Freezer\\_Criteria\\_ME\\_2012.pdf?ff08-8680](http://www.energystar.gov/ia/partners/downloads/Ref_Freezer_Criteria_ME_2012.pdf?ff08-8680)

Table 2-554655: ENERGY STAR Most Efficient Annual Energy Usage if Configuration and Volume Known

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Refrigerator Category	ENERGY STAR Most Efficient Maximum Energy Usage in kWh/yr
Manual Defrost and Automatic Defrost	AV ≤ 49.8, Eann ≤ 6.17*AV + 173.9 AV > 49.8, Eann ≤ 481
Top mount freezer without door ice	AV ≤ 42.0, Eann ≤ 6.86*AV + 193.2 AV > 42.0, Eann ≤ 481
Side mount freezer without door ice	AV ≤ 36.5, Eann ≤ 3.44*AV + 355.3 AV > 36.5, Eann ≤ 481
Bottom mount freezer without door ice	AV ≤ 49.6, Eann ≤ 3.22*AV + 321.3 AV > 49.6, Eann ≤ 481
Bottom mount freezer with door ice	AV ≤ 29.6, Eann ≤ 3.50*AV + 377.3 AV > 29.6, Eann ≤ 481
Top mount freezer with door ice	AV ≤ 32.5, Eann ≤ 7.14*AV + 249.2 AV > 32.5, Eann ≤ 481
Side mount freezer with door ice	AV ≤ 27.8, Eann ≤ 7.07*AV + 284.2 AV > 27.8, Eann ≤ 481

The default values for each ENERGY STAR Most Efficient configuration are given in [Table 2-56Table 2-4756](#).

Table 2-564756: Default Savings Values for ENERGY STAR Most Efficient Refrigerators<sup>132</sup>

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Refrigerator Category	Conventional Unit Energy Usage in kWh/yr <sup>133</sup>	ENERGY STAR Most Efficient Consumption in kWh/yr <sup>134</sup>	ΔkWh	ΔkW
Top mount freezer without door ice	477475	328350	149125	0.01790149
Side mount freezer without door ice	638	392	246	0.0281
Bottom mount freezer without door ice	569692	403	166228	0.01890192
Side mount freezer with door ice	713	457	256	0.0292
Bottom mount freezer with door ice	691569	473502	218167	0.0249026

132 Configurations of qualified models as of [August 1, 2012/July 5, 2013](#).

133 ENERGY STAR Residential Refrigerators Qualified Products List. [August 16, 2012/July 5, 2013](#). Average federal standard consumption of all qualifying models by configuration.

134 Average consumption of all qualified units as of [June August 1, 2012/July 5, 2013](#). Qualified units list from [Southern California Edison](#): <http://asset.sce.com/Documents/Residential%20-%20Rebates%20and%20Savings/MostEfficientRefrigeratorQPL.pdf> [www.energystar.gov/index.cfm?c=most\\_efficient\\_medium\\_fridges\\_freezers](http://www.energystar.gov/index.cfm?c=most_efficient_medium_fridges_freezers)

**2.24.32.23.3 Measure Life**

ENERGY STAR and ENERGY STAR Most Efficient Refrigerators: Measure Life = 13 years.<sup>135</sup>

**2.24.42.23.4 Future Standards Changes**

As of September 15, 2014 new federal minimum efficiency standards for refrigerators and refrigerators-freezers will take effect. The maximum allowable energy usage by refrigerator configuration is listed in [Table 2-57](#)~~Table 2-4857~~. These standards will take effect beginning with the 2015 TRM.

~~New ENERGY STAR standards for refrigerators are in development. Updated ENERGY STAR standards will be included in this section of the 2014 TRM.~~

Table 2-~~57~~~~4857~~: Federal Refrigerator Standards Effective as of the 2015 TRM<sup>136</sup>

Refrigerator Category	Federal Standard Maximim Usage in kWh/year (Effective 2015 TRM)
<b>Standard Size Models: 7.75 cubic feet or greater</b>	
Refrigerators-freezers and refrigerators other than all-refrigerators with manual defrost (including partial automatic defrost)	$7.99 \cdot AV + 225.0$
All-refrigerators – manual defrost	$6.79 \cdot AV + 193.6$
Automatic defrost with top-mounted freezer without through-the-door ice service	$8.07 \cdot AV + 233.7$
Automatic defrost with side-mounted freezer without through-the-door ice service	$8.51 \cdot AV + 297.8$
Automatic defrost with bottom-mounted freezer without through-the-door ice service	$8.85 \cdot AV + 317.0$
Automatic defrost with top-mounted freezer with through-the-door ice service	$8.40 \cdot AV + 385.4$
Automatic defrost with side-mounted freezer with through-the-door ice service	$8.54 \cdot AV + 432.8$
<b>Compact Size Models: Less than 7.75 cubic feet and 36 inches or less in height</b>	
Compact refrigerator-freezers and refrigerators other than all-refrigerators with manual defrost	$9.03 \cdot AV + 252.3$
Compact refrigerator-freezers – manual defrost	$7.84 \cdot AV + 219.1$
Compact refrigerator-freezer – partial automatic defrost	$5.91 \cdot AV + 335.8$
Compact refrigerator-freezers--automatic defrost with top-mounted freezer	$11.80 \cdot AV + 339.2$
Compact Refrigerator-Freezers--automatic defrost with side-mounted freezer	$6.82 \cdot AV + 456.9$
Compact Refrigerator-Freezers--automatic defrost with bottom-mounted freezer	$11.80 \cdot AV + 339.2$

135 ENERGY STAR Appliances. February 2008. U.S. Environmental Protection Agency and U.S. Department of Enegy. ENERGY STAR. <http://www.energystar.gov/>.

136 U.S. Department of Energy. *Federal Register*. 179<sup>th</sup> ed. Vol. 76. September 15, 2011. [https://www1.eere.energy.gov/buildings/appliance\\_standards/pdfs/refrig\\_finalrule\\_frnotice.pdf](https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_frnotice.pdf)

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## 2.25.2.24 ENERGY STAR Freezers

Measure Name	Freezers
Target Sector	Residential Establishments
Measure Unit	Freezer
Unit Energy Savings	Varies by Configuration
Unit Peak Demand Reduction	Varies by Configuration
Measure Life	12 years

This measure is for the purchase and installation of a new freezer meeting ENERGY STAR criteria. An ENERGY STAR freezer must be at least 10 percent more efficient than the minimum federal government standard.

### 2.25.12.24.1 Algorithms

The general form of the equation for the ENERGY STAR Freezer measure savings algorithm is:

$$\text{Total Savings} = \text{Number of Freezers} \times \text{Savings per Freezer}$$

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of freezers. The number of freezers will be determined using market assessments and market tracking.

If the volume and configuration of the freezer is known, the federal minimum efficiency and ENERGY STAR qualified models' annual energy consumption are determined using [Table 2-58](#) [Table 2-49](#) [58](#).

The energy and demand savings are given by the following algorithms:

#### ENERGY STAR Freezer

$$\Delta kWh = kWh_{base} - kWh_{EE}$$

$$\Delta kW_{peak} = (kWh_{base} - kWh_{EE}) / \text{Hours} * CF$$

### 2.25.22.24.2 Definition of Terms

$kWh_{base}$  = Annual energy consumption of baseline unit

$kWh_{EE}$  = Annual energy consumption of ENERGY STAR qualified unit

Hours = Hours of operation per year

CF = Demand coincidence factor

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**Where:**

$$CF = 1$$

$$\text{Hours} = 8,760$$

Freezer energy use is characterized by configuration (upright, chest or compact), volume and whether defrost is manual or automatic and whether. If this information is known, annual energy usage of the ENERGY STAR model and federal minimum efficiency standard model can be calculated using [Table 2-58](#)[Table 2-4958](#). The term “AV” in the equations refers to “Adjusted Volume,” which is  $AV = 1.73 \times \text{Total Volume}$ . Note this table is also provided for planning purposes to compare to the changing federal standards detailed in [Table 2-60](#)[Table 2-5160](#).

Table 2-[584958](#): Federal Standard and ENERGY STAR Freezers Maximum Annual Energy Consumption if Configuration and Volume Known<sup>138</sup>

Freezer Category	Federal Standard Maximim Usage in kWh/year	ENERGY STAR Maximum Energy Usage in kWh/year
Upright with manual defrost	$7.55 \cdot AV + 258.3$	$< 6.795 \cdot AV + 232.47$
Upright with automatic defrost	$12.43 \cdot AV + 326.1$	$< 11.187 \cdot AV + 293.49$
Chest Freezer	$9.88 \cdot AV + 143.7$	$< 8.892 \cdot AV + 129.33$
Compact Upright with manual defrost	$9.78 \cdot AV + 250.8$	$< 7.824 \cdot AV + 200.64$
Compact Upright with automatic defrost	$11.40 \cdot AV + 391$	$< 9.120 \cdot AV + 312.8$
Compact Chest Freezer	$10.45 \cdot AV + 152$	$< 8.360 \cdot AV + 121.6$

The default values for each configuration are given in [Table 2-59](#)[Table 2-5059](#). Note that a compact freezer is defined as a freezer that has a volume less than 7.75 cubic feet and is 36 inches or less in height.

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137 ENERGY STAR Freezers Savings Calculator. Accessed June 24, 2012.

138 ENERGY STAR Refrigerators and Freezers Key Product Criteria.

[http://www.energystar.gov/index.cfm?c=refrig\\_pr\\_crit\\_refrigerators](http://www.energystar.gov/index.cfm?c=refrig_pr_crit_refrigerators)

Table 2-595059; Default Savings Values for ENERGY STAR Freezers

Freezer Category	Conventional Unit Energy Usage in kWh/yr <sup>139</sup>	ENERGY STAR Energy Usage in kWh/yr <sup>140</sup>	ΔkWh	ΔkW
Upright with manual defrost	425405	372347	5358	0.00640066
Upright with automatic defrost	692681	614599	8182	0.00920094
Chest Freezer	413392	370351	4341	0.00490047
Compact Upright with manual defrost	302301	234235	6866	0.00780076
Compact Upright with automatic defrost	495	355	140	0.0160
Compact Chest Freezer	260257	202204	5854	0.00660061

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### 2.25.32.24.3 Measure Life

ENERGY STAR Freezers: Measure Life = 12 years.<sup>141</sup>

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### 2.25.42.24.4 Future Standards Changes

As of September 15, 2014 new federal minimum efficiency standards for freezers will take effect.

The maximum allowable energy usage by freezer configuration is listed in [Table 2-60Table-2-5160](#). These standards will take effect beginning with the 2015 TRM.

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~~New ENERGY STAR standards for freezers are in development. Updated ENERGY STAR standards will be included in this section of the 2014 TRM.~~

Table 2-605460: Federal Freezer Standards Effective as of the 2015 TRM<sup>142</sup>

Freezer Category	Federal Standard Maximim Usage in kWh/year (Effective 2015 TRM)
Upright with manual defrost	5.57*AV + 193.7
Upright with automatic defrost	8.62*AV + 228.3
Chest Freezer	7.29*AV + 107.8
Compact Upright with manual defrost	8.65*AV + 225.7
Compact Upright with automatic defrost	10.17*AV + 351.9
Compact Chest Freezer	9.25*AV + 136.8

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<sup>139</sup> ENERGY STAR Residential Freezers Qualified Products List. [August 16, 2012-July 10, 2013](#). Average federal standard consumption of all qualifying models by configuration.

<sup>140</sup> Ibid. Average ENERGY STAR consumption of all qualifying models by configuration.

<sup>141</sup> ENERGY STAR Appliances Savings Calculator. Accessed [August 2012-July 10, 2013](#).

<sup>142</sup> U.S. Department of Energy. *Federal Register*. 179<sup>th</sup> ed. Vol. 76. September 15, 2011.

[https://www1.eere.energy.gov/buildings/appliance\\_standards/pdfs/refrig\\_finalrule\\_frnotice.pdf](https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_frnotice.pdf)

**2.262.25 ENERGY STAR Clothes Washers**

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Measure Name	Clothes Washers
Target Sector	Residential Establishments
Measure Unit	Clothes Washer
Unit Energy Savings	Varies by Fuel Mix
Unit Peak Demand Reduction	0.0147 kW
Measure Life	11 years

This measure is for the purchase and installation of a clothes washer meeting ENERGY STAR eligibility criteria. ENERGY STAR clothes washers use less energy and hot water than non-qualified models.

**2.26.12.25.1 Algorithms**

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The general form of the equation for the ENERGY STAR Clothes Washer measure savings algorithm is:

$$\text{Total Savings} = \text{Number of Clothes Washers} \times \text{Savings per Clothes Washer}$$

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of clothes washers. The number of clothes washers will be determined using market assessments and market tracking.

Per unit energy and demand savings are given by the following algorithms:

$$\Delta kWh = \left[ \left( \frac{CAPY_{base}}{MEF_{base}} \right) \times (\% [CW_{base} + \% [DHW_{base} \times \% \text{Electric DHW}] + \% [Dryer_{base} \times \% \text{Electric Dryer}]) \right] - \left[ \left( \frac{CAPY_{EE}}{MEF_{EE}} \right) \times (\% [CW_{EE} + (\% [DHW_{EE} \times \% \text{Electric DHW}] + \% [Dryer_{EE} \times \% \text{Electric Dryer}]) \right] \right] \times \text{Cycles}$$

$$\Delta kW = DSav_{CW} \times CF$$

Where MEF is the Modified Energy Factor, which is the energy performance metric clothes washers. MEF is defined as:

*MEF is the quotient of the capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, M, the hot water energy consumption,*

*E*, and the energy required for removal of the remaining moisture in the wash load, *D*. The higher the value, the more efficient the clothes washer is.<sup>143</sup>

$$MEF = C / (M + E + D)$$

#### 2.26.22.25.2 Definition of Terms

$CAPY_{base}$	= Capacity of baseline clothes washer in cubic feet
$CAPY_{EE}$	= Capacity of ENERGY STAR clothes washer in cubic feet
$MEF_{base}$	= Modified Energy Factor of baseline clothes washer
$MEF_{EE}$	= Modified Energy Factor of ENERGY STAR clothes washer
Cycles	= Number of clothes washer cycles per year
$\%CW_{base}$	=Percentage of total energy consumption for baseline clothes washer operation
$\%CW_{EE}$	=Percentage of total energy consumption for ENERGY STAR clothes washer operation
$\%DHW_{base}$	= Percentage of total energy consumption for baseline clothes washer water heating
$\%DHW_{EE}$	= Percentage of total energy consumption for ENERGY STAR clothes washer water heating
$\%ElectricDWH$	= Percentage of clothes washers that utilize electrically heated hot water
$\%Dyer_{base}$	= Percentage of total energy consumption for dryer operation with baseline clothes washer
$\%Dyer_{EE}$	= Percentage of total energy consumption for dryer operation with ENERGY STAR clothes washer
$\%Electric\ Dryer$	= Percentage of dryers that are electric
$DSavCW$	= Summer demand savings per purchased ENERGY STAR clothes washer. <sup>144</sup>
$CF$	=Demand Coincidence Factor. The coincidence of average clothes washer demand to summer system peak

As of February 1, 2013 a clothes washer must have a  $MEF \geq 2.0$  and a  $WF \leq 6.0$  to meet ENERGY STAR standards.  $WF$  is the Water Factor, which is the measure of water efficiency of a

<sup>143</sup> Definition provided on ENERGY STAR Clothes Washers Key Product Criteria website:  
[http://www.energystar.gov/index.cfm?c=clotheswash.pr\\_crit\\_clothes\\_washers](http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers)

<sup>144</sup> Further research to update this value and  $CF$  is planned for [20142015](#) TRM update.

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clothes washer, expressed in gallons per cubic feet. WF is the quotient of the total weighted per-cycle water consumption divided by the capacity of the clothes washer.<sup>145</sup>

The federal standard for a clothes washer must have a MEF  $\geq 1.26$  and WF  $\leq 9.5.146$

The default values for the terms in the algorithms are listed in ~~Table 2-61~~~~Table 2-5261~~. If unit information is known (such as capacity, MEF, fuel mix) then actual values should be used.

Table 2-~~615261~~: ENERGY STAR Clothes Washers - References

Term	Type	Value	Source
CAPY <sub>base</sub>	Fixed	3.4910 ft <sup>3</sup>	1
CAPY <sub>EE</sub>	Variable	EDC Data Gathering	EDC Data Gathering
		Default: 3.6410 ft <sup>3</sup>	2
MEF <sub>base</sub>	Fixed	1.4326	1
MEF <sub>EE</sub>	Variable	EDC Data Gathering	EDC Data Gathering
		Default: 2.5400	2
Cycles	Fixed	276265	3
%CW <sub>base</sub>	Fixed	9%	4
%CW <sub>EE</sub>	Fixed	9%	4
%DHW <sub>base</sub>	Fixed	37%	4
%DHW <sub>EE</sub>	Fixed	22%	4
%Electric DHW	Variable	EDC Data Gathering	Appliance Saturation Studies
		Default: 1743%	53
%Dryer <sub>base</sub>	Fixed	54%	4
%Dryer <sub>EE</sub>	Fixed	69%	4

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<sup>145</sup> Based on ENERGY STAR Version 6.0 requirements, *ENERGY STAR Program Requirements Product Specification for Clothes Washers, Eligibility Criteria Version 6.0*. Accessed August 2012.

[http://www.energystar.gov/ia/partners/prod\\_development/revisions/downloads/commercial\\_clothes\\_washers/ENERGY\\_STAR\\_Final\\_Version\\_6\\_Clothes\\_Washer\\_Specification.pdf](http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/commercial_clothes_washers/ENERGY_STAR_Final_Version_6_Clothes_Washer_Specification.pdf)

<sup>146</sup> ENERGY STAR Clothes Washers Key Product Criteria website:

[http://www.energystar.gov/index.cfm?c=clotheswash.pr\\_crit\\_clothes\\_washers](http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers)

%Electric Dryer	Variable	EDC Data Gathering	Appliance Saturation Studies
		Default: 64%	6
DSav <sub>cw</sub>	Fixed	0.0147	7
CF	Fixed	1	8

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**Sources:**

1. ~~Average MEF and capacity of baseline units from the DOE database of clothes washers certified after July 2011. Energy Star Calculator, EPA research on available models. Accessed June 2013~~
4. ~~EnergyStar Calculator, Calculated by taking average of all units that met federal standards but not ENERGY STAR standards. Accessed August 2012.~~
2. Average MEF and capacity of all ENERGY STAR qualified clothes washers, ~~as of August 2012.~~ Accessed June 2013
3. ~~Based on weighted average number of loads from EIA 2009 Residential Energy Consumption Survey (RECS) appliance data for the state of Pennsylvania. <http://www.eia.gov/consumption/residential/index.cfm>~~
- 4.3. 3. Statewide average for all housing types from Pennsylvania Statewide Residential End-Use and Saturation Study, 2012. The percentage of total consumption that is used for the machine, water heating and dryer varies with efficiency. Percentages were developed using the above parameters and using the U.S. Department of Energy's Life-Cycle Cost and Payback Period tool, available at: [http://www1.eere.energy.gov/buildings/appliance\\_standards/residential/clothes\\_washers\\_support\\_stakeholder\\_negotiations.html](http://www1.eere.energy.gov/buildings/appliance_standards/residential/clothes_washers_support_stakeholder_negotiations.html)
5. ~~EIA 2009 Residential Energy Consumption Survey (RECS) water heating data for the state of Pennsylvania. <http://www.eia.gov/consumption/residential/index.cfm>~~
- 6.4. ~~EIA 2009 Residential Energy Consumption Survey (RECS) appliance data for the state of Pennsylvania. <http://www.eia.gov/consumption/residential/index.cfm>~~
- 7.5. ~~Energy and water savings based on Consortium for Energy Efficiency estimates. Assumes 75% of participants have gas water heating and 60% have gas drying (the balance being electric). Demand savings derived using NEEP screening clothes washer load shape.~~
- 8.6. ~~Coincidence factor already embedded in summer peak demand reduction estimate~~

The default values for various fuel mixes are given in ~~Table 2-62~~Table 2-5362.



Table 2-~~625362~~: Default Clothes Washer Savings

Fuel Mix	ΔkWh
Electric DHW/Electric Dryer	215
Electric DHW/Gas Dryer	159
Gas DHW/Electric Dryer	55
Gas DHW/Gas Dryer	19
Default (17% Electric DHW 64% Electric Dryer)	79

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**2-26.32.25.3 Measure Life**

ENERGY STAR Clothes Washer: Measure Life = 11 years.<sup>147</sup>

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**2-26.42.25.4 Future Standards Changes**

As of March 7, 2015 new federal minimum efficiency standards for clothes washers will take effect. Further efficiency standards for top-loading clothes washers go into effect beginning January 1, 2018. The 2015 efficiency standards for front-loading clothes washers will continue to be effective in 2018. The efficiency standards and the effective TRM that these standards become the baseline are detailed in [Table 2-63](#)~~Table 2-5463~~.

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Note that the current standards are based on the MEF and WF, but beginning in 2015 the standards will be based on the Integrated Modified Energy Factor (IMEF) and Integrated Water Factor (IWF). The IMEF incorporates energy use in standby and off modes and includes updates to the provisions of per-cycle measurements. The IWF more accurately represents consumer usage patterns as compared to the current metric.<sup>148</sup><sup>149</sup>

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These standards are effective for both compact- and standard-size clothes washers. A compact clothes washer is defined to have a capacity of less than 1.6 ft<sup>3</sup> and a standard-size clothes washer has a capacity of 1.6 ft<sup>3</sup> or greater.<sup>150</sup><sup>151</sup>

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<sup>147</sup> ENERGY STAR Appliances, February 2008, U.S. Environmental Protection Agency and U.S. Department of Energy, ENERGY STAR, <http://www.energystar.gov/>, ENERGY STAR Calculator, Accessed July 10, 2013.

<sup>148</sup> Ibid.

<sup>149</sup> Ibid.

<sup>150</sup> U.S. Department of Energy, 10 CFR Parts 429 and 430, Energy Conservation Program: Energy Conservation Standards for Residential Clothes Washers, Direct Final Rule.

<sup>151</sup> U.S. Department of Energy, 10 CFR Parts 429 and 430, Energy Conservation Program: Energy Conservation Standards for Residential Clothes Washers, Direct Final Rule.

Table 2-635463: Future Federal Standards for Clothes Washers<sup>152</sup>

	2015 TRM		2018 TRM	
	Minimum IMEF	Maximum IWF	Minimum IMEF	Maximum IWF
Top-loading, Compact	0.86	14.4	1.15	12.0
Top-loading, Standard	1.29	8.4	1.57	6.5
Front-loading, Compact	1.13	8.3	N/A	
Front-loading, Standard	1.84	4.7	N/A	

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<sup>152</sup> U.S. Department of Energy. 10 CFR Parts 429 and 430. *Energy Conservation Program: Energy Conservation Standards for Residential Clothes Washers*. Direct Final Rule.

**2.27.2.26 ENERGY STAR Dishwashers**

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Measure Name	Dishwashers
Target Sector	Residential Establishments
Measure Unit	Dishwasher
Unit Energy Savings	Varies by Water Heating Fuel Mix
Unit Peak Demand Reduction	0.0225 kW
Measure Life	11 years

This measure is for the purchase and installation of a dishwasher meeting ENERGY STAR eligibility criteria. ENERGY STAR dishwashers use less energy and hot water than non-qualified models.

**2.27.12.26.1 Algorithms**

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The general form of the equation for the ENERGY STAR Dishwasher measure savings algorithm is:

$$\text{Total Savings} = \text{Number of Dishwashers} \times \text{Savings per Dishwasher}$$

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of dishwashers. The number of dishwashers will be determined using market assessments and market tracking.

Per unit energy and demand savings algorithms for dishwashers utilizing electrically heated hot water:

$$\Delta kWh = ((kWh_{base} - kWh_{EE}) \times (\%kWh_{op} + (\%kWh_{heat} \times \%Electric_{DHW})))$$

$$\Delta kW = DSaV_{DW} \times CF$$

**2.27.22.26.2 Definition of Terms**

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$kWh_{base}$  = Annual energy consumption of baseline dishwasher

$kWh_{EE}$  = Annual energy consumption of ENERGY STAR qualified unit

$\%kWh_{op}$  = Percentage of unit dishwasher energy consumption used for operation

$\%kWh_{heat}$  = Percentage of dishwasher unit energy consumption used for water heating

$\%Electric_{DHW}$  = Percentage of dishwashers assumed to utilize electrically heated hot water.

$DSaV_{DW}$  = Summer demand savings per purchased ENERGY STAR dishwasher.

**CF** = Demand Coincidence Factor. The coincidence of average dishwasher demand to summer system peak

ENERGY STAR qualified dishwashers must use less than or equal to the water and energy consumption values given in [Table 2-64](#)~~Table 2-5564~~. Note, as of May 30, 2013, ENERGY STAR compact dishwashers have the same maximum water and energy consumption requirements as the federal standard and therefore are not included in the TRM since there is not energy savings to be calculated for installation of an ENERGY STAR compact dishwasher. A standard sized dishwasher is defined as any dishwasher that can hold 8 or more place settings and at least six serving pieces.<sup>153</sup>

Table 2-~~645564~~: Federal Standard and ENERGY STAR v 5.0 Residential Dishwasher ~~Standard~~Standard

Product Type	Federal Standard <sup>154</sup>		ENERGY STAR v 5.0 <sup>155</sup>	
	Water (gallons per cycle)	Energy (kWh per year)	Water (gallons per cycle)	Energy (kWh per year)
Standard	≤ <del>5.06</del> .50	≤ <del>307</del> 355	≤ 4.25	≤ 295

Table 2-~~655665~~: ENERGY STAR Dishwashers - References

Component	Type	Value	Source
kWh <sub>base</sub>	Fixed	244151 kWh/yr	1
kWh <sub>EE</sub>	Fixed	215126 kWh/yr	21
%kWh <sub>op</sub>	Fixed	44%	31
%kWh <sub>heat</sub>	Fixed	56%	31
%Electric <sub>DHW</sub>	Variable	Default: 43% or EDC Data Gathering	Appliance Saturation Studies
DSav <sub>DW</sub>	Fixed	0.0225156	43
CF	Fixed	1	54

153 Dishwashers Key Product Criteria. [http://www.energystar.gov/index.cfm?c=dishwash.pr\\_crit\\_dishwashers](http://www.energystar.gov/index.cfm?c=dishwash.pr_crit_dishwashers)

154 U.S. Department of Energy. *Federal Register*. 104<sup>th</sup> ed. Vol. 77, May 30, 2012.

[http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0060-0005\\_lbid](http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-STD-0060-0005_lbid)

155 ENERGY STAR Program Requirements Product Specification for Residential Dishwashers.

[http://www.energystar.gov/ia/partners/prod\\_development/revisions/downloads/res\\_dishwashers/ES\\_V5\\_Dishwashers\\_Specification.pdf](http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/res_dishwashers/ES_V5_Dishwashers_Specification.pdf)

156 Further research to update this value and CF is planned for 20142015 TRM update.

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**Sources:**

1. ~~Federal baseline assumption adjusted based on 2009 Residential Energy Consumption (RECS) data on average dishwasher cycles per year for Pennsylvania. DOE assumes 215 cycles per year and Pennsylvania average cycles per year is 171.~~
2. ~~ENERGY STAR Dishwashers Qualified Products List. August 16, 2012. Average consumption of all qualified units adjusted based on Pennsylvania cycles per year.~~
- 3.1. ~~ENERGY STAR Appliances Calculator. Accessed August 2012 July 2013.~~
- 4.2. ~~3. Statewide average for all housing types from Pennsylvania Statewide Residential End-Use and Saturation Study, 2012. Demand savings derived using dishwasher load shape.~~
- 5.3. ~~Coincidence factor already embedded in summer peak demand reduction estimate~~

~~For EDCs where water heating fuel mix is unknown (%Electric<sub>DHW</sub>), use data from EDC specific values from residential appliance saturation studies (or similar studies). If such studies are unavailable use the default fuel mix given in Table 2-57.~~

Table 2-57: Default Dishwasher Hot Water Fuel Mix<sup>157</sup>

DHW Fuel	DHW Fuel Mix
Electric	17%
Other	83%

The default values for electric and non-electric water heating and the default fuel mix from ~~Table 2-57~~ ~~Table 2-64~~ is given in ~~Table 2-66~~ ~~Table 2-58~~ ~~66~~.

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Table 2-~~66~~ ~~58~~ ~~66~~: Default Dishwasher Energy and Demand Savings

Water Heating	$\Delta$ kWh/yr
Electric (%Electric <sub>DHW</sub> = 100%)	<del>2925</del>
Non-Electric (%Electric <sub>DHW</sub> = 0%)	<del>1311</del>
Default Fuel Mix (%Electric <sub>DHW</sub> = 42%)	<del>1617</del>

**2.27.32.26.3 Measure Life**

ENERGY STAR Dishwashers: Measure Life = ~~4110~~ years<sup>158</sup>

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<sup>157</sup> Default fuel mix from EIA 2009 Residential Energy Consumption Survey (RECS) water heating data for the state of Pennsylvania. <http://www.eia.gov/consumption/residential/index.cfm>

<sup>158</sup> ENERGY STAR Appliances. February 2008. U.S. Environmental Protection Agency and U.S. Department of Energy. ENERGY STAR. <http://www.energystar.gov/>. EnergyStar Calculator. Accessed July 2013.

## 2.28.2.27 ENERGY STAR Dehumidifiers

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Measure Name	Dehumidifiers
Target Sector	Residential Establishments
Measure Unit	Dehumidifier
Unit Energy Savings	Varies based on capacity
Unit Peak Demand Reduction	0.0098 kW
Measure Life	12 years

ENERGY STAR qualified dehumidifiers are 15 percent more efficient than non-qualified models due to more efficient refrigeration coils, compressors and fans.

### 2.28.12.27.1 Algorithms

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The general form of the equation for the ENERGY STAR Dehumidifier measure savings algorithm is:

$$\text{Total Savings} = \text{Number of Dehumidifiers} \times \text{Savings per Dehumidifier}$$

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of dehumidifiers. The number of dehumidifiers will be determined using market assessments and market tracking.

Per unit energy and demand savings algorithms:

$$\begin{aligned} \Delta kWh &= ((\text{Avg Capacity} * 0.473) / 24) * \text{Hours} * (1 / (L/kWh_{\text{base}}) - 1 / (L/kWh_{\text{EE}})) \\ \Delta kW_{\text{peak}} &= DS_{\text{avDH}} \times CF \end{aligned}$$

### 2.28.22.27.2 Definition of Terms

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<i>Avg Capacity</i>	= Average capacity of the unit (pints/day)
<i>0.473</i>	= Conversion factor from pints to liters
<i>24</i>	= Conversion factor from liters/day to liters/hour
<i>Hours</i>	= Annual hours of operation
	= 16201632 <sup>159</sup>
<i>L/kWh<sub>base</sub></i>	= Baseline unit liters of water per kWh consumed
<i>L/kWh<sub>EE</sub></i>	= ENERGY STAR qualified unit liters of water per kWh consumed

159 ENERGY STAR Dehumidifier Calculator, Accessed July 2013.

$DSav_{DH}$  = Summer demand savings per purchased ENERGY STAR dehumidifier  
 $= 0.0098 \text{ kW}^{160 \ 161}$

$CF$  = Demand Coincidence Factor. The coincidence of average dehumidifier demand to summer system peak  
 $= 1^{162}$

[Table 2-67](#)~~Table 2-59~~[67](#) shows the federal standard minimum efficiency and ENERGY STAR standards, effective October 1, 2012. Federal standards do not limit residential dehumidifier capacity, but since ENERGY STAR standards do limit the capacity to 185 pints per day, [Table 2-59](#) only presents standards for the range of dehumidifier capacities that savings can be claimed.

Table 2-~~67~~[67](#)~~59~~[67](#): Dehumidifier Minimum Federal Efficiency and ENERGY STAR Standards

Capacity (pints/day)	Federal Standard <sup>163</sup> (L/kWh)	ENERGY STAR <sup>164</sup> (L/kWh)
≤ 35	1.35	≥ 1.85
> 35 ≤ 45	1.50	
> 45 ≤ 54	1.60	
> 54 < 75	1.70	
75 ≤ 185	2.5	≥ 2.80

The annual energy usage and savings of an ENERGY STAR unit over the federal minimum standard are presented in

[Table 2-60](#) for each capacity range.

[Table 2-68](#) for each capacity range.

<sup>160</sup> Conservatively assumes same kW/kWh ratio as Refrigerators.

<sup>161</sup> Further research to update this value and CF is planned for [20142015](#) TRM update.

<sup>162</sup> Coincidence factor already embedded in summer peak demand reduction estimate.

<sup>163</sup> [EnergyStar Calculator Accessed July 2013 using](#) U.S. Department of Energy. *Federal Register*. 66<sup>th</sup> ed. Vol. 74. April 8, 2009.

[https://www1.eere.energy.gov/buildings/appliance\\_standards/residential/pdfs/74fr16040.pdf](https://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/74fr16040.pdf)[https://www1.eere.energy.gov/buildings/appliance\\_standards/residential/pdfs/74fr16040.pdf](https://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/74fr16040.pdf)

<sup>164</sup> [EnergyStar Calculator Accessed July 2013 using](#) ENERGY STAR Program Requirements Product Specification for Dehumidifiers, Eligibility Criteria Version 3.0.

[http://www.energystar.gov/ia/partners/prod\\_development/revisions/downloads/dehumid/ES\\_Dehumidifiers\\_Final\\_V3.0\\_Eligibility\\_Criteria.pdf?3cbf-7a48](http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/dehumid/ES_Dehumidifiers_Final_V3.0_Eligibility_Criteria.pdf?3cbf-7a48)

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Table 2-686068: Dehumidifier Default Energy Savings

Capacity Range (pints/day)	Default Capacity (pints/day) <sup>165</sup>	Federal Standard (kWh/yr)	ENERGY STAR (kWh/yr)	ΔkWh
≤ 35	35	686	500	186
> 35 ≤ 45	45	905	733	172
>45 ≤ 54	54	988	854	134
>54 < 75	74	1,211	1,113	98
75 ≤ 185	130	1,660	1,482	178

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**2.28.32.27.3 Measure Life**ENERGY STAR Dehumidifiers: Measure Life = 12 years.<sup>166</sup>

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<sup>165</sup> Default capacity is midpoint of each capacity range except those units with capacity less than 35 pints per day, where 29 pints per day was used based on the average capacity of all ENERGY STAR dehumidifiers available in this capacity range as of August 2012.

<sup>166</sup> EnergyStar Calculator Accessed July 2013 using ENERGY STAR Appliances. February 2008. U.S. Environmental Protection Agency and U.S. Department of Energy. ENERGY STAR. <http://www.energystar.gov/>.



## 2.29.28 ENERGY STAR Room Air Conditioners

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Measure Name	Room Air Conditioners
Target Sector	Residential Establishments
Measure Unit	Room Air Conditioner
Unit Energy Savings	Varies
Unit Peak Demand Reduction	0.059 kW
Measure Life	9 years

This measure relates to the purchase and installation of a room air conditioner meeting ENERGY STAR criterion.

### 2.29.12.28.1 Algorithms

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The general form of the equation for the ENERGY STAR Room Air Conditioners (RAC) measure savings algorithm is:

$$\text{Total Savings} = \text{Number of Room Air Conditioner} \times \text{Savings per Room Air Conditioner}$$

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of room air conditioners. The number of room air conditioners will be determined using market assessments and market tracking.

$$\begin{aligned} \Delta kWh &= CAPY_{RAC}/1000 \times (1/EER_b - 1/EER_{ee}) * EFLH_{RAC} \\ \Delta kW &= DSav_{RAC} \times CF \end{aligned}$$

**2.29.22.28.2 Definition of Terms**

- $CAPY_{RAC}$  =The cooling capacity (output in Btuh) of the room air conditioner (RAC) being installed
- $EER_b$  =Energy efficiency ratio of the baseline unit
- $EER_{ee}$  =Energy efficiency ratio of the RAC being installed
- $EFLH_{RAC}$  =Equivalent full load hours of the RAC being installed
- $DSav_{RAC}$  = Summer demand savings per purchased ENERGY STAR room AC  
=0.1018 kW<sup>167, 168</sup>
- CF =Demand coincidence factor  
=0.58<sup>169</sup>

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Table 2-64 Table 2-69 Table 2-69 lists the minimum federal efficiency standards as of June 2014 and minimum ENERGY STAR efficiency standards for RAC units of various capacity ranges and with and without louvered sides. Units without louvered sides are also referred to as “through the wall” units or “built-in” units.

**Table 2-61: RAC Federal Minimum Efficiency and ENERGY STAR Standards<sup>170</sup>**

Capacity (Btu/h)	Federal Standard EER, with louvered sides	ENERGY STAR EER, with louvered sides	Federal Standard EER, without louvered sides	ENERGY STAR EER, without louvered sides
<6,000	≥ 9.7	≥ 10.7	≥ 9.0	≥ 9.9
6,000 to 7,999				
8,000 to 13,999	≥ 9.8	≥ 10.8	≥ 8.5	≥ 9.4
14,000 to 19,999	≥ 9.7	≥ 10.7		
≥ 20,000	≥ 8.5	≥ 9.4		

~~Table 2-62 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for casement only and casement slider RAC units. Casement only refers to a RAC designed for mounting in a casement window with an encased assembly with a width of 14.8 inches or less and a height of 11.2 inches or less. Casement slider refers to a RAC with an encased assembly designed for mounting in a sliding or casement window with a width of 15.5 inches or less.~~

~~Table 2-62: Casement only and Casement Slider RAC Federal Minimum Efficiency and ENERGY STAR Standards<sup>171</sup>~~

Casement	Federal Standard	ENERGY STAR EER
----------	------------------	-----------------

167 Average demand savings based on engineering estimate.

168 Further research to update this value and CF is planned for 20142015 TRM update.

169 Based on data from PEPCO.

170 ENERGY STAR Program Requirements for Room Air Conditioners.

[http://www.energystar.gov/ia/partners/product\\_specs/program\\_reqs/room\\_air\\_conditioners\\_prog\\_req.pdf](http://www.energystar.gov/ia/partners/product_specs/program_reqs/room_air_conditioners_prog_req.pdf)

171 Ibid.

	EER	
Casement-only	≥ 8.7	≥ 9.6
Casement-slider	≥ 9.5	≥ 10.5

Table 2-63 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for reverse cycle RAC units.

**Table 2-63: Reverse-Cycle RAC Federal Minimum Efficiency Standards<sup>172</sup>**

Capacity (Btu/h)	Federal Standard EER, with louvered sides	ENERGY STAR EER, with louvered sides	Federal Standard EER, without louvered sides	ENERGY STAR EER, without louvered sides
< 14,000	n/a	n/a	≥ 8.5	≥ 9.4
≥ 14,000			≥ 8.0	≥ 8.8
< 20,000	≥ 9.0	≥ 9.9	n/a	n/a
≥ 20,000	≥ 8.5	≥ 9.4		

Table 2-64 provides deemed EFLH by city and default energy savings values if efficiency and capacity information is unknown.

**Table 2-64: Deemed EFLH and Default Energy Savings<sup>173</sup>**

City	EFLH <sub>RAC</sub>	ΔkWh
Allentown	243	23
Erie	149	14
Harrisburg	288	27
Philadelphia	320	30
Pittsburgh	228	22
Scranton	193	18
Williamsport	204	19

### ~~2.29.3 Measure Life~~

~~ENERGY STAR Room Air Conditioners: Measure Life = 10 years<sup>175</sup>~~

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<sup>172</sup> Ibid.

<sup>173</sup> Values taken from ENERGY STAR calculator except for EFLH estimates, which can be found in Section 2.12 (Room AC Retirement).

<sup>174</sup> Assumes 10,000 Btu/h capacity and 9.8 EER for baseline unit and 10.8 EER for ENERGY STAR unit.

<sup>175</sup> ENERGY STAR Appliances, February 2008. U.S. Environmental Protection Agency and U.S. Department of Energy. ENERGY STAR. <http://www.energystar.gov/>.

**2.29.4 — Future Standards Changes**

As of June 1, 2014 new room air conditioners must meet the federal standards given in Table 2-65, Table 2-66 and Table 2-67. Therefore the following baseline efficiencies will be effective as of the 2014 TRM. Note that the new federal standards are based on the Combined Energy Efficiency Ratio Metric (CEER), which is a metric that incorporates energy use in all modes, including standby and off modes. 176

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Also, as of October 1, 2013 ENERGY STAR Room Air Conditioner Version 3.0 will take effect. The new eligibility criteria are given in Table 2-65, Table 2-66 and Table 2-67. The new ENERGY STAR standards will be effective as of the 2014 TRM. Table 2-69, Table 2-70, Table 2-70 and Table 2-71.

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Table 2-69: RAC Federal Minimum Efficiency and ENERGY STAR Version 3.0 Standards (effective 2014 TRM)

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Capacity (Btu/h)	Federal Standard CEER, with louvered sides	ENERGY STAR EER, with louvered sides	Federal Standard EER, without louvered sides	ENERGY STAR CEER, without louvered sides
< 6,000	≥11.0	11.2	10.0	10.4
6,000 to 7,999				
8,000 to 10,999	≥10.9	11.3	9.6	9.8
11,000 to 13,999			9.5	
14,000 to 19,999			9.3	
20,000 to 24,999	≥9.4	9.8	9.4	
≥25,000	≥9.0			

Table 2-70 lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for casement-only and casement-slider RAC units. Casement-only refers to a RAC designed for mounting in a casement window with an encased assembly with a width of 14.8 inches or less and a height of 11.2 inches or less. Casement-slider refers to a RAC with an encased assembly designed for mounting in a sliding or casement window with a width of 15.5 inches or less.

Table 2-70: Casement-Only and Casement-Slider RAC Federal Minimum Efficiency and ENERGY STAR Version 3.0 Standards (effective 2014 TRM)

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Casement	Federal Standard CEER	ENERGY STAR EER
Casement-only	≥ 9.5	≥ 10.0
Casement-slider	≥ 10.4	≥ 10.9

176 Federal stanards: U.S. Department of Energy. *Federal Register*. 164<sup>th</sup> ed. Vol. 76, August 24, 2011.  
 177 Federal stanards: U.S. Department of Energy. *Federal Register*. 164<sup>th</sup> ed. Vol. 76, August 24, 2011.  
 ENERGY STAR standards: *ENERGY STAR Program Requirements Product Specification for Room Air Conditioners, Eligibility Criteria Version 3.0*. June 22, 2012.

[Table 2-71](#) lists the minimum federal efficiency standards and minimum ENERGY STAR efficiency standards for reverse-cycle RAC units.

**Table 2-71: Reverse-Cycle RAC Federal Minimum Efficiency Standards and ENERGY STAR Version 3.0 Standards (effective 2014 TRM)**

Capacity (Btu/h)	Federal Standard CEER, with louvered sides	ENERGY STAR EER, with louvered sides	Federal Standard CEER, without louvered sides	ENERGY STAR EER, without louvered sides
< 14,000	n/a	n/a	≥ 9.3	≥ 9.8
≥ 14,000			≥ 8.7	≥ 9.2
< 20,000	≥ 9.8	≥ 10.4	n/a	n/a
≥ 20,000	≥ 9.3	≥ 9.8		

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**Table 2-72**

[Table 2-72](#) provides deemed EFLH by city and default energy savings values if efficiency and capacity information is unknown.

**Table 2-72: Deemed EFLH and Default Energy Savings<sup>178, 179</sup>**

City	EFLH <sub>RAC</sub>	ΔkWh
Allentown	243	23
Erie	149	14
Harrisburg	288	27
Philadelphia	320	30
Pittsburgh	228	22
Scranton	193	18
Williamsport	204	19

**2-29.52.28.3 Measure Life**

ENERGY STAR Room Air Conditioners: Measure Life = 10 years<sup>180</sup>

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<sup>178</sup> Values taken from ENERGY STAR calculator except for EFLH estimates, which can be found in Section 2.12 (Room AC Retirement).

<sup>179</sup> Assumes 10,000 Btu/h capacity and 9.8 EER for baseline unit and 10.8 EER for ENERGY STAR unit.

<sup>180</sup> ENERGY STAR Appliances. February 2008. U.S. Environmental Protection Agency and U.S. Department of Energy. ENERGY STAR. <http://www.energystar.gov/>.

## 2.302.29 ENERGY STAR Lighting

### 2.30.12.29.1 Algorithms

Savings from installation of screw-in ENERGY STAR CFLs, ENERGY STAR fluorescent torchieres, ENERGY STAR indoor fixtures and ENERGY STAR outdoor fixtures are based on a straightforward algorithm that calculates the difference between existing and new wattage and the average daily hours of usage for the lighting unit being replaced. An “in-service” rate is used to reflect the fact that not all lighting products purchased are actually installed.

An adjustment to the baseline is also made to account for the Energy Independence and Security Act of 2007 (EISA 2007), which requires that all general service lamps between 40 W and 100 W meet minimum efficiency standards in terms of amount of light delivered per unit of energy consumed. The standard is phased in over two years, between January 1, 2012 and January 1, 2014. This adjustment affects ENERGY STAR CFLs, ENERGY STAR Torchieres, ENERGY STAR Indoor Fixtures, ENERGY STAR Outdoor Fixtures and ENERGY STAR Ceiling Fans where the baseline condition is assumed to be a standard incandescent light bulb.

The general form of the equation for the ENERGY STAR or other high-efficiency lighting energy savings algorithm is:

*Total Savings* = *Number of Units X Savings per Unit*

#### ENERGY STAR CFL Bulbs (screw-in):

$$\Delta kWh = (Watts_{base} - Watts_{CFL}) \times CFL_{hours} \times (1 + IE_{kW}) \times 365 / 1000 \times ISR_{CFL}$$

$$\Delta kW_{peak} = (Watts_{base} - Watts_{CFL}) / 1000 \times (1 + IE_{kW}) \times CF \times ISR_{CFL}$$

#### ENERGY STAR Torchieres:

$$\Delta kWh = (Watts_{base} - Watts_{Torch}) \times Torch_{hours} \times (1 + IE_{kW}) \times 365 / 1000 \times ISR_{Torch}$$

$$\Delta kW_{peak} = (Watts_{base} - Watts_{Torch}) / 1000 \times (1 + IE_{kW}) \times CF \times ISR_{Torch}$$

#### ENERGY STAR Indoor Fixture (hard-wired, pin-based):

$$\Delta kWh = (Watts_{base} - Watts_{IF}) \times IF_{hours} \times (1 + IE_{kW}) \times 365 / 1000 \times ISR_{IF}$$

$$\Delta kW_{peak} = (Watts_{base} - Watts_{IF}) / 1000 \times (1 + IE_{kW}) \times CF \times ISR_{IF}$$

#### ENERGY STAR Outdoor Fixture (hard wired, pin-based):

$$\Delta kWh = (Watts_{base} - Watts_{OF}) \times OF_{hours} \times 365 / 1000 \times ISR_{OF}$$

$$\Delta kW_{peak} = (Watts_{base} - Watts_{OF}) / 1000 \times CF \times ISR_{OF}$$

#### Ceiling Fan with ENERGY STAR Light Fixture:

$$\Delta kWh = (Watts_{base} - Watts_{Fan}) \times Fan_{hours} \times (1 - IE_{kW}) \times 365 / 1000 \times ISR_{Fan}$$

$$\Delta kW_{peak} = (Watts_{base} - Watts_{Fan}) / 1000 \times (1 - IE_{kW}) \times CF \times ISR_{Fan}$$

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**2.30.22.29.2 Definition of Terms**

4.  $Watts_{base}$  = Wattage of baseline case lamp/fixture. For general service lamps prior to EISA 2007 standards, use equivalent incandescent bulb wattage. For general service lamps past EISA 2007 standards, use new standards to determine wattage. See [Table 2-74](#)

**Table 2-74**

$Watts_{CFL}$  = Wattage of CFL

$CFL_{hours}$  = Average hours of use per day per CFL

$IE_{kWh}$  = HVAC Interactive Effect for energy

$IE_{kW}$  = HVAC Interactive Effect for demand

$ISR_{CFL}$  = In-service rate per CFL.

$Watts_{Torch}$  = Wattage of ENERGY STAR torchiere

$Torch_{hours}$  = Average hours of use per day per torchiere

$ISR_{Torch}$  = In-service rate per Torchiere

$Watts_{IF}$  = Wattage of ENERGY STAR Indoor Fixture

$IF_{hours}$  = Average hours of use per day per Indoor Fixture

$ISR_{IF}$  = In-service rate per Indoor Fixture

$Watts_{OF}$  = Wattage of ENERGY STAR Outdoor Fixture

$OF_{hours}$  = Average hours of use per day per Outdoor Fixture

$ISR_{OF}$  = In-service rate per Outdoor Fixture

$CF$  = Demand Coincidence Factor (See Section 1.4)

$Watts_{Fan}$  = Wattage of ENERGY STAR Ceiling Fan light fixture

$Fan_{hours}$  = Average hours of use per day per Ceiling Fan light fixture

$ISR_{Fan}$  = In-service rate per Ceiling Fan fixture

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Table 2-736873: ENERGY STAR Lighting - References

Component	Type	Value	Sources
Watts <sub>base</sub>	Variable	5. See Table 2-69 Table 2-74Table 2-74	6. Table 2-69 Table 2-74Table 2-74
Watts <sub>CFL</sub>	Variable	Data Gathering	Data Gathering
CFL <sub>hours</sub>	Fixed	2.8	5
I <sub>E<sub>kWh</sub></sub>	Variable	See Table 2-76Table 2-76	6
I <sub>E<sub>kW</sub></sub>	Variable	See Table 2-76Table 2-76	6
ISR <sub>CFL</sub>	Fixed	8496% <sup>181</sup>	2
Watts <sub>Torch</sub>	Variable	Data Gathering	Data Gathering
Torch <sub>hours</sub>	Fixed	3.0	1
ISR <sub>Torch</sub>	Fixed	83%	2
Watts <sub>IF</sub>	Variable	Data Gathering	Data Gathering
IF <sub>hours</sub>	Fixed	2.6	1
ISR <sub>IF</sub>	Fixed	95%	2
Watts <sub>OF</sub>	Variable	Data Gathering	Data Gathering
OF <sub>hours</sub>	Fixed	4.5	1
ISR <sub>OF</sub>	Fixed	87%	2
CF	Fixed	59.1%	3
Watts <sub>Fan</sub>	Variable	Data Gathering	Data Gathering
Fan <sub>hours</sub>	Fixed	3.5	4
ISR <sub>Fan</sub>	Fixed	95%	4

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**Sources:**

1. Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004,. p. 104 (Table 9-7). This table adjusts for differences between logged sample and the much larger telephone survey sample and should, therefore, have less bias.

~~2. Ibid. p. 42 (Table 4-7). These values reflect both actual installations and the % of units planned to be installed within a year from the logged sample. The logged % is used because the adjusted values (to account for differences between logging and telephone survey samples) were not available for both installs and planned installs. However, this~~

<sup>181</sup> Subject to verification through evaluation. The value can be updated if evaluation findings reveal a value that differs from the default.



seems appropriate because the % actual installed in the logged sample from this table is essentially identical to the % after adjusting for differences between the logged group and the telephone sample (p. 100, Table 9-3).

3. RLW Analytics, "Development of Common Demand Impacts for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)", prepared for the New-England State Program Working Group (SPWG), March 25, 2007, p. IV.
2. The ISR is based on an installation rate "trajectory" and includes savings for all program bulbs that are believed to ultimately be installed. Evaluations of the PECO Smart Lighting Discounts program determined a first year ISR of 78% for customers that purchased a bulb through a retailer or were provided a CFL through a give-a-way program<sup>182</sup>. For future installations, the recommendations of the Uniform Methods Project ("UMP") can be incorporated. The UMP recommends using the findings from the evaluation of the 2006-2008 California Residential Upstream Lighting Programs, which estimated that 99% of program bulbs get installed within three years, including the program year. Discounting the future savings back to the current program year reduces the ISR to 97%.
3. EmPOWER Maryland 2012 Final Evaluation Report: Residential Lighting Program. Prepared by Navigant Consulting and the Cadmus Group, Inc., March 2013, Table 50.
4. ENERGY STAR Ceiling Fan Savings Calculator (Calculator updated April 2009). Hours based on ENERGY STAR calculator for the Mid-Atlantic region – defer to this value since it is recognized that ceiling fans are generally installed in high-use areas such as kitchens, living rooms and dining rooms. Ceiling fans are also installed in bedrooms, but the overall average HOU for this measure is higher than the average of all CFLs (2.8) and indoor fixtures (2.6) since these values incorporate usage in low-use areas such as bathrooms and hallways where ceiling fans are generally not installed.
5. Nexus Market Research, "Residential Lighting Markdown Impact Evaluation", Final Report, January 20, 2009. Table 6-1.

Additionally, the following studies were reviewed and analyzed to support the "Residential Lighting Markdown Impact Evaluation":

- Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004. Table 9-7.
- CFL Metering Study, Final Report. Prepared for PG&E, SDG&E, and SCE by KEMA, Inc. February 25, 2005. Table 4-1.
- Nexus Market Research, ""Process and Impact Evaluation of the Efficiency Maine Lighting Program"", April 2007. Table 1-7."
- Nexus Market Research, "Residential Lighting Markdown Impact Evaluation", Final Report, January 20, 2009. Table 6-1.

<sup>182</sup> Evaluation Research Report: PECO Smart Lighting Discounts Program. Navigant Consulting, September 20, 2012

- KEMA, Inc., "Final Evaluation Report: Upstream Lighting Program." Prepared from the California Public Utilities Commission, February 8, 2010. Table 18.
- Itron, Inc. "Verification of Reported Energy and Peak Savings from the EmPOWER Maryland Energy Efficiency Programs." Prepared for the Maryland Public Service Commission, April 21, 2011. Table 3-6.
- TecMarket Works, "Duke Energy Residential Smart Saver CFL Program in North Carolina and South Carolina", February 2011. Table 29.
- Glacier Consulting Group, LLC. "Adjustments to CFL Operating Hours-Residential." Memo to Oscar Bloch, Wisconsin DOA. June 27, 2005.
- New Jersey's Clean Energy Program Residential CFL Impact Evaluation and Protocol Review. KEMA, Inc. September 28, 2008. pg. 21.

7. GDS simulation modeling.

Table 2-746974: Baseline Wattage by Lumen Output for General Service Lamps (GSL) 183

Minimum Lumens (a)	Maximum Lumens (b)	Incandescent Equivalent Watts <sub>Base</sub> <sup>183</sup> (Pre-EISA 2007) (c)	Watts <sub>Base</sub> <sup>183</sup> (Post-EISA 2007) (d)	Post-EISA 2007 Effective Date (e)
1490	2600	100	72	2012 TRM
1050	1489	75	53	2013 TRM
750	1049	60	43	2014 TRM
310	749	40	29	2014 TRM

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Minimum Lumens (a)	Maximum Lumens (b)	Incandescent Equivalent Watts <sub>Base</sub> <sup>183</sup> (Pre-EISA 2007) (c)	Watts <sub>Base</sub> <sup>183</sup> (Post-EISA 2007) (d)	Post-EISA 2007 Effective Date (e)
1490	2600	100	72	2012 TRM
1050	1489	75	53	2013 TRM
750	1049	60	43	2014 TRM
310	749	40	29	2014 TRM

183 United States Department of Energy. *Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET.*  
[http://www1.eere.energy.gov/buildings/appliance\\_standards/residential/pdfs/general\\_service\\_incandescent\\_factsheet.pdf](http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/general_service_incandescent_factsheet.pdf)

To determine the Watts<sub>Base</sub> for a non-specialty lamp, 184, GSLs, follow these steps:

1. Identify the ENERGY STAR CFL, Torchiere, Indoor Fixture or Outdoor Fixture's rated lumen output

8. In

2. Table 2-74Table 2-74, find the lumen range into which the lamp falls (see columns (a) and (b).

4-3. Find the baseline wattage (Watts<sub>Base</sub>) in column (c) or column (d). Values in column (c) are used for Watts<sub>Base</sub> until the TRM listed under column (e) is effective. Afterwards, values in column (d) are used for Watts<sub>Base</sub>.

In Table 2-69

9. For EISA exempt<sup>185</sup> GSL bulbs, use the WattsBase value in column (c) in

Table 2-74Table 2-74, above. Commonly used EISA exempt bulbs include 3-way bulbs, globes with ≥5" diameter or ≤749 lumens, and candelabra base bulbs with ≤1049 lumens. See EISA legislation for full list of exemptions.

Reflector (directional) bulbs fall under legislation different from GSL bulbs. For these bulbs, EDCs can use the manufacturer rated equivalent wattage as printed on the retail packaging, or use the default WattsBase (column (c)) in Table 2-75Table 2-75 below.

**Table 2-75. Default Baseline Wattage for Reflector Bulbs<sup>186</sup>**

<b>Bulb Type (a)</b>	<b>Incandescent Equivalent (Pre-EISA) (b)</b>	<b>Watts<sub>Base</sub> (Post-EISA) (c)</b>
PAR20	50	35
PAR30	50	35
R20	50	45
PAR38	60	55
BR30	65	EXEMPT

<sup>184</sup> The EISA 2007 standards apply to general service incandescent lamps. A non-specialty CFL is considered any lamp that does not replace one of the 22 incandescent lamps exempt from the EISA 2007 standards. A complete list of the 22 incandescent lamps exempt from EISA 2007 is listed in the United States Department of *Energy Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET*.

<sup>185</sup> The EISA 2007 standards apply to general service incandescent lamps. A complete list of the 22 incandescent lamps exempt from EISA 2007 is listed in the United States Department of *Energy Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET*.

<sup>186</sup> Based on manufacturer recommended replacements for EISA affected lamps. Manufacturer ratings may differ from the list above, in which case EDCs should default to the manufacturer equivalent rating.

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BR40	65	EXEMPT
ER40	65	EXEMPT
BR40	75	65
BR30	75	65
PAR30	75	55
PAR38	75	55
R30	75	65
R40	75	65
PAR38	90	70
PAR38	120	70
R20	≤ 45	EXEMPT
BR30	≤ 50	EXEMPT
BR40	≤ 50	EXEMPT
ER30	≤ 50	EXEMPT
ER40	≤ 50	EXEMPT

In the absence of EDC data gathering, the default values for Energy and Demand HVAC Interactive Effects are below.

**Table 2-76. Energy and Demand HVAC Interactive Effects by EDC187**

-	IE <sub>kWh</sub>	IE <sub>kW</sub>
Duquesne	8%	13%
FE (MetEd)	-8%	13%
FE (Penn Elec)	1%	10%
FE (Penn Power)	0%	20%
FE (WPP)	-2%	30%
PPL	-6%	12%
PECO	9%	14%

- 2.1. ~~find the lumen range into which the lamp falls (see columns (a) and (b)).~~
- 3.2. ~~Find the baseline wattage (Watt<sub>Base</sub>) in column (c) or column (d). Values in column (c) are used for Watt<sub>Base</sub> until the TRM listed under column (c) is effective. Afterwards, values in column (d) are used for Watt<sub>Base</sub>.~~

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In the absence of EDC data gathering, the default savings for ENERGY STAR Torchiere, Indoor Fixtures and Outdoor Fixtures are listed in the Table 2-70: Default Savings for ENERGY STAR

187 HVAC Interactive Effects modeled through REM/Rate models, using EDC specific inputs. Values were weighted to the saturation of HVAC equipment and housing types present in each EDC service territory as reported in the Pennsylvania Statewide Residential End-Use and Saturation Study, 2012.

Indoor Fixtures, ENERGY STAR Outdoor Fixtures and ENERGY STAR Torchieres (per fixture). [Table 2-77](#).

Table 2-~~77~~<sup>78</sup>: Default Savings for ENERGY STAR Indoor Fixtures, ENERGY STAR Outdoor Fixtures and ENERGY STAR Torchieres (per fixture)<sup>188</sup>

	Torchiere	Indoor Fixture	Outdoor Fixture
ΔkWh	65.0	27.1	83.6
ΔkW <sub>peak</sub>	0.0030	0.0014	0.0025

In the absence of EDC data gathering, the deemed savings for ENERGY STAR Ceiling Fans are listed in [Table 2-78](#)<sup>189</sup>.

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Table 2-~~78~~<sup>78</sup>: Default Savings for ENERGY STAR Ceiling Fans Light Fixtures (per fixture)

ΔkWh	ΔkW <sub>peak</sub>	Effective Date
146	0.0057	2013 TRM
84	0.0033	2014 TRM

<sup>188</sup> Source of change in watts (before adjusting for EISA 2007) between the baseline and efficient case is Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004, p. 43 (Table 4-9). Adjustment to account for EISA 2007 standards based on Mid-Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2011.

Adjustment made by calculating an average adjustment factor (61.77%) for all incandescent bulbs that EISA affects and applying at the midpoint of the three year EISA phase-in (2013). As an example of an adjustment factor, the 100 W incandescent the baseline is 72 watts post-EISA and the CFL equivalent assumption is a 25.3 watt CFL. Therefore the adjustment factor is calculated as follows  $(72-25.3)/(100-25.3)*100=62.5\%$ .

The "Equivalent CFL Wattage" is calculated using a ratio of 3.95. This is calculated assuming that the average wattage of a CFL is 15.5W and the replacement incandescent bulb is 61.2W (ratio of 3.95 to 1), RLW Analytics, New England Residential Lighting Markdown Impact Evaluation, January 20, 2009.

<sup>189</sup> Effective date is the date when EISA 2007 standards are incorporated. The baseline assumption is three 60 watt (ENERGY STAR Ceiling Fans Savings Calculator) incandescent lamps and therefore the EISA 2007 affects this measure beginning 2014.

## 2.34.2.30 ENERGY STAR Windows

### 2.34.12.30.1 Algorithms

The general form of the equation for the ENERGY STAR or other high-efficiency windows energy savings' algorithms is:

$$\text{Total Savings} = \text{Square Feet of Window Area} \times \text{Savings per Square Foot}$$

To determine resource savings, the per-square-foot estimates in the algorithms will be multiplied by the number of square feet of window area. The number of square feet of window area will be determined using market assessments and market tracking. Some of these market tracking mechanisms are under development. The per-unit energy and demand savings estimates are based on prior building simulations of windows.

Savings' estimates for ENERGY STAR Windows are based on modeling a typical 2,500 square foot home using REM Rate, the home energy rating tool.<sup>190</sup> Savings are per square foot of qualifying window area. Savings will vary based on heating and cooling system type and fuel. These fuel and HVAC system market shares will need to be estimated from prior market research efforts or from future program evaluation results.

#### Heat Pump HVAC System:

$$\Delta kWh = ESav_{HP}$$

$$\Delta kW_{peak} = DSav_{HP} \times CF$$

#### Electric Heat/Central Air Conditioning:

$$\Delta kWh = ESav_{RES/CAC}$$

$$\Delta kW_{peak} = DSav_{CAC} \times CF$$

#### Electric Heat/No Central Air Conditioning:

$$\Delta kWh = ESav_{RES/NOCAC}$$

$$\Delta kW_{peak} = DSav_{NOCAC} \times CF$$

### 2.34.22.30.2 Definition of Terms

$ESav_{HP}$  = Electricity savings (heating and cooling) with heat pump installed.

$ESav_{RES/CAC}$  = Electricity savings with electric resistance heating and central AC installed.

$ESav_{RES/NOCAC}$  = Electricity savings with electric resistance heating and no central AC installed.

<sup>190</sup> Energy Information Administration. *Residential Energy Consumption Survey*. 2005. [http://www.eia.doe.gov/emeu/recs/recs2005/hc2005\\_tables/detailed\\_tables2005.html](http://www.eia.doe.gov/emeu/recs/recs2005/hc2005_tables/detailed_tables2005.html)

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$DSav_{HP}$  = Summer demand savings with heat pump installed.

$DSav_{CAC}$  = Summer demand savings with central AC installed.

$DSav_{NOCAC}$  = Summer demand savings with no central AC installed.

$CF$  = Demand Coincidence Factor (See Section 1.4)

Table 2-~~797279~~: ENERGY STAR Windows - References

Component	Type	Value	Sources
ESaV <sub>HP</sub>	Fixed	2.2395 kWh/ft <sup>2</sup>	1
HP Time Period Allocation Factors	Fixed	Summer/On-Peak 10% Summer/Off-Peak 7% Winter/On-Peak 40% Winter/Off-Peak 44%	2
ESaV <sub>RES/CAC</sub>	Fixed	4.0 kWh/ft <sup>2</sup>	1
Res/CAC Time Period Allocation Factors	Fixed	Summer/On-Peak 10% Summer/Off-Peak 7% Winter/On-Peak 40% Winter/Off-Peak 44%	2
ESaV <sub>RES/NOCAC</sub>	Fixed	3.97 kWh/ft <sup>2</sup>	1
Res/No CAC Time Period Allocation Factors	Fixed	Summer/On-Peak 3% Summer/Off-Peak 3% Winter/On-Peak 45% Winter/Off-Peak 49%	2
DSaV <sub>HP</sub>	Fixed	0.000602 kW/ft <sup>2</sup>	1
DSaV <sub>CAC</sub>	Fixed	0.000602 kW/ft <sup>2</sup>	1
DSaV <sub>NOCAC</sub>	Fixed	0.00 kW/ft <sup>2</sup>	1
CF	Fixed	0.75	3

**Sources:**

1. From REMRATE Modeling of a typical 2,500 sq. ft. NJ home. Savings expressed on a per-square-foot of window area basis. New Brunswick climate data.
2. Time period allocation factors used in cost-effectiveness analysis.
3. Based on reduction in peak cooling load.
4. Prorated based on 12% of the annual degree days falling in the summer period and 88% of the annual degree days falling in the winter period.

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## **2.322.31 ENERGY STAR Audit**

### **2.32.12.31.1 Algorithms**

No algorithm was developed to measure energy savings for this program. The purpose of the program is to provide information and tools that residential customers can use to make decisions about what actions to take to improve energy efficiency in their homes. Many measure installations that are likely to produce significant energy savings are covered in other programs. These savings are captured in the measured savings for those programs. The savings produced by this program that are not captured in other programs would be difficult to isolate and relatively expensive to measure.

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### 2.33.2.32 Home Performance with ENERGY STAR

In order to implement Home Performance with ENERGY STAR, there are various standards a program implementer must adhere to in order to deliver the program. The program implementer must use software that meets a national standard for savings calculations from whole-house approaches such as home performance. The software program implementer must adhere to at least one of the following standards:

- 32.● A software tool whose performance has passed testing according to the National Renewable Energy Laboratory's HERS BESTEST software energy simulation testing protocol.<sup>191</sup>
- Software approved by the US Department of Energy's Weatherization Assistance Program.<sup>192</sup>
- RESNET approved rating software.<sup>193</sup>

There are numerous software packages that comply with these standards. Some examples of the software packages are REM/Rate, EnergyGauge, TREAT, and HomeCheck. The HomeCheck software is described below as an example of a software that can be used to determine if a home qualifies for Home Performance with ENERGY STAR.

#### 2.33.12.32.1 HomeCheck Software Example

Conservation Services Group (CSG) implements Home Performance with ENERGY STAR in several states. CSG has developed proprietary software known as HomeCheck which is designed to enable an energy auditor to collect information about a customer's site and based on what is found through the energy audit, recommend energy savings measures and demonstrate the costs and savings associated with those recommendations. The HomeCheck software is also used to estimate the energy savings that are reported for this program.

CSG has provided a description of the methods and inputs utilized in the HomeCheck software to estimate energy savings. CSG has also provided a copy of an evaluation report prepared by Nexant which assessed the energy savings from participants in the Home Performance with ENERGY STAR Program managed by the New York State Energy Research and Development Authority (NYSERDA)<sup>194</sup>. The report concluded that the savings estimated by HomeCheck and reported to NYSERDA were in general agreement with the savings estimates that resulted from the evaluation.

These algorithms incorporate the HomeCheck software by reference which will be utilized for estimating energy savings for Home Performance with ENERGY STAR. The following is a summary of the HomeCheck software which was provided by CSG: CSG's HomeCheck software

<sup>191</sup> A new standard for BESTEST-EX for existing homes is currently being developed - status is found at [http://www.nrel.gov/buildings/bestest\\_Ex.html](http://www.nrel.gov/buildings/bestest_Ex.html). The existing 1995 standard can be found at <http://www.nrel.gov/docs/legosti/fy96/7332a.pdf>.

<sup>192</sup> A listing of the approved software available at <http://www.waptac.org/si.asp?id=736>.

<sup>193</sup> A listing of the approved software available at <http://resnet.us>.

<sup>194</sup> M&V Evaluation, Home Performance with Energy Star Program, Final Report, Prepared for the New York State Energy Research and Development Authority, Nexant, June 2005.

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was designed to streamline the delivery of energy efficiency programs. The software provides the energy efficiency specialist with an easy-to-use guide for data collection, site and HVAC testing algorithms, eligible efficiency measures, and estimated energy savings. The software is designed to enable an auditor to collect information about customers' sites and then, based on what he/she finds through the audit, recommend energy-saving measures, demonstrate the costs and savings associated with those recommendations. It also enables an auditor/technician to track the delivery of services and installation of measures at a site.

This software is a part of an end-to-end solution for delivering high-volume retrofit programs, covering administrative functions such as customer relationship management, inspection scheduling, sub-contractor arranging, invoicing and reporting. The range of existing components of the site that can be assessed for potential upgrades is extensive and incorporates potential modifications to almost all energy using aspects of the home. The incorporation of building shell, equipment, distribution systems, lighting, appliances, diagnostic testing and indoor air quality represents a very broad and comprehensive ability to view the needs of a home.

The software is designed to combine two approaches to assessing energy savings opportunities at the site. One is a measure specific energy loss calculation, identifying the change in use of BTU's achieved by modifying a component of the site. Second, is the correlation between energy savings from various building improvements, and existing energy use patterns at a site. The use of both calculated savings and the analysis of existing energy use patterns, when possible, provides the most accurate prescription of the impact of changes at the site for an existing customer considering improvements on a retrofit basis.

This software is not designed to provide a load calculation for new equipment or a HERS rating to compare a site to a standard reference site. It is designed to guide facilities in planning improvements at the site with the goal of improved economics, comfort and safety. The software calculates various economic evaluations such as first year savings, simple payback, measure life cost-effectiveness, and Savings-to-Investment ratio (SIR).

#### **2.33.22.32.2 Site-Level Parameters and Calculations**

There are a number of calculations and methodologies that apply across measures and form the basis for calculating savings potentials at a site.

#### **2.33.32.32.3 Heating Degree Days and Cooling Degree Hours**

Heat transfer calculations depend fundamentally on the temperature difference between inside and outside temperature. This temperature difference is often summarized on a seasonal basis using fixed heating degree-days (HDD) and cooling degree-hours (CDH). The standard reference temperature for calculating HDD (the outside temperature at which the heating system is required), for example, has historically been 65°F. Modern houses have larger internal gains and more efficient thermal building envelopes than houses did when the 65°F standard was developed, leading to lower effective reference temperatures. This fact has been recognized in ASHRAE Fundamentals, which provides a variable-based degree-day method for calculating energy usage. CSG's Building Model calculates both HDD and CDH based on the specific characteristics and location of the site being treated.

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#### **2.33.42.32.4 Building Loads, Other Parameters, and the Building Model**

CSG is of the opinion that, in practice, detailed building load simulation tools are quite limited in their potential to improve upon simpler approaches due to their reliance on many factors that are not measurable or known, as well as limitations to the actual models themselves. Key to these limitations is the Human Factor (e.g., sleeping with the windows open; extensive use of high-volume extractor fans, etc.) that is virtually impossible to model. As such, the basic concept behind the model was to develop a series of location specific lookup tables that would take the place of performing hourly calculations while allowing the model to perform for any location. The data in these tables would then be used along with a minimum set of technical data to calculate heating and cooling building loads.

In summary, the model uses:

1. Lookup tables for various parameters that contain the following values for each of the 239 TMY2 weather stations:
  - a. Various heating and cooling infiltration factors.
  - b. Heating degree days and heating hours for a temperature range of 40 to 72°F.
  - c. Cooling degree hours and cooling hours for a temperature range of 68 to 84°F.
  - d. Heating and cooling season solar gain factors.
2. Simple engineering algorithms based on accepted thermodynamic principles, adjusted to reflect known errors, the latest research and measured results
3. Heating season iterative calculations to account for the feedback loop between conditioned hours, degree days, average “system on” indoor and outdoor temperatures and the building
4. The thermal behavior of homes is complex and commonly accepted algorithms will on occasion predict unreasonably high savings, HomeCheck uses a proprietary methodology to identify and adjust these cases. This methodology imposes limits on savings projected by industry standard calculations, to account for interactivities and other factors that are difficult to model. These limits are based on CSG’s measured experience in a wide variety of actual installations.

#### **2.33.52.32.5 Usage Analysis**

The estimation of robust building loads through the modeling of a building is not always reliable. Thus, in addition to modeling the building, HomeCheck calculates a normalized annual consumption for heating and cooling, calculated from actual fuel consumption and weather data using a Seasonal Swing methodology. This methodology uses historic local weather data and site-specific usage to calculate heating and cooling loads. The methodology uses 30-year weather data to determine spring and fall shoulder periods when no heating or cooling is likely to be in use. The entered billing history is broken out into daily fuel consumption, and these daily consumption data along with the shoulder periods is used to calculate base load usage and summer and winter seasonal swing fuel consumption.

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### **2.33.62.32.6 Multiple HVAC Systems**

HVAC system and distribution seasonal efficiencies are used in all thermal-shell measure algorithms. HVAC system and distribution seasonal efficiencies and thermostat load reduction adjustments are used when calculating the effect of interactivity between mechanical and architectural measures. If a site has multiple HVAC systems, weighted average seasonal efficiencies and thermostat load reduction adjustments are calculated based on the relative contributions (in terms of percent of total load) of each system.

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### **2.33.72.32.7 Multiple Heating Fuels**

It is not unusual to find homes with multiple HVAC systems using different fuel types. In these cases, it is necessary to aggregate the NACs for all fuel sources for use in shell savings algorithms. This is achieved by assigning a percentage contribution to total NAC for each system, converting this into BTU's, and aggregating the result. Estimated first year savings for thermal shell measures are then disaggregated into the component fuel types based on the pre-retrofit relative contributions of fuel types.

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### **2.33.82.32.8 Interactivity**

To account for interactivity between architectural and mechanical measures, CSG's HomeCheck employs the following methodology, in order:

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1. Non-interacted first year savings are calculated for each individual measure.
2. Non-interacted SIR (RawSIR) is calculated for each measure.
3. Measures are ranked in descending order of RawSIR,
4. Starting with the most cost-effective measure (as defined by RawSIR), first year savings are adjusted for each measure as follows:
  - a. Mechanical measures (such as thermostats, HVAC system upgrades or distribution system upgrades) are adjusted to account for the load reduction from measures with a higher RawSIR.
  - b. Architectural measures are adjusted to account for overall HVAC system efficiency changes and thermostat load reduction changes. Architectural measures with a higher RawSIR than that of HVAC system measures are calculated using the existing efficiencies. Those with RawSIR's lower than that of heating equipment use the new heating efficiencies.
5. Interacted SIR is then calculated for each measure, along with cumulative SIR for the entire job.
6. All measures are then re-ranked in descending order of SIR.
7. The process is repeated, replacing RawSIR with SIR until the order of measures does not change.

### **2.33.92.32.9 Lighting**

Quantification of additional savings due to the addition of high efficiency lighting will be based on the applicable algorithms presented for these appliances in the ENERGY STAR Lighting Algorithms section found in ENERGY STAR Products.

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### 2.34.2.33 ENERGY STAR Televisions

This measure applies to the purchase of an ENERGY STAR TV meeting Version 5-36.0 standards. Version 5-36.0 standards are effective as of ~~September 30, 2014~~ June 1, 2013. Additionally, in 2012 ENERGY STAR introduced the ENERGY STAR Most Efficient designation, which recognizes the most efficient of the ENERGY STAR qualified televisions.

The baseline equipment is a TV meeting ENERGY STAR Version 3.0 requirements<sup>195</sup>.

#### 2.34.12.33.1 Algorithms

Energy Savings (per TV):

$$\Delta kWh = \left[ \frac{(W_{base, active} - W_{ES, active})}{1000} \times HOURS_{active} \times 365 \right]$$

Coincident Demand Savings (per TV):

$$\Delta kW = \left[ \frac{(W_{base, active} - W_{ES, active})}{1000} \times CF \right]$$

Savings calculations are based on power consumption while the TV is in active mode only, as requirements for standby power are the same for both baseline and new units.

#### 2.34.22.33.2 Definition of Terms

$W_{base, on}$	= power use (in Watts) of baseline TV while in on mode (i.e. active mode turned on and operating).
$W_{ES, on}$	= power use (in Watts) of ENERGY STAR Version 5.3 or ENERGY STAR Most Efficient TV while in on mode (i.e. active mode turned on and operating).
$HOURS_{on}$	= number of hours per day that a typical TV is on (active mode turned on and in use).
$CF$	= Demand Coincidence Factor (See Section 1.4)
365	= days per year.

Table 2-~~807390~~: ENERGY STAR TVs - References

Component	Type	Value	Source
CF	Fixed	0.28	1
$HOURS_{on}$	Fixed	5	2

<sup>195</sup> This baseline assumption is made because there is no federal standard that specifies minimum TV efficiencies. ENERGY STAR Version 3.0 predates Version 5-36.0 standards.

**Sources:**

1. Deemed Savings Technical Assumptions, Program: ENERGY STAR Retailer Incentive Pilot Program, ~~accessed October 2010,~~  
[http://www.xcelenergy.com/SiteCollectionDocuments/docs/ES\\_Retailer\\_Incentive\\_60\\_day\\_Tech\\_Assumptions.pdf](http://www.xcelenergy.com/SiteCollectionDocuments/docs/ES_Retailer_Incentive_60_day_Tech_Assumptions.pdf)~~accessed June 2013,~~  
[http://www.xcelenergy.com/staticfiles/xel/Regulatory/Regulatory%20PDFs/ES\\_RetailerIncentiveFile.pdf](http://www.xcelenergy.com/staticfiles/xel/Regulatory/Regulatory%20PDFs/ES_RetailerIncentiveFile.pdf)
2. Calculations assume TV is in on mode (or turned on) for 5 hours per day and sleep/standby mode for 19 hours per day. Based on assumptions from ENERGY STAR Calculator, ~~Life Cycle Cost Estimate for 100 ENERGY STAR Qualified Television(s),~~  
~~accessed October 2010~~ *EPA Research on Available Models, 2012*, accessed June 2013,  
[http://www.energystar.gov/ia/business/bulk\\_purchasing/bpsavings\\_calc/Calc\\_Televisions\\_Bulk.xls](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Televisions_Bulk.xls)  
[http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&ved=0CDAQFjAA&url=http%3A%2F%2Fwww.energystar.gov%2Fia%2Fbusiness%2Fbulk\\_purchasing%2Fbpsavings\\_calc%2FConsumer\\_Electronics\\_Calculator.xlsx&ei=bzWyUbb0H4Xx0wHw4oBw&usq=AFQjCNGPH4-NaXM\\_-1IM4J29-of6P1px5g&sig2=Xau5mB6YjLf3r81hOgmWAQ&bvm=bv.47534661,d.dmQ](http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&ved=0CDAQFjAA&url=http%3A%2F%2Fwww.energystar.gov%2Fia%2Fbusiness%2Fbulk_purchasing%2Fbpsavings_calc%2FConsumer_Electronics_Calculator.xlsx&ei=bzWyUbb0H4Xx0wHw4oBw&usq=AFQjCNGPH4-NaXM_-1IM4J29-of6P1px5g&sig2=Xau5mB6YjLf3r81hOgmWAQ&bvm=bv.47534661,d.dmQ)

Table 2-74: ENERGY STAR TVs Version 5.3 maximum power consumption<sup>196</sup>

Screen Area <sup>197</sup> (square inches)	Maximum Active Power ( $P_{ES,active}$ ) Version 5.3
$A < 275$	$P_{ON,MAX} = 0.130 * A + 5$
$275 \leq A \leq 1068$	$P_{ON,MAX} = 0.084 * A + 18$
$A > 1068$	$P_{ON,MAX} = 108$

**2.33.3  $P_{ON,MAX}$  On Mode Power Consumption Requirements:**

$$P_{ON,MAX} = 100 \times \text{TAHN}(0.00085 \times (A - 140) + 0.052) + 14.1$$

Where:

- $P_{ON,MAX}$  is defined as the maximum allowable On Mode power requirement. Power consumption in Watts. All ENERGY STAR Televisions must use 1.0 watts or less while in Sleep Mode (i.e. standby mode).<sup>198</sup>

<sup>196</sup> ENERGY STAR Program Requirements for Televisions, Partner Commitments Versions 5.3, accessed August 2012, [http://www.energystar.gov/ia/partners/prod\\_development/revisions/downloads/television/V5.3\\_Program\\_Requirements.pdf](http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/television/V5.3_Program_Requirements.pdf) f208d8-61ad

<sup>197</sup> 16:9 aspect ratio is assumed for TV viewable screen size (to convert from diagonal dimensions to viewable screen area).

<sup>198</sup> ENERGY STAR Program Requirements for Televisions, Partner Commitments Versions 5-36.0, accessed August 2012 June 2013.

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- A is the viewable screen area of the product in sq. inches, calculated by multiplying the viewable image width by the viewable image height
- tanh is the hyperbolic tangent function

ENERGY STAR Most Efficient Televisions must meet all of the program requirements of ENERGY STAR Version 5.3 as well as the following additional requirement:<sup>199</sup>

$$P_{ON\ MAX} = 82 * \text{TANH}(0.00084(A-150)+0.05)+12.75$$

Where TANH is the hyperbolic tangent function.

Table 2-~~817581~~: TV power consumption

Diagonal Screen Size (inches) <sup>200</sup>	Baseline Active Power Consumption [W <sub>base,active</sub> ] <sup>201</sup>	ENERGY STAR V. <del>5-36.0</del> Active Power Consumption [W <sub>ES,active</sub> ] <sup>202</sup>	ENERGY STAR Most Efficient Power Consumption [W <sub>ES,active</sub> ]
< 20	51	<del>4716</del>	13
20 < 30	85	<del>4030</del>	<del>2520</del>
30 < 40	137	<del>6250</del>	<del>4431</del>
40 < 50	235	<del>9472</del>	<del>6043</del>
50 < 60	353	<del>108*92</del>	<del>7654</del>
≥ 60	391	<del>108*99</del>	<del>8658</del>

\* P<sub>ON MAX</sub> = 108W

#### ~~2.34.32.33.4~~ Deemed Savings

Deemed annual energy savings for ENERGY STAR ~~5-36.0~~ and ENERGY STAR Most Efficient TVs are given in ~~Table 2-82~~~~Table 2-7682~~.

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<sup>199</sup> ENERGY STAR Most Efficient Eligibility Criteria for Recognition Televisions, accessed August 2012.

[http://www.energystar.gov/ia/partners/downloads/Televisions\\_Criteria\\_ME\\_2012.pdf](http://www.energystar.gov/ia/partners/downloads/Televisions_Criteria_ME_2012.pdf)

<sup>200</sup> Calculations are based on TV dimensions at the midpoint of the specified range. For example, a diagonal of 25" was used to compute values for the range of 20"-30". 15" was used to compute the value for sizes < 20".

<sup>201</sup> Based on ENERGY STAR Version 3.0 requirements, from ENERGY STAR Program Requirements for Televisions, Partner Commitments, accessed October 2010,

[http://www.energystar.gov/ia/partners/prod\\_development/revisions/downloads/tv\\_vcr/FinalV3.0\\_TV%20Program%20Requirements.pdf](http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/tv_vcr/FinalV3.0_TV%20Program%20Requirements.pdf)

<sup>202</sup> Ibid.

Table 2-~~827682~~: Deemed energy savings for ENERGY STAR Version 5.3 and ENERGY STAR Most Efficient TVs.

Diagonal Screen Size (inches) <sup>203</sup>	Energy Savings ENERGY STAR V. 5.3 TVs (kWh/year)	Energy Savings ENERGY STAR Most Efficient TVs (kWh/yr)
< 20	<u>6264</u>	<u>7069</u>
20 < 30	<u>83100</u>	<u>144119</u>
30 < 40	<u>136159</u>	<u>174193</u>
40 < 50	<u>263297</u>	<u>319350</u>
50 < 60	<u>446476</u>	<u>506546</u>
≥ 60	<u>516533</u>	<u>565608</u>

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Coincident demand savings are given in the [Table 2-83: Deemed coincident demand savings for ENERGY STAR Version 5.3 and ENERGY STAR Most Efficient TVs.](#)~~Table 2-77: Deemed coincident demand savings for ENERGY STAR Version 5.3 and ENERGY STAR Most Efficient TVs.~~~~Table 2-83Table 2-83.~~

Table 2-~~837783~~: Deemed coincident demand savings for ENERGY STAR Version 5.3 and ENERGY STAR Most Efficient TVs.

Diagonal Screen Size (inches) <sup>204</sup>	Coincident Demand Savings ENERGY STAR V. 5.3 (kW)	Coincident Demand Savings ENERGY STAR Most Efficient (kW)
< 20	<u>0.009010</u>	0.011
20 < 30	<u>0.0130154</u>	<u>0.017018</u>
30 < 40	<u>0.021024</u>	<u>0.027030</u>
40 < 50	<u>0.040046</u>	<u>0.049054</u>
50 < 60	<u>0.068073</u>	<u>0.078084</u>
≥ 60	<u>0.079082</u>	<u>0.087093</u>

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### ~~2.34.42.33.5~~ Measure Life

Measure life = 156 years<sup>205</sup>

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203 Calculations are based on TV dimensions at the midpoint of the specified range. For example, a diagonal of 25" was used to compute values for the range of 20"-30". 15" was used to compute the value for sizes < 20". 60" was used to compute the value for sizes ≥ 60"

204 Ibid.

205 ~~Deemed Savings Technical Assumptions, Program: ENERGY STAR Retailer Incentive Pilot Program, accessed October 2010, <http://www.xcelenergy.com/SiteCollectionDocuments/docs/ES-Retailer-Incentive-60-day-Tech-Assumptions.pdf> ENERGY STAR Program Requirements for Televisions, Partner Commitments Versions 6.0, accessed June 2013.~~



## 2.352.34 ENERGY STAR Office Equipment

This protocol estimates savings for installing ENERGY STAR office equipment compared to standard efficiency equipment in residential applications. The measurement of energy and demand savings is based on a deemed savings value multiplied by the quantity of the measure.

### 2.35.12.34.1 Algorithms

The general form of the equation for the ENERGY STAR Office Equipment measure savings' algorithms is:

*Number of Units X Savings per Unit*

To determine resource savings, the per unit estimates in the algorithms will be multiplied by the number of units. Per unit savings are primarily derived from the June 2010 release of the ENERGY STAR calculator for office equipment.

#### ENERGY STAR Computer

$$\Delta kWh = ESav_{COM}$$

$$\Delta kW_{peak} = DSav_{COM} \times CF_{COM}$$

#### ENERGY STAR Fax Machine

$$\Delta kWh = ESav_{FAX}$$

$$\Delta kW_{peak} = DSav_{FAX} \times CF_{FAX}$$

#### ENERGY STAR Copier

$$\Delta kWh = ESav_{COP}$$

$$\Delta kW_{peak} = DSav_{COP} \times CF_{COP}$$

#### ENERGY STAR Printer

$$\Delta kWh = ESav_{PRI}$$

$$\Delta kW_{peak} = DSav_{PRI} \times CF_{PRI}$$

#### ENERGY STAR Multifunction

$$\Delta kWh = ESav_{MUL}$$

$$\Delta kW_{peak} = DSav_{MUL} \times CF_{MUL}$$

#### ENERGY STAR Monitor

$$\Delta kWh = ESav_{MON}$$

$$\Delta kW_{peak} = DSav_{MON} \times CF_{MON}$$

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**2.35.22.34.2 Definition of Terms**

*ESav<sub>COM</sub>* = Electricity savings per purchased ENERGY STAR computer.

*DSav<sub>COM</sub>* = Summer demand savings per purchased ENERGY STAR computer.

*ESav<sub>FAX</sub>* = Electricity savings per purchased ENERGY STAR fax machine.

*DSav<sub>FAX</sub>* = Summer demand savings per purchased ENERGY STAR fax machine.

*ESav<sub>COP</sub>* = Electricity savings per purchased ENERGY STAR copier.

*DSav<sub>COP</sub>* = Summer demand savings per purchased ENERGY STAR copier.

*ESav<sub>PRI</sub>* = Electricity savings per purchased ENERGY STAR printer.

*DSav<sub>PRI</sub>* = Summer demand savings per purchased ENERGY STAR printer.

*ESav<sub>MUL</sub>* = Electricity savings per purchased ENERGY STAR multifunction machine.

*DSav<sub>MUL</sub>* = Summer demand savings per purchased ENERGY STAR multifunction machine.

*ESav<sub>MON</sub>* = Electricity savings per purchased ENERGY STAR monitor.

*DSav<sub>MON</sub>* = Summer demand savings per purchased ENERGY STAR monitor.

*CF<sub>COM</sub>, CF<sub>FAX</sub>, CF<sub>COP</sub>,*

*CF<sub>PRI</sub>, CF<sub>MUL</sub>, CF<sub>MON</sub>* = Demand Coincidence Factor (See Section 1.4). The coincidence of average office equipment demand to summer system peak equals 1 for demand impacts for all office equipment reflecting embedded coincidence in the DSav factor.

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Table 2-~~847884~~: ENERGY STAR Office Equipment - References

Component	Type	Value	Sources
ESav <sub>COM</sub> ESav <sub>FAX</sub> ESav <sub>COP</sub> ESav <sub>PRI</sub> ESav <sub>MUL</sub> ESav <sub>MON</sub>	Fixed	see <a href="#">Table 2-85</a> <a href="#">Table 2-7985</a>	1
DSav <sub>COM</sub> DSav <sub>FAX</sub> DSav <sub>COP</sub> DSav <sub>PRI</sub> DSav <sub>MUL</sub> DSav <sub>MON</sub>	Fixed	see <a href="#">Table 2-85</a> <a href="#">Table 2-7985</a>	2
CF <sub>COM</sub> , CF <sub>FAX</sub> , CF <sub>COP</sub> , CF <sub>PRI</sub> , CF <sub>MUL</sub> , CF <sub>MON</sub>	Fixed	1.0, 1.0, 1.0, 1.0, 1.0, 1.0	3

**Sources:**

1. ENERGY STAR Office Equipment Savings Calculator (Calculator updated: June 2010). Default values were used.
2. Using a residential office equipment load shape, the percentage of total savings that occur during the top 100 system hours was calculated and multiplied by the energy savings.
3. Coincidence factors already embedded in summer peak demand reduction estimates.

Table 2-857985: ENERGY STAR Office Equipment Energy and Demand Savings Values

Measure	Energy Savings (ESav)	Demand Savings (DSav)
Computer	77 kWh	0.0100 kW
Fax Machine (laser)	78 kWh	0.0105 kW
Copier (monochrome)		
1-25 images/min	73 kWh	0.0098 kW
26-50 images/min	151 kWh	0.0203 kW
51+ images/min	162 kWh	0.0218 kW
Printer (laser, monochrome)		
1-10 images/min	26 kWh	0.0035 kW
11-20 images/min	73 kWh	0.0098 kW
21-30 images/min	104 kWh	0.0140 kW
31-40 images/min	156 kWh	0.0210 kW
41-50 images/min	133 kWh	0.0179 kW
51+ images/min	329 kWh	0.0443 kW
Multifunction (laser, monochrome)		
1-10 images/min	78 kWh	0.0105 kW
11-20 images/min	147 kWh	0.0198 kW
21-44 images/min	253 kWh	0.0341 kW
45-99 images/min	422 kWh	0.0569 kW
100+ images/min	730 kWh	0.0984 kW
Monitor	14 kWh	0.0019 kW

Sources:

33.1. ENERGYSTAR office equipment calculators

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## 2.36.2.35 ENERGY STAR LEDs

This protocol documents the energy and demand savings attributed to replacing standard incandescent lamps and fixtures in residential applications with ENERGY STAR® LED lamps, retrofit kits, and/or fixtures. LEDs provide an efficient alternative to incandescent lighting. The ENERGY STAR program began labeling qualified LED products in the latter half of 2010.

### 2.36.42.35.1 Eligibility Requirements

~~All LED lamps, retrofit kits and fixtures must be:~~

~~In order for this measure protocol to apply, the high-efficiency equipment must be a screw-in LED bulb (general service or specialty bulb), LED fixture, or efficiency kit with LED bulb with the following qualifications:~~

- **ENERGY STAR qualified**<sup>206</sup> – Criteria for ENERGY STAR qualified LED products vary by product type and include specifications for: light output (lumens), efficacy (lumens per Watt), zonal lumen density, Correlated Color Temperature (CCT), lumen maintenance (lifetime), Color Rendering Index (CRI), and power factor, among others. LED bulbs also have three-year (or longer) warranties covering material repair or replacement from the date of purchase and must turn on instantly (have no warm-up time),
- **Lighting Facts labeled**<sup>207</sup> - Contains the manufacturer's voluntary pledge that the product's performance is accurately represented in the market. Through this DOE-sponsored program, the manufacturer discloses the product's light output, efficacy, Watts, CCT, and CFI as measured by the IES LM-79-2008 testing procedure.
- ~~Dimmable – product has dimming capability that is stated on the product package~~

### 2.36.22.35.2 Definition Algorithms

~~The LED measure savings are based on the algorithms in Section 2.30, but include several adjustments. Due to the wide range of efficacy (lumens/watt) for LEDs, and the resulting difficulty in determining equivalent incandescent bulb wattages, the savings algorithms for LED products are grouped by the lumen ranges given in EISA 2007.~~

#### GENERAL SERVICE LAMPS

~~Table 2-80 shows lumen ranges and incandescent lamp equivalents for general service LEDs; 208~~

206 [http://www.energystar.gov/ia/partners/product\\_specs/program\\_reqs/SSL\\_Key\\_Product\\_Criteria.pdf](http://www.energystar.gov/ia/partners/product_specs/program_reqs/SSL_Key_Product_Criteria.pdf)

207 <http://www.lightingfacts.com/>

208 [http://www1.eere.energy.gov/buildings/appliance\\_standards/residential/incandescent\\_lamps.html](http://www1.eere.energy.gov/buildings/appliance_standards/residential/incandescent_lamps.html)

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Table 2-80. General Service Lamps

Minimum Lumens (a)	Maximum Lumens (b)	Incandescent Equivalent Watts <sub>Base</sub> (Pre-EISA 2007) (c)	Watts <sub>Base</sub> (Post-EISA 2007) (d)	Post-EISA 2007 Effective Date (e)
1490	2600	100	72	2012 TRM
1050	1489	75	53	2013 TRM
750	1049	60	43	2014 TRM
310	749	40	29	2014 TRM

To determine baseline wattage for an LED general service lamp:

2. Identify the LED's rated lumen output
3. In Table 2-80, find the lumen range into which the LED falls (see columns (a) and (b))

Find the baseline wattage in column (c) or column (d). Values in column (c) are used for Watts<sub>Base</sub> until the TRM listed under column (e). **of Baseline Equipment**

The baseline equipment is assumed to be a socket or fixture with a standard general service incandescent light bulb(s) or specialty incandescent light bulb.

An adjustment to the baseline wattage for general service screw-in LEDs is made to account for the Energy Independence and Security Act of 2007 (EISA 2007), which requires that all general service lamps between 40 W and 100 W meet minimum efficiency standards in terms of amount of light delivered per unit of energy consumed. The standard is phased in over two years, between January 1, 2012 and January 1, 2014. This adjustment affects the baseline for ENERGY STAR LEDs, and may affect the baseline for ENERGY STAR LED Torchieres, ENERGY STAR Indoor LED Fixtures, ENERGY STAR Outdoor LED Fixtures and ENERGY STAR Ceiling Fans with LEDs, where the baseline condition is assumed to be a general service, standard screw-in incandescent light bulb.

For upstream buy-down, retail (time of sale), or efficiency kit programs, baseline wattages can be determined using the tables included in this protocol below. For direct install programs, wattage of the existing lamp removed may be used in lieu of the tables below.

4. ~~Afterwards, values in column (d) are used for Watts<sub>Base</sub>.~~

Note that this TRM section is applicable only to LEDs with rated outputs between 310 and 2600 lumens that replace general service medium screw base lamps such as A-shapes and globes, as well as candelabras. This TRM section is neither applicable to LEDs with rated lumen output lower than 310, nor to LEDs with rated lumen output greater than 2600. (For reflector lamps refer to Table 2-81).

**2.36.32.35.3 Algorithms**

The LED measure savings are based on the following algorithms:

$$Energy\ Impact\ (kWh) = ((Watts_{Base} - Watts_{LED}) * (Hours_{LED} * 365) / 1000) * ISR_{LED}$$

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$$\text{Peak Demand Impact (kW)} = ((\text{Watts}_{\text{Base}} - \text{Watts}_{\text{LED}}) / 1000) * CF * \text{ISR}_{\text{LED}}$$

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### REFLECTOR LAMPS

Incandescent reflector lamps (IRLs) are the common cone-shaped light bulbs most typically used in track lighting and "recessed can" light fixtures (low-cost light fixtures that mount flush with the ceiling such that the socket and bulb are recessed into the ceiling). The cone is lined with a reflective coating to direct the light. PAR lamps are the most common type of IRLs; other common IRLs include "blown" PAR (BPAR) lamps, which are designed to be a low-cost substitute for widely used PAR lamps, and "bulged" reflector (BR) lamps. Table 2-81 shows lumen ranges and incandescent equivalents for LED reflector lamps based on the EISA 2007 amendment for reflector lamps in residential settings.

Table 2-81: Reflector Lamps

Minimum Lumens (a)	Maximum Lumens (b)	Incandescent Equivalent Watts <sub>Base</sub> <sup>209</sup> (c)
2340	3075	150
1682	2339	120
1204	1681	100
838	1203	75
561	837	60
420	560	45

To determine baseline wattage for an LED reflector lamp:

1. Identify the LED's rated lumen output
2. In Table 2-81, find the lumen range into which the LED falls (see columns (a) and (b))
3. Find the incandescent equivalent wattage in column (c).

Note that this TRM section is applicable only to LEDs with rated outputs between 420 and 3,075 lumen that replace incandescent reflector lamps (floods, recessed lights); it is not applicable to LEDs with rated lumen output lower than 420 nor to LEDs with rated lumen output greater than 3,075.

<sup>209</sup> [http://www.standardsasap.org/products/incd\\_reflector.html](http://www.standardsasap.org/products/incd_reflector.html)

<sup>210</sup> The amendment provided nominal lamp wattages and minimum average efficacies for standard incandescent reflector lamps and general service lamps. Table 2-81 adapts those averages. See: [http://www1.eere.energy.gov/buildings/appliance\\_standards/residential/incandescent\\_lamps\\_standards\\_final\\_rule.html](http://www1.eere.energy.gov/buildings/appliance_standards/residential/incandescent_lamps_standards_final_rule.html)

$$\text{Energy Impact (kWh)} = ((\text{Watts}_{\text{Base}} - \text{Watts}_{\text{LED}}) * (\text{Hours}_{\text{LED}} * 365) / 1000) * \text{ISR}_{\text{LED}}$$

$$\text{Peak Demand Impact (kW)} = ((\text{Watts}_{\text{Base}} - \text{Watts}_{\text{LED}}) / 1000) * \text{CF} * \text{ISR}_{\text{LED}}$$

**2.36.42.35.4 Definition of Terms**

Watts<sub>base</sub> = Wattage of baseline case lamp/fixture. For general service lamps prior to EISA 2007 standards, use equivalent incandescent bulb wattage. For general service lamps past EISA 2007 standards, use new standards to determine wattage.

Watts<sub>LED</sub> = Manufacturer-claimed wattage shown on product packaging

Hours<sub>LED</sub> = Average hours of use per day per LED

IE<sub>kWh</sub> = HVAC Interactive Effect for energy

IE<sub>kW</sub> = HVAC Interactive Effect for demand

ISR<sub>LED</sub> = Residential LED in-service rate—the percentage of units rebated that actually get installed

CF = Demand Coincidence Factor (See Section 1.4)

Table 2-~~868286~~: Residential LED Variables

Variable	Type	Value	Source
Watts <sub>Base</sub>	Fixed	See Table 2-80 and Table 2-84 See Table 2-87	Table 2-80 and Table 2-84 Table 2-87
Watts <sub>LED</sub>	Fixed	Variable	Data Gathering
Hours <sub>LED</sub>	Fixed	2.8	1
CF	Fixed	59.1%	2
ISR <sub>LED</sub>	Fixed	95% <sup>211</sup>	3
<u>IE<sub>kWh</sub></u>	<u>Variable</u>	See Table 2-89	4
<u>IE<sub>kW</sub></u>	<u>Variable</u>	See Table 2-89	4

211 Subject to verification through evaluation. The value can be updated if evaluation findings reveal a value that differs from the default.

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**Sources:**

1. Nexus Market Research, "Residential Lighting Markdown Impact Evaluation", Final Report, January 20, 2009. Table 6-1. Reference Section ~~02-30~~: ENERGY STAR Lighting for full citation.
2. [EmPOWER Maryland 2012 Final Evaluation Report: Residential Lighting Program. Prepared by Navigant Consulting and the Cadmus Group, Inc., March 2013, Table 50.](#)
3. [Mid-Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships, July 2011.](#)

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**2.35.5 GDS simulation modeling****Table 2-87: Baseline Wattage by Lumen Output for General Service Lamps (GSL)<sup>212</sup>**

<u>Minimum Lumens</u> (a)	<u>Maximum Lumens</u> (b)	<u>Incandescent Equivalent</u> <u>Watts<sub>Base</sub></u> <u>(Pre-EISA 2007)</u> (c)	<u>Watts<sub>Base</sub></u> <u>(Post-EISA 2007)</u> (d)	<u>Post-EISA 2007 Effective Date</u> (e)
<u>1490</u>	<u>2600</u>	<u>100</u>	<u>72</u>	<u>2012 TRM</u>
<u>1050</u>	<u>1489</u>	<u>75</u>	<u>53</u>	<u>2013 TRM</u>
<u>750</u>	<u>1049</u>	<u>60</u>	<u>43</u>	<u>2014 TRM</u>
<u>310</u>	<u>749</u>	<u>40</u>	<u>29</u>	<u>2014 TRM</u>

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To determine the Watts<sub>Base</sub> for GSLs, follow these steps:

3. [Identify the ENERGY STAR LED's rated lumen output](#)
4. [In Table 2-87, find the lumen range into which the lamp falls \(see columns \(a\) and \(b\)\).](#)
5. [Find the baseline wattage \(Watts<sub>Base</sub>\) in column \(c\) or column \(d\). Values in column \(c\) are used for Watts<sub>Base</sub> until the TRM listed under column \(e\) is effective. Afterwards, values in column \(d\) are used for Watts<sub>Base</sub>.](#)

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For EISA exempt<sup>213</sup> GSL bulbs, use the Watts<sub>Base</sub> value in column (c) in Table 2-87 above. Commonly used EISA exempt bulbs include 3-way bulbs, globes with ≥5" diameter or ≤749 lumens, and candelabra base bulbs with ≤1049 lumens. See EISA legislation for full list of exemptions.

<sup>212</sup> United States Department of Energy, [Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET](http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/general_service_incandescent_factsheet.pdf), [http://www1.eere.energy.gov/buildings/appliance\\_standards/residential/pdfs/general\\_service\\_incandescent\\_factsheet.pdf](http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/general_service_incandescent_factsheet.pdf)

<sup>213</sup> The EISA 2007 standards apply to general service incandescent lamps. A complete list of the 22 incandescent lamps exempt from EISA 2007 is listed in the United States Department of Energy [Impact of EISA 2007 on General Service Incandescent Lamps: FACT SHEET](#).

Reflector (directional) bulbs fall under legislation different from GSL bulbs. For these bulbs, EDCs can use the manufacturer rated equivalent wattage as printed on the retail packaging, or use the default  $Watts_{Base}$  (column (c)) in Table 2-88, below.

Table 2-88: Default Baseline Wattage for Reflector Bulbs<sup>214</sup>

Bulb Type (a)	Incandescent Equivalent (Pre-EISA) (b)	$Watts_{Base}$ (Post-EISA) (c)
PAR20	50	35
PAR30	50	35
R20	50	45
PAR38	60	55
BR30	65	EXEMPT
BR40	65	EXEMPT
ER40	65	EXEMPT
BR40	75	65
BR30	75	65
PAR30	75	55
PAR38	75	55
R30	75	65
R40	75	65
PAR38	90	70
PAR38	120	70
R20	$\leq 45$	EXEMPT
BR30	$\leq 50$	EXEMPT
BR40	$\leq 50$	EXEMPT
ER30	$\leq 50$	EXEMPT
ER40	$\leq 50$	EXEMPT

<sup>214</sup> Based on manufacturer recommended replacements for EISA affected lamps. Manufacturer ratings may differ from the list above, in which case EDCs should default to the manufacturer equivalent rating.

In the absence of EDC data gathering, the default values for Energy and Demand HVAC Interactive Effects are in [Table 2-89](#) below.

**Table 2-89: Energy and Demand HVAC Interactive Effects by EDC<sup>215</sup>**

	<u>IE<sub>kWh</sub></u>	<u>IE<sub>kW</sub></u>
Duquesne	8%	13%
FE (MetEd)	-8%	13%
FE (Penn Elec)	1%	10%
FE (Penn Power)	0%	20%
FE (WPP)	-2%	30%
PPL	-6%	12%
PECO	9%	14%

### 2.36.52.35.6 Measure Life

Residential LED Measure Life is 14.7 yrs<sup>216</sup>

2. RLW Analytics, "Development of Common Demand Impacts for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)," prepared for the New England State Program Working Group (SPWG), March 25, 2007, p. IV.
3. Mid Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2011.

### ~~2.36.6 Measure Life~~

~~Residential LED Measure Life is 14.7 yrs<sup>217</sup>~~

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<sup>215</sup> HVAC Interactive Effects modeled through REM/Rate models, using EDC specific inputs. Values were weighted to the saturation of HVAC equipment and housing types present in each EDC service territory as reported in the [Pennsylvania Statewide Residential End-Use and Saturation Study, 2012](#).

<sup>216</sup>All LED bulbs listed on the qualified ENERGY STAR product list have a lifetime of at least 15,000 hours. Assuming 2.8 hours per day usage, this equates to 14.7 years.

<sup>217</sup>All LED bulbs listed on the qualified ENERGY STAR product list have a lifetime of at least 15,000 hours. Assuming 2.8 hours per day usage, this equates to 14.7 years.



## 2.37.2.36 Residential Occupancy Sensors

This protocol is for the installation of occupancy sensors inside residential homes or common areas.

### 2.37.12.36.1 Algorithms

$$\Delta kWh = kW_{controlled} \times 365 \times (RH_{old} - RH_{new})$$

$$\Delta kW_{peak} = 0$$

### 2.37.22.36.2 Definition of Terms

$kW_{controlled}$  = Wattage of the fixture being controlled by the occupancy sensor (in kilowatts)

365 = Days per year

$RH_{old}$  = Daily run hours before installation

$RH_{new}$  = Daily run hours after installation

Table 2-908390: Residential Occupancy Sensors Calculations Assumptions

Component	Type	Value	Source
$kW_{controlled}$	Variable	EDC's Data Gathering	AEPS Application; EDC's Data Gathering
$RH_{old}$	Fixed	2.8	1
$RH_{new}$	Fixed	2.0 (70% of $RH_{old}$ )	2

#### Sources:

1. Nexus Market Research, "Residential Lighting Markdown Impact Evaluation", Final Report, January 20, 2009. Table 6-1. Reference Section [02-309](#): ENERGY STAR Lighting for full citation.
2. Lighting control savings fractions consistent with current programs offered by National Grid, Northeast Utilities, Long Island Power Authority, NYSEERDA, and Energy Efficient Vermont

### 2.37.32.36.3 Measure Life

The expected measure life is 10 years<sup>218</sup>.

<sup>218</sup> GDS Associates, Inc. (2007). Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures. Prepared for The New England State Program Working Group.

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**2.38.2.37 Holiday Lights**

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Measure Name	Holiday Lights
Target Sector	Residential Applications
Measure Unit	One 25-bulb Strand of Holiday lights
Unit Energy Savings	10.6 kWh
Unit Peak Demand Reduction	0 kW
Measure Life	10 years

Light Emitting Diode (LED) holiday lights are a relatively new application for this existing technology. LED holiday lights reduce energy consumption up to 90%. Up to 25 strands can be connected end-to-end in terms of residential grade lights. Commercial grade lights require different power adapters and as a result, more strands can be connected end-to-end.

**2.38.12.37.1 Eligibility**

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This protocol documents the energy savings attributed to the installation of LED holiday lights indoors and outdoors. LED lights must replace traditional incandescent holiday lights. Algorithms

$$\Delta kWh_{C9} = [(INC_{C9} - LED_{C9}) \times \#BULBS \times \#STRANDS \times HR] / 1000$$

$$\Delta kWh_{C7} = [(INC_{C7} - LED_{C7}) \times \#BULBS \times \#STRANDS \times HR] / 1000$$

$$\Delta kWh_{mini} = [(INC_{mini} - LED_{mini}) \times \#BULBS \times \#STRANDS \times HR] / 1000$$

**Key assumptions**

- All estimated values reflect the use of residential (25ct.) per strand.) bulb LED holiday lighting.
- Secondary impacts for heating and cooling were not evaluated.
- It is assumed that 50% of rebated lamps are of the "mini" variety, 25% are of the "C7" variety, and 25% are of the "C9" variety. If the lamp type is known or fixed by program design, then the savings can be calculated as described by the algorithms. Otherwise, the savings for the "mini", "C7", and "C9" varieties should be weighted by 0.5, 0.25 and 0.25 respectively.

**2.38.22.37.2 Definition of Terms**

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$LED_{mini}$  = Wattage of LED mini bulbs

$INC_{mini}$  = Wattage of incandescent mini bulbs

$LED_{C7}$  = Wattage of LED C7 bulbs

$INC_{C7}$  = Wattage of incandescent C7 bulbs

$LED_{C9}$  = Wattage of LED C9 bulbs

$INC_{C9}$  = Wattage of incandescent C9 bulbs

- #Bulbs** = Number of bulbs per strand
- #Strands** = Number of strands of lights per package
- Hr** = Annual hours of operation

Table 2-918491: Holiday Lights Assumptions

Parameter	Type	Value	Source
LED <sub>mini</sub>	Fixed	0.08 W	1
INC <sub>mini</sub>	Fixed	0.48 W	1
LED <sub>C7</sub>	Fixed	0.48 W	1
INC <sub>C7</sub>	Fixed	6.0 W	1
LED <sub>C9</sub>	Fixed	2.0 W	1
INC <sub>C9</sub>	Fixed	7.0 W	1
W <sub>Mini</sub>	Fixed	0.5	1
W <sub>C7</sub>	Fixed	0.25	1
W <sub>C9</sub>	Fixed	0.25	1
#Bulbs	Variable	Variable	EDC Data Gathering
			Default: 25 per strand
			Section 2.38.1: Key Assumptions
#Strands	Variable	Variable	EDC Data Gathering
			Default: 1 strand
			Section 2.38.1: Key Assumptions
Hr	Fixed	150	1

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**Sources:**

1. The DSMore Michigan Database of Energy Efficiency Measures: Based on spreadsheet calculations using collected data
2. <http://www.energyideas.org/documents/factsheets/HolidayLighting.pdf>

**2.38.32.37.3 Deemed Savings**

The deemed savings for installation of LED C9, C7, and mini lights is 18.7 kWh, 20.7 kWh, and 1.5 kWh, respectively. The weighted average savings are 10.6 kWh per strand. There are no demand savings as holiday lights only operate at night. Since the lights do not operate in the summer, the coincidence factor for this measure is 0.0.

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**2.38.42.37.4 Measure Life**

Measure life is 10 years<sup>219</sup>220.

**2.38.52.37.5 Evaluation Protocol**

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings. As these lights are used on a seasonal basis, verification must occur in the winter holiday season. Given the relatively small amount of impact evaluation risk that this measure represents, and given that the savings hinge as heavily on the actual wattage of the supplanted lights than the usage of the efficient LED lights, customer interviews should be considered as an appropriate channel for verification.

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<sup>219</sup>The DSMore Michigan Database of Energy Efficiency Measures: Based on spreadsheet calculations using collected data: Franklin Energy Services; "FES-L19 – LED Holiday Lighting Calc Sheet"  
<sup>220</sup> <http://www.energyideas.org/documents/factsheets/HolidayLighting.pdf>



### 2.39 Low-Income Lighting (FirstEnergy)

Measure Name	Low-Income Lighting (FirstEnergy)
Target Sector	Residential Low-Income Establishments
Measure Unit	CFL
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	12.8 years

This protocol documents the calculation methodology and the assumptions regarding certain CFLs that are installed directly by contractors as part of the “Warm Extra Measures” program administered in the FirstEnergy territories. These CFLs are specifically installed in locations that are reportedly in use 1 to 2 hours per day.

The Warm Extra Measures program is offered by the Metropolitan Edison, Pennsylvania Electric, and Pennsylvania Power Companies. Warm Extra Measures is a direct install program that layers on top of the existing Warm and Warm Plus programs.

#### 2.39.1 Eligibility

This protocol concerns the CFLs that are installed only under the WARM Extra Measures program, which are defined as CFLs in fixture that are used between one and two hours per day according to homeowners/tenants. This additional protocol is necessary because the PA TRM assumes three hours of usage per day for most residential lighting applications, while the CFLs in the WARM Extra Measures program are installed expressly in fixtures that are reported to have one to two hours of usage per day.

#### 2.39.2 Algorithm

$$\Delta kWh = (Base_{watts} - CFL_{watts}) \times CFL_{hours} \times 365 / 1000 \times ISR_{CFL}$$

$$\Delta kW = (Base_{watts} - CFL_{watts}) / 1000 \times CF \times ISR_{CFL}$$

#### 2.39.3 Definition of Terms

$Base_{watts}$  = Wattage of baseline bulb

$CFL_{watts}$  = Wattage of CFL

$CFL_{hours}$  = Daily hours of operation for CFL

365 = Days per year

$ISR_{CFL}$  = In-service rate percent of bulbs installed. Adjustment of this value can be made based on evaluation findings.

CF = Demand Coincidence Factor (See Section 1.4)

Table 2-85: Low Income Lighting Calculations Assumptions

Component	Type	Value	Source
Base <sub>watts</sub>	Fixed	See Table 2-86	Table 2-86
CFL <sub>watts</sub>	Fixed	Data-Gathering	EDC Data-Gathering
CFL <sub>hours</sub> <sup>1</sup>	Fixed	1.5	1
CF	Fixed	0.05	2
ISR <sub>CFL</sub>	Fixed	84%	3, 4

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#### Sources:

1. Based on EDC program design and a recent CFL survey.
2. RLW Analytics, "Development of Common Demand Impacts for Energy Efficiency Measures/Programs for the ISO Forward Capacity Market (FCM)", prepared for the New England State Program Working Group (SPWG), March 25, 2007, p. IV.
3. Nexus Market Research, "Impact Evaluation of the Massachusetts, Rhode Island and Vermont 2003 Residential Lighting Programs", Final Report, October 1, 2004, p. 42 (Table 4-7). These values reflect both actual installations and the % of units planned to be installed within a year from the logged sample. The logged % is used because the adjusted values (to account for differences between logging and telephone survey samples) were not available for both installs and planned installs. However, this seems appropriate because the % actual installed in the logged sample from this table is essentially identical to the % after adjusting for differences between the logged group and the telephone sample (p. 100, Table 9-3).
4. Value subject to update through evaluation.

#### 2.39.4 Deemed Savings

The deemed savings for the installation of CFL lamps compared to incandescent bulbs are listed in Table 2-86.

Table 2-86: Energy Savings and Demand Reductions

CFL <sub>watts</sub>	Base <sub>watts</sub> <sup>221</sup>	CFL <sub>hours</sub>	Energy Savings (kWh)	Demand Reduction (kW)
9	40 (29)	1.5	14.3 (9.2)	0.00155 (0.00100)
11	40 (29)	1.5	13.3 (8.3)	0.00145 (0.00090)
13	60 (43)	1.5	21.6 (13.8)	0.00235 (0.00150)
14	60 (43)	1.5	21.2 (13.3)	0.00230 (0.00145)
18	53	1.5	16.1	0.00175
19	53	1.5	15.6	0.00170
22	53	1.5	14.3	0.00155
23	72	1.5	22.5	0.00245
26	72	1.5	21.2	0.00230

**2.39.5 Measure Life**

The assumed measure life for a compact fluorescent light bulb is 7,000 hours or 12.8 years for this measure.

**2.39.6 Evaluation Protocol**

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

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<sup>221</sup> Value in ( ) are effective as of the 2014 TRM to adjust for EISA 2007. Reference Section 2.302.30 for further information on EISA 2007.

**2.40.2.38 Water Heater Tank Wrap**

Measure Name	Water Heater Tank Wrap
Target Sector	Residential
Measure Unit	Tank
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	7 years

This measure applies to the installation of an insulated tank wrap or “blanket” to existing residential electric hot water heaters.

The base case for this measure is a standard residential, tank-style, electric water heater with no external insulation wrap.

**2.40.12.38.1 Algorithms**

The annual energy savings for this measure are assumed to be dependent upon decreases in the overall heat transfer coefficient that are achieved by increasing the total R-value of the tank insulation.

$$\Delta kWh = \frac{(U_{base}A_{base} - U_{insul}A_{insul}) \times (T_{setpoint} - T_{ambient})}{3412 \times \eta_{Elec}} \times HOU$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{HOU} \times CF$$

**2.40.22.38.2 Definition of Terms**

$U_{base}$  = Overall heat transfer coefficient of water heater prior to adding tank wrap (Btu/Hr-F-ft<sup>2</sup>).

$U_{insul}$  = Overall heat transfer coefficient of water heater after addition of tank wrap (Btu/Hr-F-ft<sup>2</sup>).

$R$  =  $1/U$

$A_{base}$  = Surface area of storage tank prior to adding tank wrap (square feet)<sup>222</sup>

$A_{insul}$  = Surface area of storage tank after addition of tank wrap (square feet)<sup>223</sup>.

$\eta_{Elec}$  = Thermal efficiency of electric heater element

<sup>222</sup> Area includes tank sides and top to account for typical wrap coverage.

<sup>223</sup> Ibid.

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$T_{setpoint}$	= Temperature of hot water in tank (F).
$T_{ambient}$	= Temperature of ambient air (F).
HOU	= Annual hours of use for water heater tank.
CF	= Demand Coincidence Factor (See Section 1.4)
3412	= Conversion factor (Btu/kWh)

The U.S. Department of Energy recommends adding a water heater wrap of at least R-8 to any water heater with an existing R-value less than R-24224. The default inputs for the savings algorithms are given in [Table 2-92](#)~~Table 2-8792~~. Actual tank and blanket U-values can be used in the above algorithms as long as make/model numbers of the tank and blanket are recorded and tracked by the EDC.

Table 2-~~928792~~92: Water Heater Tank Wrap – Default Values

Component	Type	Value	Source
R <sub>base</sub>	Fixed Variable	12 Default: 12; or EDC Data Gathering	1
R <sub>insul</sub>	Fixed Variable	20 Default: 20; or EDC Data Gathering	2
$\eta_{Elec}$	Fixed	0.97	3
T <sub>hot</sub>	Fixed	120 123	5
T <sub>ambient</sub>	Fixed	70	5
HOU	Fixed	8760	4
CF	Fixed	1	4

#### Sources:

1. The baseline water heater is assumed to have 1 inch of polyurethane foam as factory insulation and an overall R-12.
2. The water heater wrap is assumed to be a fiberglass blanket with R-8, increasing the total to R-20.
3. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs. October 15, 2010. Prepared by New York Advisory Contractor Team.
4. It is assumed that the tank wrap will insulate the tank during all hours of the year.

5. ~~Program assumption~~

5. [2012 Residential SWE Baseline Study](#)

224 "Energy Savers", U.S. Department of Energy, accessed November, 2010  
[http://www.energysavers.gov/your\\_home/water\\_heating/index.cfm/mytopic=13070](http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13070)

Table 2-938893: Deemed savings by water heater capacity.

Capacity (gal)	R <sub>base</sub>	R <sub>insul</sub>	A <sub>base</sub> (ft <sup>2</sup> ) <sup>225</sup>	A <sub>insul</sub> (ft <sup>2</sup> ) <sup>226</sup>	ΔkWh	ΔkW
30	8	16	19.16	20.94	143	0.0164
30	10	18	19.16	20.94	100	0.0114
30	12	20	19.16	20.94	73	0.0083
30	8	18	19.16	20.94	163	0.0186
30	10	20	19.16	20.94	115	0.0131
30	12	22	19.16	20.94	85	0.0097
40	8	16	23.18	25.31	174	0.0198
40	10	18	23.18	25.31	120	0.0137
40	12	20	23.18	25.31	88	0.0100
40	8	18	23.18	25.31	197	0.0225
40	10	20	23.18	25.31	139	0.0159
40	12	22	23.18	25.31	103	0.0118
50	8	16	24.99	27.06	190	0.0217
50	10	18	24.99	27.06	131	0.0150
50	12	20	24.99	27.06	97	0.0111
50	8	18	24.99	27.06	214	0.0245
50	10	20	24.99	27.06	152	0.0173
50	12	22	24.99	27.06	113	0.0129
80	8	16	31.84	34.14	244	0.0279
80	10	18	31.84	34.14	171	0.0195
80	12	20	31.84	34.14	125	0.0143
80	8	18	31.84	34.14	276	0.0315
80	10	20	31.84	34.14	195	0.0223
80	12	22	31.84	34.14	145	0.0166

**2.40.32.38.3 Measure Life**

The measure life is 7 years<sup>227</sup>.

<sup>225</sup> Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.

<sup>226</sup> A<sub>insul</sub> was calculated by assuming that the water heater wrap is a 2" thick fiberglass material.

<sup>227</sup> DEER Version 2008.2.05, December 16, 2008.

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### 2.412.39 Pool Pump Load Shifting

Measure Name	Pool Pump Load Shifting
Target Sector	Residential Establishments
Measure Unit	Pool Pump Load Shifting
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	1 year

Residential pool pumps can be scheduled to avoid the noon to 8 PM peak period.

#### 2.41.1 Eligibility

This protocol documents the energy savings attributed to schedule residential single speed pool pumps to avoid run during the peak hours from noon to 8 PM. The target sector primarily consists of single-family residences. This measure is intended to be implemented by trade allies that participate in in-home audits, or by pool maintenance professionals.

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#### 2.41.2 Algorithms

The residential pool pump reschedule measure is intended to produce demand savings, but if the final daily hours of operation are different than the initial daily hours of operation, an energy savings (or increase) may result. The demand savings result from not running pool pumps during the peak hours during noon to 8PM.

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$$\Delta kWh = \Delta \text{hours/day} \times \text{Days}_{\text{operating}} \times kW_{\text{pump}}$$

$$\Delta kW_{\text{peak}} = (CF_{\text{pre}} - CF_{\text{post}}) \times kW_{\text{pump}}$$

The peak coincident factor, CF, is defined as the average coincident factor during noon and 8 PM on summer weekdays. Ideally, the demand coincidence factor for the supplanted single-speed pump can be obtained from the pump's time clock. The coincidence factor is equal to the number of hours that the pump was set to run between noon and 8 PM, divided by 8.

#### 2.41.3 Definition of Terms

$\Delta \text{hours/day}$  = The change in daily operating hours.

$kW_{\text{pump}}$  = Electric demand of single speed pump at a given flow rate.

This quantity should be measured or taken from [Table 2-94](#) [Table 2-9094](#)

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$CF_{\text{pre}}$  = Peak coincident factor of single speed pump from noon to 8PM in summer weekday prior to pump rescheduling. This quantity should be inferred from the timer settings

$CF_{post}$  = Peak coincident factor of single speed pump from noon to 8PM in summer weekday after pump rescheduling. This quantity should be inferred from the new timer settings.

$Days_{Operating}$  = Days per year pump is in operation. This quantity should be recorded by applicant.

Table 2-948994: Pool Pump Load Shifting Assumptions

Component	Type	Value	Source
$\Delta$ hours/day	Fixed	0	2
$kW_{pump}$	Fixed	See Table 2-90 Default 1.364 kW or See Table 2-95	Table 2-90 Table 2-95
$CF_{pre}$	Fixed	0.235	3
$CF_{post}$	Fixed	0	2
$Days_{Operating}$	Fixed	100	1

#### Sources:

- 35-1. Mid-Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2011.
- 36-2. Program is designed to shift load to off-peak hours, not necessarily to reduce load.
- 37-3. Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16. Statewide value calculated using the non-weather dependent coincident peak demand calculator with inland valley data.

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#### Average Single Speed Pump Electric Demand

Since this measure involves functional pool pumps, actual measurements of pump demand are encouraged. If this is not possible, then the pool pump power can be inferred from the nameplate horsepower. Table 2-90 Table 2-95 Table 2-94 shows the average service factor (over-sizing factor), motor efficiency, and electrical power demand per pump size based on California Energy Commission (CEC) appliance database for single speed pool pump<sup>228</sup>. Note that the power to horsepower ratios appear high because many pumps, in particular those under 2 HP, have high 'service factors'. The true motor capacity is the product of the nameplate horsepower and the service factor.

<sup>228</sup> "CEC Appliances Database – Pool Pumps." California Energy Commission. Updated Feb 2008. Accessed March 2008. <[http://www.energy.ca.gov/appliances/database/historical\\_excel\\_files/2009-03-01\\_excel\\_based\\_files/Pool\\_Products/Pool\\_Pumps.zip](http://www.energy.ca.gov/appliances/database/historical_excel_files/2009-03-01_excel_based_files/Pool_Products/Pool_Pumps.zip)>



Table 2-959095: Single Speed Pool Pump Specification229

Pump Horse Power (HP)	Average Pump Service Factor*	Average Pump Motor Efficiency*	Average Pump Power (W)*
0.50	1.62	0.66	946
0.75	1.29	0.65	1,081
1.00	1.28	0.70	1,306
1.50	1.19	0.75	1,512
2.00	1.20	0.78	2,040
2.50	1.11	0.77	2,182
3.00	1.21	0.79	2,666

#### 2.41.4 Measure Life

The measure life is initially assumed to be one year. If there is significant uptake of this measure then a retention study may be warranted.

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#### 2.41.5 Evaluation Protocol

The most appropriate evaluation protocol for this measure is verification of pool pump run time.

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229 Averaged for all listed single-speed pumps in the last available version of the CEC appliance efficiency database. The powers are for 'CEC Curve A' which represents hydraulic properties of 2" PVC pipes rather than older, 1.5" copper pipes.

**2.42 High Efficiency Two-Speed Pool Pump**

The following protocol for the measurement of energy and demand savings applies to the installation of efficient two-speed residential pool pump motors in place of a standard single-speed motor of equivalent horsepower for residents with swimming pools. Pool pumps and motors are one of a home's highest energy-consuming technologies.

**2.42.1 Eligibility**

High efficiency motors (capacitor start, capacitor run) and high efficiency pumps should be required. Qualifying two-speed systems must be able to reduce flow rate by 50% and provide temporary override to full flow for startup and cleaning. All systems should be encouraged to perform filtering and cleaning during off-peak hours.

**2.42.2 Algorithms**

$$\Delta kWh = kWh_{base} - kWh_{two-speed}$$

$$\Delta kW_{peak} = (kW_{base} - kW_{two-speed}) \times CF$$

**2.42.3 Definition of Terms**

$kWh_{base}$  = Assumed annual kWh consumption for a standard single-speed pump motor in a cool climate (assumes 100 day pool season)

$kWh_{two-speed}$  = Assumed annual kWh consumption for two-speed pump motor in a cool climate

$kW_{base}$  = Assumed connected load of a standard two-speed pump motor

RHRS = Annual run hours of the baseline and efficient motor

CF = Demand Coincidence Factor (See Section 1.4)

Table 2-91: High Efficiency Pool and Motor Two-Speed Pump Calculations Assumptions

Component	Type	Value	Source
$kWh_{base}$	Fixed	707 kWh	1
$kWh_{Two-Speed}$	Fixed	177 kWh	1
$kW_{Base}$	Fixed	1.364 kW	1
$kW_{Two-Speed}$	Fixed	0.171 kW	1
RHRS <sub>Base</sub>	Fixed	518	1 and 2
RHRS <sub>Two-Speed</sub>	Fixed	1,036	1 and 2
CF	Fixed	0.235%	3

**Sources:**

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~~38.4. Mid Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2014.~~

~~39. Assumes 100 day pool season and 5.18 hours per day for the base condition and an identically sized two speed pump operating at 50% speed for 10.36 hours per day.~~

~~40. Derived from Pool Pump and Demand Response Potential, DR-07.01 Report, SCE Design and Engineering, Table 16. Statewide value calculated using the non-weather dependent coincident peak demand calculator with inland valley data.~~

Table 2-92: Two-Speed Pool Pump Deemed Savings Values

Average Annual kWh Savings per Unit	Average Summer Coincident Peak kW Savings per unit
530 kWh	0.280 kW

**2.42.4 Measure Life**

The estimated useful life for a variable speed pool pump is 10 years.<sup>230</sup>

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<sup>230</sup> Mid Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2014

## 2.432.40 Variable Speed Pool Pumps (with Load Shifting Option)

Measure Name	Residential VFD Pool Pumps
Target Sector	Residential Establishments
Measure Unit	VFD Pool Pumps
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	10 years

This measure has two potential components. First, a variable speed pool pump must be purchased and installed on a residential pool. Second, the variable speed pool pump may be commissioned such that it does not operate in the noon to 8 PM period (on weekdays). This second, optional step is referred to as *load shifting*. Residential variable frequency drive pool pumps can be adjusted so that the minimal required flow is achieved for each application. Reducing the flow rate results in significant energy savings because pump power and pump energy usage scale with the cubic and quadratic powers of the flow rate respectively. Additional savings are achieved because the VSD pool pumps typically employ premium efficiency motors. Since the only difference between the VSD pool pump without load shifting and VSD pool pump with load shifting measures pertains to the pool pump operation schedule, this protocol is written in such that it may support both measures at once.

### 2.43.1 Eligibility

To qualify for the load shifting rebate, the pumps are required to be off during the hours of noon to 8 PM. This practice results in additional demand reductions.

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### 2.43.2 Algorithms

This protocol documents the energy savings attributed to variable frequency drive pool pumps in various pool sizes. The target sector primarily consists of single-family residences.

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$$\Delta kWh = kWh_{base} - kWh_{VFD}$$

$$kWh_{base} = (h_{SS} \times kW_{SS}) \times Days/year$$

$$kWh_{VFD} = (h_{VFD} \times kW_{VFD}) \times Days/year$$

The demand reductions are obtained through the following formula:

$$\Delta kW_{peak} = kW_{base} - kW_{VFD}$$

$$kW_{base} = (CF_{SS} \times kW_{SS})$$

$$kW_{VFD} = (CF_{VFD} \times kW_{VFD})$$

The peak coincident factor, CF, is defined as the average coincident factor during noon and 8 PM on summer weekdays. Ideally, the demand coincidence factor for the supplanted single-speed pump can be obtained from the pump's time clock. The coincidence factor is equal to the number

of hours that the pump was set to run between noon and 8 PM, divided by 8. If this information is not available, the recommended daily hours of operation to use are 5.18 and the demand coincidence factor is 0.27. These operation parameters are derived from the 2011 Mid Atlantic TRM.

### 2.43.3 Definition of Terms

The parameters in the above equation are listed below.

$H_{SS}$  = Hours of operation per day for Single Speed Pump. This quantity should be recorded by the applicant.

$H_{VFD}$  = Hours of operation per day for Variable Frequency Drive Pump. This quantity should be recorded by the applicant.

Days/yr = Pool pump days of operation per year.

$W_{SS}kW_{SS}$  = Electric demand of single speed pump at a given flow rate. This quantity should be recorded by the applicant or looked up through the horsepower in Table 1-1.

$W_{VFD}$   $kW_{basepeak}$  = Peak demand of single speed pump

$kW_{VFD}$  = Electric demand of variable frequency drive pump at a given flow rate. This quantity should be measured and recorded by the applicant.

$kW_{VFD peak}$  = Peak demand of VFD pump.

$CF_{SS}$  = Peak coincident factor of single speed pump from noon to 8 PM in summer weekday. This quantity can be deduced from the pool pump timer settings for the old pump.

$CF_{VFD}$  = Peak coincident factor of VFD pump from noon to 8 PM in summer weekday. This quantity should be inferred from the new timer settings.

Table 2-~~969396~~: Residential VFD Pool Pumps Calculations Assumptions

Component	Type	Values	Source
$H_{SS}$	Variable	Default: 5.18	2
$H_{VFD}$	Variable	Default: 13.00	2
Days/yr	Fixed	Default: 100	2
$W_{SS}kW_{SS}$	Variable	EDC Data Gathering Default: 1.364 W or See Table- 2-94 Table 2-97	1 and Table 2-94 and Table 2-95 or Table 2-97
$W_{VFD}kW_{VFD}$	Variable	EDC Data Gathering	EDC Data Gathering
$CF_{SS}$	Variable	Default: 0.235	3

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CF <sub>VFD</sub>	Fixed	0	Program Design
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**Sources:**

1. “CEC Appliances Database – Pool Pumps.” *California Energy Commission*. Updated Feb 2008. Accessed March 2008. [http://www.energy.ca.gov/appliances/database/historical\\_excel\\_files/2009-03-01\\_excel\\_based\\_files/Pool\\_Products/Pool\\_Pumps.zip](http://www.energy.ca.gov/appliances/database/historical_excel_files/2009-03-01_excel_based_files/Pool_Products/Pool_Pumps.zip)
2. Mid-Atlantic TRM, version 2.0. Prepared by Vermont Energy Investment Corporation. Facilitated and managed by the Northeast Energy Efficiency Partnerships. July 2011.
3. Derived from Pool Pump and Demand Response Potential, DR 07.01 Report, SCE Design and Engineering, Table 16. Statewide value calculated using the non-weather dependent coincident peak demand calculator with inland valley data.

**Average Single Speed Pump Electric Demand**

Since this measure involves functional pool pumps, actual measurements of pump demand are encouraged. If this is not possible, then the pool pump power can be inferred from the nameplate horsepower. ~~Table 2-94~~~~Table 2-97~~~~Table 2-97~~ shows the average service factor (over-sizing factor), motor efficiency, and electrical power demand per pump size based on California Energy Commission (CEC) appliance database for single speed pool pump<sup>231</sup>. Note that the power to horsepower ratios appear high because many pumps, in particular those under 2 HP, have high ‘service factors’. The true motor capacity is the product of the nameplate horsepower and the service factor.

Table 2-~~97~~~~94~~~~97~~: Single Speed Pool Pump Specification<sup>232</sup>

Pump Horse Power (HP)	Average Pump Service Factor	Average Pump Motor Efficiency	Average Pump Power (W)
0.50	1.62	0.66	946
0.75	1.29	0.65	1,081
1.00	1.28	0.70	1,306
1.50	1.19	0.75	1,512
2.00	1.20	0.78	2,040
2.50	1.11	0.77	2,182
3.00	1.21	0.79	2,666

<sup>231</sup> “CEC Appliances Database – Pool Pumps.” *California Energy Commission*. Updated Feb 2008. Accessed March 2008. <[http://www.energy.ca.gov/appliances/database/historical\\_excel\\_files/2009-03-01\\_excel\\_based\\_files/Pool\\_Products/Pool\\_Pumps.zip](http://www.energy.ca.gov/appliances/database/historical_excel_files/2009-03-01_excel_based_files/Pool_Products/Pool_Pumps.zip)>

<sup>232</sup> Averaged for all listed single-speed pumps in the last available version of the CEC appliance efficiency database. The powers are for ‘CEC Curve A’ which represents hydraulic properties of 2” PVC pipes rather than older, 1.5” copper pipes.

### Electric Demand and Pump Flow Rate

The electric demand on a pump is related to pump flow rate, pool hydraulic properties, and the pump motor efficiency. For VFD pumps that have premium efficiency (92%) motors, a regression is used to relate electric demand and pump flow rates using the data from Southern California Edison's Innovative Designs for Energy Efficiency (InDEE) Program. This regression reflects the hydraulic properties of pools that are retrofitted with VSD pool pumps. The regression is:

$$\text{Demand (W)} = 0.0978f^2 + 10.989f + 10.281$$

Where  $f$  is the pump flow rate in gallons per minute.

This regression can be used if the flow rate is known but the wattage is unknown. However, most VFD pool pumps can display instantaneous flow and power. Power measurements or readings in the final flow configuration are encouraged.

#### 2.43.4 Deemed Savings

The energy savings and demand reductions are prescriptive according to the above formulae. All other factors held constant, the sole difference between quantifying demand reductions for the *VSD Pool Pump* and the *VSD Pool Pump with Load Shifting* measures resides in the value of the parameter  $CF_{VFD}$ .

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#### 2.43.5 Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources<sup>233</sup>, a variable speed drive's lifespan is 10 years.

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#### 2.43.6 Evaluation Protocol

The most appropriate evaluation protocol for this measure is verification of installation coupled with survey on run time and speed settings.

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<sup>233</sup> DEER values, updated October 10, 2008  
[http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

## 2.41 Duct Insulation and Sealing

This measure describes evaluating the savings associated with performing duct sealing using mastic sealant or metal tape to the distribution system of homes with either central air conditioning or a ducted heating system.

Two methodologies for estimating the savings associate from sealing the ducts are provided. The first (preferred method) requires the use of a blower door and the second requires careful inspection of the duct work.

1. **Modified Blower Door Subtraction** – this technique is described in detail on p.44 of the Energy Conservatory Blower Door Manual;  
<http://www.energyconservatory.com/download/bdmanual.pdf>
2. **Evaluation of Distribution Efficiency** – this methodology requires the evaluation of three duct characteristics below, and use of the Building Performance Institutes 'Distribution Efficiency Look-Up Table':  
<http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf>
  - a. Percentage of duct work found within the conditioned space
  - b. Duct leakage evaluation
  - c. Duct insulation evaluation

### 2.43.72.41.1 Eligibility

The efficient condition is sealed duct work throughout the unconditioned space in the home. The existing baseline condition is leaky duct work within the unconditioned space in the home.

### 2.43.82.41.2 Algorithms

#### Methodology 1: Modified Blower Door Subtraction

- a) Determine Duct Leakage rate before and after performing duct sealing

$$CFM50DL = (CFM50Whole\ House - CFM50Envelope\ Only) \times SCF$$

- b) Calculate duct leakage reduction, convert to CFM25DL and factor in Supply and Return Loss Factors

$$\Delta CFM25DL = (Pre\ CFM50DL - Post\ CFM50DL) \times Conv \times (SLF + RLF)$$

- c) Calculate Energy Savings

$$\Delta kWh_{cooling} = ((\Delta CFM25DL) / ((Capcool/12,000) \times TCFM)) \times EFLH_{cool} \times Capcool / 1000 / SEER$$

$$\Delta kWh_{heating} = (((\Delta CFM25DL) / ((Capheat/12,000) \times TCFM)) \times EFLH_{heat} \times Capheat) / COP / 3412$$

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**Methodology 2: Evaluation of Distribution Efficiency**

Determine Distribution Efficiency by evaluating duct system before and after duct sealing using Building Performance Institute "Distribution Efficiency Look-Up Table"

$$\frac{\Delta kWh_{cooling}}{SEER} = \frac{((DE_{after} - DE_{before}) / DE_{after}) \times EFLH_{cool} \times Cap_{cool}}{1000}$$

$$\frac{\Delta kWh_{heating}}{COP / 3412} = \frac{((DE_{after} - DE_{before}) / DE_{after}) \times EFLH_{heat} \times Cap_{heat}}{COP / 3412}$$

**Summer Coincident Peak Demand Savings**

$$\Delta kW = \Delta kWh_{cooling} / EFLH_{cool} \times CF$$

**2.43.92.41.3 Definition of Terms**

CF = Demand Coincidence Factor (See Section 1.4) for central AC systems

CFM50DL = Duct leakage at 50 Pascal pressure differential

ΔCFM25DL = Duct Leakage Reduction in CFM25

CFM<sub>50Whole House</sub> = Standard Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential

CFM<sub>50Envelope Only</sub> = Blower Door test result finding Cubic Feet per Minute at 50 Pascal pressure differential with all supply and return registers sealed.

SCF = Subtraction Correction Factor to account for underestimation of duct leakage due to connections between the duct system and the home. Determined by measuring pressure in duct system with registers sealed, and using look up table provided by Energy Conservatory.

Conv = Conversion factor from CFM50 to CFM25

SLF = Supply Loss Factor (% leaks sealed located in Supply ducts)

RLF = Return Loss Factor (Portion of % leaks sealed located in Return ducts)

ΔkWh<sub>cooling</sub> = Cooling Energy Savings

ΔkWh<sub>heating</sub> = Heating Energy Savings

ΔkW = Summer Coincident Peak Demand Savings

Cap<sub>cool</sub> = Capacity of Air Cooling System (Btuh)

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<u><math>Cap_{heat}</math></u>	= Capacity of heating system (Btuh)
<u><math>EFLH_{cool}</math></u>	= Cooling equivalent full load hours
<u>SEER</u>	= Efficiency of cooling equipment
<u><math>EFLH_{heat}</math></u>	= Heating equivalent full load hours
<u>TCFM</u>	= Conversion from tons of cooling to CFM
<u>COP</u>	= Efficiency of Heating Equipment
<u><math>DE_{after}</math></u>	= Distribution energy after duct sealing
<u><math>DE_{before}</math></u>	= Distribution energy before duct sealing

**Table 2-98: Duct Sealing – Values and References**

<u>Term</u>	<u>Type</u>	<u>Value</u>	<u>Source</u>
<u>CF</u>	<u>Fixed</u>	<u>0.70</u>	<u>Table 2-1</u>
<u>CFM50<sub>Whole House</sub></u>	<u>Variable</u>	<u>EDC Data Gathering</u>	<u>EDC Data Gathering</u>
<u>CFM50<sub>Envelope Only</sub></u>	<u>Variable</u>	<u>EDC Data Gathering</u>	<u>EDC Data Gathering</u>
<u>SCF</u>	<u>Variable</u>	<u>Variable</u>	<u>5, 8</u>
<u>Conv</u>	<u>Fixed</u>	<u>0.64</u>	<u>2</u>
<u>SLF</u>	<u>Variable</u>	<u>Default 0.5 or EDC Data Gathering</u>	<u>3, EDC Data Gathering</u>
<u>RLF</u>	<u>Variable</u>	<u>Default 0.25 or EDC Data Gathering</u>	<u>4, EDC Data Gathering</u>
<u>Cap</u>	<u>Variable</u>	<u>EDC Data Gathering</u>	<u>EDC Data Gathering</u>
<u>TCFM</u>	<u>Fixed</u>	<u>400</u>	<u>5</u>
<u>SEER</u>	<u>Variable</u>	<u>Default 10 SEER or EDC Data Gathering</u>	<u>6, EDC Data Gathering</u>
<u>COP</u>	<u>Variable</u>	<u>Default 2.0 COP or EDC Data Gathering</u>	<u>6, EDC Data Gathering</u>
<u><math>EFLH_{cool}</math></u>	<u>Default</u>	<u>Allentown Cooling = 487 Hours Erie Cooling = 389 Hours Harrisburg Cooling = 551 Hours Philadelphia Cooling = 591 Hours Pittsburgh Cooling = 432 Hours Scranton Cooling = 417 Hours Williamsport Cooling = 422 Hours</u>	<u>Table 2-1</u>

<u>Term</u>	<u>Type</u>	<u>Value</u>	<u>Source</u>
	<u>Optional</u>	<u>An EDC can either use the Alternate EFLH Table or estimate its own EFLH based on customer billing data analysis.</u>	<u>Alternate EFLH Table (See Section 2.1.3, Table 2-2), EDC Data Gathering</u>
<u>EFLH<sub>heat</sub></u>	<u>Default</u>	<u>Allentown Heating = 1,193 Hours</u> <u>Erie Heating = 1,349 Hours</u> <u>Harrisburg Heating = 1,103 Hours</u> <u>Philadelphia Heating = 1,060 Hours</u> <u>Pittsburgh Heating = 1,209 Hours</u> <u>Scranton Heating = 1,296 Hours</u> <u>Williamsport Heating = 1,251 Hours</u>	<u>Table 2-1</u>
	<u>Optional</u>	<u>An EDC can either use the Alternate EFLH Table or estimate its own EFLH based on customer billing data analysis.</u>	<u>Alternate EFLH Table (See Section 2.1.3, Table 2-3), EDC Data Gathering</u>
<u>DE<sub>after</sub></u>	<u>Variable</u>	<u>Variable</u>	<u>5, 7</u>
<u>DE<sub>before</sub></u>	<u>Variable</u>	<u>Variable</u>	<u>5, 7</u>

### Sources

1. Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. [http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure\\_life\\_GDS%5B1%5D.pdf](http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf)
2. 25 Pascals is the standard assumption for typical pressures experienced in the duct system under normal operating conditions. To convert CFM50 to CFM25 you multiply by 0.64 (inverse of the “Can’t Reach Fifty” factor for CFM25; see Energy Conservatory Blower Door Manual).
3. Assumes that for each percent of supply air loss there is one percent annual energy penalty. This assumes supply side leaks are direct losses to the outside and are not recaptured back to the house. This could be adjusted downward to reflect regain of usable energy to the house from duct leaks. For example, during the winter some of the energy lost from supply leaks in a crawlspace will probably be regained back to the house (sometimes 1/2 or more may be regained). More information provided in

["Appendix E Estimating HVAC System Loss From Duct Airtightness Measurements"](http://www.energyconservatory.com/download/dbmanual.pdf) from <http://www.energyconservatory.com/download/dbmanual.pdf> Assumes 50% of leaks are in supply ducts.

4. Assumes that for each percent of return air loss there is a half percent annual energy penalty. Note that this assumes that return leaks contribute less to energy losses than do supply leaks. This value could be adjusted upward if there was reason to suspect that the return leaks contribute significantly more energy loss than "average" (e.g. pulling return air from a super-heated attic), or can be adjusted downward to represent significantly less energy loss (e.g. pulling return air from a moderate temperature crawl space) . More information provided in "Appendix E Estimating HVAC System Loss from Duct Airtightness Measurements" from <http://www.energyconservatory.com/download/dbmanual.pdf> Assumes 50% of leaks are in return ducts.
5. Illinois Statewide TRM, 2013, Section 5.3.4
6. Minimum Federal Standards for new Central Air Conditioners and Air Source Heat Pumps between 1990 and 2006 based on VEIC estimates.
7. Building Performance Institute, Distribution Efficiency Table, <http://www.bpi.org/files/pdf/DistributionEfficiencyTable-BlueSheet.pdf>
7. <http://www.energyconservatory.com/download/bdmanual.pdf>

[Measure Life](#)

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**2.41.4**

The assumed lifetime of this measure is 20 years<sup>234</sup>. The actual duct sealing measure cost should be used.

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<sup>234</sup> Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007. [http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure\\_life\\_GDS%5B1%5D.pdf](http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf)

## 2.42 Water Heater Temperature Setback

Measure Name	Water Heater Temperature Setback
Target Sector	Residential Establishments
Measure Unit	Water Heater Temperature
Unit Energy Savings	105 kWh/yr for storage water heater 48 kWh/yr for heat pump water heater
Unit Peak Demand Reduction	0.010 kW for storage water heater 0.0044kW for heat pump water heater
Measure Life	4 years

In homes where the water heater setpoint temperature is set high, savings can be achieved by changing the setpoint temperature to a recommended 120°F. Clothes washer hot water use and water heater tank losses are included in the savings calculation, but shower and faucet use, and dishwasher use is not included due to expected behavioral and automatic (dishwasher) adjustments in response to lower water temperature. It is expected that the net energy use for the dish washer hot water will remain the same after a temperature reduction because dishwashers will adjust hot water temperature to necessary levels using internal heating elements.

### 2.42.1 Eligibility

This protocol documents the energy savings attributed to turning down the water heater temperature to 120°F. The target sector primarily consists of single-family residences.

### 2.43.102.42.2 Algorithms

The annual energy savings calculation utilizes average performance data for available residential water heaters and typical water usage for residential homes. The energy savings are obtained through the following formula:

$$\Delta kWh/yr = \frac{1}{EF} \times 0.6 \times CAP + \frac{\left\{ \left( \frac{1}{EF} \right) \times \left( HW \times 365 \times 8.3 \frac{lb}{gal} \times (T_{hot,f} - T_{hot,r}) \right) \right\}}{3413 \frac{Btu}{kWh}}$$

Demand savings result from reduced hours of operation of the heating element, rather than a reduced connected load. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = EnergyToDemandFactor \times Energy Savings$$

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average Usage_{Summer WD Noon-8}}{Annual Energy Usage}$$

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from load shape data collected for a water heater and HVAC demand response study for PJM235. The factor is constructed as follows:

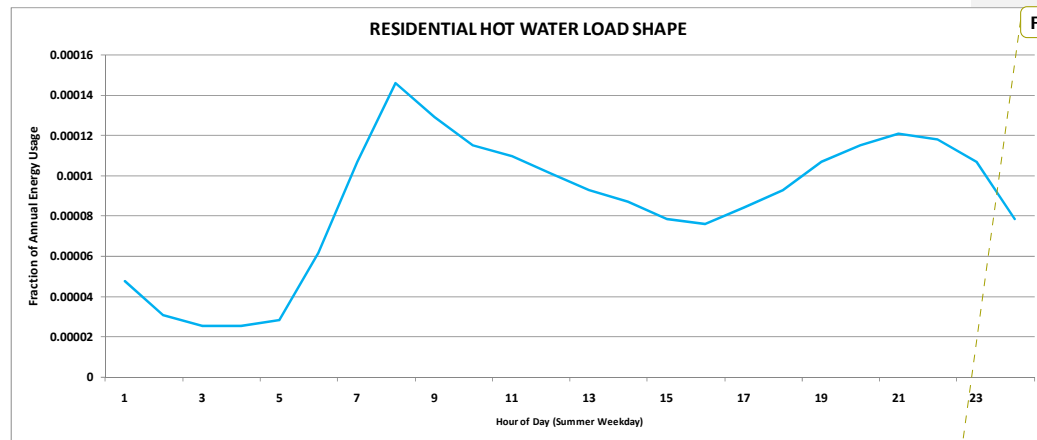
1) Obtain the average kW, as monitored for 82 water heaters in PJM territory<sup>236</sup>, for each hour of the typical day summer, winter, and spring/fall days. Weight the results (91 summer days, 91 winter days, 183 spring/fall days) to obtain annual energy usage.

2) Obtain the average kW during noon to 8 PM on summer days from the same data.

3) The average noon to 8 PM demand is converted to average *weekday* noon to 8 PM demand through comparison of weekday and weekend monitored loads from the same PJM study<sup>237</sup>.

4) The ratio of the average weekday noon to 8 PM energy demand to the annual energy usage obtained in step 1. The resulting number, 0.00009172, is the *EnergyToDemandFactor*.

The load shapes (fractions of annual energy usage that occur within each hour) during summer week days are plotted in [Figure 2-11](#) below.



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Figure 2-11: Load shapes for hot water in residential buildings taken from a PJM study.

<sup>235</sup> Deemed Savings Estimates for Legacy Air Conditioning and Water Heating Direct Load Control Programs in PJM Region. The report can be accessed online: <http://www.pjm.com/~media/committees-groups/working-groups/lrwg/20070301/20070301-pjm-deemed-savings-report.ashx>

<sup>236</sup> The average is over all 82 water heaters and over all summer, spring/fall, or winter days. The load shapes are taken from the fourth columns, labeled "Mean", in tables 14, 15, and 16 in pages 5-31 and 5-32

<sup>237</sup> The 5<sup>th</sup> column, labeled "Mean" of Table 18 in page 5-34 is used to derive an adjustment factor that scales average summer usage to summer *weekday* usage. The conversion factor is 0.925844. A number smaller than one indicates that for residential homes, the hot water usage from noon to 8 PM is slightly higher on weekends than on weekdays.

### 2.43.112.42.3 **Definition of Terms**

The parameters in the above equation are listed in [Table 2-99](#) below. Reduced tank losses are based on heat loss calculation for a 50 gallon water heater<sup>238</sup> dimensions<sup>239</sup> and average of base (R-8.33) and most efficient (R-24) tank insulation levels<sup>240</sup> 241. Estimated tank loss default is 30 kWh for a 50 gallon electric hot water heater.

[Table 2-99: Efficient Electric Water Heater Calculation Assumptions](#)

<u>Component</u>	<u>Type</u>	<u>Values</u>	<u>Source</u>
<u>EF, Energy Factor of water heater</u>	<u>Variable</u>	<u>EDC data collection</u>	<u>1</u>
	<u>Default:</u> <u>Variable</u>	<u>Electric Storage – 0.904</u> <u>HPWH – 2.0</u>	
<u>CAP, Hot water heater capacity</u>	<u>Variable</u>	<u>EDC Data Gathering</u>	<u>10</u>
		<u>Default: 50 gallon</u>	
<u>HW, Hot water used per day in gallons</u>	<u>Fixed</u>	<u>7.32 gallon/day</u>	<u>2, 6, 7, 8, 9</u>
<u>T<sub>hot, i</sub>, Temperature of hot water initially</u>	<u>Variable</u>	<u>EDC data collection</u>	<u>3</u>
		<u>Default: 130°F</u>	
<u>T<sub>hot, f</sub>, Temperature of hot water after setback</u>	<u>Fixed</u>	<u>120 °F</u>	<u>4</u>
<u>Energy To Demand Factor</u>	<u>Fixed</u>	<u>0.00009172</u>	<u>5</u>

#### **Sources:**

2. [Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is 0.904. “Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters” US Dept of Energy Docket Number: EE-2006-BT-STD-0129, p. 30](#)
3. [Daily Usage based on AWWA Research Foundation, 1998, Residential End Uses of Water, found in EPA's Water Sense guide: \[http://www.epa.gov/WaterSense/docs/home\\\_suppstat508.pdf\]\(http://www.epa.gov/WaterSense/docs/home\_suppstat508.pdf\) Clothes washer hot water use per capita per day adjusted for current water use per load and using PA Census Data. Hot water comprises 28% of total water in clothes washer load.](#)
4. [Engineering assumption](#)
- 9.5. [Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.](#)

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<sup>238</sup> [Section 2.3, Efficient Electric Water Heaters](#)

<sup>239</sup> [Lowe's, 50 gallon electric water heater tank dimensions](#)

<sup>240</sup> [Results and Methodology of the Engineering Analysis for Residential Water Heater Efficiency Standards, PNNL, 1998](#)

<sup>241</sup> [Energy Star Appliance Calculator](#)



6. [Mid-Atlantic TRM, footnote #24](#)
7. [Federal minimum Water Factor standards \(9.5\) and Energy Star minimum Water Factor standards \(6.0\) for clothes washers, Section 2.26, “Energy Star Clothes Washers”.](#)
8. [Average capacity of base \(3.19 cu. ft.\) and energy efficient \(3.64 cu. ft.\) clothes washers, Table 2-52, Section 2.26.](#)
9. [Households with Energy Star Clothes Washers 2009 \(36%\), “Energy Star Product Retrospective: Clothes Washers”, 2012. Used to determine current weighted average gallons per load \(27.3 gal\)](#)
10. [2007-2011 U.S. Census Data for Pennsylvania \(2.47 persons per household average\).](#)
11. [Section 2.3, Efficient Electric Water Heaters](#)

#### **2.42.4 Deemed Savings**

[The deemed savings for the setback of water heater temperature with is listed below, based on Energy Factor.](#)

**Table 2-100: Energy Savings and Demand Reductions**

<b><u>EF</u></b>	<b><u>Energy Savings (kWh/yr)</u></b>	<b><u>Demand Reduction (kW)</u></b>
<a href="#">0.904</a>	<a href="#">105</a>	<a href="#">0.010</a>
<a href="#">2.0</a>	<a href="#">48</a>	<a href="#">0.0044</a>

#### **2.42.5 Measure Life**

[According to an October 2008 report for the CA Database for Energy Efficiency Resources, an electric water heater’s lifespan is \*\*4 years\*\*](#)<sup>242</sup>

#### **2.43-122.42.6 Evaluation Protocols**

[The most appropriate evaluation protocol for this measure is verification of water heater temperature setpoint coupled with assignment of stipulated energy savings.](#)

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[242 GDS Associates, Inc., Measure Life Report Prepared for The New England State program Working Group \(SPWG\), June 2007](#)

## 2.43 ENERGY STAR Water Coolers

This protocol estimates savings for installing ENERGY STAR Water Coolers compared to standard efficiency equipment in residential applications. The measurement of energy and demand savings is based on a deemed savings value multiplied by the quantity of the measure.

### 2.43.1 Algorithms

The general form of the equation for the ENERGY STAR Water Coolers measure savings algorithms is:

$$\text{Total Savings} = \text{Number of Water Coolers} \times \text{Savings per Water Cooler}$$

To determine resource savings, the per unit estimates in the algorithms will be multiplied by the number of water coolers. Per unit savings are primarily derived from the May 2012 release of the ENERGY STAR calculator for water coolers.

Per unit energy and demand savings algorithms:

$$\Delta kWh = ESav_{WC}$$

$$\Delta kW_{peak} = DSav_{WC} \times CF_{WC}$$

### 2.43.2 Definition of Terms

$ESav_{WC}$  = Electricity savings per purchased ENERGY STAR water cooler.

$DSav_{WC}$  = Summer demand savings per purchased ENERGY STAR water cooler.

$CF_{WC}$  = The coincidence of average water cooler demand to summer system peak

Table 2-101: ENERGY STAR Water Coolers – References

Component	Type	Value	Sources
$ESav_{WC}$	Fixed	Water Cooler – Cold Water Only: 47 kWh Water Cooler – Hot/Cold Water Only: 361 kWh	1
$DSav_{WC}$	Fixed	0.0232 kW	2
$CF_{WC}$	Fixed	1.0	3

#### Sources:

1. ENERGY STAR Water Coolers Savings Calculator (Calculator updated: May 2012). Default values were used.
2. Average demand savings are estimated by taking an average of the energy savings values for both types of water coolers and dividing it by 8,760 hours usage.
3. Coincidence factors already embedded in summer peak demand reduction estimates.

**2.43.142.43.3 Measure Life**

The measure life for an ENERGY STAR Water Coolers is 10 years243.

243 ENERGY STAR Water Coolers Savings Calculator (Calculator updated: May 2012)



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### 3 COMMERCIAL AND INDUSTRIAL MEASURES

The following section of the TRM contains savings protocols for commercial and industrial measures.

#### 3.1 Baselines and Code Changes

All baselines are designed to reflect current market practices which are generally the higher of code or available equipment, that are updated periodically to reflect upgrades in code or information from evaluation results.

Pennsylvania has adopted the 2009 International Energy Conservation Code (IECC) per 34 Pa. Code Section 403.21, effective 12/31/09 by reference to the International Building code and the ICC electrical code. Per Section 501.1 of IECC 2009, “[t]he requirements contained in [chapter 5 of IECC 2009] are applicable to commercial buildings, or portions of commercial buildings. These commercial buildings shall meet either the requirements of ANSI/ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings Except for Low-Rise Residential Buildings*, or the requirements contain in [chapter 5 of IECC 2009]”. As noted in Section 501.2, as an alternative to complying with Sections 502, 503, 504, and 505 of IECC 2009, commercial building projects “shall comply with the requirements of ANSI/ASHRAE/IESNA 90.1 in its entirety.”

In accordance with IECC 2009, commercial protocols relying on code standards as the baseline condition may refer to either IECC 2009 or ASHRAE 90.1-2007 per the program design.

## 3.2 Lighting Equipment Improvements

### 3.2.1 Eligibility

Eligible lighting equipment and fixture/lamp types include fluorescent fixtures (lamps and ballasts), compact fluorescent lamps, LED exit signs, high intensity discharge (HID) lamps, interior and exterior LED lamps and fixtures, cold-cathode fluorescent lamps (CCFL), induction lamps, and lighting controls. The calculation of energy savings is based on algorithms through the stipulation of key variables (i.e. Coincidence Factor, Interactive Factor and Hours of Use) and through end-use metering referenced in historical studies or measured, as may be required, at the project level.

For solid state lighting products, please see [Section 0 Appendix F: Eligibility Requirements for Solid State Lighting Products in Commercial and Industrial Applications Appendix F](#) for specific eligibility requirements.

### 3.2.2 Algorithms

For all lighting ~~efficiency~~ fixture improvements, ~~with and~~ (without control improvements), the following algorithms apply:

$$\Delta kW = kW_{base} - kW_{ee}$$

$$\Delta kW_{peak} = \Delta kW \times CF \times (kW_{EE}) * HOU * (1 + IF_{demand}) * IF_{energy}$$

$$\Delta kWh = kWh_{base} - kWh_{ee}$$

$$kWh_{base} = \frac{\Delta kW_{peak}}{HOU * IF_{demand} * CF} = (kW_{base} \times kW_{EE}) * (1 + IF_{energy}) \times HOU * IF_{demand} * CF$$

$$kWh_{ee} = kW_{ee} \times (1 + IF_{energy}) \times HOU \times (1 - SVG)$$

For all lighting control improvements (without fixture improvements), the following algorithms apply:

$$\Delta kWh = kW_{controlled} * HOU * (SVG_{EE} - SVG_{base}) * (1 + IF_{energy})$$

$$\Delta kW_{peak} = kW_{controlled} * (SVG_{EE} - SVG_{base}) * (1 + IF_{demand}) * CF$$

For new construction and facility renovation projects, savings are calculated as described in Section [03-2.7](#), New Construction and Building Additions.

For retrofit projects, select the appropriate method from Section [03-2.7](#), Prescriptive Lighting Improvements.

### 3.2.3 Definition of Terms

$\Delta kW$  = Change in connected load from baseline (pre-retrofit) to installed (post-retrofit) lighting level.

$kW_{base}$  = kW of baseline lighting as defined by project classification.

$kW_{ee}$	= kW of post-retrofit or energy-efficient lighting system as defined in Section <a href="#">3-2.5.3.2.5</a> .
$kW_{controlled}$	= Total lighting load connected to the new control in kilowatts <sup>244</sup> . Savings is per control. The total connected load per control should be collected from the customer or the default values <sup>245</sup> shown in <a href="#">Table 3-8</a> should be used.
CF	= Demand Coincidence Factor (See Section <a href="#">1.4)01.4</a> )
HOU	= Hours of Use – the average annual operating hours of the baseline lighting equipment, <u>(before the lighting controls are in place)</u> , which if applied to full connected load will yield annual energy use.
IF demand	= Interactive HVAC Demand Factor – applies to C&I interior lighting in space that has air conditioning or refrigeration only. This represents the secondary demand savings in cooling required which results from decreased indoor lighting wattage.
IF energy	= Interactive HVAC Energy Factor – applies to C&I interior lighting in space that has air conditioning or refrigeration only. This represents the secondary energy savings in cooling required which results from decreased indoor lighting wattage.
SVG	= $\frac{SVG_{EE}}{SVG_{base}}$ = Savings factor for new lighting control (percent of time <del>that</del> <u>the lights are off due to</u> ).
$SVG_{base}$	= Savings factor for existing lighting <del>controls relative to control</del> (percent of time the <del>baseline controls system (lights are off)</del> , typically manual switch).

### 3.2.4 Baseline Assumptions

The following are acceptable methods for determining baseline conditions when verification by direct inspection is not possible as may occur in a rebate program where customers submit an application and equipment receipts only after installing efficient lighting equipment, or for a retroactive project as allowed by Act 129. In order of preference:

- Examination of replaced lighting equipment that is still on site waiting to be recycled or otherwise disposed of.

<sup>244</sup> Connected load is calculated by multiplying fixture wattage with total number of fixtures for each control.

<sup>245</sup> Note that the PA TRM contains savings factors for thirteen lighting control technologies ([Table 3-7](#)); however, default values are presented only for occupancy sensor control type. Default values for other control technologies will be added in the future TRM updates if information is available.



- Examination of replacement lamp and ballast inventories where the customer has replacement equipment for the retrofitted fixtures in stock. The inventory must be under the control of the customer or customer's agent.
- Interviews with and written statements from customers, facility managers, building engineers or others with firsthand knowledge about purchasing and operating practices at the affected site(s) identifying the lamp and ballast configuration(s) of the baseline condition.
- Interviews with and written statements from the project's lighting contractor or the customer's project coordinator identifying the lamp and ballast configuration(s) of the baseline equipment

### 3.2.5 Detailed Inventory Form

For lighting improvement projects, savings are generally proportional to the number of fixtures installed or replaced. The method of savings verification will vary depending on the size of the project because fixtures can be hand-counted to a reasonable degree to a limit.

#### Projects with connected load savings less than 20 kW

For projects having less than 20kW in connected load savings, a detailed inventory is not required but information sufficient to validate savings according to the algorithm in Section 3.2.2 must be included in the documentation. This includes identification of baseline equipment utilized for quantifying kW base. Appendix C contains a prescriptive lighting table, which can estimate savings for small, simple projects under 20kW in savings provided that the user self-certifies the baseline condition, and information on pre-installation conditions include, at a minimum, lamp type, lamp wattage, ballast type and fixture configuration (2 lamp, 4 lamp, etc.).

#### Projects with connected load savings of 20 kW or higher

For projects having a connected load savings of 20 kW or higher, a detailed inventory is required. Using the algorithms in Section 3.2.2,  $\Delta$ kW values will be multiplied by the number of fixtures installed. The total  $\Delta$ kW savings is derived by summing the total  $\Delta$ kW for each installed measure.

Within a single project, to the extent there are different control strategies (SVG), hours of use (HOU), coincidence factors (CF) or interactive factors (IF), the  $\Delta$ kW will be broken out to account for these different factors. This will be accomplished using Appendix C, a Microsoft Excel inventory form that specifies the lamp and ballast configuration using the Standard Wattage Table and SVG, HOU, CF and IF values for each line entry. The inventory will also specify the location and number of fixtures for reference and validation.

Appendix C was developed to automate the calculation of energy and demand impacts for retrofit lighting projects, based on a series of entries by the user defining key characteristics of the retrofit project. The main sheet, "Lighting Form", is a detailed line-by-line inventory incorporating variables required to calculate savings. Each line item represents a specific area with common baseline fixtures, retrofit fixtures, controls strategy, space cooling, and space usage.

Baseline and retrofit fixture wattages are determined by selecting the appropriate fixture code from the "Wattage Table" sheet. The "Fixture Code Locator" sheet can be used to find the appropriate

code for a particular lamp-ballast combination<sup>246</sup>. Actual wattages of fixtures determined by manufacturer's equipment specification sheets or other independent sources may not be used unless (1) the manufacturer's cut sheet indicates that the difference in delta-watts of fixture wattages (i.e. difference in delta watts of baseline and "actual" installed efficient fixture wattage and delta watts of baseline and nearest matching efficient fixture in standard wattage table of appendix C) is more than 10%<sup>247</sup> or (2) the corresponding fixture code is not listed in the Standard Wattage Table. In these cases, alternate wattages for lamp-ballast combinations can be inputted using the "User Input" sheet of Appendix C. Documentation supporting the alternate wattages must be provided in the form of manufacturer provided specification sheets or other industry accepted sources (e.g. ENERGY STAR listing, Design Lights Consortium listing). It must cite test data performed under standard ANSI procedures. These exceptions will be used as the basis for periodically updating the Standard Wattage Table to better reflect market conditions and more accurately represent savings.

Some lighting contractors may have developed in-house lighting inventory forms that are used to determine preliminary estimates of projects. In order to ensure standardization of all lighting projects, Appendix C must still be used. However, if a third-party lighting inventory form is provided, entries to Appendix C may be condensed into groups sharing common baseline fixtures, retrofit fixtures, space type, building type, and controls. Whereas Appendix C separates fixtures by location to facilitate evaluation and audit activities, third-party forms can serve that specific function if provided.

Appendix C will be updated periodically to include new fixtures and technologies available as may be appropriate. Additional guidance can be found in the "Manual" sheet of Appendix C.

### 3.2.6 Quantifying Annual Hours of Operation

#### • Usage Groups and Annual Hours of Use

##### **Projects with connected load savings less than 20 kW**

~~For~~For whole facility lighting projects with connected load savings less than 20 kW, apply stipulated whole building hours shown in ~~Table 3-4, Table 3-6~~. If the project cannot be described by the categories listed in ~~Table 3-4, Table 3-6~~, or the project retrofitted only a portion of a facility's lighting system for which whole building hours of use would not be appropriate, select the "other" category and determine hours using facility staff interviews, posted schedules, or metered data.

~~EDC evaluation contractors are permitted to revise HOU values if the perceived difference in hours stated in tables is greater than 10%.~~

##### **Projects with connected load savings of 20 kW or higher**

~~For projects with connected load savings of 20 kW or higher, fixtures should be separated into "For whole facility lighting projects where the facility's actual lighting hours deviates by more than 10%.~~

<sup>246</sup> The Locator is intended to assist users locate codes in the Standard Wattage Table. It does not generate new codes or wattages. In a few cases, the fixture code noted in the Standard Wattage Table may not use standard notation. Therefore, these fixtures may not be able to be found using the Locator and a manual search may be necessary to locate the code.

<sup>247</sup> This value was agreed upon by the Technical Working Group convened to discuss updates to the TRM. This value is subject to adjustment based on implementation feedback during PY3 and PY4.

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from Table 3-4 hours for the appropriate building type, use of the “other” category may be used at the discretion of the EDC’s implementation and evaluation contractors. If this option is chosen, EDC implementation and evaluation contractors should apply this methodology consistently throughout a program year for all projects to which it pertains.

For projects using the “other” category, “usage groups” that exhibit similar usage patterns. Usage groups” should be considered and used at the discretion of the EDCs’ implementation and evaluation contractors in place of stipulated whole building hours, but are not required. Where usage groups are used, fixtures should be separated into “usage groups” that exhibit similar usage patterns. Use of usage groups may be subject to SWE review. Annual hours of use values should be estimated for each group using Table 3-4, facility staff interviews, posted schedules, building monitoring system (BMS), or metered data.-

Metered data is required for **Projects with connected load savings of 20 kW or higher** For projects with connected load savings of 20 kW or higher, “usage groups” must be considered and used in place of stipulated whole building hours where possible. Fixtures should be separated into “usage groups” that exhibit similar usage patterns. Annual hours of use values should be estimated for each group using facility staff interviews, posted schedules, building monitoring system (BMS), or metered data.

For all projects, annual hours are subject to adjustment by EDC evaluators or SWE.

- **Metering**

**Projects with savings below 500,000 kWh**

Metering is encouraged for projects with expected savings below 500,000 kWh but have high uncertainty, i.e. where hours are unknown, variable, or difficult to verify. Exact conditions of “high uncertainty” are to be determined by the EDC evaluation contractors to appropriately manage variance. Metering is also required when the connected load savings for a project exceeds 200 kW. Metering completed by the implementation contractor maybe leveraged by the evaluation contractor, subject to a reasonableness review. Sampling methodologies within a site are to be discerned by the EDC evaluation contractor based on the characteristics of the facility in question.-

**Projects with savings of 500,000 kWh or higher**

For projects with expected savings of 500,000 kWh or higher, metering is required but trend data from BMS is an acceptable substitute. Metering completed by the implementation contractor maybe leveraged by the evaluation contractor, subject to a reasonableness review. Sampling methodologies within a site are to be discerned by the EDC evaluation contractor and communicated to implementation contractors based on the characteristics of the facility in question.

For all projects, annual hours are subject to adjustment by EDC evaluators or SWE.

### **3.2.7 Calculation Method Descriptions By Project Classification**

#### **New Construction and Building Additions**

For new construction and building addition projects, savings are calculated using ASHRAE 90.1-2007 to determine the baseline demand ( $kW_{base}$ ) and the new fixtures’ wattages as the post-

installation demand ( $kW_{ee}$ ). Pursuant to ASHRAE 90.1-2007, the interior lighting baseline is calculated using either the Building Area Method<sup>248</sup> as shown in Table 3-1, or the Space-by-Space Method<sup>249</sup> as shown in Table 3-2. For exterior lighting, the baseline is calculated using the Baseline Exterior Lighting Power Densities<sup>250</sup> as shown in Table 3-3. The new fixture wattages are specified in the Lighting Audit and Design Tool shown in Appendix C.

CF and IF values are the same as those shown in [Table 3-6](#)~~Table 3-46~~ and [Table 3-7](#)~~Table 3-57~~. HOU shall be determined in accordance with Section [3.2.6.3.2.6](#).

HOU and CF values for dusk-to-dawn lighting are the same as those shown in [Table 3-6](#)~~Table 3-46~~ unless shorter hours are required by ASHRAE or the fixtures are demonstrated to operate longer hours (e.g. for signage or shading in a parking garage).

Appendix E, a Microsoft Excel inventory form was developed to automate the calculation of energy and demand impacts for new construction lighting projects, based on a series of entries by the user defining key characteristics of the new construction project. The EDCs' implementation and evaluation contractors are allowed to use this tool as an option to simplify their lighting application forms. Appendix C must be used separately to calculate savings for measures other than lighting fixture installs such as control measures for NC lighting projects.

The calculator contains separate "Lighting Forms" for interior and exterior applications. Each lighting form, contains several tables with detailed line-by-line inventory incorporating variables required to calculate savings. The key variables required to calculate savings include building/space type, building size (gross lighted area), lighting power density (LPD), quantity and type of fixtures installed, hours of use (HOU), coincidence factors (CF) or interactive factors (IF).

The fixture wattages are determined by selecting the appropriate fixture code from the "Wattage Table" sheet. The "Fixture Code Locator" sheet can be used to find the appropriate code for a particular lamp-ballast combination<sup>251</sup>. Actual wattages of fixtures determined by manufacturer's equipment specification sheets or other independent sources may not be used unless (1) the manufacturer's cut sheet indicates that the difference in delta-watts of fixture wattages (i.e. difference in delta watts of baseline and "actual" installed efficient fixture wattage and delta watts of baseline and nearest matching efficient fixture in standard wattage table of appendix C) is more than 10%<sup>252</sup> or (2) the corresponding fixture code is not listed in the Standard Wattage Table. In these cases, alternate wattages for lamp-ballast combinations can be inputted using the separate "User Input" sheets for interior and exterior applications. Documentation supporting the alternate wattages must be provided in the form of manufacturer provided specification sheets or other industry accepted sources (e.g. ENERGY STAR listing, Design Lights Consortium listing). It must cite test data performed under standard ANSI procedures. These exceptions will be used as the

248 ASHRAE 90.1-2007, Table 9.5.1 – Building Area Method

249 ASHRAE 90.1-2007, Table 9.6.1 – Space-by-Space Method

250 ASHRAE 90.1-2007, Table 9.4.5 – Baseline Exterior Lighting Power Densities

251 The Locator is intended to assist users locate codes in the Standard Wattage Table. It does not generate new codes or wattages. In a few cases, the fixture code noted in the Standard Wattage Table may not use standard notation. Therefore, these fixtures may not be able to be found using the Locator and a manual search may be necessary to locate the code.

252 This value was agreed upon by the Technical Working Group convened to discuss updates to the TRM. This value is subject to adjustment based on implementation feedback during PY3 and PY4.

### SECTION 3: Commercial and Industrial Measures

#### Lighting Equipment Improvements

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basis for periodically updating the Standard Wattage Table to better reflect market conditions and more accurately represent savings.

Appendix E will be updated periodically to include new fixtures and technologies available as may be appropriate. Additional guidance can be found in the “Manual” sheet of the Appendix E.

Table 3-1: Lighting Power Densities from ASHRAE 90.1-2007 Building Area Method<sup>253</sup>

Building Area Type <sup>254</sup>	LPD (W/ft <sup>2</sup> )	Building Area Type	LPD (W/ft <sup>2</sup> )
Automotive facility	0.9	Multifamily	0.7
Convention center	1.2	Museum	1.1
Courthouse	1.2	Office	1.0
Dining: bar lounge/leisure	1.3	Parking garage	0.3
Dining: cafeteria/fast food	1.4	Penitentiary	1.0
Dining: family	1.6	Performing arts theater	1.6
Dormitory	1.0	Police/fire station	1.0
Exercise center	1.0	Post office	1.1
Gymnasium	1.1	Religious building	1.3
Health-care clinic	1.0	Retail	1.5
Hospital	1.2	School/university	1.2
Hotel	1.0	Sports arena	1.1
Library	1.3	Town hall	1.1
Manufacturing facility	1.3	Transportation	1.0
Motel	1.0	Warehouse	0.8
Motion picture theater	1.2	Workshop	1.4

<sup>253</sup> ASHRAE 90.1-2007, “Table 9.5.1 Lighting Power Densities Using the Building Area Method.”

<sup>254</sup> In cases where both a common space type and a building specific type are listed, the building specific space type shall apply.

Table 3-2: Lighting Power Densities from ASHRAE 90.1-2007 Space-by-Space Method<sup>255</sup>

Common Space Type <sup>256</sup>	LPD (W/ft <sup>2</sup> )	Building Specific Space Types	LPD (W/ft <sup>2</sup> )
Office-Enclosed	1.1	Gymnasium/Exercise Center	
Office-Open Plan	1.1	Playing Area	1.4
Conference/Meeting/Multipurpose	1.3	Exercise Area	0.9
Classroom/Lecture/Training	1.4	Courthouse/Police Station/Penitentiary	
For Penitentiary	1.3	Courtroom	1.9
Lobby	1.3	Confinement Cells	0.9
For Hotel	1.1	Judges Chambers	1.3
For Performing Arts Theater	3.3	Fire Stations	
For Motion Picture Theater	1.1	Fire Station Engine Room	0.8
Audience/Seating Area	0.9	Sleeping Quarters	0.3
For Gymnasium	0.4	Post Office-Sorting Area	1.2
For Exercise Center	0.3	Convention Center-Exhibit Space	1.3
For Convention Center	0.7	Library	
For Penitentiary	0.7	Card File and Cataloging	1.1
For Religious Buildings	1.7	Stacks	1.7
For Sports Arena	0.4	Reading Area	1.2
For Performing Arts Theater	2.6	Hospital	
For Motion Picture Theater	1.2	Emergency	2.7
For Transportation	0.5	Recovery	0.8
Atrium—First Three Floors	0.6	Nurse Station	1.0
Atrium—Each Additional Floor	0.2	Exam/Treatment	1.5
Lounge/Recreation	1.2	Pharmacy	1.2
For Hospital	0.8	Patient Room	0.7
Dining Area	0.9	Operating Room	2.2
For Penitentiary	1.3	Nursery	0.6
For Hotel	1.3	Medical Supply	1.4
For Motel	1.2	Physical Therapy	0.9
For Bar Lounge/Leisure Dining	1.4	Radiology	0.4
For Family Dining	2.1	Laundry—Washing	0.6
Food Preparation	1.2	Automotive—Service/Repair	0.7

<sup>255</sup> ASHRAE 90.1-2007, "Table 9.6.1 Lighting Power Densities Using the Space-by-Space Method."

<sup>256</sup> In cases where both a common space type and a building specific type are listed, the building specific space type shall apply.

### SECTION 3: Commercial and Industrial Measures

#### Lighting Equipment Improvements

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Common Space Type <sup>256</sup>	LPD (W/ft <sup>2</sup> )	Building Specific Space Types	LPD (W/ft <sup>2</sup> )
Laboratory	1.4	Manufacturing	
Restrooms	0.9	Low (<25 ft Floor to Ceiling Height)	1.2
Dressing/Locker/Fitting Room	0.6	High (>25 ft Floor to Ceiling Height)	1.7
Corridor/Transition	0.5	Detailed Manufacturing	2.1
For Hospital	1.0	Equipment Room	1.2
For Manufacturing Facility	0.5	Control Room	0.5
Stairs—Active	0.6	Hotel/Motel Guest Rooms	1.1
Active Storage	0.8	Dormitory—Living Quarters	1.1
For Hospital	0.9	Museum	
Inactive Storage	0.3	General Exhibition	1.0
For Museum	0.8	Restoration	1.7
Electrical/Mechanical	1.5	Bank/Office—Banking Activity Area	1.5
Workshop	1.9	Religious Buildings	
Sales Area	1.7	Worship Pulpit, Choir	2.4
		Fellowship Hall	0.9
		Retail [For accent lighting, see 9.3.1.2.1(c)]	
		Sales Area	1.7
		Mall Concourse	1.7
		Sports Arena	
		Ring Sports Area	2.7
		Court Sports Area	2.3
		Indoor Playing Field Area	1.4
		Warehouse	
		Fine Material Storage	1.4
		Medium/Bulky Material Storage	0.9
		Parking Garage—Garage Area	0.2
		Transportation	
		Airport—Concourse	0.6
		Air/Train/Bus—Baggage Area	1.0
		Terminal—Ticket Counter	1.5

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**SECTION 3: Commercial and Industrial Measures****Lighting Equipment Improvements**

Table 3-3: Baseline Exterior Lighting Power Densities<sup>257</sup>

Building Exterior	Space Description	LPD
Uncovered Parking Area	Parking Lots and Drives	0.15 W/ft <sup>2</sup>
Building Grounds	Walkways less than 10 ft wide	1.0 W/linear foot
	Walkways 10 ft wide or greater	0.2 W/ft <sup>2</sup>
	Plaza areas	
	Special feature areas	
	Stairways	1.0 W/ft <sup>2</sup>
Building Entrances and Exits	Main entries	30 W/linear foot of door width
	Other doors	20 W/linear foot of door width
Canopies and Overhangs	Free standing and attached and overhangs	1.25 W/ft <sup>2</sup>
Outdoor sales	Open areas (including vehicle sales lots)	0.5 W/ft <sup>2</sup>
	Street frontage for vehicle sales lots in addition to "open area" allowance	20 W/linear foot
Building facades		0.2 W/ft <sup>2</sup> for each illuminated wall or surface or 5.0 W/linear foot for each illuminated wall or surface length
Automated teller machines and night depositories		270 W per location plus 90 W per additional ATM per location
Entrances and gatehouse inspection stations at guarded facilities		1.25 W/ft <sup>2</sup> of uncovered area
Loading areas for law enforcement, fire, ambulance, and other emergency service vehicles		0.5 W/ft <sup>2</sup> of uncovered area
Drive-through windows at fast food restaurants		400 W per drive-through
Parking near 24-hour retail entrances		800 W per main entry

257 ASHRAE 90.1-2007 Table 9.4.5

### SECTION 3: Commercial and Industrial Measures

#### Lighting Equipment Improvements

Page 236

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### Prescriptive Lighting Improvements

Prescriptive Lighting Improvements include fixture or lamp and ballast replacement in existing commercial and industrial customers' facilities.

Note that the Energy Policy Act of 2005 ("EPACT 2005") and Energy Independence and Security Act ("EISA") 2007 standards introduced new efficacy standards for linear fluorescent bulbs and ballasts, effectively phasing out magnetic ballasts (effective October 1, 2010) and most T-12 bulbs (effective July 14, 2012). This induces a shift in what a participant would have purchased in the absence of the program because T-12 bulbs on magnetic ballasts are no longer viable options and, therefore, adjusts the baseline assumption. For Phase 2, Program Year 1, the The baseline for a lighting retrofit project is assumed will continue to be the existing lighting system (fixtures with the existing lamps and ballast, but this assumption will be revisited in subsequent TRMs. With this understanding,) for the entirety of Phase II 258. This is to reflect the time required for the market to adjust to the new federal code standards are, taking into account the fact that end-users may have an existing stock of T-12 lamps and do not immediately relevant for 2013 TRM 259. need to purchase new replacement lamps for several years.

With this understanding, these new code standards will not impact the EDCs' first year savings (which will be used to determine EDC compliance). However, these regulatory changes affect the TRC Test valuation for T-12 replacements as the energy savings and useful life are reduced each year due to the changing lighting baseline values as such lighting becomes unavailable. This section describes a methodology to calculate lifetime savings for linear fluorescent measures that replace T-12s in Program Years 6 (June 1, 2014 – May 31, 2015) and 7 (June 1, 2015 – May 31, 2016) (PY6 and PY7). Standard T-8s become the baseline for all T-12 linear fluorescent retrofits beginning June 1, 2016, should the Commission implement a Phase III of the Act 129 EE&C Programs. Therefore, measures installed in PY6 and PY7 will claim full savings until June 1, 2016. Savings adjustment factors<sup>260</sup> would be applied to the full savings for savings starting June 1, 2016, and for the remainder of the measure life. Savings adjustments are developed for different combinations of retrofits from T-12s to T-8 or T-5 lighting. In TRC Test calculations, the EDCs may adjust lifetime savings either by applying savings adjustment factors or by reducing the effective useful life<sup>261</sup> (EUL) to adjust lifetime savings. Savings adjustment factors and reduced EULs for HPT8 and T5 measures are in Table 3-4 and Table 3-5, below.

Table 3-4: Savings Adjustment Factors and Adjusted EULs for HPT8 Measures<sup>262</sup>

<u>Fixture Type</u>	<u>Savings Adjustment Factor</u>	<u>Adjusted EUL</u>
---------------------	----------------------------------	---------------------

258 The PEG will continue to monitor the market's activity and that the baseline for lighting retrofit projects be reconsidered during the first TRM update that would be effective during a potential Phase III.

259 The TWG will continue to monitor these standards and protocols and make improvements for future TRM updates.

260 Savings adjustment is defined as the ratio between the wattage reduction from the T-8 baseline to HPT-8 or T-5 lighting and the wattage reduction from the T-12 fixture.

261 EUL adjustments are calculated by applying the savings adjustment factor to the remaining useful life of the measure and reducing the EUL accordingly. The savings adjustment factor methodology and the adjusted EUL methodology will produce the same lifetime savings.

262 The savings adjustment is equal to the ratio between wattage reduction from T8 baseline to HPT8 or T5 lighting and wattage reduction from T12 fixture. These factors are taken from the 2013 IL TRM.

## **SECTION 3: Commercial and Industrial Measures**

### **Lighting Equipment Improvements**

	<u>T12 EEmag ballast and 34 w lamps</u>	<u>T12 EEmag ballast and 40 w lamps</u>	<u>T12 mag ballast and 40 w lamps</u>	<u>T12 EEmag ballast and 34 w lamps</u>	<u>T12 EEmag ballast and 40 w lamps</u>	<u>T12 mag ballast and 40 w lamps</u>
<u>1-Lamp Relamp/Reballast</u>	<u>53%</u>	<u>70%</u>	<u>80%</u>	<u>8.9</u>	<u>11.1</u>	<u>12.4</u>
<u>2-Lamp Relamp/Reballast</u>	<u>47%</u>	<u>70%</u>	<u>78%</u>	<u>8.1</u>	<u>11.1</u>	<u>12.1</u>
<u>3-Lamp Relamp/Reballast</u>	<u>58%</u>	<u>62%</u>	<u>79%</u>	<u>9.5</u>	<u>10.1</u>	<u>12.3</u>
<u>4-Lamp Relamp/Reballast</u>	<u>56%</u>	<u>71%</u>	<u>77%</u>	<u>9.3</u>	<u>11.2</u>	<u>12.0</u>

Table 3-5: Savings Adjustment Factors and Adjusted EULs for T5 Measures

<u>Fixture Type</u>	<u>Savings Adjustment Factor</u>			<u>Adjusted EUL</u>		
	<u>T12 EEmag ballast and 34 w lamps</u>	<u>T12 EEmag ballast and 40 w lamps</u>	<u>T12 mag ballast and 40 w lamps</u>	<u>T12 EEmag ballast and 34 w lamps</u>	<u>T12 EEmag ballast and 40 w lamps</u>	<u>T12 mag ballast and 40 w lamps</u>
<u>1-Lamp T5 Industrial/Strip</u>	<u>58%</u>	<u>71%</u>	<u>76%</u>	<u>9.5</u>	<u>11.2</u>	<u>11.9</u>
<u>2-Lamp T5 Industrial/Strip</u>	<u>39%</u>	<u>60%</u>	<u>66%</u>	<u>7.1</u>	<u>9.8</u>	<u>10.6</u>
<u>3-Lamp T5 Industrial/Strip</u>	<u>49%</u>	<u>60%</u>	<u>69%</u>	<u>8.4</u>	<u>9.8</u>	<u>11.0</u>
<u>4-Lamp T5 Industrial/Strip</u>	<u>40%</u>	<u>59%</u>	<u>49%</u>	<u>7.2</u>	<u>9.7</u>	<u>8.4</u>

Other factors required to calculate savings are shown in [Table 3-6](#) and [Table 3-7](#). Note that if HOU is stated and verified by logging lighting hours of use groupings, actual hours should be applied. The IF factors shown in [Table 3-7](#) are to be used only when the facilities are air conditioned and only for fixtures in conditioned or refrigerated space. The HOU for refrigerated spaces are to be estimated or logged separately. To the extent that operating schedules are known based on metered data, site-specific coincidence factors may be calculated using the non-weather dependent peak demand calculator in place of the default coincidence factors provided in [Table 3-46](#).

Table 3-6: Lighting HOU and CF by Building Type or Function

<b>Building Type</b>	<b>HOU</b>	<b>CF263</b>	<b>Source</b>
Auto Related	4,056	0.62*	7

263 Coincidence Factor values are taken from the 2011 Mid-Atlantic TRM. For the building types where CF values are not available in the Mid-Atlantic TRM, an average of CF values available for all building types in the Mid-Atlantic TRM is reported. Subject to revision based on detailed measurement or additional research in subsequent TRM Updates.

**SECTION 3: Commercial and Industrial Measures**

**Lighting Equipment Improvements**

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Building Type	HOU	CF263	Source
Daycare	2,590	0.62*	8
Dusk-to-Dawn / Exterior Lighting	3,833	0.00	2
Education – School	1,632	0.31	1
Education – College/University	2,348	0.76	1
Grocery	4,660	0.87	1
Health/Medical – Clinic	3,213	0.73	1
Hospitals	5,182	0.80	1
Industrial Manufacturing – 1 Shift	2,857	0.57	6
Industrial Manufacturing – 2 Shift	4,730	0.57	6
Industrial Manufacturing – 3 Shift	6,631	0.57	6
Libraries	2,566	0.62*	9
Lodging – Guest Rooms	914	0.09	1
Lodging – Common Spaces	7,884	0.90	1
Multi-Family (Common Areas) - High-rise & Low-rise	5,950	0.62*	3
Nursing Home	4,160	0.62*	4
Office	2,567	0.61	1
Parking Garages	6,552	0.62*	10
Public Order and Safety	5,366	0.62*	11
Public Assembly (one shift)	2,610	0.62*	4
Public Services (nonfood)	3,425	0.62*	5
Restaurant	3,613	0.65	1
Retail	2,829	0.73	1
Religious Worship/Church	1,810	0.62*	12
Storage Conditioned/Unconditioned	3,420	0.62*	4
Warehouse	2,316	0.54	1
24/7 Facilities or Spaces	8,760	1.00	N/A
Other <sup>264</sup>	Varies	Varies	1

\* 0.62 represents the simple average of all coincidence factors listed in the 2011 Mid-Atlantic TRM

#### Sources:

<sup>264</sup> To be used only when no other category is applicable. Hours of operation must be documented by facility staff interviews, posted schedules, or metered data.

### SECTION 3: Commercial and Industrial Measures

#### Lighting Equipment Improvements

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1. The Mid-Atlantic TRM – Northeast Energy Efficiency Partnerships, Mid-Atlantic Technical Reference Manual, Version 2.0, submitted by Vermont Energy Investment Corporation, July, 2011.
  - a. Development of Interior Lighting Hours of Use and Coincidence Factor Values for EmPOWER Maryland Commercial Lighting Program Evaluations, Itron, 2010.
  - b. California Public Utility Commission. *Database for Energy Efficiency Resources*, 2008
  - c. Small Commercial Contract Group Direct Impact Evaluation Report prepared by Itron for the California Public Utilities Commission Energy Division, February 9, 2010
2. State of Ohio Energy Efficiency Technical Reference Manual, Vermont Energy Investment Corporation, August 6, 2010. Exterior lighting 3,833 hours per year assumes 10.5 hours per day; typical average for photocell control.
3. Illinois Energy Efficiency Technical Reference Manual, Vermont Energy Investment Corporation, 2012. Multi-family common area value based on Focus on Energy Evaluation, ACES Deemed Savings Desk Review, November 2010.
4. California Public Utility Commission. *Database for Energy Efficiency Resources*, 2011
5. State of Wisconsin Public Service Commission of Wisconsin Focus on Energy Evaluation Business Programs: Deemed Savings Manual V1.0", KEMA, March, 2010.
6. UI and CL&P Program Savings Documentation for 2012 Program Year, United Illuminating Company, September 2011.
7. California Public Utility Commission. *Database for Energy Efficiency Resources*, 2011; available at [www.deeresources.com](http://www.deeresources.com)
8. Analysis of 3-"Kinder Care" daycare centers serving 150-160 children per day - average 9,175 ft<sup>2</sup>; 4.9 Watts per ft<sup>2</sup>; load factor 23.1% estimate 2,208 hours per year. Given an operating assumption of five days per week, 12 hours per day (6:00AM to 6:00 PM) closed weekends (260 days); Closed on 6 NERC holidays that fall on weekdays (2002, 2008 and 2013) deduct 144 hours: (260 X 12)-144 = 2,976 hours per year; assumption adopts an average of measured and operational bases or 2,592 hours per year.
9. Southern California Edison Company, Design & Engineering Services, Work Paper WPSCNRM10054, Revision 0, September 17, 2007, Ventura County Partnership Program, Fillmore Public Library (Ventura County); Two 8-Foot T8 Lamp and Electronic Ballast to Four 4-Foot T8 Lamps and Premium Electronic Ballast. Reference: "The Los Angeles County building study was used to determine the lighting operating hours for this work paper. At Case Site #19A (L.A. County Montebello Public Library), the lights were at full-load during work hours and at zero-load during non-work hours. This and the L.A. County Claremont Library (also referenced in the Los Angeles County building study) are small library branches similar to those of this work paper's library (Ventura County's Fillmore Library). As such, the three locations have the same lighting profile. Therefore, the lighting operating hour value of 1,664 hours/year stated above is reasonably accurate." Duquesne Light customer data on 29 libraries (SIC 8231) reflects an average load factor 26.4% equivalent to 2285 hours per year. Connecticut Light and Power and United Illuminating Company (CL&P and UI) program savings documentation for 2008

**SECTION 3: Commercial and Industrial Measures****Lighting Equipment Improvements**

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Program Year Table 2.0.0 C&I Hours, page 246 - Libraries 3,748 hours. An average of the three references is 2,566 hours.

10. CL&P and UI 2008 program documentation (referenced above) cites an estimated 4,368 hours, only 68 hours greater than dusk to dawn operating hours. ESNA RP-20-98; Lighting for Parking Facilities acknowledges "Garages usually require supplemental daytime luminance in above-ground facilities, and full day and night lighting for underground facilities." Emphasis added. The adopted assumption of 6,552 increases the CL&P and UI value by 50% (suggest data logging to document greater hours i.e., 8760 hours per year).
11. DOE 2003 Commercial Building Energy Survey (CBECS), Table B1. Summary Table: Total and Means of Floor space, Number of Workers, and Hours of Operation for Non-Mall Buildings, Released: June 2006 - 103 Mean Hours per Week for 71,000 Building Type: "Public Order and Safety" - 32 X 52 weeks = 5,366 hour per year.
12. DOE 2003 Commercial Building Energy Survey (CBECS), Table B1. Summary Table: Total and Means of Floor space, Number of Workers, and Hours of Operation for Non-Mall Buildings, Released: June 2006 - 32 Mean Hours per Week for 370,000 Building Type: "Religious Worship" - 32 X 52 weeks = 1,664 hour per year.

Table 3-757: Interactive Factors and Other Lighting Variables

Component	Type	Value	Source
IF <sub>demand</sub>	Fixed	Cooled space (60 °F – 79 °F) = 0.34 Freezer spaces (-35 °F – 20 °F) = 0.50 Medium-temperature refrigerated spaces (20 °F – 40 °F) = 0.29 High-temperature refrigerated spaces (40 °F – 60 °F) = 0.18 Un-cooled space = 0	1
IF <sub>energy</sub>	Fixed	Cooled space (60 °F – 79 °F) = 0.12 Freezer spaces (-35 °F – 20 °F) = 0.50 Medium-temperature refrigerated spaces (20 °F – 40 °F) = 0.29 High-temperature refrigerated spaces (40 °F – 60 °F) = 0.18 Un-cooled space = 0	1
kW <sub>base</sub>	Variable	See Standard Wattage Table in Appendix C	2
kW <sub>inst</sub>	Variable	See Standard Wattage Table in Appendix C	2

**Sources:**

1. PA TRM, Efficiency Vermont. Technical Reference User Manual: Measure Savings Algorithms and Cost Assumptions (July 2008).
2. NYSERDA Table of Standard Wattages (November 2009)

**Lighting Control Adjustments**

Lighting controls turn lights on and off automatically, which are activated by time, light, motion, or sound. The measurement of energy savings is based on algorithms with key variables (e.g. coincidence factor, hours of use) provided through existing end-use metering of a sample of facilities or from other utility programs with experience with these measures (i.e., % of annual lighting energy saved by lighting control). These key variables are listed in [Table 3-8](#)~~Table 3-68~~.

If a lighting improvement consists of solely lighting controls, the lighting fixture baseline is the existing fixtures with the existing lamps and ballasts or, if retrofitted, new fixtures with new lamps and ballasts as defined in Lighting Audit and Design Tool shown in Appendix C. In either case, the  $kW_{inst}$  ~~$kW_{EE}$~~  for the purpose of the algorithm is set to  $kW_{base}$ .

For new construction scenarios, baseline for lighting controls is defined by either IECC or ASHRAE 90.1, based on the EDC program design. See Section 3.1 for more detail.

Table 3-~~868~~: Lighting Controls Assumptions

Component	Type	Value	Source
<del><math>kW_{controlled}</math></del> <del><math>kW_{base}</math></del>	Variable	Lighting Audit and Design Tool in Appendix C	<del>EDC Data</del> Gathering
$kW_{inst}$	Variable	Lighting Audit and Design Tool in Appendix C Default: Wall mounted occupancy sensor: 0.350 Remote mounted occupancy sensor: 0.587 Fixture mounted occupancy sensor: 0.073	42_3
SVG	FixedVariable	Default: See <a href="#">Table 3-9: Savings Control Factors Assumptions</a>  <del><a href="#">Table 3-7: Savings Control Factors Assumptions</a></del>	21
		Based on metering	EDC Data Gathering
CF	Variable	By building type and size	See <a href="#">Table 3-6</a> <del>Table 3-46</del>
		Based on metering	EDC Data Gathering

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HOU	Variable	By building type and size	See <a href="#">Table 3-6</a> <del>Table-3-46</del>
		<a href="#">See Section 3.2.6</a>	<a href="#">EDC Data Gathering</a>
IF	Variable	By building type and size	See <a href="#">Table 3-7</a> <del>Table-3-57</del>

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Table 3-979: Savings Control Factors Assumptions<sup>265</sup>

Strategy	Definition	Technology	Savings %
Switch	Manual On/Off Switch	Light Switch	0%
Occupancy	Adjusting light levels according to the presence of occupants	Occupancy Sensors	24%
		Time Clocks	24%
		Energy Management System	24%
Daylighting	Adjusting light levels automatically in response to the presence of natural light	Photosensors	28%
		Time Clocks	28%
Personal Tuning	Adjusting individual light levels by occupants according to their personal preferences; applies, for example, to private offices, workstation-specific lighting in open-plan offices, and classrooms	Dimmers	31%
		Wireless on-off switches	31%
		Bi-level switches	31%
		Computer based controls	31%
		Pre-set scene selection	31%
Institutional Tuning	Adjustment of light levels through commissioning and technology to meet location specific needs or building policies; or provision of switches or controls for areas or groups of occupants; examples of the former include high-end trim dimming (also known as ballast tuning or reduction of ballast factor), task tuning and lumen maintenance	Dimmable ballasts	36%
		On-off or dimmer switches for non-personal tuning	36%
Multiple Types	Includes combination of any of the types described above. Occupancy and personal tuning, daylighting and occupancy are most common.	Occupancy and personal tuning/ daylighting and occupancy	38%

**Sources:**

<sup>265</sup> Subject to verification by EDC Evaluation or SWE

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1. [NYSERDA Table of Standard Wattages](#)

1. [Williams, A., Atkinson, B., Garbesi, K., Rubinstein, F., "A Meta-Analysis of Energy Savings from Lighting Controls in Commercial Buildings", Lawrence Berkeley National Laboratory, September 2011.](#)

2. [Goldberg et al, State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs, Incremental Cost Study, KEMA, October 28, 2009](#)

2-3. [2011 Efficiency Vermont TRM](#)

**LED Traffic Signals**

Traffic signal lighting improvements use the lighting algorithms with the assumptions set forth below. Projects implementing LED traffic signs and no other lighting measures are not required to fill out Appendix C because the assumptions effectively deem savings.

Table 3-~~10810~~: Assumptions for LED Traffic Signals

Component	Type	Value	Source
ΔkW	Variable	See <del>Table 3-11</del> <u><a href="#">Table 3-911</a></u>	PECO
CF	Red Round	55%	PECO
	Yellow Round	2%	
	Round Green	43%	
	Turn Yellow	8%	
	Turn Green	8%	
	Pedestrian	100%	
HOU	Variable	See <del>Table 3-11</del> <u><a href="#">Table 3-911</a></u>	PECO
IF	Fixed	0	

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Table 3-11911: LED Traffic Signals<sup>266</sup>

Type	Wattage	% Burn	HOU	kWh	$\Delta$ kW using LED	$\Delta$ kWh using LED
Round Traffic Signals						
Red 8"	69	55%	4,818	332	-	-
Red 8" LED	7	55%	4,818	34	0.062	299
Yellow 8"	69	2%	175	12	-	-
Yellow 8" LED	10	2%	175	2	0.059	10
Green 8"	69	43%	3,767	260	-	-
Green 8" LED	9	43%	3,767	34	0.060	226
Red 12"	150	55%	4,818	723	-	-
Red 12" LED	6	55%	4,818	29	0.144	694
Yellow 12"	150	2%	175	26	-	-
Yellow 12" LED	13	2%	175	2	0.137	24
Green 12"	150	43%	3,767	565	-	-
Green 12" LED	12	43%	3,767	45	0.138	520
Turn Arrows						
Yellow 8"	116	8%	701	81	-	-
Yellow 8" LED	7	8%	701	5	0.109	76
Yellow 12"	116	8%	701	81	-	-
Yellow 12" LED	9	8%	701	6	0.107	75
Green 8"	116	8%	701	81	-	-
Green 8" LED	7	8%	701	5	0.109	76
Green 12"	116	8%	701	81	-	-
Green 12" LED	7	8%	701	5	0.109	76
Pedestrian Signs						
Hand/Man 12"	116	100%	8,760	1,016	-	-
Hand/Man 12" LED	8	100%	8,760	70	0.108	946
Note: Energy Savings (kWh) are Annual & Demand Savings (kW) listed are per lamp.						

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<sup>266</sup> Source: PECO Comments on the PA TRM, received March 30, 2009.

### SECTION 3: Commercial and Industrial Measures

#### Lighting Equipment Improvements

Page 246

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Table 3-124012: Reference Specifications for Above Traffic Signal Wattages

Type	Manufacturer & Model
8" Incandescent traffic signal bulb	General Electric Traffic Signal Model 17325-69A21/TS
12" Incandescent traffic signal bulb	General Electric Traffic Signal Model 35327-150PAR46/TS
Incandescent Arrows & Hand/Man Pedestrian Signs	General Electric Traffic Signal Model 19010-116A21/TS
8" and 12" LED traffic signals	Leotek Models TSL-ES08 and TSL-ES12
8" LED Yellow Arrow	General Electric Model DR4-YTA2-01A
8" LED Green Arrow	General Electric Model DR4-GCA2-01A
12" LED Yellow Arrow	Dialight Model 431-3334-001X
12" LED Green Arrow	Dialight Model 432-2324-001X
LED Hand/Man Pedestrian Sign	Dialight Model 430-6450-001X

#### LED Exit Signs

This measure includes the early replacement of existing incandescent or fluorescent exit signs with a new LED exit sign. If the exit signs match those listed in [Table 3-13Table 3-1113](#), the deemed savings value for LED exit signs can be used without completing Appendix C. The deemed savings for this measure are:

##### Single-Sided LED Exit Signs replacing Incandescent Exit Signs

$$\Delta kWh = 176 kWh$$

$$\Delta kW_{peak} = 0.024 kW$$

##### Dual-Sided LED Exit Signs replacing Incandescent Exit Signs

$$\Delta kWh = 353 kWh$$

$$\Delta kW_{peak} = 0.048 kW$$

##### Single-Sided LED Exit Signs replacing Fluorescent Exit Signs

$$\Delta kWh = 69 kWh$$

$$\Delta kW_{peak} = 0.009 kW$$

##### Dual-Sided LED Exit Signs replacing Fluorescent Exit Signs

$$\Delta kWh = 157 kWh$$

$$\Delta kW_{peak} = 0.021 kW$$

The savings are calculated using the algorithms in Section 3.2.2 with assumptions in [Table 3-13Table 3-1113](#).

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Table 3-~~131113~~: LED Exit Signs

Component	Type	Value	Source
kW <sub>base</sub>	Fixed/Variable	Single-Sided Incandescent: 20W Dual-Sided Incandescent: 40W Single-Sided Fluorescent: 9W Dual-Sided Fluorescent: 20W	Appendix C: Standard Wattage Table
		Actual Wattage	EDC Data Gathering
kW <sub>inst</sub>	Fixed/Variable	Single-Sided: 2W Dual-Sided: 4W	Appendix C: Standard Wattage Table
		Actual Wattage	EDC Data Gathering
CF	Fixed	1.0	1
HOU	Fixed	8760	1
IF <sub>energy</sub>	Fixed	Cooled Space: 0.12	<a href="#">Table 3-8: Lighting Controls Assumptions</a> <del>Table 3-6: Lighting Controls Assumptions</del>
IF <sub>demand</sub>	Fixed	Cooled Space: 0.34	<a href="#">Table 3-8: Lighting Controls Assumptions</a> <del>Table 3-6: Lighting Controls Assumptions</del>

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**Sources:**

1. WI Focus on Energy, "Business Programs: Deemed Savings Manual V1.0." Update Date: March 22, 2010. LED Exit Sign.

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### 3.3 Premium Efficiency Motors

For constant speed and uniformly loaded motors, the prescriptive measurement and verification protocols described below apply for replacement of old motors with new energy efficient motors of the same rated horsepower and for New Construction. Replacements where the old motor and new motor have different horsepower ratings are considered custom measures. Motors with variable speeds, variable loading, or industrial-specific applications are also considered custom measures.

Note that the Coincidence Factor and Run Hours of Use for motors specified below do not take into account systems with multiple motors serving the same load, such as duplex motor sets with a lead-lag setup. Under these circumstances, a custom measure protocol is required. Duplex motor sets in which the second motor serves as a standby motor can utilize this protocol with an adjustment made such that savings are correctly attributed to a single motor.

#### 3.3.1 Algorithms

From AEPS application form or EDC data gathering calculate  $\Delta kW$  where:

$$\begin{aligned}\Delta kWh &= kWh_{base} - kWh_{ee} \\ kWh_{base} &= 0.746 \times HP \times LF / \eta_{base} \times RHRS \\ kWh_{ee} &= 0.746 \times HP \times LF / \eta_{ee} \times RHRS \\ \Delta kW_{peak} &= kW_{base} - kW_{ee} \\ kW_{base} &= 0.746 \times HP \times LF / \eta_{base} \times CF \\ kW_{ee} &= 0.746 \times HP \times LF / \eta_{ee} \times CF\end{aligned}$$

#### 3.3.2 Definition of Terms

<i>HP</i>	= Rated horsepower of the baseline and energy efficient motor
<i>LF</i>	= Load Factor. Ratio between the actual load and the rated load. Motor efficiency curves typically result in motors being most efficient at approximately 75% of the rated load. The default value is 0.75. Variable loaded motors should use custom measure protocols.; $LF = \text{Measured motor kW} / (\text{Rated motor HP} \times 0.746 / \text{nameplate efficiency})$ <sup>267</sup>
$\eta_{base}$	= Efficiency of the baseline motor
$\eta_{ee}$	= Efficiency of the energy-efficient motor
<i>RHRS</i>	= Annual run hours of the motor
<i>CF</i>	= Demand Coincidence Factor (See Section <del>1.4</del> <u>01-4</u> )

<sup>267</sup> In order to use Motor Master you would need to log. This can be done for custom measure but is not allowed for stipulated measures.

### 3.3.3 Description of Calculation Method

Relative to the algorithms in section ~~(3.3.4)~~(3.3.1),  $\Delta kW$  values will be calculated for each motor improvement in any project (account number). For the efficiency of the baseline motor, if a new motor was purchased as an alternative to rewinding an old motor, the nameplate efficiency of the old motor may be used as the baseline.

Table 3-~~141214~~: Building Mechanical System Variables for Premium Efficiency Motor Calculations

Component	Type	Value	Source
HP	Variable	Nameplate	EDC Data Gathering
RHRS268	Variable	Based on logging <del>and panel data or</del> modeling <del>269</del>	EDC Data Gathering
		Default <del>Table 3-17</del> Table 3-1517	From <del>Table 3-17</del> Table 3-1517
LF270	Variable	Based on spot metering <del>274 272 and</del> nameplate	EDC Data Gathering
		Default 75%	1
$\eta_{base}$	Variable	Early Replacement: Nameplate	EDC Data Gathering
		New Construction or Replace on Burnout: Default comparable standard motor. For PY1 and PY2, EPACK Standard (See Table 3-13). For PY3 and PY3, NEMA Premium (See Table 3-14)	From <del>Table 3-15</del> Table 3-1315 for PY1 and PY2. From <del>Table 3-16</del> Table 3-1416 for PY3 and PY4.
$\eta_{ee}$	Variable	Nameplate	EDC Data Gathering
CF273	Variable	Single Motor Configuration: 74%	1
		Duplex Motor Configuration: 37%	

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#### Sources:

- California Public Utility Commission. *Database for Energy Efficiency Resources 2005*

268 Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE

~~269 Modeling is an acceptable substitute to metering and panel data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).~~

270 Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE

~~271 See definition in section 3.3.2 for specific algorithm to be used when performing spot metering analysis to determine alternate load factor.~~

~~272 See definition in section 3.3.2 for specific algorithm to be used when performing spot metering analysis to determine alternate load factor.~~

273 Need to confirm source through TWG

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Table 3-154315: Baseline Motor Nominal Efficiencies for PY1 and PY2274

Size HP	Open Drip Proof (ODP) # of Poles			Totally Enclosed Fan-Cooled (TEFC) # of Poles		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
	1200	1800	3600	1200	1800	3600
1	80.0%	82.5%	75.5%	80.0%	82.5%	75.5%
1.5	84.0%	84.0%	82.5%	85.5%	84.0%	82.5%
2	85.5%	84.0%	84.0%	86.5%	84.0%	84.0%
3	86.5%	86.5%	84.0%	87.5%	87.5%	85.5%
5	87.5%	87.5%	85.5%	87.5%	87.5%	87.5%
7.5	88.5%	88.5%	87.5%	89.5%	89.5%	88.5%
10	90.2%	89.5%	88.5%	89.5%	89.5%	89.5%
15	90.2%	91.0%	89.5%	90.2%	91.0%	90.2%
20	91.0%	91.0%	90.2%	90.2%	91.0%	90.2%
25	91.7%	91.7%	91.0%	91.7%	92.4%	91.0%
30	92.4%	92.4%	91.0%	91.7%	92.4%	91.0%
40	93.0%	93.0%	91.7%	93.0%	93.0%	91.7%
50	93.0%	93.0%	92.4%	93.0%	93.0%	92.4%
60	93.6%	93.6%	93.0%	93.6%	93.6%	93.0%
75	93.6%	94.1%	93.0%	93.6%	94.1%	93.0%
100	94.1%	94.1%	93.0%	94.1%	94.5%	93.6%
125	94.1%	94.5%	93.6%	94.1%	94.5%	94.5%
150	94.5%	95.0%	93.6%	95.0%	95.0%	94.5%
200	94.5%	95.0%	94.5%	95.0%	95.0%	95.0%

274 Table is based on NEMA EPACT efficiency motor standards. Source to the table can be found at:  
[http://www.cee1.org/ind/motrs/CEE\\_NEMA.pdf](http://www.cee1.org/ind/motrs/CEE_NEMA.pdf)

### SECTION 3: Commercial and Industrial Measures

#### Premium Efficiency Motors

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Table 3-16416: Baseline Motor Nominal Efficiencies for PY3 and PY4275

Size HP	Open Drip Proof (ODP)			Totally Enclosed Fan-Cooled (TEFC)		
	# of Poles			# of Poles		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
	1200	1800	3600	1200	1800	3600
1	82.50%	85.50%	77.00%	82.50%	85.50%	77.00%
1.5	86.50%	86.50%	84.00%	87.50%	86.50%	84.00%
2	87.50%	86.50%	85.50%	88.50%	86.50%	85.50%
3	88.50%	89.50%	85.50%	89.50%	89.50%	86.50%
5	89.50%	89.50%	86.50%	89.50%	89.50%	88.50%
7.5	90.20%	91.00%	88.50%	91.00%	91.70%	89.50%
10	91.70%	91.70%	89.50%	91.00%	91.70%	90.20%
15	91.70%	93.00%	90.20%	91.70%	92.40%	91.00%
20	92.40%	93.00%	91.00%	91.70%	93.00%	91.00%
25	93.00%	93.60%	91.70%	93.00%	93.60%	91.70%
30	93.60%	94.10%	91.70%	93.00%	93.60%	91.70%
40	94.10%	94.10%	92.40%	94.10%	94.10%	92.40%
50	94.10%	94.50%	93.00%	94.10%	94.50%	93.00%
60	94.50%	95.00%	93.60%	94.50%	95.00%	93.60%
75	94.50%	95.00%	93.60%	94.50%	95.40%	93.60%
100	95.00%	95.40%	93.60%	95.00%	95.40%	94.10%
125	95.00%	95.40%	94.10%	95.00%	95.40%	95.00%
150	95.40%	95.80%	94.10%	95.80%	95.80%	95.00%
200	95.40%	95.80%	95.00%	95.80%	96.20%	95.40%
250	95.40%	95.80%	95.00%	95.80%	96.20%	95.80%
300	95.40%	95.80%	95.40%	95.80%	96.20%	95.80%
350	95.40%	95.80%	95.40%	95.80%	96.20%	95.80%
400	95.80%	95.80%	95.80%	95.80%	96.20%	95.80%
450	96.20%	96.20%	95.80%	95.80%	96.20%	95.80%
500	96.20%	96.20%	95.80%	95.80%	96.20%	95.80%

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275 Table is based on NEMA premium efficiency motor standards. Source to the table can be found at: <http://www.nema.org/stds/complimentary-docs/upload/MG1premium.pdf>

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Table 3-174517: Stipulated Hours of Use for Motors in Commercial Buildings<sup>276</sup>

Facility Type	Fan Motor	Chilled Water Pumps/Cooling Tower Fan	Heating Pumps
Auto Related	4,056	1,878	6,000
Bakery	2,854	1,445	6,000
Banks, Financial Centers	3,748	1,767	6,000
Church	1,955	1,121	6,000
College – Cafeteria	6,376	2,713	6,000
College - Classes/Administrative	2,586	1,348	6,000
College - Dormitory	3,066	1,521	6,000
Commercial Condos	4,055	1,877	6,000
Convenience Stores	6,376	2,713	6,000
Convention Center	1,954	1,121	6,000
Court House	3,748	1,767	6,000
Dining: Bar Lounge/Leisure	4,182	1,923	6,000
Dining: Cafeteria / Fast Food	6,456	2,742	6,000
Dining: Family	4,182	1,923	6,000
Entertainment	1,952	1,120	6,000
Exercise Center	5,836	2,518	6,000
Fast Food Restaurants	6,376	2,713	6,000
Fire Station (Unmanned)	1,953	1,121	6,000
Food Stores	4,055	1,877	6,000
Gymnasium	2,586	1,348	6,000
Hospitals	7,674	3,180	6,000
Hospitals / Health Care	7,666	3,177	6,000
Industrial - 1 Shift	2,857	1,446	6,000
Industrial - 2 Shift	4,730	2,120	6,000
Industrial - 3 Shift	6,631	2,805	6,000
Laundromats	4,056	1,878	6,000
Library	3,748	1,767	6,000
Light Manufacturers	2,857	1,446	6,000
Lodging (Hotels/Motels)	3,064	1,521	6,000
Mall Concourse	4,833	2,157	6,000
Manufacturing Facility	2,857	1,446	6,000
Medical Offices	3,748	1,767	6,000
Motion Picture Theatre	1,954	1,121	6,000
Multi-Family (Common Areas)	7,665	3,177	6,000

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<sup>276</sup> Operating hours subject to adjustment with data provided by EDCs and accepted by SWE

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### SECTION 3: Commercial and Industrial Measures

#### Premium Efficiency Motors

Museum	3,748	1,767	6,000
Nursing Homes	5,840	2,520	6,000
Office (General Office Types)	3,748	1,767	6,000
Office/Retail	3,748	1,767	6,000
Parking Garages & Lots	4,368	1,990	6,000
Penitentiary	5,477	2,389	6,000
Performing Arts Theatre	2,586	1,348	6,000
Police / Fire Stations (24 Hr)	7,665	3,177	6,000
Post Office	3,748	1,767	6,000
Pump Stations	1,949	1,119	6,000
Refrigerated Warehouse	2,602	1,354	6,000
Religious Building	1,955	1,121	6,000
Residential (Except Nursing Homes)	3,066	1,521	6,000
Restaurants	4,182	1,923	6,000
Retail	4,057	1,878	6,000
School / University	2,187	1,205	6,000
Schools (Jr./Sr. High)	2,187	1,205	6,000
Schools (Preschool/Elementary)	2,187	1,205	6,000
Schools (Technical/Vocational)	2,187	1,205	6,000
Small Services	3,750	1,768	6,000
Sports Arena	1,954	1,121	6,000
Town Hall	3,748	1,767	6,000
Transportation	6,456	2,742	6,000
Warehouse (Not Refrigerated)	2,602	1,354	6,000
Waste Water Treatment Plant	6,631	2,805	6,000
Workshop	3,750	1,768	6,000
Other277	3,985	1,852	6,000

#### Sources:

1. UI and CL&P Program Savings Documentation for 2012 Program Year, United Illuminating Company, September 2011
2. Other category calculated based on simple averages.

#### 3.3.4 Evaluation Protocol

Motor projects achieving ~~reported~~expected kWh savings ~~greater than 50 of 250,000 kWh and~~ ~~selected in the evaluator sample or higher~~ must be metered to ~~verify reported~~ calculate ex ante and/or ex post savings. In addition, if any motor within a sampled project uses the ~~other~~ “Other” category to stipulate hours, the threshold is decreased to 25,000 kWh. Metering is not mandatory

277 To be used only when no other category is applicable.

### SECTION 3: Commercial and Industrial Measures

#### Premium Efficiency Motors

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where the motors in question are constant speed and hours can be easily verified through a building automation system schedule that clearly shows motor run time.

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### 3.4 Variable Frequency Drive (VFD) Improvements

The following protocol for the measurement of energy and demand savings applies to the installation of Variable Frequency Drives (VFDs) in standard commercial building applications shown in

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Table 3-17. The baseline condition is a motor without a VFD control. The efficient condition is a motor with a VFD control.

Table 3-19. The baseline condition is a motor without a VFD control. The efficient condition is a motor with a VFD control.

#### 3.4.1 Algorithms

$$\Delta kWh = 0.746 \times HP \times LF / \eta_{motor} \times RHRS_{base} \times ESF$$

$$\Delta kW_{peak} = 0.746 \times HP \times LF / \eta_{motor} \times CF \times DSF$$

#### 3.4.2 Definitions of Terms

*HP* = Rated horsepower of the motor

*LF* = Load Factor. Ratio between the actual load and the rated load. Motor efficiency curves typically result in motors being most efficient at approximately 75% of the rated load. The default value is 0.75. 278

*$\eta_{motor}$*  = Motor efficiency at the full-rated load. For VFD installations, this can be either an energy efficient motor or standard efficiency motor. Motor efficiency varies with load and decreases dramatically below 50% load; this is reflected in the ESF term of the algorithm.

278 In order to use Motor Master you would need to log. This can be done for custom measure but is not allowed for stipulated measures. A standard practice and/or load shape study would be required.

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$RHRS_{base}$	= Annual run hours of the baseline motor
$CF$	= Demand Coincidence Factor (See Section <a href="#">1.4</a> <del>01.4</del> )
$ESF$	= Energy Savings Factor. Percent of baseline energy consumption saved by installing VFD.
$DSF$	= Demand Savings Factor. Percent of baseline demand saved by installing VFD

### 3.4.3 Description of Calculation Method

Relative to the algorithms in section ~~(3.4.1)~~, [\(3.4.1\)](#),  $\Delta kW$  values will be calculated for each VFD improvement in any project (account number).

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Table 3-181618: Variables for VFD Calculations

Component	Type	Value	Source
Motor HP	Variable	Nameplate	EDC Data Gathering
RHRS279	Variable	Based on logging <del>and panel data or</del> modeling	EDC Data Gathering
		Default <del>Table 3-17Table 3-1517</del>	See <del>Table 3-17Table 3-1517</del>
LF280	Variable	Based on spot metering and nameplate	EDC Data Gathering
		Default 75%	1
ESF	Variable	Default See <del>Table 3-19</del>	See
		<del>Table 3-1719</del>	<del>Table 3-17See Table 3-19Table 3-19</del>
		Based on logging and panel data	EDC Data Gathering
DSF	Variable	See	See

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279 Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE  
 280 Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE

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		<a href="#">Table 3-17Default See Table 3-19Table 3-19</a>	<a href="#">Table 3-17See Table 3-19Table 3-19</a>
		<a href="#">Based on logging and panel data</a>	<a href="#">EDC Data Gathering</a>
Efficiency - $\eta_{base}$	<a href="#">FixedVariable</a>	Nameplate_	EDC Data Gathering
CF281	Fixed	74%	1

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**Sources:**

1. California Public Utility Commission. *Database for Energy Efficiency Resources 2005*

Table 3-~~19~~<sup>17</sup>~~19~~: ESF and DSF for Typical Commercial VFD Installations<sup>282</sup> 283

HVAC Fan VFD Savings Factors		
Baseline	ESF	DSF

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281 Need to confirm source through TWG

282 UI and CL&P Program Savings Documentation for 2012 Program Year, United Illuminating Company, September 2011, Page 45.

283 UI and CL&P Program Savings Documentation for 2011 Program Year, United Illuminating Company, September 2010, Page 44.

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Constant Volume <sup>284</sup>	0.534	0.347
Air Foil/Backward Incline	0.354	0.26
Air Foil/Backward Incline with Inlet Guide Vanes	0.227	0.13
Forward Curved	0.179	0.136
Forward Curved with Inlet Guide Vanes	0.092	0.029
<b>HVAC Pump VFD Savings Factors</b>		
<b>System</b>	<b>ESF</b>	<b>DSF</b>
Chilled Water Pump	0.411	0.299
Hot Water Pump	0.424	0

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#### 3.4.4 Evaluation Protocol

VFD projects achieving ~~reported~~expected kWh savings ~~greater than 50 of 250,000 kWh and selected in the evaluator sample or higher~~ must be metered to ~~verify reported~~calculate ex ante and/or ex post savings. In addition, if any VFD within a sampled project uses the ~~other~~“Other” category to stipulate hours, the threshold is decreased to 25,000 kWh. Metering is not mandatory where hours can be easily verified through a building automation system schedule that clearly shows motor run time.

<sup>284</sup> The ESF and DSF values for the constant volume baseline condition are taken from the 2011 Connecticut TRM whereas 2012 Connecticut TRM was used to report values for all other baseline conditions. This is because the 2012 Connecticut TRM does not report values for constant volume condition. Note that the values for all baseline conditions for HVAC fans are same in both versions of the Connecticut TRM. The values were only updated for the HVAC pump baseline conditions.

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### 3.5 Variable Frequency Drive (VFD) Improvement for Industrial Air Compressors

The energy and demand savings for variable frequency drives (VFDs) installed on industrial air compressors is based on the loading and hours of use of the compressor. In industrial settings, these factors can be highly variable and may be best evaluated using a custom path. The method for measurement set forth below may be appropriate for systems that have a single compressor servicing a single load and that have some of the elements of both a deemed and custom approach.

Systems with multiple compressors are defined as non-standard applications and must follow a custom measure protocol.

#### 3.5.1 Algorithms

$$\Delta kWh = 0.129 \times HP \times LF / \eta_{motor} \times RHRS_{base}$$

$$\Delta kW = 0.129 \times HP$$

$$\Delta kW_{peak} = 0.106 \times HP$$

#### 3.5.2 Definition of Terms

*HP* = Rated horsepower of the motor

*LF* = Load Factor. Ratio between the actual load and the rated load. Motor efficiency curves typically result in motors being most efficient at approximately 75% of the rated load. The default value is 0.75.285

*$\eta_{base}$*  = Efficiency of the baseline motor

*RHRS* = Annual run hours of the motor

*CF* = Demand Coincidence Factor (See Section [1.4\)01.4](#))

285 In order to use Motor Master you would need to log. This can be done for custom measures but is not allowed for stipulated measures. A standard practice and/or load shape study would be required.

Table 3-~~201820~~: Variables for Industrial Air Compressor Calculation

Component	Type	Value	Source
Motor HP	Variable	Nameplate	EDC Data Gathering
RHRS	Variable	Based on logging <del>and</del> <u>panel data or</u> modeling	EDC Data Gathering
kW/motor HP, Saved	Fixed	0.129	1
Coincident Peak kW/motor HP	Fixed	0.106	1
LF	Variable	Based on spot metering <del>and</del> <u>and</u> nameplate	EDC Data Gathering

**Sources:**

1. Aspen Systems Corporation, Prescriptive Variable Speed Drive Incentive Development Support for Industrial Air Compressors, Executive Summary, June 20, 2005.286

286 The basis for these factors has not been determined or independently verified.

**SECTION 3: Commercial and Industrial Measures****Variable Frequency Drive (VFD) Improvement for Industrial Air Compressors**

Page 262

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### 3.6 HVAC Systems

The energy and demand savings for Commercial and Industrial HVAC is determined from the algorithms listed in below. This protocol excludes water source, ground source, and groundwater source heat pumps.

#### 3.6.1 Algorithms

**Air Conditioning (includes central AC, air-cooled DX, split systems, and packaged terminal AC)**

For A/C units < 65,000 BtuH, use SEER instead of EER to calculate  $\Delta kWh$  and convert SEER to EER to calculate  $\Delta kW_{peak}$  using 11.3/13 as the conversion factor.

$$\begin{aligned}\Delta kWh &= (BtuH_{cool} / 1000) \times (1/EER_{base} - 1/EER_{ee}) \times EFLH_{cool} \\ &= (BtuH_{cool} / 1000) \times (1/SEER_{base} - 1/SEER_{ee}) \times EFLH_{cool}\end{aligned}$$

$$\Delta kW_{peak} = (BtuH_{cool} / 1000) \times (1/EER_{base} - 1/EER_{ee}) \times CF$$

**Air Source and Packaged Terminal Heat Pump**

For ASHP units < 65,000 BtuH, use SEER instead of EER to calculate  $\Delta kWh_{cool}$  and HSPF instead of COP to calculate  $\Delta kWh_{heat}$ . Convert SEER to EER to calculate  $\Delta kW_{peak}$  using 11.3/13 as the conversion factor.

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\begin{aligned}\Delta kWh_{cool} &= (BtuH_{cool} / 1000) \times (1/EER_{base} - 1/EER_{ee}) \times EFLH_{cool} \\ &= (BtuH_{cool} / 1000) \times (1/SEER_{base} - 1/SEER_{ee}) \times EFLH_{cool}\end{aligned}$$

$$\begin{aligned}\Delta kWh_{heat} &= (BtuH_{heat} / 1000) / 3.412 \times (1/COP_{base} - 1/COP_{ee}) \times EFLH_{heat} \\ &= (BtuH_{heat} / 1000) \times (1/HSPF_{base} - 1/HSPF_{ee}) \times EFLH_{heat}\end{aligned}$$

$$\Delta kW_{peak} = (BtuH_{cool} / 1000) \times (1/EER_{base} - 1/EER_{ee}) \times CF$$

#### 3.6.2 Definition of Terms

$BtuH_{cool}$  = Rated cooling capacity of the energy efficient unit in  $BtuH_{cool}$

$BtuH_{heat}$  = Rated heating capacity of the energy efficient unit in  $BtuH_{heat}$

$EER_{base}$  = Efficiency rating of the baseline unit. For air-source AC and ASHP units < 65,000 BtuH, SEER should be used for cooling savings.

$EER_{ee}$  = Efficiency rating of the energy efficiency unit. For air-source AC and ASHP units < 65,000 BtuH, SEER should be used for cooling savings.

$SEER_{base}$  = Seasonal efficiency rating of the baseline unit. For units > 65,000 BtuH, EER should be used for cooling savings.

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$SEER_{ee}$	= Seasonal efficiency rating of the energy efficiency unit. For units > 65,000 BtuH, EER should be used for cooling savings.
$COP_{base}$	= Efficiency rating of the baseline unit. For ASHP units < 65,000 BtuH, HSPF should be used for heating savings.
$COP_{ee}$	= Efficiency rating of the energy efficiency unit. For ASHP units < 65,000 BtuH, HSPF should be used for heating savings.
$HSPF_{base}$	= Heating seasonal performance factor of the baseline unit. For units > 65,000 BtuH, COP should be used for heating savings.
$HSPF_{ee}$	= Heating seasonal performance factor of the energy efficiency unit. For units > 65,000 BtuH, COP should be used for heating savings.
CF	= Demand Coincidence Factor (See Section <a href="#">1.4</a> ) <u>01.4</u> )
$EFLH_{cool}$	= Equivalent Full Load Hours for the cooling season – The kWh during the entire operating season divided by the kW at design conditions.
$EFLH_{heat}$	= Equivalent Full Load Hours for the heating season – The kWh during the entire operating season divided by the kW at design conditions.
11.3/13	= Conversion factor from SEER to EER, based on average EER of a SEER 13 unit. See Section 2.1.

Table 3-~~21~~~~19~~~~21~~: Variables for HVAC Systems

Component	Type	Value	Source
BtuH	Variable	Nameplate data (AHRI or AHAM)	EDC's Data Gathering
EER <sub>base</sub>	Variable	Early Replacement: Nameplate data	EDC's Data Gathering
		New Construction or Replace on Burnout: Default values from <a href="#">Table 3-22</a> <a href="#">Table 3-2022</a>	See <a href="#">Table 3-22</a> <a href="#">Table 3-2022</a>
EER <sub>ee</sub>	Variable	Nameplate data (AHRI or AHAM)	EDC's Data Gathering
SEER <sub>base</sub>	Variable	Early Replacement: Nameplate data	EDC's Data Gathering
		New Construction or Replace on Burnout: Default values from <a href="#">Table 3-22</a> <a href="#">Table 3-2022</a>	See <a href="#">Table 3-22</a> <a href="#">Table 3-2022</a>
SEER <sub>ee</sub>	Variable	Nameplate data (AHRI or AHAM)	EDC's Data Gathering
COP <sub>base</sub>	Variable	Early Replacement: Nameplate data	EDC's Data Gathering
		New Construction or Replace on Burnout: Default values from <a href="#">Table 3-22</a> <a href="#">Table 3-2022</a>	See <a href="#">Table 3-22</a> <a href="#">Table 3-2022</a>
COP <sub>ee</sub>	Variable	Nameplate data (AHRI or AHAM)	EDC's Data Gathering
HSPF <sub>base</sub>	Variable	Early Replacement: Nameplate data	EDC's Data Gathering
		New Construction or Replace on Burnout: Default values from <a href="#">Table 3-22</a> <a href="#">Table 3-2022</a>	See <a href="#">Table 3-22</a> <a href="#">Table 3-2022</a>
HSPF <sub>ee</sub>	Variable	Nameplate data (AHRI or AHAM)	EDC's Data Gathering
CF	Fixed	80%	2
EFLH <sub>cool</sub>	Variable	Based on Logging, <a href="#">BMS data</a> or Modeling <sup>287</sup>	EDC's Data Gathering
		Default values from <a href="#">Table 3-23</a> <a href="#">Table 3-2423</a>	See <a href="#">Table 3-23</a> <a href="#">Table 3-2423</a>
EFLH <sub>heat</sub>	Variable	Based on Logging, <a href="#">BMS data</a> or Modeling <sup>288</sup>	EDC's Data Gathering
		Default values from <a href="#">Table 3-24</a> <a href="#">Table 3-2224</a>	See <a href="#">Table 3-24</a> <a href="#">Table 3-2224</a>

**Sources:**

<sup>287</sup> Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

<sup>288</sup> Ibid

**SECTION 3: Commercial and Industrial Measures****HVAC Systems**

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1. The Equivalent Full Load Hours (ELFH) for Pennsylvania are calculated based on the degree day scaling methodology. The EFLH values reported in the Connecticut Program Savings Documentation were adjusted using full load hours (FLH) from the US DOE ENERGY STAR Calculator to account for differences in weather conditions. Degree day scaling ratios were calculated using heating degree day and cooling degree day values for seven Pennsylvania cities: Allentown, Erie, Harrisburg, Philadelphia, Pittsburgh, Scranton, and Williamsport.
  - a. US Department of Energy. ENERGY STAR Calculator and Bin Analysis Models
  - b. UI and CL&P Program Savings Documentation for 2012 Program Year, United Illuminating Company, September 2011, Pages 219-220.
2. Average based on coincidence factors from Ohio, New Jersey, Mid-Atlantic, Massachusetts, Connecticut, Illinois, New York, CEE and Minnesota. (74%, 67%, 81%, 94%, 82%, 72%, 100%, 70% and 76% respectively)

Table 3-~~222022~~: HVAC Baseline Efficiencies<sup>289</sup>

Equipment Type and Capacity	Cooling Baseline	Heating Baseline
<b>Air-Source Air Conditioners</b>		
< 65,000 BtuH	13.0 SEER	N/A
≥ 65,000 BtuH and <135,000 BtuH	11.2 EER	N/A
≥ 135,000 BtuH and < 240,000 BtuH	11.0 EER	N/A
≥ 240,000 BtuH and < 760,000 BtuH (IPLV for units with capacity-modulation only)	10.0 EER / 9.7 IPLV	N/A
≥ 760,000 BtuH (IPLV for units with capacity-modulation only)	9.7 EER / 9.4 IPLV	N/A
<b>Water-Source and Evaporatively-Cooled Air Conditioners</b>		
< 65,000 BtuH	12.1 EER	N/A
≥ 65,000 BtuH and <135,000 BtuH	11.5 EER	N/A
≥ 135,000 BtuH and < 240,000 BtuH	11.0 EER	N/A
≥ 240,000 BtuH	11.5 EER	N/A
<b>Air-Source Heat Pumps</b>		
< 65,000 BtuH	13 SEER	7.7 HSPF
≥ 65,000 BtuH and <135,000 BtuH	11.0 EER	3.3 COP
≥ 135,000 BtuH and < 240,000 BtuH	10.6 EER	3.2 COP
≥ 240,000 BtuH (IPLV for units with capacity-modulation only)	9.5 EER / 9.2 IPLV	3.2 COP
<b>Water-Source Heat Pumps</b>		
< 17,000 BtuH	11.2 EER	4.2 COP
≥ 17,000 BtuH and ≤ 65,000 BtuH	12.0 EER	4.2 COP
<b>Ground-Water-Source Heat Pumps</b>		

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<sup>289</sup> Baseline values from IECC 2009, after Jan 1, 2010 or Jan 23, 2010 as applicable.

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< 135,000 BtuH		16.2 EER	3.6 COP
Ground Source Heat Pumps-			
< 135,000 BtuH		13.4 EER	3.1 COP
Packaged Terminal Systems (Replacements)290			
PTAC (cooling)	10.9 - (0.213 x Cap / 1000) EER		
PTHP	10.8 - (0.213 x Cap / 1000) EER	2.9 - (0.026 x Cap / 1000) COP	
Packaged Terminal Systems (New Construction)291			
PTAC (cooling)	12.5 - (0.213 x Cap / 1000) EER		
PTHP	12.3 - (0.213 x Cap / 1000) EER	3.2 - (0.026 x Cap / 1000) COP	

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Table 3-232123: Cooling EFLH for Pennsylvania Cities292 293

Space and/or Building Type	Allentown	Erie	Harrisburg	Pittsburgh	Williamsport	Philadelphia	Scranton
Arena/Auditorium/Convention Center	602	332	640	508	454	711	428
College: Classes/Administrative	690	380	733	582	520	815	490
Convenience Stores	1,216	671	1,293	1,026	917	1,436	864
Dining: Bar Lounge/Leisure	912	503	969	769	688	1,077	648
Dining: Cafeteria / Fast Food	1,227	677	1,304	1,035	925	1,449	872
Dining: Restaurants	912	503	969	769	688	1,077	648
Gymnasium/Performing Arts Theatre	690	380	733	582	520	815	490
Hospitals/Health care	1,396	770	1,483	1,177	1,052	1,648	992
Industrial: 1 Shift/Light Manufacturing	727	401	773	613	548	859	517
Industrial: 2 Shift	988	545	1,050	833	745	1,166	702
Industrial: 3 Shift	1,251	690	1,330	1,055	944	1,478	889
Lodging: Hotels/Motels/Dormitories	756	418	805	638	571	894	538
Lodging: Residential	757	418	805	638	571	894	538
Multi-Family (Common Areas)	1,395	769	1,482	1,176	1,052	1,647	991
Museum/Library	851	469	905	718	642	1,005	605

290 Cap represents the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the calculation.

291 Cap represents the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the calculation.

292 US Department of Energy. Energy Star Calculator and Bin Analysis Models

293 The Equivalent Full Load Hours (ELFH) for Pennsylvania are calculated based on the degree day scaling methodology. The EFLH values reported in the Connecticut Program Savings Documentation were adjusted using full load hours (FLH) from the US DOE ENERGY STAR Calculator to account for differences in weather conditions.

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### SECTION 3: Commercial and Industrial Measures

#### HVAC Systems

Space and/or Building Type	Allentown	Erie	Harrisburg	Pittsburgh	Williamsport	Philadelphia	Scranton
Nursing Homes	1,141	630	1,213	963	861	1,348	811
Office: General/Retail	851	469	905	718	642	1,005	605
Office: Medical/Banks	851	469	905	718	642	1,005	605
Parking Garages & Lots	938	517	997	791	707	1,107	666
Penitentiary	1,091	602	1,160	920	823	1,289	775
Police/Fire Stations (24 Hr)	1,395	769	1,482	1,176	1,052	1,647	991
Post Office/Town Hall/Court House	851	469	905	718	642	1,005	605
Religious Buildings/Church	602	332	640	508	454	711	428
Retail	894	493	950	754	674	1,055	635
Schools/University	634	350	674	535	478	749	451
Warehouses (Not Refrigerated)	692	382	735	583	522	817	492
Warehouses (Refrigerated)	692	382	735	583	522	817	492
Waste Water Treatment Plant	1,251	690	1,330	1,055	944	1,478	889

Table 3-242224: Heating EFLH for Pennsylvania Cities 294-295.

Space and/or Building Type	Allentown	Erie	Harrisburg	Pittsburgh	Williamsport	Philadelphia	Scranton
Arena/Auditorium/Convention Center	1,719	2,002	1,636	1,642	1,726	1,606	1,747
College: Classes/Administrative	1,559	1,815	1,484	1,489	1,565	1,457	1,584
Convenience Stores	603	3,1487 01	2,573	2,5825 76	2,7156 05	2,5265 63	2,7476 12
Dining: Bar Lounge/Leisure	1,156	1,346	1,100	1,104	1,161	1,080	1,175
Dining: Cafeteria / Fast Food	582	2,0666 78	1,6895 54	1,6955 56	1,7825 85	1,6685 44	1,8035 92
Dining: Restaurants	1,156	1,346	1,100	1,104	1,161	1,080	1,175
Gymnasium/Performing Arts Theatre	1,559	1,815	1,484	1,489	1,565	1,457	1,584
Hospitals/Health care	276	321	263	264	277	2,5262 58	280
Industrial: 1 Shift/Light Manufacturing	1,491	1,737	1,420	1,425	1,498	1,394	1,516
Industrial: 2 Shift	1,017	1,184	968	972	1,022	951	1,034

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294 US Department of Energy. Energy Star Calculator and Bin Analysis Models

295 The Equivalent Full Load Hours (EFLH) for Pennsylvania are calculated based on the degree day scaling methodology. The EFLH values reported in the Connecticut Program Savings Documentation were adjusted using full load hours (FLH) from the US DOE ENERGY STAR Calculator to account for differences in weather conditions.

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### SECTION 3: Commercial and Industrial Measures

#### HVAC Systems



Industrial: 3 Shift	538	626	512	513	540	502	546
Lodging: Hotels/Motels/Dormitories	1,438	1,675	1,369	1,374	1,444	1,344	1,462
Lodging: Residential	1,438	1,675	1,369	1,374	1,444	1,344	1,462
Multi-Family (Common Areas)	277	<u>3,148</u> <u>22</u>	<u>2,573</u> <u>63</u>	<u>2,582</u> <u>64</u>	<u>2,715</u> <u>78</u>	<u>2,526</u> <u>59</u>	<u>2,747</u> <u>81</u>
Museum/Library	1,266	1,474	1,205	1,209	1,271	1,183	1,286
Nursing Homes	738	<u>3,148</u> <u>59</u>	<u>2,573</u> <u>02</u>	<u>2,582</u> <u>04</u>	<u>2,715</u> <u>40</u>	<u>2,526</u> <u>89</u>	<u>2,747</u> <u>49</u>
Office: General/Retail	1,266	<u>884</u> <u>74</u>	<u>722</u> <u>05</u>	<u>725</u> <u>09</u>	<u>762</u> <u>71</u>	<u>709</u> <u>83</u>	<u>771</u> <u>86</u>
Office: Medical/Banks	1,266	1,474	1,205	1,209	1,271	1,183	1,286
Parking Garages & Lots	1,110	1,292	1,056	1,060	1,114	1,037	1,128
Penitentiary	829	<u>3,148</u> <u>65</u>	<u>2,573</u> <u>89</u>	<u>2,582</u> <u>92</u>	<u>2,715</u> <u>32</u>	<u>2,526</u> <u>74</u>	<u>2,747</u> <u>42</u>
Police/Fire Stations (24 Hr)	277	<u>3,148</u> <u>22</u>	<u>2,573</u> <u>63</u>	<u>2,582</u> <u>64</u>	<u>2,715</u> <u>78</u>	<u>2,526</u> <u>59</u>	<u>2,747</u> <u>81</u>
Post Office/Town Hall/Court House	1,266	1,474	1,205	1,209	1,271	1,183	1,286
Religious Buildings/Church	1,718	2,001	1,635	1,641	1,725	1,605	1,746
Retail	1,188	1,383	1,130	1,135	1,193	1,110	1,207
Schools/University	1,661	<u>984</u> <u>33</u>	<u>805</u> <u>80</u>	<u>808</u> <u>86</u>	<u>849</u> <u>67</u>	<u>790</u> <u>51</u>	<u>859</u> <u>87</u>
Warehouses (Not Refrigerated)	<u>538</u> <u>55</u>	<u>567</u> <u>10</u>	<u>463</u> <u>80</u>	<u>465</u> <u>85</u>	<u>489</u> <u>61</u>	<u>455</u> <u>53</u>	<u>495</u> <u>80</u>
Warehouses (Refrigerated)	1,555	1,810	1,480	1,485	1,561	1,453	1,580
Waste Water Treatment Plant	<u>1,265</u> <u>38</u>	<u>1,473</u> <u>26</u>	<u>1,204</u> <u>12</u>	<u>1,208</u> <u>13</u>	<u>1,270</u> <u>40</u>	<u>1,182</u> <u>02</u>	<u>1,285</u> <u>46</u>

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**SECTION 3: Commercial and Industrial Measures****HVAC Systems**

### 3.7 Electric Chillers

This protocol estimates savings for installing high efficiency electric chillers as compared to chillers that meet the minimum performance allowed by the current PA Energy Code. The measurement of energy and demand savings for chillers is based on algorithms with key variables (i.e., Efficiency, Coincidence Factor, and Equivalent Full Load Hours). These prescriptive algorithms and stipulated values are valid for standard commercial applications, defined as unitary electric chillers serving a single load at the system or sub-system level. The savings calculated using the prescriptive algorithms need to be supported by a certification that the chiller is appropriately sized for site design load condition.

All other chiller applications, including existing multiple chiller configurations, existing chillers serving multiple load groups, and chillers in industrial applications are defined as non-standard applications and must follow a site specific custom protocol. Situations with existing non-VFD chillers upgrading to VFD chillers may use the protocol algorithm. The algorithms, assumptions and default factors in this Section may be applied to New Construction applications.

#### 3.7.1 Algorithms

##### Efficiency ratings in EER

$$\Delta kWh = Tons_{ee} \times 12 \times (1 / EER_{base} - 1 / EER_{ee}) \times EFLH$$

$$\Delta kW_{peak} = Tons_{ee} \times 12 \times (1 / EER_{base} - 1 / EER_{ee}) \times CF$$

##### Efficiency ratings in kW/ton

$$\Delta kWh = Tons_{ee} \times (kW/ton_{base} - kW/ton_{ee}) \times EFLH$$

$$\Delta kW_{peak} = Tons_{ee} \times (kW/ton_{base} - kW/ton_{ee}) \times CF$$

#### 3.7.2 Definition of Terms

$Tons_{ee}$  = The capacity of the chiller (in tons) at site design conditions accepted by the program.

$kW/ton_{base}$  = Design Rated Efficiency of the baseline chiller. See [Table 3-25](#) for values.

$kW/ton_{ee}$  = Design Rated Efficiency of the energy efficient chiller from the manufacturer data and equipment ratings in accordance with ARI Standards.

$EER_{base}$  = Energy Efficiency Ratio of the baseline unit. See [Table 3-24](#) for values.

$EER_{ee}$  = Energy Efficiency Ratio of the efficient unit from the manufacturer data and equipment ratings in accordance with ARI Standards.

$CF$  = Demand Coincidence Factor (See [Section 1.4.01.4](#))

**EFLH** = Equivalent Full Load Hours – The kWh during the entire operating season divided by the kW at design conditions. The most appropriate EFLH from Table 3-26 shall be utilized in the calculation.

Table 3-25: Electric Chiller Variables

Component	Type	Value	Source
Tons <sub>ee</sub>	Variable	Nameplate Data	EDC Data Gathering
kW/ton <sub>base</sub>	Variable	New Construction or Replace on Burnout: Default value from <a href="#">Table 3-26</a>	See <a href="#">Table 3-26</a>
		Early Replacement: Nameplate Data	EDC Data Gathering
kW/ton <sub>ee</sub>	Variable	Nameplate Data (ARI Standards 550/590). At minimum, must satisfy standard listed in <a href="#">Table 3-24</a>	EDC Data Gathering
EER <sub>base</sub>	Variable	New Construction or Replace on Burnout: Default value from <a href="#">Table 3-26</a>	See <a href="#">Table 3-26</a>
		Early Replacement: Nameplate Data	EDC Data Gathering
EER <sub>ee</sub>	Variable	Nameplate Data (ARI Standards 550/590). At minimum, must satisfy standard listed in <a href="#">Table 3-26</a>	EDC Data Gathering
CF	Fixed	80%	1
EFLH	Fixed	Default value from <a href="#">Table 3-27</a>	See <a href="#">Table 3-27</a>
		Based on Logging, BMS data or Modeling	EDC Data Gathering

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**Sources:**

1. Average based on coincidence factors from Ohio, New Jersey, Mid-Atlantic, Massachusetts, Connecticut, Illinois, New York, CEE and Minnesota. (74%, 67%, 81%, 94%, 82%, 72%, 100%, 70% and 76% respectively)

296 Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

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Table 3-262426: Electric Chiller Baseline Efficiencies (IECC 2009)297

Chiller Type	Size	Path A	Path B	Source
Air Cooled Chillers	< 150 tons	Full load: 9.562 EER IPLV: 12.500 EER	N/A	IECC 2009 Table 503.2.3 (7) Post 1/1/2010
	>=150 tons	Full load: 9.562 EER IPLV: 12.750 EER	N/A	
Water Cooled Positive Displacement or Reciprocating Chiller	< 75 tons	Full load: 0.780 kW/ton IPLV: 0.630 kW/ton	Full load: 0.800 kW/ton IPLV: 0.600 kW/ton	
	>=75 tons and < 150 tons	Full load: 0.775 kW/ton IPLV: 0.615 kW/ton	Full load: 0.790 kW/ton IPLV: 0.586 kW/ton	
	>=150 tons and < 300 tons	Full load: 0.680 kW/ton IPLV: 0.580 kW/ton	Full load: 0.718 kW/ton IPLV: 0.540 kW/ton	
	>=300 tons	Full load: 0.620 kW/ton IPLV: 0.540 kW/ton	Full load: 0.639 kW/ton IPLV: 0.490 kW/ton	
Water Cooled Centrifugal Chiller	<300 tons	Full load: 0.634 kW/ton IPLV: 0.596 kW/ton	Full load: 0.639 kW/ton IPLV: 0.450 kW/ton	
	>=300 tons and < 600 tons	Full load: 0.576 kW/ton IPLV: 0.549 kW/ton	Full load: 0.600 kW/ton IPLV: 0.400 kW/ton	
	>=600 tons	Full load: 0.570 kW/ton IPLV: 0.539 kW/ton	Full load: 0.590 kW/ton IPLV: 0.400 kW/ton	

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297 IECC 2009 – Table 503.2.3(7). Chillers must satisfy efficiency requirements for both full load and IPLV efficiencies for either Path A or Path B. The table shows the efficiency ratings to be used for the baseline chiller efficiency in the savings estimation algorithm, which must be consistent with the expected operating conditions of the efficient chiller. For example, if the efficient chiller satisfies Path A and generally performs at part load, the appropriate baseline chiller efficiency is the IPLV value under Path A for energy savings. If the efficient chiller satisfies Path B and generally performs at full load, the appropriate baseline chiller efficiency is the full load value under Path B for energy savings. Generally, chillers operating above 70 percent load for a majority (50% or more) of operating hours should use Path A and chillers below 70% load for a majority of operating hours should use Path B. The “full load” efficiency from the appropriate Path A or B should be used to calculate the Peak Demand Savings as it is expected that the chillers would be under full load during the peak demand periods.

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Table 3-272527: Chiller Cooling EFLH by Location<sup>298, 299</sup>

Space and/or Building Type	Allentown	Erie	Harrisburg	Pittsburgh	Williamsport	Philadelphia	Scranton
Arena/Auditorium/Convention Center	602	332	640	508	454	711	428
College: Classes/Administrative	690	380	733	582	520	815	490
Convenience Stores	1,216	671	1,293	1,026	917	1,436	864
Dining: Bar Lounge/Leisure	912	503	969	769	688	1,077	648
Dining: Cafeteria / Fast Food	1,227	677	1,304	1,035	925	1,449	872
Dining: Restaurants	912	503	969	769	688	1,077	648
Gymnasium/Performing Arts Theatre	690	380	733	582	520	815	490
Hospitals/Health care	1,396	770	1,483	1,177	1,052	1,648	992
Lodging: Hotels/Motels/Dormitories	756	418	805	638	571	894	538
Lodging: Residential	757	418	805	638	571	894	538
Multi-Family (Common Areas)	1,395	769	1,482	1,176	1,052	1,647	991
Museum/Library	851	469	905	718	642	1,005	605
Nursing Homes	1,141	630	1,213	963	861	1,348	811
Office: General/Retail	851	469	905	718	642	1,005	605
Office: Medical/Banks	851	469	905	718	642	1,005	605
Parking Garages & Lots	938	517	997	791	707	1,107	666
Penitentiary	1,091	602	1,160	920	823	1,289	775
Police/Fire Stations (24 Hr)	1,395	769	1,482	1,176	1,052	1,647	991
Post Office/Town Hall/Court House	851	469	905	718	642	1,005	605
Religious Buildings/Church	602	332	640	508	454	711	428
Retail	894	493	950	754	674	1,055	635
Schools/University	634	350	674	535	478	749	451
Warehouses (Not Refrigerated)	692	382	735	583	522	817	492
Warehouses (Refrigerated)	692	382	735	583	522	817	492
Waste Water Treatment Plant	1,251	690	1,330	1,055	944	1,478	889

<sup>298</sup> US Department of Energy. Energy Star Calculator and Bin Analysis Models

<sup>299</sup> The Equivalent Full Load Hours (EFLH) for Pennsylvania are calculated based on the degree day scaling methodology. The EFLH values reported in the Connecticut Program Savings Documentation were adjusted using full load hours (FLH) from the US DOE ENERGY STAR Calculator to account for differences in weather conditions.

### SECTION 3: Commercial and Industrial Measures

#### Electric Chillers

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### 3.8 Anti-Sweat Heater Controls

Anti-sweat heater (ASH) controls sense the humidity in the store outside of reach-in, glass door refrigerated cases and turn off anti-sweat heaters during periods of low humidity. Without controls, anti-sweat heaters run continuously whether they are necessary or not. Savings are realized from the reduction in energy used by not having the heaters running at all times. In addition, secondary savings result from reduced cooling load on the refrigeration unit when the heaters are off. The ASH control is applicable to glass doors with heaters, and the savings given below are based on adding controls to doors with uncontrolled heaters. The savings calculated from these algorithms is on a per door basis for two temperatures: Refrigerator/Coolers and Freezers. A default value to be used when the case service temperature is unknown is also calculated. Furthermore, impacts are calculated for both a per-door and a per-linear-feet of case unit basis, because both are used for Pennsylvania energy efficiency programs.

#### 3.8.1 Algorithms

##### Refrigerator/Cooler

$$\Delta kWh_{per\ unit} = (kW_{CoolerBase} / DoorFt) * (8,760 * CHA_{off}) * (1+R_H/COP_{Cool})$$

$$\Delta kW_{peak\ per\ unit} = (kW_{CoolerBase} / DoorFt) * CHP_{off} * (1+R_H/COP_{Cool}) * DF$$

$$\Delta kWh = N * \Delta kWh_{per\ unit}$$

$$\Delta kW_{peak} = N * \Delta kW_{peak\ per\ unit}$$

##### Freezer

$$\Delta kWh_{per\ unit} = (kW_{FreezerBase} / DoorFt) * (8,760 * FHA_{off}) * (1+R_H/COP_{Freeze})$$

$$\Delta kW_{peak\ per\ unit} = (kW_{FreezerBase} / DoorFt) * FHP_{off} * (1+R_H/COP_{Freeze}) * DF$$

$$\Delta kWh = N * \Delta kWh_{per\ unit}$$

$$\Delta kW_{peak} = N * \Delta kW_{peak\ per\ unit}$$

##### Default (case service temperature is unknown)

This algorithm should only be used when the refrigerated case type or service temperature is unknown or this information is not tracked as part of the EDC data collection.

$$\Delta kWh_{per\ unit} = \{(1-PctCooler) * kWh_{Freezer} / DoorFt + PctCooler * kWh_{Cooler} / DoorFt\}$$

$$\Delta kW_{peak\ per\ unit} = \{(1- PctCooler) * kW_{Freezer} / DoorFt + PctCooler * kW_{Cooler} / DoorFt\}$$

$$\Delta kWh = N * \Delta kWh_{per\ unit}$$

$$\Delta kW_{peak} = N * \Delta kW_{peak\ per\ unit}$$

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### 3.8.2 Definition of Terms

$N$	= Number of doors or case length in linear feet having ASH controls installed
$kW_{CoolerBase}$	= Per door power consumption (kW) of cooler case ASHs without controls
$kW_{FreezerBase}$	= Per door power consumption (kW) of freezer case ASHs without controls
8760	= Operating hours (365 days * 24 hr/day)
$CHP_{off}$	= Percent of time cooler case ASH with controls will be off during the peak period
$CHA_{off}$	= Percent of time cooler case ASH with controls will be off annually
$FHP_{off}$	= Percent of time freezer case ASH with controls will be off during the peak period
$FHA_{off}$	= Percent of time freezer case ASH with controls will be off annually
$DF$	= Demand diversity factor, accounting for the fact that not all anti-sweat heaters in all buildings in the population are operating at the same time.
$R_H$	= Residual heat fraction; estimated percentage of the heat produced by the heaters that remains in the freezer or cooler case and must be removed by the refrigeration unit.
$COP_{Cool}$	= Coefficient of performance of cooler
$COP_{Freeze}$	= Coefficient of performance of freezer
$DoorFt$	= Conversion factor to go between per door or per linear foot basis. Either 1 if per door or linear feet per door if per linear foot. Both unit basis values are used in Pennsylvania energy efficiency programs.
$PctCooler$	= Typical percent of cases that are medium-temperature refrigerator/cooler cases.

Table 3-282628 Anti-Sweat Heater Controls – Values and References

Component	Type	Value	Sources
N	Variable	# of doors or case length in linear feet	EDC Data Gathering
R <sub>H</sub>	Fixed	0.65	1
Unit	Fixed	Door = 1 Linear Feet= 2.5	2
Refrigerator/Cooler			
kW <sub>CoolerBase</sub>	Fixed	0.109	1
CHP <sub>off</sub>	Fixed	20%	1
CHA <sub>off</sub>	Fixed	85%	1
DF <sub>Cool</sub>	Fixed	1	3
COP <sub>Cool</sub>	Fixed	2.5	1
Freezer			
kW <sub>FreezerBase</sub>	Fixed	0.191	1
FHP <sub>off</sub>	Fixed	10%	1
FHA <sub>off</sub>	Fixed	75%	1
DF <sub>Freeze</sub>	Fixed	1	3
COP <sub>Freeze</sub>	Fixed	1.3	1
PctCooler	Fixed	68%	4

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**Sources:**

1. State of Wisconsin, Public Service Commission of Wisconsin, Focus on Energy Evaluation, Business Programs Deemed Savings Manual, March 22, 2010.
  - a. Three door heating configurations are presented in this reference: Standard, low-heat, and no-heat. The standard configuration was chosen on the assumption that low-heat and no-heat door cases will be screened from participation.
2. Review of various manufacturers' web sites yields 2.5' average door length. Sites include:
  - a. [http://www.bushrefrigeration.com/bakery\\_glass\\_door\\_coolers.php](http://www.bushrefrigeration.com/bakery_glass_door_coolers.php)
  - b. <http://www.brrr.cc/home.php?cat=427>
  - c. [http://refrigeration-equipment.com/gdm\\_s\\_c\\_series\\_swing\\_door\\_reac.html](http://refrigeration-equipment.com/gdm_s_c_series_swing_door_reac.html)
3. New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, Sept 1, 2009.

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4. 2010 ASHRAE Refrigeration Handbook, page 15.1 “Medium- and low-temperature display refrigerator line-ups account for roughly 68 and 32%, respectively, of a typical supermarket’s total display refrigerators.”

Table 3-~~292729~~ Recommended Fully Deemed Impact Estimates

Description	Per Door Impact	Per Linear Ft of Case Impact
Refrigerator/Cooler		
Energy Impact	1,023 kWh per door	409 kWh per linear ft
Peak Demand Impact	0.0275 kW per door	0.0110 kW per linear ft
Freezer		
Energy Impact	1,882 kWh per door	753 kWh per linear ft
Peak Demand Impact	0.0287 kW per door	0.0115 kW per linear ft
Default (case service temperature unknown)		
Energy Impact	1,298 kWh per door	519 kWh per linear ft
Peak Demand Impact	0.0279 kW per door	0.0112 kW per linear ft

**3.8.3 Measure Life**

12 Years (DEER 2008, Regional Technical Forum)

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### 3.9 High-Efficiency Refrigeration/Freezer Cases

This protocol estimates savings for installing high efficiency refrigeration and freezer cases that qualify under the ENERGY STAR rating compared to refrigeration and freezer cases allowed by federal standards. The measurement of energy and demand savings is based on algorithms with volume as the key variable.

#### 3.9.1 Algorithms

##### Products that can be ENERGY STAR 2.0 qualified:

Examples of product types that may be eligible for qualification include: reach-in, roll-in, or pass-through units; merchandisers; under counter units; milk coolers; back bar coolers; bottle coolers; glass frosters; deep well units; beer-dispensing or direct draw units; and bunker freezers.

$$\Delta kWh = (kWh_{base} - kWh_{ee}) * days/year$$

$$\Delta kW_{peak} = (kWh_{base} - kWh_{ee}) * CF/24$$

##### Products that cannot be ENERGY STAR qualified:

Drawer cabinets, prep tables, deli cases, and open air units are not eligible for ENERGY STAR under the Version 2.0 specification.

For these products, savings should be treated under a high-efficiency case fan, Electronically Commutated Motor (ECM) option.

#### 3.9.2 Definition of Terms

$kWh_{base}$  = The unit energy consumption of a standard unit (kWh/day)

$kWh_{ee}$  = The unit energy consumption of the ENERGY STAR-qualified unit (kWh/day)

CF = Demand Coincidence Factor (See Section [1.4.01.4](#))

V = Internal Volume

Table 3-~~302830~~: Refrigeration Cases - References

Component	Type	Value	Sources
$kWh_{base}$	-Calculated	See <a href="#">Table 3-31</a> , <a href="#">Table 3-2931</a> and <a href="#">Table 3-32</a> , <a href="#">Table 3-3032</a>	1
$kWh_{ee}$	-Calculated	See <a href="#">Table 3-31</a> , <a href="#">Table 3-2931</a> and <a href="#">Table 3-32</a> , <a href="#">Table 3-3032</a>	1
V	Variable	<a href="#">EDC data gathering</a>	EDC data gathering
Days/year	Fixed	365	1
CF	Fixed	1.0	2

##### Sources:

**SECTION 3:** Commercial and Industrial Measures

High-Efficiency Refrigeration/Freezer Cases

Page 278

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## 1. ENERGY STAR calculator, March, 2010 update.

Load shape for commercial refrigeration equipment

Table 3-~~312931~~: Refrigeration Case Efficiencies

Volume (ft <sup>3</sup> )	Glass Door		Solid Door	
	kWh <sub>ee</sub> /day	kWh <sub>base</sub> /day	kWh <sub>ee</sub> /day	kWh <sub>base</sub> /day
V < 15	0.118*V + 1.382	0.12*V + 3.34	0.089*V + 1.411	0.10*V + 2.04
15 ≤ V < 30	0.140*V + 1.050		0.037*V + 2.200	
30 ≤ V < 50	0.088*V + 2.625		0.056*V + 1.635	
50 ≤ V	0.110*V + 1.50		0.060*V + 1.416	

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Table 3-~~323032~~: Freezer Case Efficiencies

Volume (ft <sup>3</sup> )	Glass Door		Solid Door	
	kWh <sub>ee</sub> /day	kWh <sub>base</sub> /day	kWh <sub>ee</sub> /day	kWh <sub>base</sub> /day
V < 15	0.607*V+0.893	0.75*V + 4.10	0.250*V + 1.25	0.4*V + 1.38
15 ≤ V < 30	0.733*V - 1.00		0.40*V - 1.00	
30 ≤ V < 50	0.250*V + 13.50		0.163*V + 6.125	
50 ≤ V	0.450*V + 3.50		0.158*V + 6.333	

If precise case volume is unknown, default savings given in tables below can be used.

Table 3-~~333133~~: Refrigeration Case Savings

Volume (ft <sup>3</sup> )	Annual Energy Savings (kWh)		Demand Impacts (kW)	
	Glass Door	Solid Door	Glass Door	Solid Door
V < 15	722	268	0.0824	0.0306
15 ≤ V < 30	683	424	0.0779	0.0484
30 ≤ V < 50	763	838	0.0871	0.0957
50 ≤ V	927	1,205	0.1058	0.1427

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Table 3-343234: Freezer Case Savings

Volume (ft <sup>3</sup> )	Annual Energy Savings (kWh)		Demand Impacts (kW)	
	Glass Door	Solid Door	Glass Door	Solid Door
V < 15	1,901	814	0.2170	0.0929
15 ≤ V < 30	1,992	869	0.2274	0.0992
30 ≤ V < 50	4,417	1,988	0.5042	0.2269
50 ≤ V	6,680	3,405	0.7625	0.3887

**3.9.3 Measure Life**

12 years

**Sources:**

1. Food Service Technology Center (as stated in ENERGY STAR calculator).

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### 3.10 High-Efficiency Evaporator Fan Motors for Reach-In Refrigerated Cases

This protocol covers energy and demand savings associated with retrofit of existing shaded-pole evaporator fan motors in reach-in refrigerated display cases with either an Electronically Commutated (ECM) or Permanent Split Capacitor (PSC) motor. PSC motors must replace shaded pole (SP) motors, and ECM motors can replace either SP or PSC motors. A default savings option is offered if case temperature and/or motor size are not known. However, these parameters should be collected by EDCs for greatest accuracy.

There are two sources of energy and demand savings through this measure. There are the direct savings associated with replacement of an inefficient motor with a more efficient one, and there are the indirect savings of a reduced cooling load on the refrigeration unit due to less heat gain from the more efficient evaporator fan motor in the air-stream.

#### 3.10.1 Algorithms

##### Cooler

$$\Delta kW_{\text{peak per unit}} = (W_{\text{base}} - W_{\text{ee}}) / 1,000 * LF * DC_{\text{EvapCool}} * (1 + 1 / (DG * COP_{\text{cooler}}))$$

$$\Delta kWh_{\text{per unit}} = \Delta kW_{\text{peak per unit}} * 8,760$$

$$\Delta kW_{\text{peak}} = N * \Delta kW_{\text{peak per unit}}$$

$$\Delta kWh = N * \Delta kWh_{\text{per unit}}$$

##### Freezer

$$\Delta kW_{\text{peak per unit}} = (W_{\text{base}} - W_{\text{ee}}) / 1,000 * LF * DC_{\text{EvapFreeze}} * (1 + 1 / (DG * COP_{\text{freezer}}))$$

$$\Delta kWh_{\text{per unit}} = \Delta kW_{\text{peak per unit}} * 8,760$$

$$\Delta kW_{\text{peak}} = N * \Delta kW_{\text{peak per unit}}$$

$$\Delta kWh = N * \Delta kWh_{\text{per unit}}$$

##### Default (case service temperature not known)

$$\Delta kW_{\text{peak per unit}} = \{(1 - PctCooler) * kW_{\text{Freezer}} / \text{motor} + PctCooler * kW_{\text{Cooler}} / \text{motor}\}$$

$$\Delta kWh_{\text{per unit}} = \Delta kW_{\text{peak per unit}} * 8,760$$

$$\Delta kW_{\text{peak}} = N * \Delta kW_{\text{peak per unit}}$$

$$\Delta kWh = N * kWh_{\text{default}} / \text{motor}$$

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### 3.10.2 Definition of Terms

$N$	= Number of motors replaced
$W_{base}$	= Input wattage of existing/baseline evaporator fan motor
$W_{ee}$	= Input wattage of new energy efficient evaporator fan motor
$LF$	= Load factor of evaporator fan motor
$DC_{EvapCool}$	= Duty cycle of evaporator fan motor for cooler
$DC_{EvapFreeze}$	= Duty cycle of evaporator fan motor for freezer
$DG$	= Degradation factor of compressor COP
$COP_{cooler}$	= Coefficient of performance of compressor in the cooler
$COP_{freezer}$	= Coefficient of performance of compressor in the freezer
$PctCooler$	= Percentage of coolers in stores vs. total of freezers and coolers
8760	= Hours per year

Table 3-~~353335~~: Variables for High-Efficiency Evaporator Fan Motor

Variable	Type	Value	Source
$W_{base}$	Fixed Variable	Default	Table 3-34 Table 3-36
		Nameplate Input Wattage	EDC Data Gathering
$W_{ee}$	Variable	Default	Table 3-36 Table 3-3436
		Nameplate Input Wattage	EDC Data Gathering
$LF$	Fixed	0.9	1
$DC_{EvapCool}$	Fixed	100%	2
$DC_{EvapFreeze}$	Fixed	94.4%	2
$DG$	Fixed	0.98	3
$COP_{cooler}$	Fixed	2.5	1
$COP_{freezer}$	Fixed	1.3	1
$PctCooler$	Fixed	68%	4

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#### Sources:

1. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106.

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Table 3-363436: Variables for HE Evaporator Fan Motor

Motor Category	Weighting Percentage (population) <sup>1</sup>	Motor Output Watts	SP Efficiency <sup>1</sup>	SP Input Watts	PSC Efficiency <sup>2</sup>	PSC Input Watts	ECM Efficiency <sup>1</sup>	ECM Input Watts
1-14 watts (Using 9 watt as industry average)	91%	9	18%	50	41%	22	66%	14
16-23 watts (Using 19.5 watt as industry average)	3%	19.5	21%	93	41%	48	66%	30
-1/20 HP (~37 watts)	6%	37	26%	142	41%	90	66%	56

**Sources:**

1. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Grocery Display Case ECM, FY2010, V2. Accessed from RTF website <http://www.nwcouncil.org/rtf/measures/Default.asp> on July 30, 2010.
2. AO Smith New Product Notification. I-motor 9 & 16 Watt. Stock Numbers 9207F2 and 9208F2. Web address: [http://www.aosmithmotors.com/uploadedFiles/Bulletin%206029B\\_6-09\\_web.pdf](http://www.aosmithmotors.com/uploadedFiles/Bulletin%206029B_6-09_web.pdf). Accessed July 30, 2010.

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Table 3-~~373537~~: Shaded Pole to PSC Deemed Savings

Measure	W <sub>base</sub> (Shaded Pole)	W <sub>ee</sub> (PSC)	LF	DC <sub>Evap</sub>	DG	COP per case Temp	Demand Impact (kW)	Energy Impact (kWh)
Cooler: Shaded Pole to PSC: 1-14 Watt	50	22	0.9	100%	0.98	2.5	0.0355	311
Cooler: Shaded Pole to PSC: 16-23 Watt	93	48	0.9	100%	0.98	2.5	0.0574	503
Cooler: Shaded Pole to PSC: 1/20 HP (37 Watt)	142	90	0.9	100%	0.98	2.5	0.0660	578
Freezer: Shaded Pole to PSC: 1-14 Watt	50	22	0.9	94.4%	0.98	1.3	0.0425	373
Freezer: Shaded Pole to PSC: 16-23 Watt	93	48	0.9	94.4%	0.98	1.3	0.0687	602
Freezer: Shaded Pole to PSC: 1/20 HP (37 Watt)	142	90	0.9	94.4%	0.98	1.3	0.0790	692

Table 3-~~383638~~: PSC to ECM Deemed Savings

Measure	W <sub>base</sub> (PSC)	W <sub>ee</sub> (ECM)	LF	DC <sub>Evap</sub>	DG	COP per case Temp	Demand Impact (kW)	Energy Impact (kWh)
Cooler: PSC to ECM: 1-14 Watt	22	14	0.9	100%	0.98	2.5	0.0105	92
Cooler: PSC to ECM: 16-23 Watt	48	30	0.9	100%	0.98	2.5	0.0228	200
Cooler: PSC to ECM: 1/20 HP (37 Watt)	90	56	0.9	100%	0.98	2.5	0.0433	380
Freezer: PSC to ECM: 1-14 Watt	22	14	0.9	94.4%	0.98	1.3	0.0126	110
Freezer: PSC to ECM: 16-23 Watt	48	30	0.9	94.4%	0.98	1.3	0.0273	239
Freezer: PSC to ECM: 1/20 HP (37 Watt)	90	56	0.9	94.4%	0.98	1.3	0.0518	454

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Table 3-~~393739~~: Shaded Pole to ECM Deemed Savings

Measure	W <sub>base</sub> (Shaded Pole)	W <sub>ee</sub> (ECM)	LF	DC <sub>Evap</sub>	DG	COP per case Temp	Demand Impact (kW)	Energy Impact (kWh)
Cooler: Shaded Pole to ECM: 1-14 Watt	50	14	0.9	100%	0.98	2.5	0.0461	404
Cooler: Shaded Pole to ECM: 16-23 Watt	93	30	0.9	100%	0.98	2.5	0.0802	703
Cooler: Shaded Pole to ECM: 1/20 HP (37 Watt)	142	56	0.9	100%	0.98	2.5	0.1093	958
Freezer: Shaded Pole to ECM: 1-14 Watt	50	14	0.9	94.4%	0.98	1.3	0.0551	483
Freezer: Shaded Pole to ECM: 16-23 Watt	93	30	0.9	94.4%	0.98	1.3	0.0960	841
Freezer: Shaded Pole to ECM: 1/20 HP (37 Watt)	142	56	0.9	94.4%	0.98	1.3	0.1308	1146

Table 3-~~403840~~: Default High-Efficiency Evaporator Fan Motor Deemed Savings

Measure	Cooler Weighted Demand Impact (kW)	Cooler Weighted Energy Impact (kWh)	Freezer Weighted Demand Impact (kW)	Freezer Weighted Energy Impact (kWh)	Default Demand Impact (kW)	Default Energy Impact (kWh)
Shaded Pole to PSC	0.0380	333	0.0455	399	0.0404	354
PSC to ECM	0.0129	113	0.0154	135	0.0137	120
Shaded Pole to ECM	0.0509	446	0.0609	534	0.0541	474

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### 3.10.3 Measure Life

15 years

#### Sources:

1. "ActOnEnergy; Business Program-Program Year 2, June, 2009 through May, 2010. Technical Reference Manual, No. 2009-01." Published 12/15/2009.
2. "Efficiency Maine; Commercial Technical Reference User Manual No. 2007-1." Published 3/5/07.
3. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. *Grocery Display Case ECM, FY2010, V2*. Accessed from RTF website <http://www.nwcouncil.org/rtf/measures/Default.asp> on July 30, 2010.

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### 3.11 High-Efficiency Evaporator Fan Motors for Walk-in Refrigerated Cases

This protocol covers energy and demand savings associated with retrofit of existing shaded-pole (SP) or permanent-split capacitor (PSC) evaporator fan motors in walk-in refrigerated display cases with an electronically commutated motor (ECM). A default savings option is offered if case temperature and/or motor size are not known. However, these parameters should be collected by EDCs for greatest accuracy.

There are two sources of energy and demand savings through this measure. There are the direct savings associated with replacement of an inefficient motor with a more efficient one, and there are the indirect savings of a reduced cooling load on the refrigeration unit due to less heat gain from the more efficient evaporator fan motor in the air-stream.

#### 3.11.1 Algorithms

##### Cooler

$$\Delta kW_{\text{peak per unit}} = (W_{\text{base}} - W_{\text{ee}}) / 1,000 * LF * DC_{\text{EvapCool}} * (1 + 1 / (DG * COP_{\text{cooler}}))$$

$$\Delta kWh_{\text{per unit}} = \Delta kW_{\text{peak per unit}} * HR$$

$$\Delta kW_{\text{peak}} = N * \Delta kW_{\text{peak per unit}}$$

$$\Delta kWh = N * \Delta kWh_{\text{per unit}}$$

##### Freezer

$$\Delta kW_{\text{peak per unit}} = (W_{\text{base}} - W_{\text{ee}}) / 1,000 * LF * DC_{\text{EvapFreeze}} * (1 + 1 / (DG * COP_{\text{freezer}}))$$

$$\Delta kWh_{\text{per unit}} = \Delta kW_{\text{peak per unit}} * HR$$

$$\Delta kW_{\text{peak}} = N * \Delta kW_{\text{peak per unit}}$$

$$\Delta kWh = N * \Delta kWh_{\text{per unit}}$$

##### Default (case service temperature not known)

$$\Delta kW_{\text{peak per unit}} = \{(1 - PctCooler) * kW_{\text{Freezer}} / \text{motor} + PctCooler * kW_{\text{Cooler}} / \text{motor}\}$$

$$\Delta kWh_{\text{per unit}} = \Delta kW_{\text{peak per unit}} * HR$$

$$\Delta kW_{\text{peak}} = N * \Delta kW_{\text{peak per unit}}$$

$$\Delta kWh = N * \Delta kWh_{\text{per unit}}$$

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### 3.11.2 Definition of Terms

$N$	= Number of motors replaced
$W_{base}$	= Input wattage of existing/baseline evaporator fan motor
$W_{ee}$	= Input wattage of new energy efficient evaporator fan motor
$LF$	= Load factor of evaporator fan motor
$DC_{EvapCool}$	= Duty cycle of evaporator fan motor for cooler
$DC_{EvapFreeze}$	= Duty cycle of evaporator fan motor for freezer
$DG$	= Degradation factor of compressor COP
$COP_{cooler}$	= Coefficient of performance of compressor in the cooler
$COP_{freezer}$	= Coefficient of performance of compressor in the freezer
$PctCooler$	= Percentage of walk-in coolers in stores vs. total of freezers and coolers
$HR$	= Operating hours per year

Table 3-413941: Variables for High-Efficiency Evaporator Fan Motor

Variable	Type	Value	Source
$W_{base}$	Fixed Variable	Default	Table 3-42 Table 3-4042
		Nameplate Input Wattage	EDC Data Gathering
$W_{ee}$	Variable	Default	Table 3-42 Table 3-4042
		Nameplate Input Wattage	EDC Data Gathering
$LF$	Fixed	0.9	1
$DC_{EvapCool}$	Fixed	100%	2
$DC_{EvapFreeze}$	Fixed	94.4%	2
$DG$	Fixed	0.98	3
$COP_{cooler}$	Fixed	2.5	1
$COP_{freezer}$	Fixed	1.3	1
$PctCooler$	Fixed	69%	3
$HR$	Fixed	8,273	2

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**Sources:**

1. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106.
2. Efficiency Vermont, Technical Reference Manual 2009-54, 12/08. Hours of operation accounts for defrosting periods where motor is not operating.
3. PEI presentation to Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Energy Smart March 2009 SP to ECM – 090223.ppt. Accessed from RTF website <http://www.nwcouncil.org/energy/rtf/meetings/2009/03/default.htm> on September 7, 2010.

Table 3-424042: Variables for HE Evaporator Fan Motor

Motor Category	Weighting Number (population) <sup>2</sup>	Motor Output Watts	SP Efficiency <sup>1,2</sup>	SP Input Watts	PSC Efficiency <sup>3</sup>	PSC Input Watts	ECM Efficiency <sup>1</sup>	ECM Input Watts
1/40 HP (16-23 watts) (Using 19.5 watt as industry average)	25%	19.5	21%	93	41%	48	66%	30
1/20 HP (~37 watts)	11.5%	37	26%	142	41%	90	66%	56
1/15 HP (~49 watts)	63.5%	49	26%	191	41%	120	66%	75

**Sources:**

1. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Grocery Display Case ECM, FY2010, V2. Accessed from RTF website: <http://www.nwcouncil.org/rtf/measures/Default.asp> on July 30, 2010
2. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Deemed MeasuresV26\_walkinevapfan. Provided by Adam Hadley (adam@hadleyenergy.com). Should be made available on RTF website <http://www.nwcouncil.org/rtf/measures/Default.asp>
3. AO Smith New Product Notification. I-motor 9 & 16 Watt. Stock Numbers 9207F2 and 9208F2. Web address: [http://www.aosmithmotors.com/uploadedFiles/Bulletin%206029B\\_6-09\\_web.pdf](http://www.aosmithmotors.com/uploadedFiles/Bulletin%206029B_6-09_web.pdf). Accessed July 30, 2010.

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Table 3-434143: PSC to ECM Deemed Savings

Measure	W <sub>base</sub> (PSC)	W <sub>ee</sub> (ECM)	LF	DC <sub>Evap</sub>	DG	COP per case Temp	Demand Impact (kW)	Energy Impact (kWh)
Cooler: PSC to ECM: 1/40 HP (16-23 Watt)	48	30	0.9	100%	0.98	2.5	0.0228	189
Cooler: PSC to ECM: 1/20 HP (37 Watt)	90	56	0.9	100%	0.98	2.5	0.0431	356
Cooler: PSC to ECM: 1/15 HP (49 Watt)	120	75	0.9	100%	0.98	2.5	0.0570	472
Freezer: PSC to ECM: 1/40 HP (16-23 Watt)	48	30	0.9	94.4%	0.98	1.3	0.0273	226
Freezer: PSC to ECM: 1/20 HP (37 Watt)	90	56	0.9	94.4%	0.98	1.3	0.0516	427
Freezer: PSC to ECM: 1/15 HP (49 Watt)	120	75	0.9	94.4%	0.98	1.3	0.0682	565

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Table 3-444244: Shaded Pole to ECM Deemed Savings

Measure	W <sub>base</sub> (Shaded Pole)	W <sub>ee</sub> (ECM)	LF	DC <sub>Evap</sub>	DG	COP per case Temp	Demand Impact (kW)	Energy Impact (kWh)
Cooler: Shaded Pole to ECM: 1/40 HP (16-23 Watt)	93	30	0.9	100%	0.98	2.5	0.0798	661
Cooler: Shaded Pole to ECM: 1/20 HP (37 Watt)	142	56	0.9	100%	0.98	2.5	0.1090	902
Cooler: Shaded Pole to ECM: 1/15 HP (49 Watt)	191	75	0.9	100%	0.98	2.5	0.1470	1,216
Freezer: Shaded Pole to ECM: 1/40 HP (16-23 Watt)	93	30	0.9	94.4%	0.98	1.3	0.0955	790
Freezer: Shaded Pole to ECM: 1/20 HP (37 Watt)	142	56	0.9	94.4%	0.98	1.3	0.1304	1,079
Freezer: Shaded Pole to ECM: 1/15 HP (49 Watt)	191	75	0.9	94.4%	0.98	1.3	0.1759	1,455

Table 3-454345: Default High-Efficiency Evaporator Fan Motor Deemed Savings

Measure	Cooler Weighted Demand Impact (kW)	Cooler Weighted Energy Impact (kWh)	Freezer Weighted Demand Impact (kW)	Freezer Weighted Energy Impact (kWh)	Default Demand Impact (kW)	Default Energy Impact (kWh)
PSC to ECM	0.0469	388	0.0561	464	0.0499	413
Shaded Pole to ECM	0.1258	1,041	0.1506	1,246	0.1335	1,105

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### 3.11.3 Measure Life

15 years

#### Sources:

1. "ActOnEnergy; Business Program-Program Year 2, June, 2009 through May, 2010. Technical Reference Manual, No. 2009-01." Published 12/15/2009.
2. "Efficiency Maine; Commercial Technical Reference User Manual, No. 2007-1." Published 3/5/07.
3. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Deemed MeasuresV26\_walkinevapfan. Provided by Adam Hadley (adam@hadleyenergy.com). Should be made available on RTF website <http://www.nwcouncil.org/rtf/measures/Default.asp>

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### 3.12 ENERGY STAR Office Equipment

This protocol estimates savings for installing ENERGY STAR office equipment compared to standard efficiency equipment. The measurement of energy and demand savings is based on a deemed savings value multiplied by the quantity of the measure.

#### 3.12.1 Algorithms

The general form of the equation for the ENERGY STAR Office Equipment measure savings' algorithms is:

*Number of Units X Savings per Unit*

To determine resource savings, the per unit estimates in the algorithms will be multiplied by the number of units. Per unit savings are primarily derived from the June 2010 release of the ENERGY STAR calculator for office equipment.

##### ENERGY STAR Computer

$$\Delta kWh = ESav_{COM}$$

$$\Delta kW_{peak} = DSav_{COM} \times CF_{COM}$$

##### ENERGY STAR Fax Machine

$$\Delta kWh = ESav_{FAX}$$

$$\Delta kW_{peak} = DSav_{FAX} \times CF_{FAX}$$

##### ENERGY STAR Copier

$$\Delta kWh = ESav_{COP}$$

$$\Delta kW_{peak} = DSav_{COP} \times CF_{COP}$$

##### ENERGY STAR Printer

$$\Delta kWh = ESav_{PRI}$$

$$\Delta kW_{peak} = DSav_{PRI} \times CF_{PRI}$$

##### ENERGY STAR Multifunction

$$\Delta kWh = ESav_{MUL}$$

$$\Delta kW_{peak} = DSav_{MUL} \times CF_{MUL}$$

##### ENERGY STAR Monitor

$$\Delta kWh = ESav_{MON}$$

$$\Delta kW_{peak} = DSav_{MON} \times CF_{MON}$$

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### 3.12.2 Definition of Terms

$ESav_{COM}$  = Electricity savings per purchased ENERGY STAR computer.

$DSav_{COM}$  = Summer demand savings per purchased ENERGY STAR computer.

$ESav_{FAX}$  = Electricity savings per purchased ENERGY STAR fax machine.

$DSav_{FAX}$  = Summer demand savings per purchased ENERGY STAR fax machine.

$ESav_{COP}$  = Electricity savings per purchased ENERGY STAR copier.

$DSav_{COP}$  = Summer demand savings per purchased ENERGY STAR copier.

$ESav_{PRI}$  = Electricity savings per purchased ENERGY STAR printer.

$DSav_{PRI}$  = Summer demand savings per purchased ENERGY STAR printer.

$ESav_{MUL}$  = Electricity savings per purchased ENERGY STAR multifunction machine.

$DSav_{MUL}$  = Summer demand savings per purchased ENERGY STAR multifunction machine.

$ESav_{MON}$  = Electricity savings per purchased ENERGY STAR monitor.

$DSav_{MON}$  = Summer demand savings per purchased ENERGY STAR monitor.

$CF_{COM}, CF_{FAX}, CF_{COP},$

$CF_{PRI}, CF_{MUL}, CF_{MON}$  = Demand Coincidence Factor (See Section 1.4). The coincidence of average office equipment demand to summer system peak equals 1 for demand impacts for all office equipment reflecting embedded coincidence in the DSav factor.

Table 3-464446: ENERGY STAR Office Equipment - References

Component	Type	Value	Sources
ESav <sub>COM</sub> ESav <sub>FAX</sub> ESav <sub>COP</sub> ESav <sub>PRI</sub> ESav <sub>MUL</sub> ESav <sub>MON</sub>	Fixed	seeSee Table 3-47Table 3-4547	1
DSav <sub>COM</sub> DSav <sub>FAX</sub> DSav <sub>COP</sub> DSav <sub>PRI</sub> DSav <sub>MUL</sub> DSav <sub>MON</sub>	Fixed	seeSee Table 3-47Table 3-4547	2
CF <sub>COM</sub> , CF <sub>FAX</sub> , CF <sub>COP</sub> , CF <sub>PRI</sub> , CF <sub>MUL</sub> , CF <sub>MON</sub>	Fixed	1.0, 1.0, 1.0, 1.0, 1.0, 1.0	3

**Sources:**

1. ENERGY STAR Office Equipment Savings Calculator (Calculator updated: June 2010). Default values were used.
2. Using a commercial office equipment load shape, the percentage of total savings that occur during the top 100 system hours was calculated and multiplied by the energy savings.
3. Coincidence factors already embedded in summer peak demand reduction estimates.

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Table 3-474547: ENERGY STAR Office Equipment Energy and Demand Savings Values

Measure	Energy Savings (ESav)	Demand Savings (DSav)
Computer	133 kWh	0.018 kW
Fax Machine (laser)	78 kWh	0.0105 kW
Copier (monochrome)		
1-25 images/min	73 kWh	0.0098 kW
26-50 images/min	151 kWh	0.0203 kW
51+ images/min	162 kWh	0.0218 kW
Printer (laser, monochrome)		
1-10 images/min	26 kWh	0.0035 kW
11-20 images/min	73 kWh	0.0098 kW
21-30 images/min	104 kWh	0.0140 kW
31-40 images/min	156 kWh	0.0210 kW
41-50 images/min	133 kWh	0.0179 kW
51+ images/min	329 kWh	0.0443 kW
Multifunction (laser, monochrome)		
1-10 images/min	78 kWh	0.0105 kW
11-20 images/min	147 kWh	0.0198 kW
21-44 images/min	253 kWh	0.0341 kW
45-99 images/min	422 kWh	0.0569 kW
100+ images/min	730 kWh	0.0984 kW
Monitor	15 kWh	0.0020 kW

**Sources:**

1. ENERGYSTAR office equipment calculators

### 3.12.3 Measure Life

Table 3-484648: ENERGY STAR Office Equipment Measure Life

Equipment	Residential Life (years)	Commercial Life (years)
Computer	4	4
Monitor	5	4
Fax	4	4
Multifunction Device	6	6
Printer	5	5
Copier	6	6

**Sources:**

1. ENERGYSTAR office equipment calculators

### 3.13 Smart Strip Plug Outlets

Smart Strips are power strips that contain a number of controlled sockets with at least one uncontrolled socket. When the appliance that is plugged into the uncontrolled socket is turned off, the power strips then shuts off the items plugged into the controlled sockets. Qualified power strips must automatically turn off when equipment is unused / unoccupied.

#### 3.13.1 Eligibility

This protocol documents the energy savings attributed to the installation of smart strip plugs. The most likely area of application is within commercial spaces such as isolated workstations and computer systems with standalone printers, scanners or other major peripherals that are not dependent on an uninterrupted network connection (e.g. routers and modems).

#### 3.13.2 Algorithms

The DSMore Michigan Database of Energy Efficiency Measures performed engineering calculations using standard standby equipment wattages for typical computer and TV systems and idle times. This commercial protocol will use the computer system assumptions except it will utilize a lower idle time for commercial office use.

The computer system usage is assumed to be 10 hours per day for 5 workdays per week. The average daily idle time including the weekend (2 days of 100% idle) is calculated as follows:

*(Hours per week – (Workdays x daily computer usage))/days per week = average daily commercial computer system idle time*

*(168 hours – (5 x 10 hours))/7 days = 16.86 hours*

The energy savings and demand reduction were obtained through the following calculations:

$$\Delta kWh = (kW_{comp} \times Hr_{comp}) \times 365 = 123.69kWh \text{ (rounded to 124kWh)}$$

$$\Delta kW_{peak} = CF \times kW_{comp} = 0.0101 kW$$

#### 3.13.3 Definition of Terms

The parameters in the above equation are listed below.

Table 3-494749: Smart Strip Calculation Assumptions

Parameter	Component	Type	Value	Source
$kW_{comp}$	Idle kW of computer system	Fixed	0.0201	1
$Hr_{comp}$	Daily hours of computer idle time	Fixed	16.86	1
CF	Coincidence Factor	Fixed	0.50	1

#### Sources:

1. DSMore Michigan Database of Energy Efficiency Measures

### 3.13.4 Deemed Savings

$$\Delta kWh = 124 kWh$$

$$\Delta kW_{peak} = 0.0101 kW$$

### 3.13.5 Measure Life

To ensure consistency with the annual savings calculation procedure used in the DSMore MI database, the measure of **5 years** is taken from DSMore.

### 3.13.6 Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings.

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### 3.14 Beverage Machine Controls

This measure is intended for the addition of control systems to existing, non-ENERGY STAR, beverage vending machines. The applicable machines contain refrigerated non-perishable beverages that are kept at an appropriate temperature. The control systems are intended to reduce energy consumption due to lighting and refrigeration during times of lower customer sales. Typical control systems contain a passive infrared occupancy sensor to shut down the machine after a period of inactivity in the area. The compressor will power on one to three hour intervals sufficient to maintain beverage temperature, and when powered on at any time will be allowed to complete at least one cycle to prevent excessive wear and tear.

The baseline equipment is taken to be an existing standard refrigerated beverage vending machine that does not contain control systems to shut down the refrigeration components and lighting during times of low customer use.

#### 3.14.1 Algorithms

Energy savings are dependent on decreased machine lighting and cooling loads during times of lower customer sales. The savings will be dependent on the machine environment, noting that machines placed in locations such as a day-use office will result in greater savings than those placed in high-traffic areas such as hospitals that operate around the clock. The algorithm below takes into account varying scenarios and can be taken as representative of a typical application.

$$\Delta kWh = kWh_{base} \times E$$

$$\Delta kW_{peak} = 0$$

There are no peak demand savings because this measure is aimed to reduce demand during times of low beverage machine use, which will typically occur during off-peak hours.

#### 3.14.2 Definition of Terms

$kWh_{base}$  = baseline annual beverage machine energy consumption (kWh/year)

$E$  = efficiency factor due to control system, which represents percentage of energy reduction from baseline

#### 3.14.3 Energy Savings Calculations

The decrease in energy consumption due to the addition of a control system will depend on the number or hours per year during which lighting and refrigeration components of the beverage machine are powered down. The average decrease in energy use from refrigerated beverage vending machines with control systems installed is 46%. It should be noted that

300 Deru, M., et al., (2003), *Analysis of NREL Cold-Drink Vending Machines for Energy Savings*, National Renewable Energy Laboratory, NREL/TP-550-34008, <http://www.nrel.gov/docs/fy03osti/34008.pdf>



various studies found savings values ranging between 30-65%, most likely due to differences in customer occupation.

The default baseline energy consumption and default energy savings are shown in [Table 3-50](#)[Table 3-48](#)[50](#). The default energy savings were derived by applying a default efficiency factor of  $E_{\text{default}} = 46\%$  to the energy savings algorithm above. Where it is determined that the default efficiency factor (E) or default baseline energy consumption ( $\text{kWh}_{\text{base}}$ ) is not representative of specific applications, EDC data gathering can be used to determine an application-specific energy savings factor (E), and/or baseline energy consumption ( $\text{kWh}_{\text{base}}$ ), for use in the Energy Savings algorithm.

Table 3-[50](#)[48](#)[50](#): Beverage Machine Controls Energy Savings<sup>304</sup>

Machine Can Capacity	Default Baseline Energy Consumption ( $\text{kWh}_{\text{base}}$ ) (kWh/year)	Default Energy Savings ( $\Delta\text{kWh}$ ); (kWh/year)
< 500	3,113	1,432
500	3,916	1,801
600	3,551	1,633
700	4,198	1,931
800+	3,318	1,526

#### 3.14.4 Measure Life

Measure life = 5 years

##### Sources:

1. DEER EUL Summary, Database for Energy Efficient Resources, accessed 8/2010, [http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)
2. Deru et al. suggest that beverage machine life will be extended from this measure due to fewer lifetime compressor cycles.
3. U.S. Department of Energy Appliances and Commercial Equipment Standards, [http://www1.eere.energy.gov/buildings/appliance\\_standards/commercial/beverage\\_machines.html](http://www1.eere.energy.gov/buildings/appliance_standards/commercial/beverage_machines.html)

301 Ritter, J., Huggins, J., (2000), *Vending Machine Energy Consumption and VendingMiser Evaluation*, Energy Systems Laboratory, Texas A&M University System, <http://repository.tamu.edu/bitstream/handle/1969.1/2006/ESL-TR-00-11-01.pdf;jsessionid=6E215C09FB80BC5D2593AC81E627DA97?sequence=1>

302 *State of Ohio Energy Efficiency Technical Reference Manual, Including Predetermined Savings Values and Protocols for Determining Energy and Demand Savings*, August 6, 2010. Prepared for the Public Utilities Commission of Ohio by Vermont Energy Investment Corporation

303 *Vending Machine Energy Savings*, Michigan Energy Office Case Study 05-0042, [http://www.michigan.gov/documents/CIS\\_EO\\_Vending\\_Machine\\_05-0042\\_155715\\_7.pdf](http://www.michigan.gov/documents/CIS_EO_Vending_Machine_05-0042_155715_7.pdf)

304 ENERGY STAR Calculator, Assumptions for Vending Machines, accessed 8/2010 [http://www.energystar.gov/ia/business/bulk\\_purchasing/bpsavings\\_calc/Calc\\_Vend\\_MachBulk.xls](http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Vend_MachBulk.xls)

### 3.15 High-Efficiency Ice Machines

This measure applies to the installation of a high-efficiency ice machine as either a new item or replacement for an existing unit. The machine must be air-cooled to qualify, which can include self-contained, ice-making heads, or remote-condensing units. The machine must conform with the minimum ENERGY STAR efficiency requirements, which are equivalent to the CEE Tier 2 specifications for high-efficiency commercial ice machines<sup>305</sup>. A qualifying machine must also meet the ENERGY STAR requirements for water usage given under the same criteria.

The baseline equipment is taken to be a unit with efficiency specifications less than or equal to CEE Tier 1 equipment.

#### 3.15.1 Algorithms

The energy savings are dependent on machine type and capacity of ice produced on a daily basis. A machine’s capacity is generally reported as an ice harvest rate, or amount of ice produced each day.

$$\Delta kWh = \frac{(kWh_{base} - kWh_{he})}{100} \times H \times 365 \times D$$

$$\Delta kW_{peak} = \frac{\Delta kWh}{8760 \times D} \times CF$$

#### 3.15.2 Definition of Terms

$kWh_{base}$	= baseline ice machine energy usage per 100 lbs of ice (kWh/100lbs)
$kWh_{he}$	= high-efficiency ice machine energy usage per 100 lbs of ice (kWh/100lbs)
$H$	= Ice harvest rate per 24 hrs (lbs/day)
$D$	= duty cycle of ice machine expressed as a percentage of time machine produces ice.
365	= (days/year)
100	= conversion to obtain energy per pound of ice (lbs/100lbs)
8760	= (hours/year)
$CF$	= Demand Coincidence Factor (See Section 4.4) <del>04-4</del>

The reference values for each component of the energy impact algorithm are shown in [Table 3-51](#)~~Table 3-49~~<sup>51</sup>. A default duty cycle (D) is provided as based on referenced values from several studies, however, EDC data gathering may be used to adjust the duty cycle for custom applications.

<sup>305</sup> Commercial Ice Machines Key Product Criteria, ENERGY STAR, accessed 8/2010, [http://www.energystar.gov/index.cfm?c=comm\\_ice\\_machines.pr\\_crit\\_comm\\_ice\\_machines](http://www.energystar.gov/index.cfm?c=comm_ice_machines.pr_crit_comm_ice_machines)

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Table 3-514951: Ice Machine Reference values for algorithm components

Term	Type	Value	Source
kWh <sub>base</sub>	Variable	<a href="#">Table 3-52Table-3-5052</a>	1
kWh <sub>he</sub>	Variable	<a href="#">Table 3-52Table-3-5052</a>	2
H	Variable	Manufacturer Specs	EDC Data Gathering
D	Variable	Default = 0.4306	3
		Custom	EDC Data Gathering
Ice maker type	Variable	Manufacturer Specs	EDC Data Gathering
CF	Fixed	0.77	4

**Sources:**

1. Specifications for CEE Tier 1 ice machines.
2. Specifications for CEE Tier 2 ice machines.
3. *State of Ohio Energy Efficiency Technical Reference Manual* cites a default duty cycle of 40% as a conservative value. Other studies range as high as 75%.
4. *State of Ohio Energy Efficiency Technical Reference Manual* cites a CF = 0.772 as adopted from the Efficiency Vermont TRM. Assumes CF for ice machines is similar to that for general commercial refrigeration equipment.

**3.15.3 Energy Savings Calculations**

Ice machine energy usage levels are dependent on the ice harvest rate (H), and are calculated using CEE specifications as shown in [Table 3-52Table-3-5052](#). The default energy consumption for the baseline ice machine (kWh<sub>base</sub>) is calculated using the formula for CEE Tier 1 specifications, and the default energy consumption for the high-efficiency ice machine (kWh<sub>he</sub>) is calculated using the formula for CEE Tier 2 specifications<sup>307</sup>. The two energy consumption values are then applied to the energy savings algorithm above.

306 *State of Ohio Energy Efficiency Technical Reference Manual, Including Predetermined Savings Values and Protocols for Determining Energy and Demand Savings*, August 6, 2010. Prepared for the Public Utilities Commission of Ohio by Vermont Energy Investment Corporation.

307 *High Efficiency Specifications for Commercial Ice Machines*, Consortium for Energy Efficiency, accessed 8/2010, <http://www.cee1.org/com/com-kit/files/IceSpecification.pdf>

Table 3-525052: Ice Machine Energy Usage<sup>308</sup>

Ice machine type	Ice harvest rate (H) (lbs/day)	Baseline energy use per 100 lbs of ice (kWh <sub>base</sub> )	High-efficiency energy use per 100 lbs of ice (kWh <sub>he</sub> )
Ice-Making Head	<450	10.26 – 0.0086*H	9.23 – 0.0077*H
	≥450	6.89 – 0.0011*H	6.20 – 0.0010*H
Remote-Condensing w/out remote compressor	<1000	8.85 – 0.0038*H	8.05 – 0.0035*H
	≥1000	5.1	4.64
Remote-Condensing with remote compressor	<934	8.85 – 0.0038*H	8.05 – 0.0035*H
	≥934	5.3	4.82
Self-Contained	<175	18 – 0.0469*H	16.7 – 0.0436*H
	≥175	9.8	9.11

### 3.15.4 Measure Life

Measure life = 10 years<sup>309</sup>.

#### Sources:

1. Karas, A., Fisher, D. (2007), *A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify Saving Potential*, Food Service Technology Center, December 2007, [http://www.fishnick.com/publications/appliancereports/special/Ice-cube\\_machine\\_field\\_study.pdf](http://www.fishnick.com/publications/appliancereports/special/Ice-cube_machine_field_study.pdf)
2. *Energy-Efficient Products, How to Buy an Energy-Efficient Commercial Ice Machine*, U.S. Department of Energy, Energy Efficiency and Renewable Energy, accessed August 2010 at [http://www1.eere.energy.gov/femp/procurement/eep\\_ice\\_makers.html](http://www1.eere.energy.gov/femp/procurement/eep_ice_makers.html)

<sup>308</sup> Specifications for Tier 1 and Tier 2 ice machines are being revised by CEE, however exact criteria and timeline have not been set as of the time of this report.

<sup>309</sup> *DEER EUL Summary*, Database for Energy Efficient Resources, accessed 8/2010, [http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

### 3.16 Wall and Ceiling Insulation

Wall and ceiling insulation is one of the most important aspects of the energy system of a building. Insulation dramatically minimizes energy expenditure on heating and cooling. Increasing the R-value of wall insulation above building code requirements generally lowers heating and cooling costs. Incentives are offered with regard to increases in R-value rather than type, method, or amount of insulation.

An R-value indicates the insulation's resistance to heat flow – the higher the R-value, the greater the insulating effectiveness. The R-value depends on the type of insulation and its material, thickness, and density. When calculating the R-value of a multilayered installation, add the R-values of the individual layers.

#### 3.16.1 Eligibility

This measure applies to non-residential buildings or common areas in multifamily complexes heated and/or cooled using electricity. Existing construction buildings are required to meet or exceed the code requirement. New construction buildings must exceed the code requirement. Eligibility may vary by PA EDC; savings from chiller-cooled buildings are not included.

#### 3.16.2 Algorithms

The savings depend on four main factors: baseline condition, heating system type and size, cooling system type and size, and location. The algorithm for Central AC and Air Source Heat Pumps (ASHP) is as follows

##### Ceiling Insulation

$$\begin{aligned}\Delta kWh &= \Delta kWh_{cool} + \Delta kWh_{heat} \\ \Delta kWh_{cool} &= (A \times CDD \times 24) / (EER \times 1000) \times (1/R_i - 1/R_f) \\ \Delta kWh_{heat} &= (A \times HDD \times 24) / (COP \times 3413) \times (1/R_i - 1/R_f) \\ \Delta kW_{peak} &= \Delta kWh_{cool} / EFLH_{cool} \times CF\end{aligned}$$

##### Wall Insulation

$$\begin{aligned}\Delta kWh &= \Delta kWh_{cool} + \Delta kWh_{heat} \\ \Delta kWh_{cool} &= (A \times CDD \times 24) / (EER \times 1000) \times (1/R_i - 1/R_f) \\ \Delta kWh_{heat} &= (A \times HDD \times 24) / (COP \times 3413) \times (1/R_i - 1/R_f) \\ \Delta kW_{peak} &= \Delta kWh_{cool} / EFLH_{cool} \times CF\end{aligned}$$

**3.16.3 Definition of Terms**

<i>A</i>	= area of the insulation that was installed in square feet
<i>HDD</i>	= heating degree days with 65 degree base
<i>CDD</i>	= cooling degree days with a 65 degree base
<i>24</i>	= hours per day
<i>1000</i>	= W per kW
<i>3413</i>	= Btu per kWh
<i>R<sub>i</sub></i>	= the R-value of the insulation and support structure before the additional insulation is installed
<i>R<sub>f</sub></i>	= the total R-value of all insulation after the additional insulation is installed
<i>EFLH</i>	= equivalent full load hours
<i>CF</i>	= Demand Coincidence Factor (See Section 4.4)01-4)
<i>EER</i>	= efficiency of the cooling system
<i>COP</i>	= efficiency of the heating system

Table 3-535153: Non-Residential Insulation – Values and References

Component	Type	Values	Sources
A	Variable	Application	AEPS Application; EDC Data Gathering
HDD	Fixed	Allentown = 5318 Erie = 6353 Harrisburg = 4997 Philadelphia = 4709 Pittsburgh = 5429 Scranton = 6176 Williamsport = 5651	1
CDD	Fixed	Allentown = 787 Erie = 620 Harrisburg = 955 Philadelphia = 1235 Pittsburgh = 726 Scranton = 611 Williamsport = 709	1
24	Fixed	24	n/a

Component	Type	Values	Sources
1000	Fixed	1000	n/a
Ceiling R <sub>i</sub>	Existing: Variable New Construction: Fixed	For new construction buildings and when variable is unknown for existing buildings: See <a href="#">Table 3-54</a> <a href="#">Table 3-52</a> <a href="#">54</a> and <a href="#">Table 3-55</a> <a href="#">Table 3-53</a> <a href="#">55</a> for values by building type	AEPS Application; EDC Data Gathering; 2, 4
Wall R <sub>i</sub>	Existing: Variable New Construction: Fixed	For new construction buildings and when variable is unknown for existing buildings: See <a href="#">Table 3-54</a> <a href="#">Table 3-52</a> <a href="#">54</a> and <a href="#">Table 3-55</a> <a href="#">Table 3-53</a> <a href="#">55</a> for values by building type	AEPS Application; EDC Data Gathering; 3, 4
R <sub>f</sub>	Variable	<a href="#">EDC Data Gathering</a>	AEPS Application; EDC Data Gathering;
EFLH <sub>cool</sub>	<a href="#">Fixed</a> <a href="#">Variable</a>	Default: See <a href="#">Table 3-57</a> <a href="#">Table 3-55</a> <a href="#">57</a>	5
		<a href="#">Based on Logging, BMS data or Modeling<sup>310</sup></a>	<a href="#">EDC Data Gathering</a>
CF	Fixed	67%	5
EER	<a href="#">Fixed</a> <a href="#">Variable</a>	Default: See <a href="#">Table 3-56</a> <a href="#">Table 3-54</a> <a href="#">56</a>	6, 7
		<a href="#">Nameplate</a>	<a href="#">EDC Data Gathering</a>
COP	<a href="#">Fixed</a> <a href="#">Variable</a>	Default: See <a href="#">Table 3-56</a> <a href="#">Table 3-54</a> <a href="#">56</a>	6, 7
		<a href="#">Nameplate</a>	<a href="#">EDC Data Gathering</a>

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**Sources:**

1. U.S. Department of Commerce. Climatology of the United States No. 81 Supplement No. 2. Annual Degree Days to Selected Bases 1971 – 2000. Scranton uses the values for Wilkes-Barre. HDD were adjusted downward to account for business hours. CDD were not adjusted for business hours, as the adjustment resulted in an increase in CDD and so not including the adjustment provides a conservative estimate of energy savings.
2. The initial R-value for a ceiling for existing buildings is based on the EDC eligibility requirement that at least R-11 be installed and that the insulation must meet at least IECC 2009 code. The initial R-value for new construction buildings is based on IECC 2009 code for climate zone 5.
3. The initial R-value for a wall assumes that there was no existing insulation, or that it has fallen down resulting in an R-value equivalent to that of the building materials. Building simulation modeling using DOE-2.2 model (eQuest) was performed for a building with no

[310 Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data \(pre-retrofit\).](#)

**SECTION 3: Commercial and Industrial Measures****Wall and Ceiling Insulation**

Page 307

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wall insulation. The R-value is dependent upon the construction materials and their thickness. Assumptions were made about the building materials used in each sector.

4. 2009 International Energy Conservation Code. Used climate zone 5 which covers the majority of Pennsylvania. The R-values required by code were used as inputs in the eQuest building simulation model to calculate the total R-value for the wall including the building materials.
5. EFLH values and coincidence factors for HVAC peak demand savings calculations come from the Pennsylvania Technical Reference Manual. June 2010.
6. Baseline values from ASHRAE 90.1-2004 for existing buildings.
7. Baseline values from IECC 2009 for new construction buildings.

Table 3-545254: Ceiling R-Values by Building Type

Building Type	Ceiling R <sub>i</sub> -Value (New Construction)	Ceiling R <sub>i</sub> -Value (Existing)
Large Office Large Retail Lodging Health Education Grocery	20	9
Small Office Warehouse	24.4	13.4
Small Retail Restaurant Convenience Store	20	9

Table 3-555355: Wall R-Values by Building Type

Building Type	Wall R <sub>i</sub> -Value (New Construction)	Wall R <sub>i</sub> -Value (Existing)
Large Office	14	1.6
Small Office Large Retail Small Retail Convenience Store	14	3.0
Lodging Health Education Grocery	13	2.0
Restaurant	14	3.2

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Warehouse	14	2.5
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Table 3-565456: HVAC Baseline Efficiencies for Non-Residential Buildings

Equipment Type and Capacity	Existing Building <sup>311</sup>		New Construction <sup>312</sup>	
	Cooling Efficiency	Heating Efficiency	Cooling Efficiency	Heating Efficiency
<b>Air-Source Air Conditioners</b>				
< 65,000 BtuH	10.0 SEER	N/A	13.0 SEER	N/A
≥ 65,000 BtuH and <135,000 BtuH	10.3 EER	N/A	11.2 EER	N/A
≥ 135,000 BtuH and < 240,000 BtuH	9.7 EER	N/A	11.0 EER	N/A
≥ 240,000 BtuH and < 760,000 BtuH (IPLV for units with capacity-modulation only)	9.5 EER	N/A	10.0 EER / 9.7 IPLV	N/A
≥ 760,000 BtuH (IPLV for units with capacity-modulation only)	9.2 EER	N/A	9.7 EER / 9.4 IPLV	N/A
<b>Water-Source and Evaporatively-Cooled Air Conditioners</b>				
< 65,000 BtuH	12.1 EER	N/A	12.1 EER	N/A
≥ 65,000 BtuH and <135,000 BtuH	11.5 EER	N/A	11.5 EER	N/A
≥ 135,000 BtuH and < 240,000 BtuH	11.0 EER	N/A	11.0 EER	N/A
≥ 240,000 BtuH	11.0 EER	N/A	11.5 EER	N/A
<b>Air-Source Heat Pumps</b>				
< 65,000 BtuH	10.0 SEER	6.8 HSPF	13 SEER	7.7 HSPF
≥ 65,000 BtuH and <135,000 BtuH	10.1 EER	3.2 COP	11.0 EER	3.3 COP
≥ 135,000 BtuH and < 240,000 BtuH	9.3 EER	3.1 COP	10.6 EER	3.2 COP
≥ 240,000 BtuH (IPLV for units with capacity-modulation only)	9.0 EER	3.1 COP	9.5 EER / 9.2 IPLV	3.2 COP
<b>Water-Source Heat Pumps</b>				
< 17,000 BtuH	11.2 EER	4.2 COP	11.2 EER	4.2 COP
≥ 17,000 BtuH and ≤ 65,000 BtuH	12.0 EER	4.2 COP	12.0 EER	4.2 COP
<b>Ground Water Source Heat Pumps</b>				
< 135,000 BtuH	16.2 EER	3.6 COP	16.2 EER	3.6 COP
<b>Ground Source Heat Pumps</b>				
< 135,000 BtuH	13.4 EER	3.1 COP	13.4 EER	3.1 COP

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311 ASHRAE 90.1-2004, Tables 6.8.1A, 6.8.1B, and 6.8.1D  
 312 IECC 2009, Tables 503.2.3(1), 503.2.3(2), and 503.2.3(3)

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**SECTION 3: Commercial and Industrial Measures**

## Wall and Ceiling Insulation

Packaged Terminal Systems				
PTAC (cooling)	10.9 - (0.213 x Cap / 1000) EER	N/A	12.5 - (0.213 x Cap / 1000) EER	N/A
PTHP	10.8 - (0.213 x Cap / 1000) EER	2.9 - (0.026 x Cap / 1000) COP	12.3 - (0.213 x Cap / 1000) EER	3.2 - (0.026 x Cap / 1000) COP

Table 3-575557: Cooling EFLH for Key PA Cities<sup>313</sup>

Space and/or Building Type	Allentown	Erie	Harrisburg	Pittsburgh	Williamsport	Philadelphia	Scranton
Arena/Auditorium/Convention Center	602	332	640	508	454	711	428
College: Classes/Administrative	690	380	733	582	520	815	490
Convenience Stores	1,216	671	1,293	1,026	917	1,436	864
Dining: Bar Lounge/Leisure	912	503	969	769	688	1,077	648
Dining: Cafeteria / Fast Food	1,227	677	1,304	1,035	925	1,449	872
Dining: Restaurants	912	503	969	769	688	1,077	648
Gymnasium/Performing Arts Theatre	690	380	733	582	520	815	490
Hospitals/Health care	1,396	770	1,483	1,177	1,052	1,648	992
Lodging: Hotels/Motels/Dormitories	756	418	805	638	571	894	538
Lodging: Residential	757	418	805	638	571	894	538
Multi-Family (Common Areas)	1,395	769	1,482	1,176	1,052	1,647	991
Museum/Library	851	469	905	718	642	1,005	605
Nursing Homes	1,141	630	1,213	963	861	1,348	811
Office: General/Retail	851	469	905	718	642	1,005	605
Office: Medical/Banks	851	469	905	718	642	1,005	605
Parking Garages & Lots	938	517	997	791	707	1,107	666
Penitentiary	1,091	602	1,160	920	823	1,289	775
Police/Fire Stations (24 Hr)	1,395	769	1,482	1,176	1,052	1,647	991
Post Office/Town Hall/Court House	851	469	905	718	642	1,005	605
Religious Buildings/Church	602	332	640	508	454	711	428
Retail	894	493	950	754	674	1,055	635
Schools/University	634	350	674	535	478	749	451
Warehouses (Not Refrigerated)	692	382	735	583	522	817	492
Warehouses (Refrigerated)	692	382	735	583	522	817	492

313 US Department of Energy. ENERGY STAR Calculator and Bin Analysis Models

### SECTION 3: Commercial and Industrial Measures

#### Wall and Ceiling Insulation

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Space and/or Building Type	Allentown	Erie	Harrisburg	Pittsburgh	Williamsport	Philadelphia	Scranton
Waste Water Treatment Plant	1,251	690	1,330	1,055	944	1,478	889

### 3.16.4 Measure Life

15 years

#### Source:

1. DEER uses 20 years; Northwest Regional Technical Forum uses 45 years. Capped based on the requirements of the Pennsylvania Technical Reference Manual (June 2010). This value is less than that used by other jurisdictions for insulation.

### 3.17 Strip Curtains for Walk-In Freezers and Coolers

Measure Name	Strip Curtains for Walk-In Coolers and Freezers
Target Sector	Commercial Refrigeration
Measure Unit	Walk-in unit door
Unit Energy Savings	Fixed
Unit Peak Demand Reduction	Fixed
Measure Life	4 years

Strip curtains are used to reduce the refrigeration load associated with the infiltration of non-refrigerated air into the refrigerated spaces of walk-in coolers or freezers.

The primary cause of air infiltration into walk-in coolers and freezers is the air density difference between two adjacent spaces of different temperatures. The total refrigeration load due to infiltration through the main door into the unit depends on the temperature differential between the refrigerated and non-refrigerated airs, the door area and height, and the duration and frequency of door openings. The avoided infiltration depends on the efficacy of the newly installed strip curtains as infiltration barriers<sup>314</sup>, and on the efficacy of the supplanted infiltration barriers, if applicable. The calculation of the refrigeration load due to air infiltration and the energy required to meet that load is rather straightforward, but relies on critical assumptions regarding the aforementioned operating parameters. All the assumptions in this protocol are based on values that were determined by direct measurement and monitoring of over 100 walk-in units in the 2006-2008 evaluation for the CA Public Utility Commission<sup>315</sup>.

#### 3.17.1 Eligibility

This protocol documents the energy savings attributed to strip curtains applied on walk-in cooler and freezer doors in commercial applications. The most likely areas of application are large and small grocery stores, supermarkets, restaurants and refrigerated warehouse. The baseline case is a walk-in cooler or freezer that previously had either no strip curtain installed or an old, ineffective strip curtain installed. The efficient equipment is a strip curtain added to a walk-in cooler or freezer. Strip curtains must be at least 0.06 inches thick. Low temp strip curtains must be used on low temp applications<sup>316</sup>.

#### 3.17.2 Algorithms

$$\Delta kWh = \Delta kWh/sqft \times A$$

$$\Delta kW_{peak} = \Delta kW/sqft \times A$$

<sup>314</sup> We define *curtain efficacy* as the fraction of the potential airflow that is blocked by an infiltration barrier. For example, a brick wall would have an efficacy of 1.0, while the lack of any infiltration barrier corresponds to an efficacy of 0.

<sup>315</sup> See source 1 for [Table 3-14](#) [Table 3-1214](#).

<sup>316</sup> [http://energysmartonline.org/documents/EnergySmart\\_BPA\\_T&Cs.pdf](http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf)

The annual energy savings due to infiltration barriers is quantified by multiplying savings per square foot by area using assumptions for independent variables described in the protocol introduction. The source algorithm from which the savings per square foot values are determined is based on Tamm's equation<sup>317</sup> (an application of Bernoulli's equation) and the ASHRAE handbook<sup>318</sup>. To the extent that evaluation findings are able to provide more reliable site specific inputs assumptions, they may be used in place of the default per square foot savings using the following equation.

$$\Delta kWh = 365 \times t_{open} \times (\eta_{new} - \eta_{old}) \times 20C_D \times A \times \left\{ \left[ \frac{(T_i - T_r)}{T_i} gH \right]^{0.5} \times \frac{(\rho_i h_i - \rho_r h_r)}{(3413 \times COP_{adj})} \right\} \times 60$$

The peak demand reduction is quantified by multiplying savings per square foot by area. The source algorithm is the annual energy savings divided by 8760. This assumption is based on general observation that refrigeration is constant for food storage, even outside of normal operating conditions. This is the most conservative approach in lieu of a more sophisticated model.

$$\Delta kW_{peak} = \Delta kWh / 8760$$

The ratio of the average energy usage during Peak hours to the total annual energy usage is taken from the load shape data collected by ADM for a recent evaluation for the CA Public Utility Commission<sup>319</sup> in the study of strip curtains in supermarkets, convenience stores, and restaurants.

### 3.17.3 Definition of Terms

The variables in the main equations are defined below:

$\Delta kWh/sqft$	= Average annual kWh savings per square foot of infiltration barrier
$\Delta kW/sqft$	= Average kW savings per square foot of infiltration barrier
A	= Doorway area, ft <sup>2</sup>

The variables in the source equation are defined below:

$t_{open}$	= Minutes walk-in door is open per day
$\eta_{new}$	= Efficacy of the new strip curtain – an efficacy of 1 corresponds to the strip curtain thwarting all infiltration, while an efficacy of zero corresponds to the absence of strip curtains.
$\eta_{old}$	= Efficacy of the old strip curtain

317 *Kalterverluste durch kuhlraumoffnungen*. Tamm W., Kältetechnik-Klimatisierung 1966;18;142-144

318 American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE). 2006. *ASHRAE Handbook, Refrigeration*: 13.4, 13.6

319 [http://www.calmac.org/publications/ComFac\\_Evaluation\\_V1\\_Final\\_Report\\_02-18-2010.pdf](http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf)

20	= Product of 60 minutes per hour and an integration factor of 1/3320
$C_D$	= Discharge Coefficient: empirically determined scale factors that account for differences between infiltration as rates predicted by application Bernoulli's law and actual observed infiltration rates
$T_i$	= Dry-bulb temperature of infiltrating air, Rankine
$T_r$	= Dry-bulb temperature of refrigerated air, Rankine
$g$	= Gravitational constant = 32.174 ft/s <sup>2</sup>
$H$	= Doorway height, ft
$h_i$	= Enthalpy of the infiltrating air, Btu/lb. Based on 55% RH.
$h_r$	= Enthalpy of the refrigerated air, Btu/lb. Based on 80% RH.
$\rho_i$	= Density of the infiltration air, lb/ft <sup>3</sup> . Based on 55% RH.
$\rho_r$	= Density of the refrigerated air, lb/ft <sup>3</sup> . Based on 80% RH.
3413	= Conversion factor: number of BTUs in one kWh
$COP_{adj}$	= Time-dependent (weather dependent) coefficient of performance of the refrigeration system. Based on nominal COP of 1.5 for freezers and 2.5 for coolers.
ETD	= Average Usage <sub>Peak</sub> / Annual Energy Usage

The default savings values are listed in [Table 3-58](#)~~Table 3-5658~~. Default parameters used in the source equations are listed in [Table 3-59](#)~~Table 3-5759~~, [Table 3-60](#)~~Table 3-5860~~, [Table 3-61](#)~~Table 3-5964~~, and [Table 3-62](#)~~Table 3-6062~~. The source equations and the values for the input parameters are adapted from the 2006-2008 California Public Utility Commission's evaluation of strip curtains<sup>321</sup>. The original work included 8760-hourly bin calculations. The values used

<sup>321</sup> In the original equation (Tamm's equation) the height is taken to be the difference between the midpoint of the opening and the 'neutral pressure level' of the cold space. In the case that there is just one dominant doorway through which infiltration occurs, the neutral pressure level is half the height of the doorway to the walk-in refrigeration unit. The refrigerated air leaks out through the lower half of the door, and the warm, infiltrating air enters through the top half of the door. We deconstruct the lower half of the door into infinitesimal horizontal strips of width  $W$  and height  $dh$ . Each strip is treated as a separate window, and the air flow through each infinitesimal strip is given by  $60 \times C_D \times A \times \left[ \frac{(T_i - T_r)}{T_i} \right] \times g \times \Delta H_{NPL} \}^{0.5}$  where  $\Delta H_{NPL}$  represents the distance to the vertical midpoint of the door. In effect, this replaces the implicit  $wh^{1.5}$  (one power from the area, and the other from  $\Delta H_{NPL}$ ) with the integral from 0 to  $h/2$  of  $wh^{0.5} dh$  which results in  $wh^{1.5} (3 \times 20.5)$ . For more information see: Are They Cool(ing)? Quantifying the Energy Savings from Installing / Repairing Strip Curtains, Alereza, Baroiant, Dohrmann, Mort, Proceedings of the 2008 IEPEC Conference.

<sup>321</sup> [http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EM+and+V/2006-](http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EM+and+V/2006-2008+Energy+Efficiency+Evaluation+Report.htm)

[2008+Energy+Efficiency+Evaluation+Report.htm](http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EM+and+V/2006-2008+Energy+Efficiency+Evaluation+Report.htm). The scale factors have been determined with tracer gas measurements on over 100 walk-in refrigeration units during the California Public Utility Commission's evaluation of the 2006-2008 CA investor owned utility energy efficiency programs. The door-open and close times, and temperatures of the infiltrating and refrigerated airs are taken from short-term monitoring of over 100 walk-in units. The temperature and humidity of the infiltrating air and the COP of the units have been modified to reflect the PA climate.

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### SECTION 3: Commercial and Industrial Measures

#### Strip Curtains for Walk-In Freezers and Coolers

herein represent annual average values. For example, the differences in the temperature between the refrigerated and infiltrating airs are averaged over all times that the door to the walk-in unit is open. Recommendations made by the evaluation team have been adopted to correct for errors observed in the ex ante savings calculation.

Table 3-585658: Deemed Energy Savings and Demand Reductions for Strip Curtains

Type	Pre-existing Curtains	Energy Savings $\Delta$ kWh/sqft	Demand Savings $\Delta$ kW/sqft
Supermarket - Cooler	Yes	37	0.0042
Supermarket - Cooler	No	108	0.0123
Supermarket - Cooler	Unknown	108	0.0123
Supermarket - Freezer	Yes	119	0.0136
Supermarket - Freezer	No	349	0.0398
Supermarket - Freezer	Unknown	349	0.0398
Convenience Store - Cooler	Yes	5	0.0006
Convenience Store - Cooler	No	20	0.0023
Convenience Store - Cooler	Unknown	11	0.0013
Convenience Store - Freezer	Yes	8	0.0009
Convenience Store - Freezer	No	27	0.0031
Convenience Store - Freezer	Unknown	17	0.0020
Restaurant - Cooler	Yes	8	0.0009
Restaurant - Cooler	No	30	0.0034
Restaurant - Cooler	Unknown	18	0.0020
Restaurant - Freezer	Yes	34	0.0039
Restaurant - Freezer	No	119	0.0136
Restaurant - Freezer	Unknown	81	0.0092
Refrigerated Warehouse	Yes	254	0.0290
Refrigerated Warehouse	No	729	0.0832
Refrigerated Warehouse	Unknown	287	0.0327

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Table 3-595759: Strip Curtain Calculation Assumptions for Supermarkets

Component	Type	Value		Source
		Cooler	Freezer	
$\eta_{\text{new}}$	Fixed	0.88	0.88	1
$\eta_{\text{old}}$ with Pre-existing curtain with no Pre-existing curtain unknown	Fixed	0.58	0.58	1
		0.00	0.00	
		0.00	0.00	
$C_D$	Fixed	0.366	0.415	1
$t_{\text{open}}$ (minutes/day)	Fixed	132	102	1
A (ft <sup>2</sup> )	Fixed	35	35	1
H (ft)	Fixed	7	7	1
$T_i$ (°F)	Fixed	71	67	1 and 2
$T_r$ (°F)	Fixed	37	5	1
$\rho_i$	Fixed	0.074	0.074	3
$h_i$	Fixed	26.935	24.678	3
$\rho_r$	Fixed	0.079	0.085	3
$h_r$	Fixed	12.933	2.081	3
$COP_{\text{adj}}$	Fixed	3.07	1.95	1 and 2

Table 3-605860: Strip Curtain Calculation Assumptions for Convenience Stores

Component	Type	Value		Source
		Cooler	Freezer	
$\eta_{\text{new}}$	Fixed	0.79	0.83	1
$\eta_{\text{old}}$ with Pre-existing curtain with no Pre-existing curtain unknown	Fixed	0.58	0.58	1
		0.00	0.00	
		0.34	0.30	
$C_D$	Fixed	0.348	0.421	1
$t_{\text{open}}$ (minutes/day)	Fixed	38	9	1
A (ft <sup>2</sup> )	Fixed	21	21	1
H (ft)	Fixed	7	7	1
$T_i$ (°F)	Fixed	68	64	1 and 2
$T_r$ (°F)	Fixed	39	5	1

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Component	Type	Value		Source
		Cooler	Freezer	
$\rho_i$	Fixed	0.074	0.075	3
$h_i$	Fixed	25.227	23.087	3
$\rho_r$	Fixed	0.079	0.085	3
$h_r$	Fixed	13.750	2.081	3
$COP_{adj}$	Fixed	3.07	1.95	1 and 2

Table 3-615961: Strip Curtain Calculation Assumptions for Restaurant

Component	Type	Value		Source
		Cooler	Freezer	
$\eta_{new}$	Fixed	0.80	0.81	1
$\eta_{old}$ with Pre-existing curtain with no Pre-existing curtain unknown	Fixed	0.58 0.00 0.33	0.58 0.00 0.26	1
$C_D$	Fixed	0.383	0.442	1
$t_{open}$ (minutes/day)	Fixed	45	38	1
A (ft <sup>2</sup> )	Fixed	21	21	1
H (ft)	Fixed	7	7	1
$T_i$ (°F)	Fixed	70	67	1 and 2
$T_r$ (°F)	Fixed	39	8	1
$\rho_i$	Fixed	0.074	0.074	3
$h_i$	Fixed	26.356	24.678	3
$\rho_r$	Fixed	0.079	0.085	3
$h_r$	Fixed	13.750	2.948	3
$COP_{adj}$	Fixed	3.07	1.95	1 and 2

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Table 3-626062: Strip Curtain Calculation Assumptions for Refrigerated Warehouse

Component	Type	Value	Source
$\eta_{new}$	Fixed	0.89	1
$\eta_{old}$ with Pre-existing curtain with no Pre-existing curtain unknown	Fixed	0.58 0.00 0.54	1
$C_D$	Fixed	0.425	1
$t_{open}$ (minutes/day)	Fixed	494	1
A (ft <sup>2</sup> )	Fixed	80	1
H (ft)	Fixed	10	1
$T_i$ (°F)	Fixed	59	1 and 2
$T_r$ (°F)	Fixed	28	1
$\rho_i$	Fixed	0.076	3
$h_i$	Fixed	20.609	3
$\rho_r$	Fixed	0.081	3
$h_r$	Fixed	9.462	3
$COP_{adj}$	Fixed	1.91	1 and 2

**Sources:**

1. [http://www.calmac.org/publications/ComFac\\_Evaluation\\_V1\\_Final\\_Report\\_02-18-2010.pdf](http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf). The scale factors have been determined with tracer gas measurements on over 100 walk-in refrigeration units during the California Public Utility Commission's evaluation of the 2006-2008 CA investor owned utility energy efficiency programs. The door-open and close times, and temperatures of the infiltrating and refrigerated airs are taken from short-term monitoring of over 100 walk-in units.
2. For refrigerated warehouses, we used a bin calculation method to weight the outdoor temperature by the infiltration that occurs at that outdoor temperature. This tends to shift the average outdoor temperature during times of infiltration higher (e.g. from 54 °F year-round average to 64 °F). We also performed the same exercise to find out effective outdoor temperatures to use for adjustment of nominal refrigeration system COPs.
3. Density and enthalpy of infiltrating and refrigerated air are based on psychometric equations based on the dry bulb temperature and relative humidity. Relative humidity is estimated to be 55% for infiltrating air and 80% for refrigerated air. Dry bulb temperatures were determined through the evaluation cited in Source 1.

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### 3.17.4 Measure Life

The measure life is estimated to be 4 years.

#### Sources:

1. Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation, [http://www.calmac.org/publications/ComFac\\_Evaluation\\_V1\\_Final\\_Report\\_02-18-2010.pdf](http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf)
2. The Measure Life Report for Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007

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### 3.17.5 Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings according to store type. The strip curtains are not expected to be installed directly. As such, the program tracking / evaluation effort must capture the following key information:

- Fraction of strip curtains installed in each of the categories (e.g. freezer / cooler and store type)
- Fraction of customers that had pre-existing strip curtains

The rebate forms should track the above information. During the M&V process, interviews with site contacts should track this fraction, and savings should be adjusted accordingly.

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### 3.18 Water Source and Geothermal Heat Pumps

This protocol shall apply to ground source, groundwater source, [water source heat pumps](#), and water source [heat pumps and evaporatively cooled air conditioners](#) in commercial applications as further described below. This measure may apply to early replacement of an existing system, replacement on burnout, or installation of a new unit in a new or existing non-residential building for HVAC applications. The base case may employ a different system than the retrofit case.

#### 3.18.1 Eligibility

In order for this characterization to apply, the efficient equipment is a high-efficiency groundwater source, water source, or ground source heat pump system that meets or exceeds the energy efficiency requirements of the International Energy Conservation Code (IECC) 2009, Table 503.2.3(2). The following retrofit scenarios are considered:

- Ground source heat pumps for existing or new non-residential HVAC applications
- Groundwater source heat pumps for existing or new non-residential HVAC applications
- Water source heat pumps for existing or new non-residential HVAC applications

These retrofits reduce energy consumption by the improved thermodynamic efficiency of the refrigeration cycle of new equipment, by improving the efficiency of the cooling and heating cycle, and by lowering the condensing temperature when the system is in cooling mode and raising the evaporating temperature when the equipment is in heating mode as compared to the base case heating or cooling system. It is expected that the retrofit system will use a similar conditioned-air distribution system as the base case system.

This protocol does not apply to heat pump systems coupled with non-heat pump systems such as chillers, rooftop AC units, boilers, or cooling towers. Projects that use unique, combined systems such as these should use a site-specific M&V plan (SSMVP) to describe the particulars of the project and how savings are calculated.

#### Definition of Baseline Equipment

In order for this protocol to apply, the baseline equipment could be a standard-efficiency air source, water source, groundwater source, or ground source heat pump system, or an electric chiller and boiler system, or other chilled/hot water loop system. To calculate savings, the baseline system type is assumed to be an air source heat pump of similar size except for cases where the project is replacing a ground source, groundwater source, or water source heat pump; in those cases, the baseline system type is assumed to be a similar system at code.

Table 3-636163: Water Source or Geothermal Heat Pump Baseline Assumptions

Baseline Scenario		Baseline Efficiency Assumptions
New Construction		Standard efficiency air source heat pump system
Retrofit	Replacing any technology besides a ground source, groundwater source, or water source heat pump	Standard efficiency air source heat pump system
	Replacing a ground source, groundwater source, or water source heat pump	Efficiency of the replaced geothermal system for early replacement only (if known), else code for a similar system

### 3.18.2 Algorithms

There are three primary components that must be accounted for in the energy and demand calculations. The first component is the heat pump unit energy and power, the second is the circulating pump in the ground/water loop system energy and power, and the third is the well pump in the ground/water loop system energy and power. For projects where the retrofit system is similar to the baseline system, such as a standard efficiency ground source system replaced with a high efficiency ground source system, the pump energy is expected to be the same for both conditions and does not need to be calculated. The kWh savings should be calculated using the basic equations below.

**For air-cooled base case units with cooling capacities less than 65 kBtu/h:**

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat} + \Delta kWh_{pump}$$

$$\Delta kWh_{cool} = \left\{ \left( \frac{BtuH_{cool}}{1000} \right) \times \left( \frac{1}{SEER_{base}} \right) \times EFLH_{cool} \right\} - \left\{ \left( \frac{BtuH_{cool}}{1000} \right) \times \left( \frac{1}{EER_{ee}} \right) \times EFLH_{cool} \right\}$$

$$\Delta kWh_{heat} = \left\{ \left( \frac{BtuH_{heat}}{1000} \right) \times \left( \frac{1}{HSPF_{base}} \right) \times EFLH_{heat} \right\} - \left\{ \left( \frac{BtuH_{heat}}{1000} \right) \times \left( \frac{1}{COP_{ee}} \right) \times \left( \frac{1}{3.412} \right) \times EFLH_{heat} \right\}$$

$$\Delta kWh_{pump} = \left\{ \left( HP_{basemotor} \times LF_{base} \times 0.746 \times \left( \frac{1}{\eta_{basemotor}} \right) \times \left( \frac{1}{\eta_{basepump}} \right) \times \left( HOURS_{basepump} \right) \right\} - \left\{ \left( HP_{eemotor} \times LF_{ee} \times 0.746 \times \left( \frac{1}{\eta_{eemotor}} \right) \times \left( \frac{1}{\eta_{eepump}} \right) \times \left( HOURS_{eepump} \right) \right\}$$

$$\Delta kW_{peak} = \Delta kW_{peak cool} + \Delta kW_{peak pump}$$

$$\Delta kW_{peak cool} = \left\{ \left( \frac{BtuH_{cool}}{1000} \right) \times \left[ \left( \frac{1}{EER_{base}} \right) \right] \times CF_{cool} \right\} - \left\{ \left( \frac{BtuH_{cool}}{1000} \right) \times \left[ \left( \frac{1}{EER_{ee}} \right) \right] \times CF_{cool} \right\}$$

$$\Delta kW_{peak pump} = \left\{ \left( HP_{basemotor} \times LF_{base} \times 0.746 \times \left( \frac{1}{\eta_{basemotor}} \right) \times \left( \frac{1}{\eta_{basepump}} \right) \times CF_{pump} \right\} - \left\{ \left( HP_{eemotor} \times LF_{ee} \times 0.746 \times \left( \frac{1}{\eta_{eemotor}} \right) \times \left( \frac{1}{\eta_{eepump}} \right) \right\} \times CF_{pump}$$

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**For air-cooled base case units with cooling capacities equal to or greater than 65 kBtu/h, and all other units:**

$$\begin{aligned} \Delta kWh &= \Delta kWh_{cool} + \Delta kWh_{heat} + \Delta kWh_{pump} \\ \Delta kWh_{cool} &= \{(BtuH_{cool}/1000) \times (1/EER_{base}) \times EFLH_{cool}\} - \{(BtuH_{cool}/1000) \times (1/EER_{ee}) \times EFLH_{cool}\} \\ \Delta kWh_{heat} &= \{(BtuH_{heat}/1000) \times (1/COP_{base}) \times (1/3.412) \times EFLH_{heat}\} - \{(BtuH_{heat}/1000) \times (1/COP_{ee}) \times (1/3.412) \times EFLH_{heat}\} \\ \Delta kWh_{pump} &= \{(HP_{basemotor} \times LF_{base} \times 0.746 \times (1/\eta_{basemotor}) \times (1/\eta_{basepump}) \times (HOURS_{basepump})\} - \{(HP_{eemotor} \times LF_{ee} \times 0.746 \times (1/\eta_{eemotor}) \times (1/\eta_{eepump}) \times (HOURS_{eepump})\} \\ \Delta kW_{peak} &= \Delta kW_{peak cool} + \Delta kW_{peak pump} \\ \Delta kW_{peak cool} &= \{(BtuH_{cool}/1000) \times [(1/EER_{base})] \times CF_{cool}\} - \{(BtuH_{cool}/1000) \times [(1/EER_{ee})] \times CF_{cool}\} \\ \Delta kW_{peak pump} &= \{HP_{basemotor} \times LF_{base} \times 0.746 \times (1/\eta_{basemotor}) \times (1/\eta_{basepump}) \times CF_{pump}\} - \{HP_{eemotor} \times LF_{ee} \times 0.746 \times (1/\eta_{eemotor}) \times (1/\eta_{eepump})\} \times CF_{pump} \end{aligned}$$

### 3.18.3 Definition of Terms

$BtuH_{cool}$	= Rated cooling capacity of the energy efficient unit in $BtuH_{cool}$ /hour
$BtuH_{heat}$	= Rated heating capacity of the energy efficient unit in $BtuH_{heat}$ /hour
$SEER_{base}$	= the cooling SEER of the baseline unit
$EER_{base}$	= the cooling EER of the baseline unit
$HSPF_{base}$	= Heating Season Performance Factor of the Baseline Unit
$COP_{base}$	= Coefficient of Performance of the Baseline Unit
$EER_{ee}$	= the cooling EER of the new ground source, groundwater source, or water source heat pumpground being installed
$COP_{ee}$	= Coefficient of Performance of the new ground source, groundwater source, or water source heat pump being installed
$EFLH_{cool}$	= Cooling annual Equivalent Full Load Hours EFLH for Commercial HVAC for different occupancies
$EFLH_{heat}$	= Heating annual Equivalent Full Load Hours EFLH for Commercial HVAC for different occupancies

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$CF_{cool}$	= Demand Coincidence Factor (See Section 1.4)01.4) for Commercial HVAC
$CF_{pump}$	= Demand Coincidence Factor (See Section 1.4)01.4) for ground source loop pump
$HP_{basemotor}$	= Horsepower of base case ground loop pump motor
$LF_{base}$	= Load factor of the base case ground loop pump motor; Ratio of the peak running load to the nameplate rating of the pump motor.
$\eta_{basemotor}$	= efficiency of base case ground loop pump motor
$\eta_{basepump}$	= efficiency of base case ground loop pump at design point
$HOURS_{basepump}$	= Run hours of base case ground loop pump motor
$HP_{eemotor}$	= Horsepower of retrofit case ground loop pump motor
$LF_{ee}$	= Load factor of the retrofit case ground loop pump motor; Ratio of the peak running load to the nameplate rating of the pump motor.
$\eta_{eemotor}$	= efficiency of retrofit case ground loop pump motor
$\eta_{eepump}$	= efficiency of retrofit case ground loop pump at design point
$HOURS_{eepump}$	= Run hours of retrofit case ground loop pump motor
3.412	= kBtu per kWh
0.746	= conversion factor from horsepower to kW (kW/hp)

Table 3-646264: Geothermal Heat Pump– Values and References

Component	Type	Values	Sources
BtuH <sub>cool</sub>	Variable	Nameplate data (ARI or AHAM)	EDC Data Gathering
BtuH <sub>heat</sub>	Variable	Nameplate data (ARI or AHAM) Use BtuH <sub>cool</sub> if the heating capacity is not known	EDC Data Gathering
SEER <sub>base</sub>	Fixed	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from <a href="#">Table 3-67Table 3-6567</a>	See <a href="#">Table 3-67Table 3-6567</a>
EER <sub>base</sub>	Fixed	Early Replacement: Nameplate data = SEER <sub>base</sub> X (11.3/13) if EER not available <sup>322</sup>	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from <a href="#">Table 3-67Table 3-6567</a>	See <a href="#">Table 3-67Table 3-6567</a>
HSPF <sub>base</sub>	Fixed	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from <a href="#">Table 3-67Table 3-6567</a>	See <a href="#">Table 3-67Table 3-6567</a>
COP <sub>base</sub>	Fixed	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from <a href="#">Table 3-67Table 3-6567</a>	See <a href="#">Table 3-67Table 3-6567</a>
EER <sub>ee</sub>	Variable	Nameplate data (ARI or AHAM) = SEER <sub>ee</sub> X (11.3/13) if EER not available <sup>323</sup>	EDC Data Gathering
COP <sub>ee</sub>	Variable	Nameplate data (ARI or AHAM)	EDC Data Gathering
EFLH <sub>cool</sub>	Variable	Based on Logging, <a href="#">BMS data</a> or Modeling <sup>324</sup>	EDC Data Gathering
		Default values from <a href="#">Table 3-23Table 3-2123</a> and <a href="#">Table 3-24Table 3-2224</a>	See <a href="#">Table 3-23Table 3-2123</a> and <a href="#">Table 3-24Table 3-2224</a>
EFLH <sub>heat</sub>	Variable	Based on Logging, <a href="#">BMS data</a> or Modeling <sup>325</sup>	EDC Data Gathering
		Default values from <a href="#">Table 3-23Table 3-2123</a> and <a href="#">Table 3-24Table 3-2224</a>	See <a href="#">Table 3-23Table 3-2123</a> and <a href="#">Table 3-24Table 3-2224</a>
CF <sub>cool</sub>	Fixed	Default = 0.80	3

<sup>322</sup> 11.3/13 = Conversion factor from SEER to EER, based on average EER of a SEER 13 unit.

<sup>323</sup> 11.3/13 = Conversion factor from SEER to EER, based on average EER of a SEER 13 unit.

<sup>324</sup> Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

<sup>325</sup> Ibid.

### SECTION 3: Commercial and Industrial Measures

#### Water Source and Geothermal Heat Pumps

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Component	Type	Values	Sources
CF <sub>pump</sub>	Fixed	If unit runs 24/7/365, default = 1.0; If unit runs only with heat pump unit compressor, default = 0.67	4
HP <sub>basemotor</sub>	Variable	Nameplate	EDC Data Gathering
LF <sub>base</sub>	Variable	Based on spot metering <u>and nameplate</u> .	EDC Data Gathering
		Default 75%	1
$\eta$ <sub>basemotor</sub>	Variable	Nameplate	EDC's Data Gathering
		If unknown, assume the federal minimum efficiency requirements in <a href="#">Table 3-65Table-3-6365</a>	See <a href="#">Table 3-65Table-3-6365</a>
$\eta$ <sub>basepump</sub>	Variable	Nameplate	EDC's Data Gathering
		If unknown, assume program compliance efficiency in <a href="#">Table 3-66Table 3-6466</a>	See <a href="#">Table 3-66Table-3-6466</a>
HOURS <sub>basepump</sub>	Fixed	Based on Logging, <a href="#">BMS data</a> or Modeling <sup>326</sup>	EDC's Data Gathering
		EFLH <sub>cool</sub> + EFLH <sub>heat</sub> <sup>327</sup> Default values from <a href="#">Table 3-23Table 3-2123</a> and <a href="#">Table 3-24Table 3-2224</a>	2
HP <sub>eemotor</sub>	Variable	Nameplate	EDC's Data Gathering
LF <sub>ee</sub>	Variable	Based on spot metering <u>and nameplate</u> .	EDC Data Gathering
		Default 75%	1
$\eta$ <sub>eemotor</sub>	Variable	Nameplate	EDC's Data Gathering
		If unknown, assume the federal minimum efficiency requirements in <a href="#">Table 3-65Table-3-6365</a>	<a href="#">Table 3-63Table 3-65</a>
$\eta$ <sub>eepump</sub>	Variable	Nameplate	EDC's Data Gathering
		If unknown, assume program compliance efficiency in <a href="#">Table 3-66Table 3-6466</a>	See <a href="#">Table 3-66Table-3-6466</a>
HOURS <sub>eepump</sub>	Variable	Based on Logging, <a href="#">BMS data</a> or Modeling <sup>328</sup>	EDC Data Gathering
		EFLH <sub>cool</sub> + EFLH <sub>heat</sub> <sup>329</sup> Default values from <a href="#">Table 3-23Table 3-2123</a> and <a href="#">Table 3-24Table 3-2224</a>	2

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**Sources:**

1. California Public Utility Commission. *Database for Energy Efficiency Resources* 2005
2. Provides a conservative estimate in the absence of logging or modeling data.

[326 Ibid](#)

<sup>327</sup> EFLH<sub>cool</sub> + EFLH<sub>heat</sub> represent the addition of cooling and heating annual equivalent full load hours for commercial HVAC for different occupancies, respectively.

[328 Ibid](#)

<sup>329</sup> EFLH<sub>cool</sub> + EFLH<sub>heat</sub> represent the addition of cooling and heating annual equivalent full load hours for commercial HVAC for different occupancies, respectively.

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**SECTION 3: Commercial and Industrial Measures****Water Source and Geothermal Heat Pumps**

3. Average based on coincidence factors from Ohio, New Jersey, Mid-Atlantic, Massachusetts, Connecticut, Illinois, New York, CEE and Minnesota. (74%, 67%, 81%, 94%, 82%, 72%, 100%, 70% and 76% respectively)
4. Engineering Estimate - See definition in section 3.3.2 for specific algorithm to be used when performing spot metering analysis to determine alternate load factor.

Table 3-~~656365~~: Federal Minimum Efficiency Requirements for Motors330

Size HP	Open Drip Proof (ODP) # of Poles			Totally Enclosed Fan-Cooled (TEFC)		
	6	4	2	6	4	2
	Speed (RPM)			Speed (RPM)		
	1200	1800	3600	1200	1800	3600
1	82.50%	85.50%	77.00%	82.50%	85.50%	77.00%
1.5	86.50%	86.50%	84.00%	87.50%	86.50%	84.00%
2	87.50%	86.50%	85.50%	88.50%	86.50%	85.50%
3	88.50%	89.50%	85.50%	89.50%	89.50%	86.50%
5	89.50%	89.50%	86.50%	89.50%	89.50%	88.50%
7.5	90.20%	91.00%	88.50%	91.00%	91.70%	89.50%
10	91.70%	91.70%	89.50%	91.00%	91.70%	90.20%
15	91.70%	93.00%	90.20%	91.70%	92.40%	91.00%
20	92.40%	93.00%	91.00%	91.70%	93.00%	91.00%

Table 3-~~666466~~: Ground/Water Loop Pump and Circulating Pump Efficiency331

HP	Minimum Pump Efficiency at Design Point ( $\eta_{\text{pump}}$ )
1.5	65%
2	65%
3	67%
5	70%
7.5	73%
10	75%
15	77%
20	77%

330 Table is based on NEMA premium efficiency motor standards. Source to the table can be found at: <http://www.nema.org/stds/complimentary-docs/upload/MG1premium.pdf>  
 331 Based on program requirements submitted during protocol review.

### SECTION 3: Commercial and Industrial Measures

#### Water Source and Geothermal Heat Pumps

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Table 3-676567: Default Baseline Equipment Efficiencies

Equipment Type and Capacity	Cooling Baseline	Heating Baseline
<b>Air-Source Air Conditioners</b>		
< 65,000 BtuH	13.0 SEER	N/A
≥ 65,000 BtuH and <135,000 BtuH	11.2 EER	N/A
≥ 135,000 BtuH and < 240,000 BtuH	11.0 EER	N/A
≥ 240,000 BtuH and < 760,000 BtuH (IPLV for units with capacity modulation only)	10.0 EER / 9.7 IPLV	N/A
≥ 760,000 BtuH (IPLV for units with capacity modulation only)	9.7 EER / 9.4 IPLV	N/A
<b>Water-Source and Evaporatively-Cooled Air Conditioners</b>		
< 65,000 BtuH	12.1 EER	N/A
≥ 65,000 BtuH and <135,000 BtuH	11.5 EER	N/A
≥ 135,000 BtuH and < 240,000 BtuH	11.0 EER	N/A
≥ 240,000 BtuH	11.5 EER	N/A
<b>Air-Source Heat Pumps</b>		
< 65,000 BtuH	13 SEER	7.7 HSPF
≥ 65,000 BtuH and <135,000 BtuH	11.0 EER	3.3 COP
≥ 135,000 BtuH and < 240,000 BtuH	10.6 11.5 EER	3.2 COP/N/A
≥ 240,000 BtuH (IPLV for units with capacity modulation only)	9.5 EER / 9.2 IPLV	3.2 COP
<b>Water-Source Heat Pumps</b>		
< 17,000 BtuH	11.2 EER	4.2 COP
≥ 17,000 BtuH and ≤ 65,000 BtuH	12.0 EER	4.2 COP
<b>Ground Water Source Heat Pumps</b>		
< 135,000 BtuH	16.2 EER	3.6 COP
<b>Ground Source Heat Pumps</b>		
< 135,000 BtuH	13.4 EER	3.1 COP
<b>Packaged Terminal Systems (Replacements)332</b>		
PTAC (cooling)	$10.9 - (0.213 \times \text{Cap} / 1000)$ EER	
PTHP	$10.8 - (0.213 \times \text{Cap} / 1000)$ EER	$2.9 - (0.026 \times \text{Cap} / 1000)$ COP
<b>Packaged Terminal Systems (New Construction)333</b>		
PTAC (cooling)	$12.5 - (0.213 \times \text{Cap} / 1000)$ EER	
PTHP	$12.3 - (0.213 \times \text{Cap} / 1000)$ EER	$3.2 - (0.026 \times \text{Cap} / 1000)$ COP

332-Cap represents the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the calculation.  
 333-Cap represents the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the calculation.

**SECTION 3: Commercial and Industrial Measures**

**Water Source and Geothermal Heat Pumps**

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### 3.18.4 Measure Life

The expected measure life is assumed to be 15 years.<sup>334</sup>

### 3.18.5 Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with ~~assignment of stipulated energy savings.~~ [EDC Data Gathering.](#)

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<sup>334</sup> Measure Life Report: Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007.

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### 3.19 Ductless Mini-Split Heat Pumps – Commercial < 5.4 tons

Measure Name	Ductless Heat Pumps
Target Sector	Commercial (non-residential) Establishments
Measure Unit	Ductless Heat Pumps
Unit Energy Savings	Variable based on efficiency of systems
Unit Peak Demand Reduction	Variable based on efficiency of systems
Measure Life	15

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ENERGY STAR ductless “mini-split” heat pumps (DHP) utilize high efficiency SEER/EER and HSPF energy performance factors of 14.5/12 and 8.2, respectively, or greater. This technology typically converts an electric resistance heated space into a space heated/cooled with a single or multi-zonal ductless heat pump system.

#### 3.19.1 Eligibility

This protocol documents the energy savings attributed to ENERGY STAR ductless mini-split heat pumps with energy-efficiency performance of 14.5/12 SEER/EER and 8.2 HSPF or greater with inverter technology.<sup>335</sup> The baseline heating system could be an existing electric resistance, a lower-efficiency ductless heat pump system, a ducted heat pump, packaged terminal heat pump (PTHP), electric furnace, or a non-electric fuel-based system. The baseline cooling system could be a standard efficiency heat pump system, central air conditioning system, packaged terminal air conditioner (PTAC), or room air conditioner. The DHP could be a new device in an existing space, a new device in a new space, or could replace an existing heating/cooling device. The DHP systems could be installed as a single-zone system (one indoor unit, one outdoor unit) or a multi-zone system (multiple indoor units, one outdoor unit).

#### 3.19.2 Algorithms

The savings depend on three main factors: baseline condition, usage, and the capacity of the indoor unit.

The algorithm is separated into two calculations: single zone and multi-zone ductless heat pumps. The savings algorithm is as follows:

For Heat Pump units < 65,000 BtuH, use SEER to calculate  $\Delta kWh_{cool}$  and HSPF to calculate  $\Delta kWh_{heat}$ . Convert SEER to EER to calculate  $\Delta kW_{peak}$  using 11.3/13 as the conversion factor.

##### Single Zone:

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{heat} = CAPY_{heat} / 1000 \times (1/HSPF_b - 1/HSPF_e) \times EFLH_{heat} \times LF$$

<sup>335</sup> The measure energy efficiency performance is based on ENERGY STAR minimum specification requirements as specified in ARHI and CEE directory for ductless mini-split heat pumps. Ductless heat pumps fit these criteria and can easily exceed SEER levels of 16 or greater.

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$$\Delta kWh_{cool} = CAPY_{cool} / 1000 \times (1/SEER_b - 1/SEER_e) \times EFLH_{cool} \times LF$$

$$\Delta kW_{peak} = CAPY_{cool} / 1000 \times (1/EER_b - 1/EER_e) \times CF$$

**Multi-Zone:**

$$\Delta kWh = \Delta kWh_{cool} + \Delta kWh_{heat}$$

$$\Delta kWh_{heat} = [CAPY_{heat} / 1000 \times (1/HSPF_b - 1/HSPF_e) \times EFLH_{heat} \times LF]_{ZONE1} + [CAPY_{heat} / 1000 \times (1/HSPF_b - 1/HSPF_e) \times EFLH_{heat} \times LF]_{ZONE2} + [CAPY_{heat} / 1000 \times (1/HSPF_b - 1/HSPF_e) \times EFLH_{heat} \times LF]_{ZONE n}$$

$$\Delta kWh_{cool} = [CAPY_{cool} / 1000 \times (1/SEER_b - 1/SEER_e) \times EFLH_{cool} \times LF]_{ZONE1} + [CAPY_{cool} / 1000 \times (1/SEER_b - 1/SEER_e) \times EFLH_{cool} \times LF]_{ZONE2} + [CAPY_{cool} / 1000 \times (1/SEER_b - 1/SEER_e) \times EFLH_{cool} \times LF]_{ZONE n}$$

$$\Delta kW_{peak} = [CAPY_{cool} / 1000 \times (1/EER_b - 1/EER_e) \times CF]_{ZONE1} + [CAPY_{cool} / 1000 \times (1/EER_b - 1/EER_e) \times CF]_{ZONE2} + [CAPY_{cool} / 1000 \times (1/EER_b - 1/EER_e) \times CF]_{ZONE n}$$

**3.19.3 Definition of Terms**

$CAPY_{cool}$  = The cooling capacity of the indoor unit, given in BTUH as appropriate for the calculation. This protocol is limited to units < 65,000 BTUh (5.4 tons)

$CAPY_{heat}$  = The heating capacity of the indoor unit, given in BTUH as appropriate for the calculation.

$EFLH_{cool}$  = Equivalent Full Load Hours for cooling

$EFLH_{heat}$  = Equivalent Full Load Hours for heating

$HSPF_b$  = Heating Seasonal Performance Factor, heating efficiency of baseline unit

$HSPF_e$  = Heating Seasonal Performance Factor, heating efficiency of the installed DHP

$SEER_b$  = Seasonal Energy Efficiency Ratio cooling efficiency of baseline unit

$SEER_e$  = Seasonal Energy Efficiency Ratio cooling efficiency of the installed DHP

$LF$  = Load factor

$CF$  = Demand Coincidence Factor (See Section 1.4)

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Table 3-686668: DHP – Values and References

Component	Type	Values	Sources
CAPY <sub>cool</sub> CAPY <sub>heat</sub>	Variable	Nameplate	AEPS Application; EDC Data Gathering
EFLH <sub>cool</sub> EFLH <sub>heat</sub>	FixedVariable	Default: See Table 3-69: Table 3-67: 69 and Table 3-70: Table 3-68: 70  Based on Logging, BMS data or Modeling <sup>336</sup>	1  EDC Data Gathering
HSPF <sub>b</sub>	Fixed	Standard DHP: 7.7 Electric resistance: 3.413 ASHP: 7.7 PTHP337 (Replacements): 2.9 - (0.026 x Cap / 1000) COP PTHP (New Construction): 3.2 - (0.026 x Cap / 1000) COP Electric furnace: 3.242 For new space, no heat in an existing space, or non-electric heating in an existing space: use standard DHP: 7.7	2, 4,9
SEER <sub>b</sub>	Fixed	DHP, ASHP, or central AC: 13 Room AC: 11.3 PTAC338 (Replacements): 10.9 - (0.213 x Cap / 1000) EER PTAC (New Construction): 12.5 - (0.213 x Cap / 1000) EER PTHP (Replacements): 10.8 - (0.213 x Cap / 1000) EER PTHP (New Construction): 12.3 - (0.213 x Cap / 1000) EER For new space or no cooling in an existing space: use Central AC: 13	3,4,5,7,9
HSPF <sub>e</sub>	Variable	Based on nameplate information. Should be at least ENERGY STAR.	AEPS Application; EDC Data Gathering
SEER <sub>e</sub>	Variable	Based on nameplate information. Should be at least ENERGY STAR.	AEPS Application; EDC Data Gathering
CF	Fixed	70%	6

Merged Cells  
Merged Cells

336 Ibid

337 Cap represents the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the calculation. Use HSPF = COP X 3.413.

338 Cap represents the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the calculation. Use SEER = EER X (13/11.3).

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**SECTION 3: Commercial and Industrial Measures**

Ductless Mini-Split Heat Pumps – Commercial < 5.4 tons

Component	Type	Values	Sources
LF	FixedVariable	25%	8
		Based on spot metering and nameplate	EDC Data Gathering

Merged Cells

Merged Cells

**Sources:**

1. US Department of Energy. ENERGY STAR Calculator and Bin Analysis Models.
2. COP = HSPF/3.413. HSPF = 3.413 for electric resistance heating, HSPF = 7.7 for standard DHP. Electric furnace COP typically varies from 0.95 to 1.00 and thereby assumed a COP 0.95 (HSPF = 3.242).
3. Federal Register, Vol. 66, No. 14, Monday, January 22, 2001/Rules and Regulations, p. 7170-7200.
4. Air-Conditioning, Heating, and Refrigeration Institute (AHRI); the directory of the available ductless mini-split heat pumps and corresponding efficiencies (lowest efficiency currently available). Accessed 8/16/2010.
5. SEER based on average EER of 9.8 for room AC unit. From Pennsylvania's Technical Reference Manual.
6. Based on an analysis of six different utilities by Proctor Engineering. From Pennsylvania's Technical Reference Manual.
7. Average EER for SEER 13 unit. From Pennsylvania's Technical Reference Manual.
8. The load factor is used to account for inverter-based DHP units operating at partial loads. The value was chosen to align savings with what is seen in other jurisdictions: based on personal communication with Bruce Manclark, Delta-T, Inc. who is working with Northwest Energy Efficiency Alliance (NEEA) on the Northwest DHP Project <<http://www.nwductless.com/>>, and the results found in the "Ductless Mini Pilot Study" by KEMA, Inc., June 2009. The adjustment is required to account for partial load conditions and because the EFLH used are based on central ducted systems which may overestimate actual usage for baseboard systems.
9. Package terminal air conditioners (PTAC) and package terminal heat pumps (PTHP) COP and EER minimum efficiency requirements is based on CAPY value. If the unit's capacity is less than 7,000 BTUH, use 7,000 BTUH in the calculation. If the unit's capacity is greater than 15,000 BTUH, use 15,000 BTUH in the calculation.

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Table 3-696769: Cooling EFLH for Pennsylvania Cities339-340-341

Space and/or Building Type	Allentown	Erie	Harrisburg	Pittsburgh	Williamsport	Philadelphia	Scranton
Arena/Auditorium/Convention Center	602	332	640	508	454	711	428
College: Classes/Administrative	690	380	733	582	520	815	490
Convenience Stores	1,216	671	1,293	1,026	917	1,436	864
Dining: Bar Lounge/Leisure	912	503	969	769	688	1,077	648
Dining: Cafeteria / Fast Food	1,227	677	1,304	1,035	925	1,449	872
Dining: Restaurants	912	503	969	769	688	1,077	648
Gymnasium/Performing Arts Theatre	690	380	733	582	520	815	490
Hospitals/Health care	1,396	770	1,483	1,177	1,052	1,648	992
Industrial: 1 Shift/Light Manufacturing	727	401	773	613	548	859	517
Industrial: 2 Shift	988	545	1,050	833	745	1,166	702
Industrial: 3 Shift	1,251	690	1,330	1,055	944	1,478	889
Lodging: Hotels/Motels/Dormitories	756	418	805	638	571	894	538
Lodging: Residential	757	418	805	638	571	894	538
Multi-Family (Common Areas)	1,395	769	1,482	1,176	1,052	1,647	991
Museum/Library	851	469	905	718	642	1,005	605
Nursing Homes	1,141	630	1,213	963	861	1,348	811
Office: General/Retail	851	469	905	718	642	1,005	605
Office: Medical/Banks	851	469	905	718	642	1,005	605
Parking Garages & Lots	938	517	997	791	707	1,107	666
Penitentiary	1,091	602	1,160	920	823	1,289	775
Police/Fire Stations (24 Hr)	1,395	769	1,482	1,176	1,052	1,647	991
Post Office/Town Hall/Court House	851	469	905	718	642	1,005	605
Religious Buildings/Church	602	332	640	508	454	711	428
Retail	894	493	950	754	674	1,055	635
Schools/University	634	350	674	535	478	749	451
Warehouses (Not Refrigerated)	692	382	735	583	522	817	492
Warehouses (Refrigerated)	692	382	735	583	522	817	492
Waste Water Treatment Plant	1,251	690	1,330	1,055	944	1,478	889

339 US Department of Energy. Energy Star Calculator and Bin Analysis Models

340 A zip code mapping table is located in Appendix F. This table should be used to identify the reference Pennsylvania city for all zip codes in Pennsylvania

341 US Department of Energy. Energy Star Calculator and Bin Analysis Models

### SECTION 3: Commercial and Industrial Measures

Ductless Mini-Split Heat Pumps – Commercial < 5.4 tons

Page 333

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Table 3-~~706870~~: Heating EFLH for Pennsylvania Cities 342: 343- 344

Space and/or Building Type	Allentown	Erie	Harrisburg	Pittsburgh	Williamsport	Philadelphia	Scranton
Arena/Auditorium/Convention Center	1,719	2,002	1,636	1,642	1,726	1,606	1,747
College: Classes/Administrative	1,559	1,815	1,484	1,489	1,565	1,457	1,584
Convenience Stores	603	<u>3,1487</u> <u>01</u>	<u>2,573</u>	<u>2,5825</u> <u>76</u>	<u>2,7156</u> <u>05</u>	<u>2,5265</u> <u>63</u>	<u>2,7476</u> <u>12</u>
Dining: Bar Lounge/Leisure	1,156	1,346	1,100	1,104	1,161	1,080	1,175
Dining: Cafeteria / Fast Food	582	<u>2,0666</u> <u>78</u>	<u>1,6895</u> <u>54</u>	<u>1,6955</u> <u>56</u>	<u>1,7825</u> <u>85</u>	<u>1,6585</u> <u>44</u>	<u>1,8035</u> <u>92</u>
Dining: Restaurants	1,156	1,346	1,100	1,104	1,161	1,080	1,175
Gymnasium/Performing Arts Theatre	1,559	1,815	1,484	1,489	1,565	1,457	1,584
Hospitals/Health care	276	321	263	264	277	<u>2,5262</u> <u>58</u>	280
Industrial: 1 Shift/Light Manufacturing	1,491	1,737	1,420	1,425	1,498	1,394	1,516
Industrial: 2 Shift	1,017	1,184	968	972	1,022	951	1,034
Industrial: 3 Shift	538	626	512	513	540	502	546
Lodging: Hotels/Motels/Dormitories	1,438	1,675	1,369	1,374	1,444	1,344	1,462
Lodging: Residential	1,438	1,675	1,369	1,374	1,444	1,344	1,462
Multi-Family (Common Areas)	277	<u>3,1483</u> <u>22</u>	<u>2,5732</u> <u>63</u>	<u>2,5822</u> <u>64</u>	<u>2,7152</u> <u>78</u>	<u>2,5262</u> <u>59</u>	<u>2,7472</u> <u>81</u>
Museum/Library	1,266	1,474	1,205	1,209	1,271	1,183	1,286
Nursing Homes	738	<u>3,1488</u> <u>59</u>	<u>2,5737</u> <u>02</u>	<u>2,5827</u> <u>04</u>	<u>2,7157</u> <u>40</u>	<u>2,5266</u> <u>89</u>	<u>2,7477</u> <u>49</u>
Office: General/Retail	1,266	<u>8841,4</u> <u>74</u>	<u>7221,2</u> <u>05</u>	<u>7251,2</u> <u>09</u>	<u>7621,2</u> <u>71</u>	<u>7091,1</u> <u>83</u>	<u>7741,2</u> <u>86</u>
Office: Medical/Banks	1,266	1,474	1,205	1,209	1,271	1,183	1,286
Parking Garages & Lots	1,110	1,292	1,056	1,060	1,114	1,037	1,128
Penitentiary	829	<u>3,1489</u> <u>65</u>	<u>2,5737</u> <u>89</u>	<u>2,5827</u> <u>92</u>	<u>2,7158</u> <u>32</u>	<u>2,5267</u> <u>74</u>	<u>2,7478</u> <u>42</u>
Police/Fire Stations (24 Hr)	277	<u>3,1483</u> <u>22</u>	<u>2,5732</u> <u>63</u>	<u>2,5822</u> <u>64</u>	<u>2,7152</u> <u>78</u>	<u>2,5262</u> <u>59</u>	<u>2,7472</u> <u>81</u>
Post Office/Town Hall/Court House	1,266	1,474	1,205	1,209	1,271	1,183	1,286
Religious Buildings/Church	1,718	2,001	1,635	1,641	1,725	1,605	1,746

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342 US Department of Energy. Energy Star Calculator and Bin Analysis Models

343 A zip code mapping table is located in Appendix F. This table should be used to identify the refereneec Pennsylvania city for all zip codes in Pennsylvania

344 US Department of Energy. Energy Star Calculator and Bin Analysis Models

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**SECTION 3: Commercial and Industrial Measures**

Ductless Mini-Split Heat Pumps – Commercial &lt; 5.4 tons

Page 334

Retail	1,188	1,383	1,130	1,135	1,193	1,110	1,207
Schools/University	1,661	<u>9841.9</u> <u>33</u>	<u>8051.5</u> <u>80</u>	<u>8081.5</u> <u>86</u>	<u>8491.6</u> <u>67</u>	<u>7901.5</u> <u>51</u>	<u>8591.6</u> <u>87</u>
Warehouses (Not Refrigerated)	<u>5381.5</u> <u>55</u>	<u>5671.8</u> <u>10</u>	<u>4631.4</u> <u>80</u>	<u>4651.4</u> <u>85</u>	<u>4891.5</u> <u>61</u>	<u>4551.4</u> <u>53</u>	<u>4951.5</u> <u>80</u>
Warehouses (Refrigerated)	1,555	1,810	1,480	1,485	1,561	1,453	1,580
Waste Water Treatment Plant	<u>1,2655</u> <u>38</u>	<u>1,4736</u> <u>26</u>	<u>1,2045</u> <u>12</u>	<u>1,2085</u> <u>13</u>	<u>1,2705</u> <u>40</u>	<u>1,1825</u> <u>02</u>	<u>1,2855</u> <u>46</u>

### 3.19.4 Measure Life

According to an October 2008 report for the CA Database for Energy Efficiency Resources, a heat pump's lifespan is 15 years.<sup>345</sup>

### 3.19.5 Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings-EDC data gathering.

<sup>345</sup> DEER values, updated October 10, 2008. Various sources range from 12 to 20 years, DEER represented a reasonable mid-range. [http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

### 3.20 ENERGY STAR Electric Steam Cooker

This measure applies to the installation of electric ENERGY STAR steam cookers as either a new item or replacement for an existing unit. Gas steam cookers are not eligible. The steam cookers must meet minimum ENERGY STAR efficiency requirements. A qualifying steam cooker must meet a minimum cooking efficiency of 50 percent and meet idle energy rates specified by pan capacity.

The baseline equipment is a unit with efficiency specifications that do not meet the minimum ENERGY STAR efficiency requirements.

#### 3.20.1 Algorithms

The savings depend on three main factors: pounds of food steam cooked per day, pan capacity, and cooking efficiency.

$$\Delta kWh = \Delta kWh_{\text{cooking}} + \Delta kWh_{\text{idle}}$$

$$\Delta kWh_{\text{cooking}} = \text{lbsfood} \times \text{EnergyToFood} \times (1/\text{Eff}_b - 1/\text{Eff}_{ee})$$

$$\Delta kWh_{\text{idle}} = [(\text{Power}_{\text{idle-b}} \times (1 - \% \text{HOURS}_{\text{consteam}}) + \% \text{HOURS}_{\text{consteam}} \times \text{CAPY}_b \times \text{Qty}_{\text{pans}} \times (\text{EnergyToFood}/\text{Eff}_b) \times (\text{HOURS}_{\text{op}} - \text{lbsfood}/(\text{CAPY}_b \times \text{Qty}_{\text{pans}}) - \text{HOURS}_{\text{pre}})] - [(\text{Power}_{\text{idle-ee}} \times (1 - \% \text{HOURS}_{\text{consteam}}) + \% \text{HOURS}_{\text{consteam}} \times \text{CAPY}_{ee} \times \text{Qty}_{\text{pans}} \times (\text{EnergyToFood}/\text{Eff}_{ee}) \times (\text{HOURS}_{\text{op}} - \text{lbsfood}/(\text{CAPY}_{ee} \times \text{Qty}_{\text{pans}}) - \text{HOURS}_{\text{pre}})]$$

$$\Delta kW_{\text{peak}} = (\Delta kWh / \text{EFLH}) \times \text{CF}$$

#### 3.20.2 Definition of Terms

<i>lbsfood</i>	= Pounds of food cooked per day in the steam cooker
<i>EnergyToFood</i>	= ASTM energy to food ratio; energy (kilowatt-hours) required per pound of food during cooking
<i>Eff<sub>ee</sub></i>	= Cooking energy efficiency of the new unit
<i>Eff<sub>b</sub></i>	= Cooking energy efficiency of the baseline unit
<i>Power<sub>idle-b</sub></i>	= Idle power of the baseline unit in kilowatts
<i>Power<sub>idle-ee</sub></i>	= Idle power of the new unit in kilowatts
<i>%HOURS<sub>consteam</sub></i>	= Percentage of idle time per day the steamer is in continuous steam mode instead of timed cooking. The power used in this mode is the same as the power in cooking mode.
<i>HOURS<sub>op</sub></i>	= Total operating hours per day
<i>HOURS<sub>pre</sub></i>	= Daily hours spent preheating the steam cooker

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$CAPY_b$	= Production capacity per pan of the baseline unit in pounds per hour of the baseline unit
$CAPY_{ee}$	= Production capacity per pan of the new unit in pounds per hour
$Qty_{pans}$	= Quantity of pans in the unit
$EFLH$	= Equivalent full load hours per year
$CF$	= Demand Coincidence Factor (See Section 1.4) <del>01.4</del>
1000	= Conversion from watts to kilowatts

Table 3-~~716971~~: Steam Cooker - Values and References

Component	Type	Values	Sources
Lbsfood	Variable	Nameplate	EDC Data Gathering
		Default values in <a href="#">Table 3-72Table-3-7072</a>	<a href="#">Table 3-72Table 3-7072</a>
EnergyToFood	Fixed	0.0308 kWh/pound	1
$Eff_{ee}$	Variable	Nameplate	EDC Data Gathering
		Default values in <a href="#">Table 3-72Table-3-7072</a>	<a href="#">Table 3-72Table 3-7072</a>
$Eff_b$	Fixed	See <a href="#">Table 3-72Table 3-7072</a>	<a href="#">Table 3-72Table 3-7072</a>
$Power_{idle-b}$	Variable	See <a href="#">Table 3-72Table 3-7072</a>	<a href="#">Table 3-72Table 3-7072</a>
$Power_{idle-ee}$	Variable	Nameplate	EDC Data Gathering
		Default values in <a href="#">Table 3-72Table-3-7072</a>	<a href="#">Table 3-72Table 3-7072</a>
$HOURS_{op}$	Variable	Nameplate	EDC Data Gathering
		12 hours	1
$HOURS_{pre}$	Fixed	0.25	1
$\%HOURS_{consteam}$	Fixed	40%	1
$CAPY_b$	Fixed	See <a href="#">Table 3-72Table 3-7072</a>	<a href="#">Table 3-72Table 3-7072</a>
$CAPY_{ee}$	Fixed	See <a href="#">Table 3-72Table 3-7072</a>	<a href="#">Table 3-72Table 3-7072</a>
$Qty_{pans}$	Variable	Nameplate	EDC Data Gathering
$EFLH$	Fixed	4380	2
$CF$	Fixed	0.84	4, 5

**Sources:**

1. US Department of Energy. ENERGY STAR Calculator.

- 2.3. Food Service Technology Center (FSTC), based on an assumption that the restaurant is open 12 hours a day, 365 days a year.
- 3.4. FSTC (2002). *Commercial Cooking Appliance Technology Assessment*. Chapter 8: Steamers.
- 4.5. *State of Ohio Energy Efficiency Technical Reference Manual* cites a CF = 0.84 as adopted from the Efficiency Vermont TRM. Assumes CF is similar to that for general commercial industrial lighting equipment.
- 5.6. RLW Analytics. *Coincidence Factor Study – Residential and Commercial Industrial Lighting Measures*. Spring 2007.

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Table 3-727072: Default Values for Electric Steam Cookers by Number of Pans<sup>346</sup>

# of Pans	Parameter	Baseline Model	Efficient Model	Savings
3	Power <sub>idle</sub> (kW) <sup>347</sup>	1.000	0.27	
	CAPY (lb/h)	23.3	16.7	
	lbsfood	100	100	
	Eff <sup>348</sup>	30%	59%	
	ΔkWh			2,813
	ΔkW <sub>peak</sub>			0.54
4	Power <sub>idle</sub> (kW)	1.325	0.30	
	CAPY (lb/h)	21.8	16.8	
	lbsfood	128	128	
	Eff	30%	57%	
	ΔkWh			3,902
	ΔkW <sub>peak</sub>			0.75

<sup>346</sup> Values for ASTM parameters for baseline and efficient conditions (unless otherwise noted) were determined by FSTC according to ASTM F1484, the Standard Test Method for Performance of Steam Cookers. Pounds of Food Cooked per Day based on the default value for a 3 pan steam cooker (100 lbs from FSTC) and scaled up based on the assumption that steam cookers with a greater number of pans cook larger quantities of food per day.

<sup>347</sup> Efficient values calculated from a list of ENERGY STAR qualified products.

<sup>348</sup> Ibid.

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# of Pans	Parameter	Baseline Model	Efficient Model	Savings
5	Power <sub>idle</sub> (kW)	1.675	0.31	
	CAPY (lb/h)	20.6	16.6	
	lbsfood	160	160	
	Eff	30%	70%	
	ΔkWh			5,134
	ΔkW <sub>peak</sub>			0.98
6	Power <sub>idle</sub> (kW)	2.000	0.31	
	CAPY (lb/h)	20.0	16.7	
	lbsfood	192	192	
	Eff	30%	65%	
	ΔkWh			6,311
	ΔkW <sub>peak</sub>			1.21

### 3.20.3 Measure Life

According to Food Service Technology Center (FSTC) data provided to ENERGY STAR, the lifetime of a steam cooker is 12 years<sup>349</sup>.

### 3.20.4 Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with [EDC data gathering](#) or assignment of stipulated energy savings.

<sup>349</sup> [http://www.energystar.gov/index.cfm?fuseaction=find\\_a\\_product.showProductGroup&pgw\\_code=COC](http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=COC)

### 3.21 Refrigeration – Night Covers for Display Cases

Measure Name	Night Covers for Display Cases
Target Sector	Commercial Refrigeration
Measure Unit	Display Cases
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	5 years

This measure is the installation of night covers on existing open-type refrigerated display cases, where covers are deployed during the facility unoccupied hours in order to reduce refrigeration energy consumption.. These types of display cases can be found in small and medium to large size grocery stores. The air temperature inside low-temperature display cases is below 0°F350 and between 0°F to 30°F for medium-temperature and between 35°F to 55°F for high-temperature display cases351. The main benefit of using night covers on open display cases is a reduction of infiltration and radiation cooling loads. It is recommended that these covers have small, perforated holes to decrease moisture buildup.

#### 3.21.1 Algorithms

The energy savings and demand reduction are obtained through the following calculations352.

$$\Delta kWh = W \times SF \times HOU$$

There are no demand savings for this measure because the covers will not be in use during the peak period353.

#### 3.21.2 Definition of Terms

The variables in the above equation are defined below:

*W* = Width of the opening that the night covers protect (ft)

*SF* = Savings factor based on the temperature of the case (kW/ft)

*HOU* = Annual hours that the night covers are in use

350 <http://www.smud.org/en/business/rebates/Pages/express-refrigeration.aspx>

351 Massachusetts 2011 Technical Reference Manual

352 "Effects Of The Low Emissivity Shields On Performance And Power Use Of A Refrigerated Display Case" *Southern California Edison Refrigeration Technology and Test Center Energy Efficiency Division* August 8,1997.

353 Assumed that the continuous covers are deployed at night (usually 1:00 a.m. – 5:00 a.m.); therefore no demand savings is usually reported for this measure.



Table 3-~~7374~~73: Night Covers Calculations Assumptions

Component	Type	Value	Source
W	Variable	EDC's Data Gathering	EDC's Data Gathering
SF	Fixed	Default values in <a href="#">Table 3-74: Savings Factors</a> <del>Table 3-72: Savings Factors</del> <a href="#">74</a>	1
HOU	Variable	EDC's Data Gathering Default: 2190354	EDC's Data Gathering

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**Sources:**

1. CL&P Program Savings Documentation for 2011 Program Year (2010). Factors based on Southern California Edison (1997). *Effects of the Low Emissive Shields on Performance and Power Use of a Refrigerated Display Case.*

Table 3-~~7472~~74: Savings Factors

Cooler Case Temperature	Savings Factor
Low Temperature (-35 F to -5 F)	0.03 kW/ft
Medium Temperature (0 F to 30 F)	0.02 kW/ft
High Temperature (35 F to 55 F)	0.01 kW/ft

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The demand and energy savings assumptions are based on analysis performed by Southern California Edison (SCE). SCE conducted this test at its Refrigeration Technology and Test Center (RTTC). The RTTC's sophisticated instrumentation and data acquisition system provided detailed tracking of the refrigeration system's critical temperature and pressure points during the test period. These readings were then utilized to quantify various heat transfer and power related parameters within the refrigeration cycle. The results of SCE's test focused on three typical scenarios found mostly in supermarkets.

**3.21.3 Measure Life**

The expected measure life is 5 years<sup>355</sup>356.

<sup>354</sup> Hours should be determined on a case-by-case basis. Default value of 2190 hours is estimated assuming that the annual operating hours of the refrigerated case is 8,760 hours as per Ohio 2010 Technical Reference Manual and night covers must be applied for a period of at least six hours in a 24-hour period.

[http://energysmartonline.org/documents/EnergySmart\\_BPA\\_T&Cs.pdf](http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf)

<sup>355</sup> 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008.

<sup>356</sup> The Measure Life Report for Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, Inc., June 2007

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## 3.22 Office Equipment – Network Power Management Enabling

Over the last three years, a number of strategies have evolved to save energy in desktop computers. One class of products uses software implemented at the network level for desktop computers that manipulates the internal power settings of the central processing unit (CPU) and of the monitor. These power settings are an integral part of a computer's operating system (most commonly, Microsoft Windows) including "on", "standby", "sleep", and "off" modes and can be set by users from their individual desktops.

Most individual computer users are unfamiliar with these energy saving settings, and hence, settings are normally set by an IT administrator to minimize user complaints related to bringing the computer back from standby, sleep, or off modes. However, these strategies use a large amount of energy during times when the computer is not in active use. Studies have shown that energy consumed during non-use periods is large, and is often the majority of total energy consumed.

Qualifying software must control desktop computer and monitor power settings within a network from a central location.

### 3.22.1 Eligibility Requirements

The deemed savings reported in [Table 3-75: Network Power Controls, Per Unit Summary](#) ~~Table 3-73: Network Power Controls, Per Unit Summary~~ [Table 75](#) are applicable to any software that meets the following Pacific Northwest Regional Technical Forum's ("RTF") Networked Computer Power Management Control Software Specifications<sup>357</sup>:

- Workstation is defined as the computer monitor and the PC box.
- The software shall have wake-on-LAN capability to allow networked workstations to be remotely wakened from or placed into any power-saving mode and to remotely boot or shut down ACPI-compliant workstations.
- The software shall give the IT administrator easily-accessible central control over the power management settings of networked workstations that optionally overrides settings made by users.
- The software shall be capable of applying specific power management policies to network groups, utilizing existing network grouping capabilities.
- The software shall be compatible with multiple operating systems and hardware configurations on the same network.
- The software shall monitor workstation keyboard, mouse, CPU and disk activity in determining workstation idleness.

### 3.22.2 Deemed Savings

The energy savings per unit found in various studies specific to the Verdiem Surveyor software varied from 33.8 kWh/year to 330 kWh/year, with an average savings of about 200 kWh/year. This includes the power savings from the PC as well as the monitor. Deemed savings are based

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<sup>357</sup> Network PC Power Management Presentation, Regional Technical Forum, May 4, 2010.

on a research study conducted by Regional Technical Forum which involves actual field measurements of the Verdiem Surveyor product. The study reports deemed energy and demand savings for three different building types (schools, large office and small office) in combination with different HVAC systems types (electric heat, gas heat, and heat pumps). The deemed savings values in [Table 3-75: Network Power Controls, Per Unit Summary Table](#) also take into account the HVAC interactive effects. A simple average is reported for Pennsylvania.

Table 3-~~75~~~~75~~: Network Power Controls, Per Unit Summary Table

Measure Name	Unit	Gross Peak kW Reduction per Unit	Gross Peak kWh Reduction per Unit	Effective Useful Life	IMC per-unit (\$)	Net-to-Gross Ratio
Network PC Plug Load Power Management Software	One copy of licensed software installed on a PC workstation	0.0078358	135359	5	20	0.8

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### 3.22.3 Effective Useful Life

The EUL for this technology is estimated to be five (5) years. While DEER lists the EUL of electro-mechanical plug load sensors at ten years, this product is subject to the cyclical nature of the PC software and hardware industry, so a more conservative number is appropriate. This is the same value used in the SDG&E program.

#### Sources:

1. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Network Computer Power Management, v3.0.
  - a. Office Plug Load Field Monitoring Report, Laura Moorefield et al, Ecos Consulting, Dec, 2008.
  - b. PSE PC Power Management Results, Cadmus Group, Feb, 2011.
  - c. Non-Residential Network Computer Power Management, Avista, Feb, 2011.
  - d. After-hours Power Status of Office Equipment and Inventory of Miscellaneous Plug-Load Equipment, LBNL, Jan 2004.
  - e. Ecos Commercial Field Research Report, 2008.
2. Dimetrosky, S., Luedtke, J. S., & Seiden, K. (2005). *Surveyor Network Energy Manager: Market Progress Evaluation Report, No. 2* (Northwest Energy Efficiency Alliance report

358 <http://www.nwcouncil.org/energy/rtf/measures/measure.asp?id=95&decisionid=117>  
359 ibid

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#E05-136). Portland, OR: Quantec LLC.

<http://www.nwalliance.org/research/reports/136.pdf>

3. Dimetrosky, S., Steiner, J., & Vellinga, N. (2006). *San Diego Gas & Electric 2004-2005 Local Energy Savers Program Evaluation Report* (Study ID: SDG0212). Portland, OR: Quantec LLC.  
[http://www.calmac.org/publications/SDGE\\_ESP\\_EMV\\_Report\\_073106\\_Final.pdf](http://www.calmac.org/publications/SDGE_ESP_EMV_Report_073106_Final.pdf)
4. Greenberg, D. (2004). *Network Power Management Software: Saving Energy by Remote Control* (E source report No. ER-04-15). Boulder, CO: Platts Research & Consulting.
5. Roth, K., Larocque, G., & Kleinman, J. (2004). *Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings Volume II: Energy Savings Potential* (U.S. DOE contract No. DE-AM26-99FT40465). Cambridge, MA: TIAX LLC.  
[http://www.eere.energy.gov/buildings/info/documents/pdfs/office\\_telecom-vol2\\_final.pdf](http://www.eere.energy.gov/buildings/info/documents/pdfs/office_telecom-vol2_final.pdf)

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### 3.23 Refrigeration – Auto Closers

Measure Name	Auto Closers
Target Sector	Commercial Refrigeration
Measure Unit	Walk-in Coolers and Freezers
Unit Energy Savings	Fixed
Unit Peak Demand Reduction	Fixed
Measure Life	8 years

The auto-closer should be applied to the main insulated opaque door(s) of a walk-in cooler or freezer. Auto-closers on freezers and coolers can reduce the amount of time that doors are open, thereby reducing infiltration and refrigeration loads. These measures are for retrofit of doors not previously equipped with auto-closers, and assume the doors have strip curtains.

#### 3.23.1 Eligibility<sup>360</sup>

This protocol documents the energy savings attributed to installation of auto closers in walk-in coolers and freezers. The auto-closer must be able to firmly close the door when it is within one inch of full closure. The walk-in door perimeter must be  $\geq 16$  ft.

#### 3.23.2 Algorithms

Auto-Closers are treated in Database for Energy Efficient Resources (DEER) as weather-sensitive; therefore the recommended deemed savings values indicated below are derived from the DEER runs in California climate zones most closely associated to the climate zones of the main seven Pennsylvania cities. The association between California climate zones and the Pennsylvania cities is based on [Cooling Degree Days \(CDDs\), cooling degree hours \(CDHs\) and wet bulb temperatures](#). Savings estimates for each measure are averaged across six building vintages for each climate-zone for building type 9, Grocery Stores. \_

##### Main Cooler Doors

$$\Delta kWh = \Delta kWh_{cooler}$$

$$\Delta kW_{peak} = \Delta kW_{cooler}$$

##### Main Freezer Doors

$$\Delta kWh = \Delta kWh_{freezer}$$

$$\Delta kW_{peak} = \Delta kW_{freezer}$$

#### 3.23.3 Definition of Terms

$$\Delta kWh_{cooler,} = \text{Annual kWh savings for main cooler doors}$$

<sup>360</sup> [http://energysmartonline.org/documents/EnergySmart\\_BPA\\_T&Cs.pdf](http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf)

$\Delta kW_{\text{cooler}}$  = Summer peak kW savings for main cooler doors

$\Delta kWh_{\text{freezer}}$  = Annual kWh savings for main freezer doors

$\Delta kW_{\text{freezer}}$  = Summer peak kW savings for main freezer doors

Table 3-767476: Refrigeration Auto Closers Calculations Assumptions

Reference City	Associated California Climate Zone <sup>361</sup>	Value				Source
		Cooler		Freezer		
		kWh <sub>cooler</sub>	kW <sub>cooler</sub>	kWh <sub>freezer</sub>	kW <sub>freezer</sub>	
Allentown	415	961 kWh <sub>882</sub>	0.135 kW <sub>061</sub>	2351 kWh <sub>2349</sub>	0.327 kW <sub>142</sub>	1
Williamstown	415	961 kWh <sub>882</sub>	0.135 kW <sub>061</sub>	2319 kWh <sub>2351</sub>	0.327 kW <sub>142</sub>	1
Pittsburgh	4	961 kWh	0.135 kW	2319 kWh	0.327 kW	1
HarrisburgPhiladelphia	815	981 kWh <sub>882</sub>	0.108 kW <sub>061</sub>	2348 kWh <sub>2351</sub>	0.272 kW <sub>142</sub>	1
PhiladelphiaErie	139	1017 kWh <sub>989</sub>	0.143 kW <sub>175</sub>	2457 kWh <sub>2369</sub>	0.426 kW <sub>395</sub>	1
ScrantonHarrisburg	1615	924 kWh <sub>882</sub>	0.146 kW <sub>061</sub>	2329 kWh <sub>2351</sub>	0.296 kW <sub>142</sub>	1
ErieScranton	64	952 kWh <sub>961</sub>	0.116 kW <sub>135</sub>	2319 kWh <sub>2329</sub>	0.191 kW <sub>327</sub>	1

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Sources:

- 2005 DEER weather sensitive commercial data; DEER Database, <http://www.deeresources.com/>

3.23.4 Measure Life

The expected measure life is 8 years<sup>362</sup>.

<sup>361</sup> The deemed savings values were adopted from the California region and are adjusted to account for differences in weather conditions in Pennsylvania based on cooling degree hours and wet bulb temperatures. The Refrigeration – Auto Closers measure protocol follows the weather mapping table shown in Section 1.17.  
<sup>362</sup> [http://energysmartonline.org/documents/EnergySmart\\_BPA\\_T&Cs.pdf](http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf)

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### 3.24 Refrigeration – Door Gaskets for Walk-in and Reach-in Coolers and Freezers

The following protocol for the measurement of energy and demand savings is applicable to commercial refrigeration and applies to the replacement of worn-out gaskets with new better-fitting gaskets. Applicable gaskets include those located on the doors of walk-in and/or reach-in coolers and freezers.

Tight fitting gaskets inhibit infiltration of warm, moist air into the cold refrigerated space, thereby reducing the cooling load. Aside from the direct reduction in cooling load, the associated decrease in moisture entering the refrigerated space also helps prevent frost on the cooling coils. Frost build-up adversely impacts the coil's heat transfer effectiveness, reduces air passage (lowering heat transfer efficiency), and increases energy use during the defrost cycle. Therefore, replacing defective door gaskets reduces compressor run time and improves the overall effectiveness of heat removal from a refrigerated cabinet.

#### 3.24.1 Eligibility

This protocol applies to the main doors of both low temperature (“freezer” – below 32°F) and medium temperature (“cooler” – above 32°F) walk-ins.

#### 3.24.2 Algorithms

The energy savings and demand reduction are obtained through the following calculations:

$$\Delta kWh = \Delta kWh/ft \times L$$

$$\Delta kW_{peak} = \Delta kW/ft \times L$$

#### 3.24.3 Definition of Terms

$\Delta kWh/ft$  = Annual energy savings per linear foot of gasket

$\Delta kW/ft$  = Demand savings per linear foot of gasket

L = Total gasket length in linear feet

Table 3-~~77~~~~77~~: Door Gasket Assumptions

Component	Type	Value	Source
$\Delta kWh/ft$	Variable	From <del>Table 3-76</del> Table 3-78 to <del>Table 3-80</del> Table 3-83 Table 3-83	1, 2
$\Delta kW/ft$	Variable	From <del>Table 3-76</del> Table 3-78 to <del>Table 3-80</del> Table 3-83 Table 3-83	1, 2
L	Variable	As Measured	EDC Data Gathering

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**Sources:**

1. Southern California Edison Company, Design & Engineering Services, Work Paper WPSCNRRN0001, [Door Gaskets for Main Door of Walk-in Coolers and Freezers](#), 2006 – 2008 Program Planning Cycle.
2. [Southern California Edison Company, Design & Engineering Services, Work Paper WPSCNRRN00013, Revision 0, Door Gaskets for Glass Doors of Medium and Low Temp Reach-in Display Cases & Solid Doors of Reach-in Coolers and Freezers, October 15, 2007.](#)

The deemed savings values below are weather sensitive, therefore the values for each reference city are taken from the associated California climate zones listed in the Southern California Edison work paper. The Commercial Facilities Contract Group 2006-2008 Direct Impact Evaluation363 prepared for the California Public Utilities Commission, which mainly focuses on refrigerated display cases versus walk-in coolers, have shown low realization rates and net-to-gross ratios compared to the SCE work papers, mostly attributable to the effectiveness of baseline door gaskets being much higher than assumed. Due to the relatively small contribution of savings toward EDC portfolios as a whole and lack of Pennsylvania specific data, the ex ante savings based on the SCE work paper will be used until further research is conducted.

[Walk-in Coolers and Freezers364:](#)

Table 3-~~787678~~: Door Gasket Savings per Linear Foot [for Walk-in Coolers and Freezers \(CZ 4 Allentown, Pittsburgh, WilliamstownScranton\)](#)

Building Type	Coolers		Freezers	
	ΔkW/ft	ΔkWh/ft	ΔkW/ft	ΔkW/ft
Restaurant	0.000886	18	0.001871	63
Small Grocery Store/ Convenience Store	0.000658	15	<a href="#">0.00162900162</a>	64
Medium/Large Grocery Store/ Supermarkets	0.000647	15	0.001593	91

Table 3-~~797779~~: Door Gasket Savings per Linear Foot [for Walk-in Coolers and Freezers \(CZ 815 Allentown, Harrisburg, Philadelphia, Williamstown\)](#)

Building Type	Coolers		Freezers	
	ΔkW/ft	ΔkWh/ft	ΔkW/ft	ΔkWh/ft
Restaurant	<a href="#">0.000908001589</a>	<a href="#">4931</a>	<a href="#">0.001928003551</a>	<a href="#">65105</a>
Small Grocery Store/ Convenience Store	<a href="#">0.000675001185</a>	<a href="#">4524</a>	<a href="#">0.001669003089</a>	<a href="#">67106</a>
Medium/Large Grocery Store/ Supermarkets	<a href="#">0.000663001158</a>	<a href="#">4524</a>	<a href="#">0.001642003054</a>	<a href="#">95150</a>

363 [http://www.calmac.org/publications/ComFac\\_Evaluation\\_V1\\_Final\\_Report\\_02-18-2010.pdf](http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf)

364 [The deemed savings values were adopted from the California region and are adjusted to account for differences in weather conditions in Pennsylvania based on cooling degree hours and wet bulb temperatures. The Refrigeration – Door Gaskets measure protocol follows the weather mapping table shown in Section 1.17.](#)

**SECTION 3: Commercial and Industrial Measures**

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Table 3-807880: Door Gasket Savings per Linear Foot for Walk-in Coolers and Freezers (CZ 13 Philadelphia9 Erie)

Building Type	Coolers		Freezers	
	ΔkW/ft	ΔkWh/ft	ΔkW/ft	ΔkWh/ft
Restaurant	0.001228001028	2320	0.002729002235	8071
Small Grocery Store/ Convenience Store	0.000915000765	4816	0.002368001937	8472
Medium/Large Grocery Store/ Supermarkets	0.000899000747	4816	0.002336001907	115102

Reach-in Coolers and Freezers365:

Table 3-817981: Door Gasket Savings per Linear Foot for Reach-in Coolers and Freezers (CZ 164 Pittsburgh, Scranton)

Building Type	Coolers		Freezers	
	ΔkW/ft	ΔkWh/ft	ΔkW/ft	ΔkWh/ft
Restaurant	0.000908	17	0.001928	58
Small Grocery Store/ Convenience Store	0.000675	14	0.001669	60
Medium/Large Grocery Store/ Supermarkets	0.000663	14	0.001642	85

Table 3-80: Door Gasket Savings per Linear Foot (CZ 6 Erie)

Building Type	Coolers		Freezers	
	ΔkW/ft	ΔkWh/ft	ΔkW/ft	ΔkWh/ft
Grocery/Restaurant	0.000803001788	479	0.001659003783	5919
Small Grocery Store/ Convenience Store	0.000596	44	0.001435	64
Medium/Large Grocery Store/ Supermarkets	0.000586	44	0.001410	86

3.24.4 — Measure Life

The expected measure life is 4 years366.

365 The deemed savings values were adopted from the California region and are adjusted to account for differences in weather conditions in Pennsylvania based on cooling degree hours and wet bulb temperatures. The Refrigeration – Door Gaskets measure protocol follows the weather mapping table shown in Section 1.17.

366 [http://www.calmac.org/publications/ComFac\\_Evaluation\\_V1\\_Final\\_Report\\_02-18-2010.pdf](http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf)

SECTION 3: Commercial and Industrial Measures

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### 3.25 Refrigeration – Suction Pipes Insulation

Table 3-82: Door Gasket Savings per Linear Foot for Reach-in Coolers and Freezers (CZ 15 Allentown, Harrisburg, Philadelphia, Williamstown)

Measure Name	Building Type	Refrigeration Suction Pipes Insulation		Freezers	
		Coolers	Freezers	Coolers	Freezers
Target Sector		Commercial-Refrigeration	Refrigeration		
Grocery/Restaurant	Measure Unit		13	0.005526	28
Unit Energy Savings		Fixed	0.002597		
Unit Peak Demand Reduction		Fixed-			
Measure Life		11 years			

Table 3-83: Door Gasket Savings per Linear Foot for Reach-in Coolers and Freezers (CZ 9 Erie)

Building Type	Coolers		Freezers	
	ΔkW/ft	ΔkWh/ft	ΔkW/ft	ΔkWh/ft
Grocery/Restaurant	0.001959	10	0.004167	21

#### 3.24.4 Measure Life

The expected measure life is 4 years367.

367 [http://www.calmac.org/publications/ComFac\\_Evaluation\\_V1\\_Final\\_Report\\_02-18-2010.pdf](http://www.calmac.org/publications/ComFac_Evaluation_V1_Final_Report_02-18-2010.pdf)

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### 3.25 Refrigeration – Suction Pipes Insulation for Walk-in Coolers and Freezers

<u>Measure Name</u>	<u>Refrigeration Suction Pipes Insulation</u>
<u>Target Sector</u>	<u>Commercial Refrigeration</u>
<u>Measure Unit</u>	<u>Refrigeration</u>
<u>Unit Energy Savings</u>	<u>Fixed</u>
<u>Unit Peak Demand Reduction</u>	<u>Fixed</u>
<u>Measure Life</u>	<u>11 years</u>

This measure applies to the installation of insulation on existing bare suction lines (the larger diameter lines that run from the evaporator to the compressor) that are located outside of the refrigerated space for Walk-in Coolers and Freezers. Insulation impedes heat transfer from the ambient air to the suction lines, thereby reducing undesirable system superheat. This decreases the load on the compressor, resulting in decreased compressor operating hours, and energy savings.

#### **3.25.1 Eligibility**

This protocol documents the energy savings attributed to insulation of bare refrigeration suction pipes. The following are the eligibility requirements<sup>368</sup>:

- Must insulate bare refrigeration suction lines of 1-5/8 inches in diameter or less on existing equipment only
- Medium temperature lines require 3/4 inch of flexible, closed-cell, nitrite rubber or an equivalent insulation
- Low temperature lines require 1-inch of insulation that is in compliance with the specifications above
- Insulation exposed to the outdoors must be protected from the weather (i.e. jacketed with a medium-gauge aluminum jacket)

#### **3.25.2 Algorithms**

The demand and energy savings assumptions are based on analysis performed by Southern California Edison (SCE)<sup>369</sup>. Measure savings per linear foot of insulation installed on bare suction lines in Restaurants and Grocery Stores is provided in Table 3-84: Insulate Bare Refrigeration Suction Pipes Calculations Assumptions~~Table 3-81: Insulate Bare Refrigeration Suction Pipes Calculations Assumptions~~Table 3-84~~Table 3-84~~ Table 3-85~~Table 3-82~~85 below lists the “deemed” savings for the associated California Climate zones and their respective Pennsylvania city.

368

[http://www.energysmartgrocer.org/pdfs/PGE/2010\\_2012%20External%20Equipment%20SpecificationTandCs%20v3.pdf](http://www.energysmartgrocer.org/pdfs/PGE/2010_2012%20External%20Equipment%20SpecificationTandCs%20v3.pdf)  
369 Work papers developed by SCE filed with the CA PUC in support of its 2006 – 2008 energy efficiency program plans

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$$\Delta kWh = \Delta kW/ft \times L$$

$$\Delta kW_{peak} = \Delta kW/ft \times L$$

### 3.25.3 Definition of Terms

The variables in the above equation are defined below:

$$\Delta kWh/ft = \text{Annual energy savings per linear foot of insulation}$$

$$\Delta kW/ft = \text{Demand savings per linear foot of insulation}$$

$$L = \text{Total insulation length in linear feet}$$

Table 3-848184: Insulate Bare Refrigeration Suction Pipes Calculations Assumptions

Component	Type	Value	Source
ΔkW/ft	Variable	<a href="#">Table 3-85Table-3-8285</a>	1
ΔkWh/ft	Variable	<a href="#">Table 3-85Table-3-8285</a>	1
L	Variable	As Measured	EDC Data Gathering

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Table 3-858285: Insulate Bare Refrigeration Suction Pipes Savings per Linear Foot [370 for Walk-in Coolers and Freezers of Restaurants and Grocery Stores371](#)

City	Associated California Climate Zone <a href="#">372</a>	Medium-Temperature Coolers <a href="#">Temperature Walk-in Coolers</a>		Low-Temperature Freezers <a href="#">Temperature Walk-in Freezers</a>	
		ΔkW/ft	ΔkWh/ft	ΔkW/ft	ΔkWh/ft
Allentown	<a href="#">415</a>	<a href="#">0.004507002488</a>	<a href="#">8.014.5</a>	<a href="#">0.0023002861</a>	<a href="#">13.017.6</a>
Williamstown	<a href="#">415</a>	<a href="#">0.004507002488</a>	<a href="#">8.014.5</a>	<a href="#">0.0023002861</a>	<a href="#">13.017.6</a>
Pittsburgh	4	0.001507	8.0	0.0023	13.0
Philadelphia	<a href="#">4315</a>	<a href="#">0.002059002488</a>	<a href="#">11.014.5</a>	<a href="#">0.00233002861</a>	<a href="#">13.417.6</a>
Erie	<a href="#">69</a>	<a href="#">0.004345001757</a>	<a href="#">7.39.5</a>	<a href="#">0.00217500246</a>	<a href="#">12.414</a>
Harrisburg	<a href="#">815</a>	<a href="#">0.004548002488</a>	<a href="#">8.414.5</a>	<a href="#">0.00233002861</a>	<a href="#">13.417.6</a>
Scranton	<a href="#">164</a>	<a href="#">0.004548001507</a>	<a href="#">7.58</a>	<a href="#">0.002330023</a>	<a href="#">12.013</a>

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[370](#) A zip code mapping table is located in Appendix F. This table should be used to identify the refereneec Pennsylvania city for all zip codes in Pennsylvania

[371](#) A zip code mapping table is located in Appendix F. This table should be used to identify the refereneec Pennsylvania city for all zip codes in Pennsylvania

[372](#) The deemed savings values were adopted from the California region and are adjusted to account for differences in weather conditions in Pennsylvania based on cooling degree hours and wet bulb temperatures. The Refrigeration – Suction Pipes Insulation measure protocol follows the weather mapping table shown in Section 1.17.

## SECTION 3: Commercial and Industrial Measures

**Sources:**

1. Southern California Edison Company, "Insulation of Bare Refrigeration Suction Lines", Work Paper WPSCNRRN0003.1

**3.25.4 Measure Life**

The expected measure life is 11 years<sup>373</sup><sup>374</sup>.

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<sup>373</sup> California Measurement Advisory Committee Public Workpapers on PY 2001 Energy Efficiency Programs. September 2000. Appendix F, P.14  
<sup>374</sup> DEER database, EUL/RUL for insulation bare suction pipes

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### 3.26 Refrigeration – Evaporator Fan Controllers

This measure is for the installation of evaporator fan controls<sup>375</sup> in medium-temperature walk-in coolers with no pre-existing controls. Evaporator fans run constantly to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. The equations specified in the Algorithms section are for fans that are turned off and/or cycled. A fan controller saves energy by reducing fan usage, by reducing the refrigeration load resulting from the heat given off by the fan and by reducing compressor energy resulting from the electronic temperature control. This protocol documents the energy savings attributed to evaporator fan controls.

#### 3.26.1 Eligibility

This protocol documents the energy savings attributed to installation of evaporator fan controls in medium-temperature walk-in coolers and low temperature walk-in freezers.

#### 3.26.2 Algorithms<sup>376</sup>

$$\begin{aligned}\Delta kWh &= \Delta kWh_{Fan} + \Delta kWh_{Heat} + \Delta kWh_{Control} \\ \Delta kWh_{Fan} &= kW_{Fan} \times 8760 \times \%Off \\ \Delta kWh_{Heat} &= \Delta kWh_{Fan} \times 0.28 \times Eff_{RS} \\ \Delta kWh_{Control} &= [kW_{CP} \times Hours_{CP} + kW_{Fan} \times 8760 \times (1 - \%Off)] \times 5\% \\ \Delta kW &= \Delta kWh / 8760\end{aligned}$$

Determine  $kW_{Fan}$  and  $kW_{CP}$  variables using any of the following methods:

1. Calculate using the nameplate horsepower and load factor.
 
$$kW_{Fan} \text{ or } kW_{CP} = [(HP \times LF \times 0.746) / \eta]$$
2. Calculate using the nameplate amperage and voltage and a power factor.
 
$$kW_{Fan} \text{ or } kW_{CP} = [V \times A \times PF_{motor} \times LF]$$
3. Measure the input kW fan using a power meter reading true RMS power.

#### 3.26.3 Definition of Terms

$$\begin{aligned}\Delta kWh_{Fan} &= \text{Energy savings due to evaporator being shut off} \\ \Delta kWh_{Heat} &= \text{Heat energy savings due to reduced heat from evaporator fans}\end{aligned}$$

<sup>375</sup> An evaporator fan controller is a device or system that lowers airflow across an evaporator in medium-temperature walk-in coolers when there is no refrigerant flow through the evaporator (i.e., when the compressor is in an off-cycle).

<sup>376</sup> The assumptions and algorithms used in this section are specific to NRM products and are taken from the Massachusetts Statewide Technical Reference Manual for Estimating Savings from Energy Efficiency Measures, Version 1.0 [http://www.ma-eeac.org/docs/MA%20TRM\\_2011%20PLAN%20VERSION.PDF](http://www.ma-eeac.org/docs/MA%20TRM_2011%20PLAN%20VERSION.PDF)

$\Delta kWh_{Control}$	= Control energy savings due to electronic controls on compressor and evaporator
$kW_{Fan}$	= Power demand of evaporator fan calculated from any of the methods described above
$kW_{CP}$	= Power demand of compressor motor and condenser fan calculated from any of the methods described above
%Off	= Percent of annual hours that the evaporator is turned off
HP	= Rated horsepower of the motor
$\eta_{emotor}$	= efficiency of the motor
LF	= Load factor of motor
Voltage	= Voltage of the motor
Amperage	= Rated amperage of the motor
PF	= Power factor of the motor
$Eff_{RS}$	= Efficiency of typical refrigeration system
$Hours_{CP}$	= Equivalent annual full load hours of compressor operation
0.28	= Conversion of kW to tons: 3,413 Btuh/kW divided by 12,000 Btuh/ton
5%	= Reduced run-time of compressor and evaporator due to electronic controls <sup>377</sup>
0.746	= conversion factor from horsepower to kW (kW/hp)

<sup>377</sup> Conservative estimate supported by less conservative values given by several utility-sponsored 3<sup>rd</sup> party studies including: Select Energy (2004). *Analysis of Cooler Control Energy Conservation Measures*. Prepared for NSTAR.

Table 3-868386: Evaporator Fan Controller Calculations Assumptions

Component	Type	Value	Source
PF	Fixed	Fan motor: 0.675 Compressor motor: 0.9	1, 7, 8
%Off	Fixed	46%	2
Eff <sub>RS</sub>	Fixed	1.6 kW/ton	3
Hours <sub>CP</sub>	Variable	4,072	1, 6
		EDC Data Gathering	EDC Data Gathering
Motor HP	Variable	EDC Data Gathering	EDC Data Gathering
Motor Eff	Variable	EDC Data Gathering	EDC Data Gathering
LF	Fixed	0.9	Section 3.10
Voltage	Variable	EDC Data Gathering	EDC Data Gathering
Amperage	Variable	EDC Data Gathering	EDC Data Gathering

**Sources:**

1. Conservative value based on 15 years of NRM field observations and experience.
2. Select Energy (2004). *Analysis of Cooler Control Energy Conservation Measures*. Prepared for NSTAR.
3. Estimated average refrigeration efficiency for small business customers, Massachusetts Technical Reference Manual
4. Southern California Edison. Non-Residential Express 2003 Refrigeration Work Paper. Pg. 27
5. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106.
6. 2012 Program Year Rhode Island Technical Reference Manual for Estimating Savings from Energy Efficiency Measures
7. [ESource Customer Direct to Touchstone Energy for Evaporator Fan Controllers, 2005](#)
8. [LBNL 57651 Energy Savings in Refrigerated Walk-in Boxes, 1998](#)

**3.26.4 Measure Life**

The expected measure life is 10 years<sup>378</sup>.

<sup>378</sup> Energy & Resource Solutions (2005). Measure Life Study. Prepared for The Massachusetts Joint Utilities; Table 1-1.

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### 3.27 ENERGY STAR Clothes Washer

Measure Name	Clothes Washer
Target Sector	Multifamily Common Area Laundry and Laundromats
Measure Unit	Per Washing Machine
Unit Energy Savings	<del>See Table 3-85: Deemed Savings for Top Loading ENERGY STAR Clothes Washer for Laundry in Multifamily Buildings to See Table 3-88 to Table 3-91: Deemed Savings Front Loading ENERGY STAR Clothes Washer for Laundromats Table 3-88: Deemed Savings Front Loading ENERGY STAR Clothes Washer for Laundromats Table 3-91 Table 3-91</del>
Unit Peak Demand Reduction	<del>See Table 3-85: Deemed Savings for Top Loading ENERGY STAR Clothes Washer for Laundry in Multifamily Buildings to See Table 3-88 to Table 3-91: Deemed Savings Front Loading ENERGY STAR Clothes Washer for Laundromats Table 3-88: Deemed Savings Front Loading ENERGY STAR Clothes Washer for Laundromats Table 3-91 Table 3-91</del>
Measure Life	11.3 years for Multifamily and 7.1 years for Laundromats

This protocol discusses the calculation methodology and the assumptions regarding baseline equipment, efficient equipment, and usage patterns used to estimate annual energy savings expected from the replacement of a standard clothes washer with an ENERGY STAR clothes washer with a minimum Modified Energy Factor (MEF) of  $\geq 2.2$  (ft<sup>3</sup> × cycle) / (kWh). The Federal efficiency standard is  $\geq 1.60$  (ft<sup>3</sup> × cycle) / (kWh) for Top Loading washers and  $\geq 2.0$  (ft<sup>3</sup> × cycle) / (kWh) for Front Loading washers<sup>379</sup>.

#### 3.27.1 Eligibility

This protocol documents the energy savings attributed to efficient clothes washers meeting ENERGY STAR or better in small commercial applications. This protocol is limited to clothes washers in laundry rooms of multifamily complexes and commercial Laundromats.

#### 3.27.2 Algorithms

The general form of the equation for the ENERGY STAR Clothes Washer measure savings algorithm is:

$$\text{Total Savings} = \text{Number of Clothes Washers} \times \text{Savings per Clothes Washer}$$

To determine resource savings, the per-unit estimates in the algorithms will be multiplied by the number of clothes washers.

Per unit energy and demand savings are obtained through the following calculations:

<sup>379</sup> DOE Technical Support Document, 2009. Web address: [http://www1.eere.energy.gov/buildings/appliance\\_standards/commercial/clothes\\_washers.html](http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers.html)

$$\Delta kWh = [(HE_{T, base} + ME_{T, base} + D_{E, base}) - (HE_{T, new} + ME_{T, new} + D_{E, new})] \times N$$

Where:

$$D_E = LAF \times WGHT_{max} \times DEF \times DUF \times (RMC380 - 4\%)$$

$$RMC = (-0.156 \times MEF) + 0.734$$

$$HE_T = (Cap/MEF) - ME_T - D_E$$

$$\Delta kW_{peak} = kWh \text{ Savings} \times UF$$

The algorithms used to calculate energy savings are taken from the U.S. Department of Energy's Life-Cycle Cost and Payback Period tool.<sup>381</sup> DOE adopted the algorithms for commercial clothes washers in a final rule published on October 18, 2005. Commercial clothes washer per-cycle energy consumption is composed of three components: water-heating energy, machine energy, and drying energy. DOE established the annual energy consumption of commercial clothes washers by multiplying the per-cycle energy and water use by the number of cycles per year.

In the above equations, MEF is the Modified Energy Factor, which is the energy performance metric for clothes washers. MEF is defined as:

*MEF is the quotient of the capacity of the clothes container, C, divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, M, the hot water energy consumption, E, and the energy required for removal of the remaining moisture in the wash load, D. The higher the value, the more efficient the clothes washer is.<sup>382</sup>*

$$MEF = C / (M + E + D)$$

The following steps should be taken to determine per-cycle energy consumption for top-loading and front-loading commercial clothes washers for both old and new clothes washers. Per-cycle energy use is disaggregated into water heating, machine, and clothes drying.

1. Calculate the remaining moisture content (RMC) based on the relationship between RMC and MEF.
2. Calculate the per-cycle clothes-drying energy use using the equation that determines the per-cycle energy consumption for the removal of moisture.
3. Use the per-cycle machine energy use value of 0.133kWh/cycle for MEFs up to 1.40 and 0.114kWh/cycle for MEFs greater than 1.40. These values are estimated from 2000 TSD for residential clothes washers' database.

<sup>380</sup> DOE used its residential clothes washer analysis from the year 2000 to determine a relationship between remaining moisture content (RMC) and modified energy factor (MEF) for the purpose of calculating the dryer energy for commercial clothes washers. RMC was determined using the dryer energy, the clothes container volume, and the resulting maximum test-load weight

<sup>381</sup> [http://www1.eere.energy.gov/buildings/appliance\\_standards/commercial/clothes\\_washers\\_snopr\\_spreadsheets.html](http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers_snopr_spreadsheets.html)

<sup>382</sup> Definition provided on ENERGY STAR Clothes Washers Key Product Criteria website:

[http://www.energystar.gov/index.cfm?c=clotheswash.pr\\_crit\\_clothes\\_washers](http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers)

4. With the per-cycle clothes dryer and machine energy known, determine the per-cycle water-heating energy use by first determining the total per-cycle energy use (the clothes container volume divided by the MEF) and then subtracting from it the per-cycle clothes-drying and machine energy.

The utilization factor, (UF) is equal to the average energy usage between noon and 8PM on summer weekdays to the annual energy usage. The utilization rate is derived as follows:

1. Obtain normalized, hourly load shape data for residential clothes washing
2. Smooth the load shape by replacing each hourly value with a 5-hour average centered about that hour. This step is necessary because the best available load shape data exhibits erratic behavior commonly associated with metering of small samples. The smoothing out effectively simulates diversification.
3. Take the UF to be the average of all load shape elements corresponding to the hours between noon and 8PM on weekdays from June to September.

The value is the June-September, weekday noon to 8 PM average of the normalized load shape values associated with residential clothes washers in PG&E service territory (northern CA). Although Northern CA is far from PA, the load shape data is the best available at the time and the temporal dependence washer usage is not expected to have a strong geographical dependency. Figure 3-1 shows the utilization factor for each hour of a sample week in July. Because the load shape data derived from monitoring of in-house clothes washers is being imputed to multifamily laundry room washers (which have higher utilization rates), it is important to check that the resulting minutes of usage per hour is significantly smaller than 60. If the minutes of usage per hour approach 60, then it should be assumed that the load shape for multi-family laundry room clothes washers must be different than the load shape for in-house clothes washers. The maximum utilization per hour is 36.2 minutes.

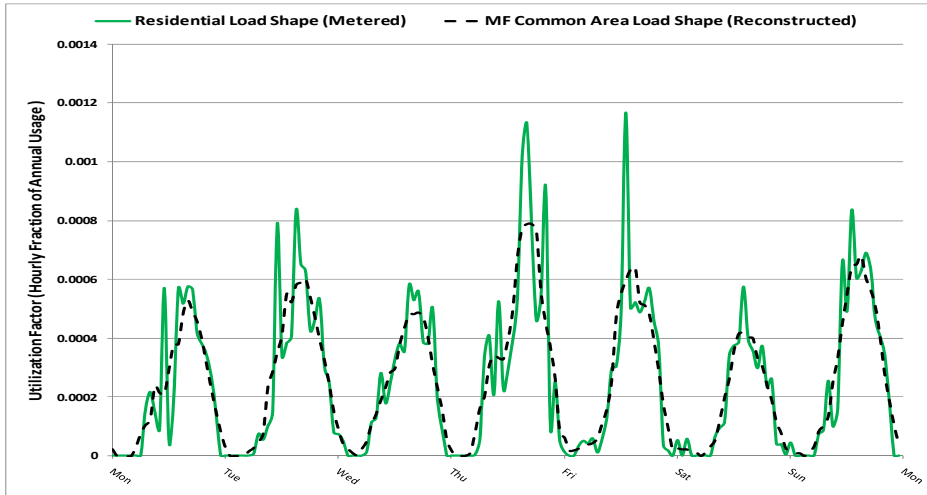


Figure 3-1: Utilization factor for a sample week in July383

383 The solid green profile is derived from a normalized load shape based on metering of residential in-unit dryers. The dashed black profile is a smoothed version of the green profile and represents the utilization factors for common laundry facilities in multifamily establishments

**SECTION 3: Commercial and Industrial Measures**

**ENERGY STAR Clothes Washer**

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### 3.27.3 Definition of Terms

The parameters in the above equation are listed in [Table 3-87: Commercial Clothes Washer Calculation Assumptions](#) [Table 3-84: Commercial Clothes Washer Calculation Assumptions](#) [Table 3-87](#) below.

Table 3-~~87~~~~84~~~~97~~: Commercial Clothes Washer Calculation Assumptions

Component	Type	Values	Source
MEF <sub>B</sub> , Base Federal Standard Modified Energy Factor	Fixed	Top loading: 1.6 Front loading: 2.0	4
MEF <sub>P</sub> , Modified Energy Factor of ENERGY STAR Qualified Washing Machine	Variable	Nameplate	EDC Data Gathering
	Default	2.2	4
HE <sub>T</sub> , Per-cycle water heating consumption (kWh/cycle)	Variable	Calculation	Calculation
DE, Per-cycle energy consumption for removal of moisture i.e. dryer energy consumption (kWh/cycle)	Variable	Calculation	Calculation
ME <sub>T</sub> , Per-cycle machine electrical energy consumption (kWh/cycle)	Fixed	0.114384	1
Cap <sub>base</sub> , Capacity of baseline clothes washer (Cu. Ft.)	Variable	Nameplate	EDC Data Gathering
	Default	Front Loading: 2.84 Top Loading: 2.95	5
Cap <sub>EE</sub> , Capacity of baseline and efficient clothes washer (Cu. Ft.)	Variable	Nameplate	EDC Data Gathering
	Default	2.84 Front Loading: 2.84 Top Loading: 2.84	25
LAF, Load adjustment factor	Fixed	0.52	1, 2
DEF, Nominal energy required for clothes dryer to remove moisture from clothes (kWh/lb.)	Fixed	0.5	1, 2
DUF, Dryer usage factor, percentage of washer loads dried in a clothes dryer	Fixed	0.84	1, 2
WGHT <sub>max</sub> , Maximum test-load weight (lbs./cycle)	Fixed	11.7	1, 2
RMC, Remaining moisture content (lbs.)	Variable	Calculation <sup>385</sup>	Calculation
N, Number of cycles per year	Fixed	Multifamily: 1,241 Laundromats: 2,190	1, 2

384 Based on residential clothes washer data from DOE 2000 TSD

385 Based on the relationship: RMC = -0.156\* MEF + 0.734

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UF, Utilization Factor	Fixed	0.0002382	3
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**Sources:**

1. [http://www1.eere.energy.gov/buildings/appliance\\_standards/commercial/pdfs/ccw\\_snopr\\_chap6.pdf](http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/ccw_snopr_chap6.pdf)
2. U.S. Department of Energy's Life-Cycle Cost and Payback Period tool, available at: [http://www1.eere.energy.gov/buildings/appliance\\_standards/commercial/clothes\\_washers\\_snopr\\_spreadsheets.html](http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers_snopr_spreadsheets.html)
3. Annual hourly load shapes taken from Energy Environment and Economics (E3), Resviewer2: [http://www.ethree.com/cpuc\\_ee\\_tools.html](http://www.ethree.com/cpuc_ee_tools.html). The average normalized usage for the hours noon to 8 PM, Monday through Friday, June 1 to September 30 is 0.000243
4. [http://www1.eere.energy.gov/buildings/appliance\\_standards/commercial/clothes\\_washers.html](http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers.html)
- 4-5. [California Energy Commission \("CEC"\) Appliance Efficiency database.   
http://www.appliances.energy.ca.gov/QuickSearch.aspx](http://www.appliances.energy.ca.gov/QuickSearch.aspx)

**3.27.4 Deemed Savings**

The deemed savings for the installation of a washing machine with a MEF of 2.2 or higher, is dependent on the energy source for washer. The table below shows savings for washing machines for different combinations of water heater and dryer types. The values are based on the difference between the baseline clothes washer with MEF Federal efficiency standard of  $\geq 1.60$  (ft<sup>3</sup> × cycle)/ (kWh) for Top Loading washers and  $\geq 2.0$  (ft<sup>3</sup> × cycle)/ (kWh) for Front Loading washers and minimum ENERGY STAR qualified front loading 386 clothes washer of  $\geq 2.2$  (ft<sup>3</sup> × cycle)/ (kWh).

For clothes washers where fuel mix is unknown, calculate default savings using the algorithms below and EDC specific saturation values. For EDCs where saturation information is not accessible, use "Default values" described in tables below.

$$ESav_{CW} = kWh_{GWH-GD} \times \%GWH-GD_{CW} + kWh_{GWH-ED} \times \%GWH-ED_{CW} + kWh_{EWH-GD} \times \%EWH-GD_{CW} + kWh_{EWH-ED} \times \%EWH-ED_{CW}$$

Where:

$kWh_{GWH-GD}$  = Energy savings for clothes washers with gas water heater and non-electric dryer fuel from tables below.

$kWh_{GWH-ED}$  = Energy savings for clothes washers with gas water heater and electric dryer fuel from tables below.

386 ENERGY STAR-qualified commercial clothes washers in 2013 are likely to be front-loading units because there are no top-loading commercial clothes washers at this time which have been certified by DOE as meeting the 2013 standards

- $kWh_{EWH-GD}$  = Energy savings for clothes washers with electric water heater and non-electric dryer fuel from tables below.
- $KWh_{EWH-ED}$  = Energy savings for clothes washers with electric water heater and electric dryer fuel from tables below.
- $\%GWH-GD_{CW}$  = Percent of clothes washers with gas water heater and non-electric dryer fuel
- $\%GWH-ED_{CW}$  = Percent of clothes washers with gas water heater and electric dryer fuel
- $\%EWH-GD_{CW}$  = Percent of clothes washers with electric water heater and non-electric dryer fuel
- $\%EWH-ED_{CW}$  = Percent of clothes washers with electric water heater and electric dryer fuel

Table 3-888598: Deemed Savings for Top Loading ENERGY STAR Clothes Washer for Laundry in Multifamily Buildings387

Fuel Source	Cycles/Year	Energy Savings (kWh)	Demand Reduction (kW)
Electric Hot Water Heater, Electric Dryer	1,241	592 — 686	0.1411163
Electric Hot Water Heater, Gas Dryer	1,241	295341	0.0704081
Gas Hot Water Heater, Electric Dryer	1,241	297345	0.0707082
Gas Hot Water Heater, Gas Dryer	1,241	0	0
Default (20% Electric DHW 40% Electric Dryer)388	1,241	178206	0.0424049

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Table 3-898689: Deemed Savings for Front Loading ENERGY STAR Clothes Washer for Laundry in Multifamily Buildings 389

Fuel Source	Cycles/Year	Energy Savings (kWh)	Demand Reduction (kW)
Electric Hot Water Heater, Electric Dryer	1,241	158 — 160	0.0376038
Electric Hot Water Heater, Gas Dryer	1,241	5961	0.0144015
Gas Hot Water Heater, Electric Dryer	1,241	99	0.0236024
Gas Hot Water Heater, Gas Dryer	1,241	0	0

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387Based on a container volume of 2.8 cu. ft., maximum test-load weight of 11.7 lb./cycle and electric water heater at 100% efficiency.

388 [http://www1.eere.energy.gov/buildings/appliance\\_standards/commercial/clothes\\_washers\\_snopr\\_spreadsheets.html](http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers_snopr_spreadsheets.html)

389ibid

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SECTION 3: Commercial and Industrial Measures

ENERGY STAR Clothes Washer

Default (20% Electric DHW 40% Electric Dryer)390	1,241	5152	0.0122012
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Table 3-908790: Deemed Savings for Top Loading ENERGY STAR Clothes Washer for Laundromats 391

Fuel Source	Cycles/Year	Energy Savings (kWh)	Demand Reduction (kW)
Electric Hot Water Heater, Electric Dryer	2,190	40451,211	0.2490288
Electric Hot Water Heater, Gas Dryer	2,190	524602	0.4242143
Gas Hot Water Heater, Electric Dryer	2,190	524609	0.4248145
Gas Hot Water Heater, Gas Dryer	2,190	0	0
Default (0% Electric DHW 0% Electric Dryer)392	2,190	0	0

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Table 3-918891: Deemed Savings Front Loading ENERGY STAR Clothes Washer for Laundromats 393

Fuel Source	Cycles/Year	Energy Savings (kWh)	Demand Reduction (kW)
Electric Hot Water Heater, Electric Dryer	2,190	279283	0.0664067
Electric Hot Water Heater, Gas Dryer	2,190	404108	0.0248026
Gas Hot Water Heater, Electric Dryer	2,190	175	0.0416042
Gas Hot Water Heater, Gas Dryer	2,190	0	0
Default (0% Electric DHW 0% Electric Dryer)394	2,190	0	0

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### 3.27.5 Measure Life

The measure life is 11.3 years for Multifamily and 7.1 years for Laundromats395.

### 3.27.6 Evaluation Protocols

The most appropriate evaluation protocol for this measure is verification of installation coupled with [EDC data gathering or](#) assignment of stipulated energy savings.

390 ibid

391 ibid

392 ibid

393 ibid

394 ibid

395 [http://www1.eere.energy.gov/buildings/appliance\\_standards/commercial/clothes\\_washers\\_snopr\\_spreadsheets.html](http://www1.eere.energy.gov/buildings/appliance_standards/commercial/clothes_washers_snopr_spreadsheets.html)

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### 3.28 Electric Resistance Water Heaters

Measure Name	Efficient Electric Water Heaters
Target Sector	Small Commercial Establishments
Measure Unit	Water Heater
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	15 years

Efficient electric resistance water heaters use resistive heating coils to heat the water. Premium efficiency models primarily generally use increased tank insulation to achieve energy factors of 0.93 to 0.96.

#### 3.28.1 Eligibility

This protocol documents the energy savings attributed to efficient electric resistance water heaters with a minimum energy factor of 0.93 compared to a baseline electric resistance water heater with an energy factor of 0.904. However, other energy factors are accommodated with the partially deemed scheme. The target sector includes domestic hot water applications in small commercial settings such as small retail establishments, small offices, small clinics, and small lodging establishments such as small motels.

#### 3.28.2 Algorithms

The energy savings calculation utilizes average performance data for available premium and standard electric resistance water heaters and typical hot water usages. The energy savings are obtained through the following formula:

$$\Delta kWh = \frac{\left\{ \left( \frac{1}{EF_{Base}} - \frac{1}{EF_{Proposed}} \right) \times HW \times 8.3 \frac{lb}{gal} \times 1.0 \frac{Btu}{lb-F} \times (T_{hot} - T_{cold}) \right\}}{3413 \frac{Btu}{kWh}}$$

For efficient resistive water heaters, demand savings result primarily from reduction in standby losses. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = \frac{EnergyToDemandFactor \times Energy Savings}{ResistiveDiscountFactor}$$

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average Usage_{Summer WD Noon-8}}{Annual Energy Usage}$$

## Loads

The annual loads are taken from data from the DEER database<sup>396</sup>. The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The loads are averaged over all 16 climate zones and all six vintage types in the DEER database. Finally, the loads are converted to average annual gallons of use using the algorithm below. The loads are summarized in [Table 3-92: Typical water heating loads](#). ~~Table 3-89: Typical water heating loads~~.<sup>92</sup> below.

$$HW \text{ (Gallons)} = \frac{Load \times EF_{NG, Base} \times 1000 \frac{Btu}{kBTU} \times Typical SF}{8.3 \frac{lb}{gal} \times (T_{hot} - T_{cold}) \times 1000 SF}$$

Table 3-~~92~~<sup>92</sup>: Typical water heating loads.

Building Type	Typical Square Footage	Average Annual Load In kBTU	Average Annual Use, Gallons
Motel	30,000	2,963	97,870
Small Office	10,000	2,214	24,377
Small Retail	7,000	1,451	11,183

## Energy to Demand Factor

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA<sup>397</sup>. The usage profiles are shown in Figure 3-2. To ensure that the load shape data derived from observations in CA can be applied to PA, we compared the annual energy usage to peak demand factors for two disparate climate zones in CA. The results, shown in Figure 3-3, indicate that the ratio of peak demand to annual energy usage is not strongly influenced by climate. Also, though the actual usage profiles may be different, the average usage between noon and 8 PM on summer weekdays is quite similar for all building types. The close level of agreement between disparate climate zones and building types suggest that the results will carry over to Pennsylvania<sup>398</sup>.

<sup>396</sup> <http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe>

<sup>397</sup> *ibid*

<sup>398</sup> One reason for the close agreement is that the factor is a ratio of the energy usage to peak demand for the same location. Even though the energy usages may vary significantly in different climate zones, the hot water usage patterns may be driven by underlying practices that carry over well from state to state (e.g. dishwashing after lunch or dinner in restaurants).



Figure 3-2: Load shapes for hot water in four commercial building types

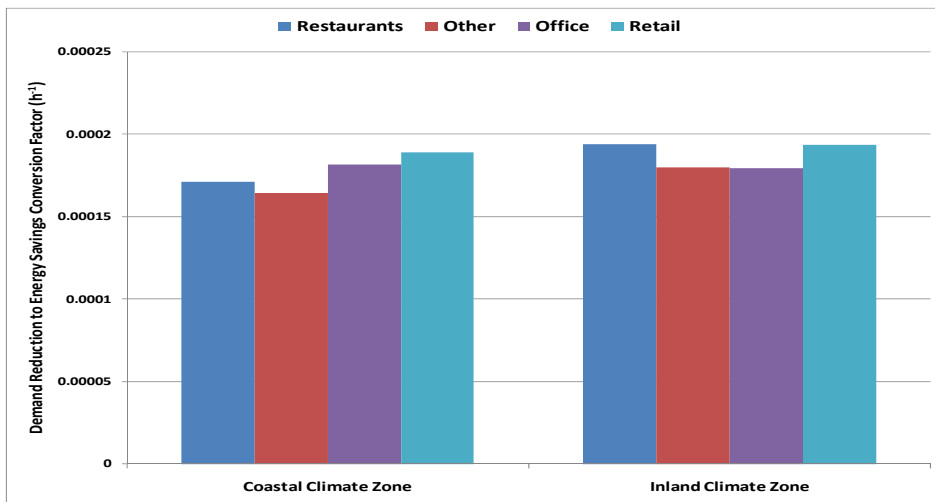


Figure 3-3: Energy to demand factors for four commercial building types

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**3.28.3 Definition of Terms**

The parameters in the above equation are listed in [Table 3-](#)

[93Table 3-9093.](#)

Table 3-90: ~~Electric Resistance Water Heater Calculation Assumptions~~

Component	Type	Values	Source
EF <sub>base</sub> , Energy Factor of baseline water heater	Fixed	0.904	1
EF <sub>proposed</sub> , Energy Factor of proposed efficient water heater	Variable	≥0.93	Program Design

[93: Electric Resistance Water Heater Calculation Assumptions](#)

Component	Type	Values	Source
EF <sub>base</sub> , Energy Factor of baseline water heater	Variable	See <a href="#">Table 3-94</a>	1
EF <sub>proposed</sub> , Energy Factor of proposed efficient water heater	Variable	Default: 0.93	Program Design
		Nameplate	EDC Data Gathering
Load, Average annual Load in kBTU	Fixed	Varies	DEER Database
T <sub>hot</sub> , Temperature of hot water	Fixed	120 °F	2
T <sub>cold</sub> , Temperature of cold water supply	Fixed	55 °F	3
EnergyToDemandFactor	Fixed	0.0001916	4
HW, Average annual gallons of Use	FixedVariable	Default: See <a href="#">Table 3-92</a>	CalculationSee <a href="#">Table 3-92</a> : Typical water-heating loads
		Varies	
		EDC Data Gathering	EDC Data Gathering
EF <sub>NG, base</sub> , Energy Factor of baseline gas water heater	Fixed	0.594	5
ResistiveDiscountFactor	Fixed	1.0	6

**[3.28.4 Energy Factors based on Tank Size](#)**

[Federal Standards for Energy Facotrs are equal to 0.97 -0.00132 x Rated Storage in Gallons. The following table shows the Energy Factors for various tank sizes.](#)

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**Table 3-94: Energy Factors based on Tank Size**

Tank Size (gallons)	Energy Factor
40	0.9172
50	0.9040
65	0.8842
80	0.8644
120	0.8116

**Sources:**

1. Federal Standards are  $0.97 - 0.00132 \times \text{Rated Storage in Gallons}$ . For a 50-gallon tank this is approximately 0.90. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE-2006-BT-STD-0129, p. 30

2-7. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.

3-8. Mid-Atlantic TRM, footnote #24

4-9. The load shapes can be accessed online:  
<http://www.ethree.com/CPUC/PG&ENonResViewer.zip>

5-10. Federal Standards are  $0.67 - 0.0019 \times \text{Rated Storage in Gallons}$ . For a 40-gallon tank this is 0.594. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE-2006-BT-STD-0129, p. 30

6-11. Engineering Estimate. No discount factor is needed because this measure is already an electric resistance water heater system.

**3.28.43.28.5 Deemed Savings**

As an example, the deemed savings for the installation of efficient electric water heaters with an energy factor of 0.95 in various applications are listed below.

**Table 3-95: Energy Savings and Demand Reductions**

Building Type	Average Annual Use, Gallons	EF	Energy Savings (kWh)	Demand Reduction (kW)
Motel	97,870	0.95	829	0.16
Small Office	24,377	0.95	207	0.04
Small Retail	11,183	0.95	95	0.02

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**3-28-53.28.6 Measure Life**

According to an October 2008 report for the CA Database for Energy Efficiency Resources, an electric water heater's lifespan is 15 years<sup>399</sup>.

**3-28-63.28.7 Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installation coupled with [EDC data gathering](#) or assignment of stipulated energy savings.

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399 DEER values, updated October 10, 2008

[http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

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### 3.29 Heat Pump Water Heaters

Measure Name	Heat Pump Water Heaters
Target Sector	Commercial Establishments
Measure Unit	Water Heater
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	10 years

Heat Pump Water Heaters take heat from the surrounding air and transfer it to the water in the tank, unlike conventional electrical water heaters which use resistive heating coils to heat the water.

#### 3.29.1 Eligibility

This protocol documents the energy savings attributed to heat pump water heaters with Energy Factors of 2.2. However, other energy factors are accommodated with the partially deemed scheme. The target sector includes domestic hot water applications in small commercial settings such as small retail establishments, small offices, small clinics, and small lodging establishments such as small motels. The measure described here involves a direct retrofit of a resistive electric water heater with a heat pump water heater. It does not cover systems where the heat pump is a pre-heater or is combined with other water heating sources. More complicated installations can be treated as custom projects.

#### 3.29.2 Algorithms

The energy savings calculation utilizes average performance data for available heat pump and standard electric resistance water heaters and typical hot water usages. The energy savings are obtained through the following formula:

$$\Delta kW_{Wh} = \frac{\left\{ \left( \frac{1}{EF_{Base}} - \left( \frac{1}{EF_{Proposed}} \times \frac{1}{F_{Adjust}} \right) \right) \times HW \times 8.3 \frac{lb}{gal} \times 1.0 \frac{Btu}{lb-F} \times (T_{hot} - T_{cold}) \right\}}{3413 \frac{Btu}{kWh}}$$

For heat pump water heaters, demand savings result primarily from a reduced connected load. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = \text{EnergyToDemandFactor} \times \text{Energy Savings} \times \text{ResistiveDiscountFactor}$$

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average\ Usage_{Summer\ WD\ Noon-8}}{Annual\ Energy\ Usage}$$

**Loads**

The annual loads are taken from data from the DEER database<sup>400</sup>. The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The loads are averaged over all 16 climate zones and all six vintage types in the DEER database. Finally, the loads are converted to average annual gallons of use using the algorithm below. The loads are summarized in [Table 3-96: Typical water heating loads](#)~~Table 3-92: Typical water heating loads~~<sup>96</sup> below.

$$HW\ (Gallons) = \frac{Load \times EF_{NG, Base} \times 1000 \frac{Btu}{kBTU} \times Typical\ SF}{8.3 \frac{lb}{gal} \times (T_{hot} - T_{cold}) \times 1000\ SF}$$

Table 3-~~96~~<sup>92</sup>~~96~~: Typical water heating loads

Building Type	Typical Square Footage	Average Annual Load In kBTU	Average Annual Use, Gallons
Motel	30,000	2,963	97,870
Small Office	10,000	2,214	24,377
Small Retail	7,000	1,451	11,183

**Energy to Demand Factor**

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA<sup>401</sup>. The usage profiles are shown in Figure 3-4. To ensure that the load shape data derived from observations in CA can be applied to PA, we compared the annual energy usage to peak demand factors for two disparate climate zones in CA. The results, shown in Figure 3-5, indicate that the ratio of peak demand to annual energy usage is not strongly influenced by climate. Also, though the actual usage profiles may be different, the average usage between noon and 8 PM on summer weekdays is quite similar for all building types. The close level of agreement between disparate climate zones and building types suggest that the results will carry over to Pennsylvania<sup>402</sup>.

400 <http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe>

401 *ibid*

402 One reason for the close agreement is that the factor is a ratio of the energy usage to peak demand for the same location. Even though the energy usages may vary significantly in different climate zones, the hot water usage patterns may be driven by underlying practices that carry over well from state to state (e.g. dishwashing after lunch or dinner in restaurants).

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Figure 3-4: Load shapes for hot water in four commercial building types

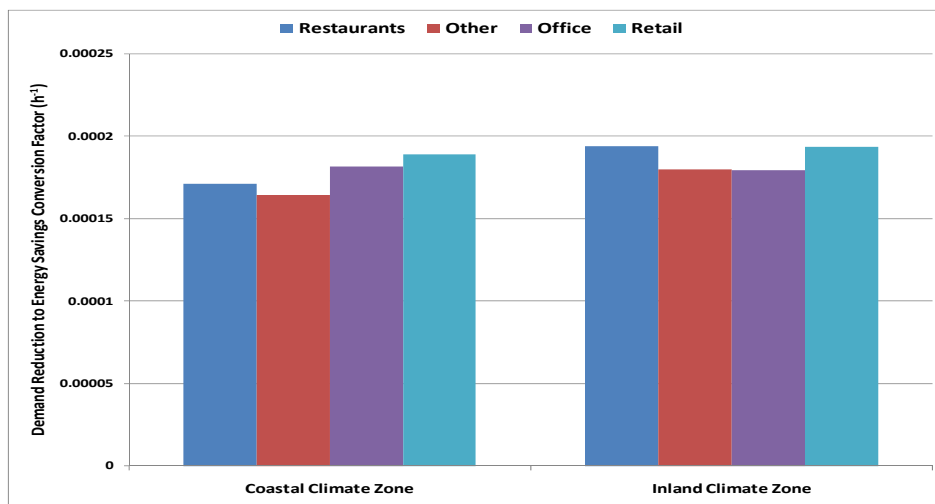


Figure 3-5: Energy to demand factors for four commercial building types

**Resistive Heating Discount Factor**

The resistive heating discount factor is an attempt to account for possible increased reliance on back-up resistive heating elements during peak usage conditions. Although a brief literature review failed to find data that may lead to a quantitative adjustment, two elements of the demand reduction calculation are worth considering.

- The hot water temperature in this calculation is somewhat conservative at 120 °F.
- The peak usage window is eight hours long.

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- In conditioned space, heat pump capacity is somewhat higher in the peak summer window.
- In unconditioned space, heat pump capacity is dramatically higher in the peak summer window.

Under these operating conditions, one would expect a properly sized heat pump water heater with adequate storage capacity to require minimal reliance on resistive heating elements. A resistive heating discount factor of 0.9, corresponding to a 10% reduction in COP during peak times, is therefore taken as a conservative estimation for this adjustment.

#### Heat Pump COP Adjustment Factor

The Energy Factors are determined from a DOE testing procedure that is carried out at 56 °F wetbulb temperature. However, the average wetbulb temperature in PA is closer to 45 °F<sup>403</sup>, while the average wetbulb temperature in conditioned typically ranges from 50 °F to 80 °F. The heat pump performance is temperature dependent. Figure 3-6 below shows relative coefficient of performance (COP) compared to the COP at rated conditions<sup>404</sup>. According to the plotted profile, the following adjustments are recommended.

Table 3-~~979397~~: COP Adjustment Factors

Heat Pump Placement	Typical WB Temperature °F	COP Adjustment Factor
Unconditioned Space	44	0.80
Conditioned Space	63	1.09
Kitchen	80	1.30

<sup>403</sup> Based on TMY2 weather files from DOE2.com for Erie, Harrisburg, Pittsburgh, Wilkes-Barre, And Williamsport, the average annual wetbulb temperature is  $45 \pm 1.3$  °F. The wetbulb temperature in garages or attics, where the heat pumps are likely to be installed, are likely to be two or three degrees higher, but for simplicity, 45 °F is assumed to be the annual average wetbulb temperature.

<sup>404</sup> The performance curve is adapted from Table 1 in <http://wescorhvac.com/HPWH%20design%20details.htm#Single-stage%20HPWHs>. The performance curve depends on other factors, such as hot water set point. Our adjustment factor of 0.84 is a first order approximation based on the information available in literature.

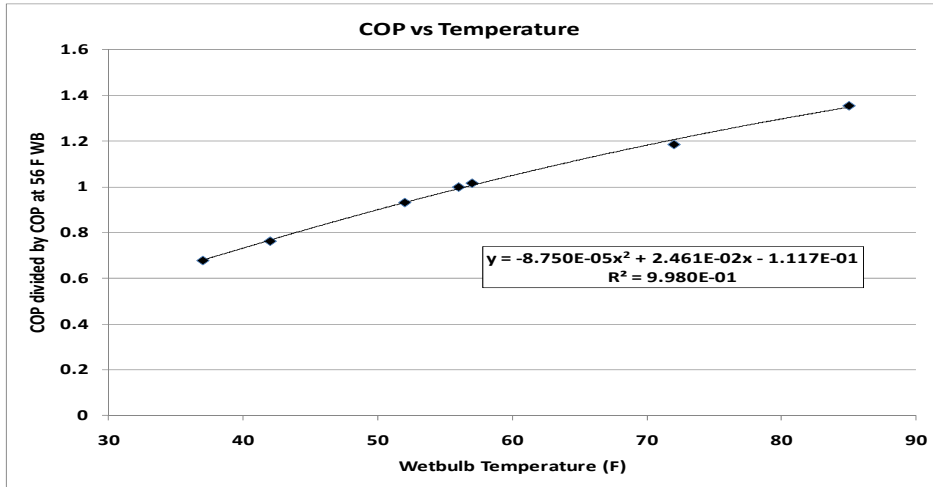


Figure 3-6: Dependence of COP on outdoor wetbulb temperature.

**3.29.3 Definition of Terms**

The parameters in the above equation are listed in [Table 3-98Table 3-9497](#).

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Table 3-98: Electric Resistance Water Heater Calculation Assumptions

<u>Component</u>	<u>Type</u>	<u>Values</u>	<u>Source</u>
<b>94: Electric Resistance Water Heater Calculation Assumptions</b>			
<u>EF<sub>base</sub></u> , Energy Factor of baseline water heater	Fixed	0.904	1
<u>EF<sub>proposed</sub></u> , Energy Factor of proposed efficient water heater	Variable	Nameplate	EDC Data Gathering
<u>EF<sub>base</sub></u> , Energy Factor of baseline water heater	Variable	See Table 3-99	1
<u>EF<sub>proposed</sub></u> , Energy Factor of proposed efficient water heater	Variable	Default: 2.2	Program Design
		Nameplate	EDC Data Gathering
Load, Average annual Load in kBTU	Fixed	Varies	5
T <sub>hot</sub> , Temperature of hot water	Fixed	120 °F	2
T <sub>cold</sub> , Temperature of cold water supply	Fixed	55 °F	3
EnergyToDemandFactor	Fixed	0.0001916	4
F <sub>Adjust</sub> , COP Adjustment factor	Fixed	0.80 if outdoor 1.09 if indoor 1.30 if in kitchen	4
ResistiveDiscountFactor	Fixed	0.90	6
<u>HW</u> , Average annual gallons of Use	FixedVariable	VariesDefault: See Table 3-96: Typical water heating loadsTable 3-96	CalculationSee- Table 3-92:- Typical water heating loads
			EDC Data Gathering
<u>EF<sub>NG, base</sub></u> , Energy Factor of baseline gas water heater	Fixed	0.594	7

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**3.29.4 Energy Factors based on Tank Size**

Federal Standards for Energy Facotrs are equal to 0.97 -0.00132 x Rated Storage in Gallons. The following table shows the Energy Factors for various tank sizes.

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**Table 3-99: Energy Factor Based on Tank Size**

Tank Size (gallons)	Energy Factor
40	0.9172
50	0.9040
65	0.8842
80	0.8644
120	0.8116

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**Sources:**

1. Federal Standards are  $0.97 - 0.00132 \times \text{Rated Storage in Gallons}$ . For a 50-gallon tank this is approximately 0.90. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE-2006-BT-STD-0129, p. 30

2-12. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.

3-13. Mid-Atlantic TRM, footnote #24

4-14. The load shapes can be accessed online:  
<http://www.ethree.com/CPUC/PG&ENonResViewer.zip>

5-15. DEER Database

6-16. Engineering Estimate

7-17. Federal Standards are  $0.67 - 0.0019 \times \text{Rated Storage in Gallons}$ . For a 40-gallon tank this is 0.594. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: **EE-2006-BT-STD-0129**, p. 30

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**3-29.43.29.5 Deemed Savings**

TheAsn an example, the deemed savings for the installation of heat pump electric water heaters with energy factor of 2.2 in various applications are listed below.

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Table 3-10095100: Energy Savings and Demand Reductions

Building Type	Location Installed	Average Annual Use, Gallons	EF	COP Adjustment Factor	Energy Savings (kWh)	Demand Reduction (kW)
Motel	Unconditioned Space	97,870	2.2	0.80	8,324	1.44
Motel	Conditioned Space	97,870	2.2	1.09	10,662	1.84
Motel	Kitchen	97,870	2.2	1.30	11,704	2.02
Small Office	Unconditioned Space	24,377	2.2	0.80	2,073	0.36
Small Office	Conditioned Space	24,377	2.2	1.09	2,656	0.46
Small Office	Kitchen	24,377	2.2	1.30	2,915	0.50
Small Retail	Unconditioned Space	11,183	2.2	0.80	951	0.16
Small Retail	Conditioned Space	11,183	2.2	1.09	1,218	0.21
Small Retail	Kitchen	11,183	2.2	1.30	1,338	0.23

**3.29.53.29.6 Measure Life**

According to an October 2008 report for the CA Database for Energy Efficiency Resources, an electric water heater's lifespan is 10 years<sup>405</sup>.

**3.29.63.29.7 Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installation coupled with [EDC data gathering](#) or assignment of stipulated energy savings.

<sup>405</sup> DEER values, updated October 10, 2008.

[http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

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### 3.30 LED Channel Signage

Channel signage refers to the illuminated signs found inside and outside shopping malls to identify store names. Typically these signs are constructed from sheet metal sides forming the shape of letters and a translucent plastic lens. Luminance is most commonly provided by single or double strip neon lamps, powered by neon sign transformers. Retrofit kits are available to upgrade existing signage from neon to LED light sources, substantially reducing the electrical power and energy required for equivalent sign luminance. Red, green, blue, yellow, and white LEDs are available, but at higher cost than red. Red is the most common color and the most cost-effective to retrofit, currently comprising approximately 80% of the market.

#### 3.30.1 Eligibility Requirements

This measure must replace ~~incandescent lighted~~~~inefficient argon-mercury~~ or neon-lighted channel letter signs- with efficient LED channel letter signs. Retrofit kits or complete replacement LED signs are eligible. Neon lamps are used for red signage and argon-mercury lamps for white signage. Replacement signs cannot use more than 20%406 of the actual input power of the sign that is replaced. Measure the length of the sign as follows:

- Measure the length of each individual letter at the centerline. Do not measure the distance between letters.
- Add up the measurements of each individual letter to get the length of the entire sign being replaced.

#### 3.30.2 Algorithms

The savings are calculated using the equations below and the assumptions in Table 1-1-Table 3-101.

$$\Delta kW = kW_{base} - kW_{ee}$$

$$kW_{base} = kW_{LED} / ft \times L$$

**Indoor applications:**  $kW_{ee} = kW_{LED} / ft \times L$

$$\Delta kW_{peak} = \Delta kW \times CF \times (1 + IF \text{ demand})$$

$$\Delta kWh = [kW_{base} \times (1 + IF \text{ energy}) \times EFLH \times HOU] - [kW_{ee} \times (1 + IF \text{ energy}) \times EFLH \times HOU \times (1 - SVG)]$$

$$\Delta kW_{peak} = [kW_{base} \times (1 + IF \text{ demand}) \times CF] - [kW_{ee} \times (1 + IF \text{ demand}) \times CF \times (1 - SVG)]$$

**Outdoor applications:**

$$\Delta kWh_{407} = [kW_{base} \times HOU] - [kW_{ee} \times HOU \times (1 - SVG)]$$

$$\Delta kW_{peak} = 0.408$$

406 [http://www.aepohio.com/global/utilities/lib/docs/save/programs/Application\\_Steps\\_Incentive\\_Process.pdf](http://www.aepohio.com/global/utilities/lib/docs/save/programs/Application_Steps_Incentive_Process.pdf)  
 407 For exterior measures, energy interactive effects are not included in the energy savings calculations.

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### 3.30.3 Definition of Terms

$\Delta kWh$	= Annual energy savings (kWh/ft) <u>letter</u>
$\Delta kW/kW_{base}$	= Change in connected load from baseline (pre-retrofit) to installed (post-retrofit) lighting level (kW/ft-of sign) <u>letter</u>
$kW_N/ft$	= kW of the baseline (neon) lighting per foot (kW <sub>N</sub> /ft)
$kW_{LED}/ft-kW_{ee}$	= kW of post-retrofit or energy-efficient lighting system (LED) lighting per foot (kW <sub>LED</sub> /ft) <u>letter</u>
$L$	= length of the sign (feet)
CF	= Demand Coincidence Factor (See Section 1.4) <u>01.4</u>
<del>EFLH</del>	<del>= Equivalent Full Load Hours – the average annual operating hours of the baseline lighting equipment, which if applied to full connected load will yield annual energy use.</del>
<del>IF<sub>demand</sub></del>	<del>HOU = Hours of Use</del>
<u>IF<sub>demand</sub></u>	= Interactive HVAC Demand Factor – applies to C&I interior lighting in space that has air conditioning or refrigeration only. This represents the secondary demand savings in cooling required which results from decreased indoor lighting wattage.
<u>IF<sub>energy</sub></u>	= Interactive HVAC Energy Factor – applies to C&I interior lighting in space that has air conditioning or refrigeration only. This represents the secondary energy savings in cooling required which results from decreased indoor lighting wattage.
SVG	= The percent of time that lights are off due to lighting controls relative to the baseline controls system (typically manual switch).

408 The peak demand reduction is zero, as the exterior lighting applications are assumed to be in operation during off-peak hours and have a peak coincidence factor of 0.0.



Table 3-101: LED Channel Signage Calculation Assumptions

Component	Type	Value	Source
$kW_{base}$	Variable	EDC Data Gathering Default: 0.00457	EDC Data Gathering
$kW_{LED}$	Variable	EDC Data Gathering Default: 0.00136410	EDC Data Gathering
CF	Fixed	See Table 3-6	Table 3-6
EFLH	Fixed	EDC Data Gathering Default: See Table 3-6	EDC Data Gathering Table 3-6
IF <sub>demand</sub>	Fixed	See Table 3-7	Table 3-7
IF <sub>energy</sub>	Fixed	See Table 3-7	Table 3-7
L	Variable	EDC Data Gathering	EDC Data Gathering
SVG	Fixed	See Table 3-7	See Table 3-7 Table 3-8

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Table 3-102: Power demand of baseline (neon and argon-mercury) and energy-efficient (LED) signs

Sign Height	Power Demand (kW/letter)		Power Demand (kW/letter)	
	Neon	Red LED	Argon-mercury	White LED
≤ 2 ft	0.043	0.006	0.034	0.004
> 2 ft	0.108	0.014	0.086	0.008

3.30.4 Measure Life

Expected measure life is 15 years.

409 Average values were estimated based on wattages data obtained from major channel letter lighting product manufacturers. Southern California Edison Company San Diego Gas & Electric, LED Channel Letter Signage (Red), Signs, Work Paper WPSCNRLG0052/SCE13LG052, Revision 4, April 6, 2012, DEER only includes an LED Exit Sign measure which was used to estimate the effective useful life of the LED Channel Letter Signage. Actual The Work Paper assumes 16 years for interior and exterior applications. The measure life is 15 years per Act 129.

410 ibid

411 ibid

412 Southern California Edison Company, LED Channel Letter Signage (Red), Work Paper WPSCNRLG0052/SCE13LG052, Revision 4, April 6, 2012, DEER only includes an LED Exit Sign measure which was used to estimate the effective useful life of the LED Channel Letter Signage. Actual The Work Paper assumes 16 years for interior and exterior applications. The measure life is 15 years per Act 129.

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### 3.31 Low Flow Pre-Rinse Sprayers for Retrofit Programs

Measure Name	Low Flow Pre-Rinse Sprayers for Retrofit Programs
Target Sector	Commercial Kitchens
Measure Unit	Pre Rinse Sprayer
Unit Energy Savings	Groceries: 151 kWh; Non-Groceries: 1,222 kWh
Unit Peak Demand Reduction	Groceries: 0.03kW; Non-Groceries: 0.23 kW
Measure Life	5 years

This protocol documents the energy savings and demand reductions attributed to efficient low flow pre-rinse sprayers in grocery and non-grocery (primarily food service) applications. The most likely areas of application are kitchens in restaurants and hotels. Only premises with electric water heating may qualify for this incentive. In addition, the replacement pre-rinse spray nozzle must use less than 1.6 gallons per minute with a cleanability performance of 26 seconds per plate or less. Low flow pre-rinse sprayers reduce hot water usage and save energy associated with water heating.

This protocol is applicable to Retrofit programs only. The baseline for Retrofit Program is assumed to be an 2.25 GPM413 and 2.15 GPM414 for non-grocery and grocery applications respectively.

#### 3.31.1 Algorithms

The energy savings and demand reduction are calculated through the protocols documented below.

$$\Delta kWh \text{ for Non-Groceries} = ((F_{BNG} \times U_{BNG}) - (F_{PNG} \times U_{PNG})) \times 365 \times 8.33 \times (T_{HNG} - T_C) / (EF \times 3413 \text{ Btu/kWh})$$

$$\Delta kWh \text{ for Groceries} = ((F_{BG} \times U_{BG}) - (F_{PG} \times U_{PG})) \times 365 \times 8.33 \times (T_{HG} - T_C) / (EF \times 3413 \text{ Btu/kWh})$$

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = \text{EnergyToDemandFactor} \times \text{Energy Savings}$$

The Energy to Demand Factor is defined below:

$$\text{EnergyToDemandFactor} = \frac{\text{Average Usage}_{\text{Summer WD Noon-8}}}{\text{Annual Energy Usage}}$$

413 Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2), SBW Consulting, 2007, Table 3-4, p. 23  
414 ibid

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA. The usage profiles are shown in Figure 3-7. To ensure that the load shape data derived from observations in CA can be applied to PA, we compared the annual energy usage to peak demand factors for two disparate climate zones in CA. The results, shown in Figure 3-8, indicate that the ratio of peak demand to annual energy usage is not strongly influenced by climate. Also, though the actual usage profiles may be different, the average usage between noon and 8 PM on summer weekdays is quite similar for all building types. The close level of agreement between disparate climate zones and building types suggest that the results will carry over to Pennsylvania<sup>415</sup>.

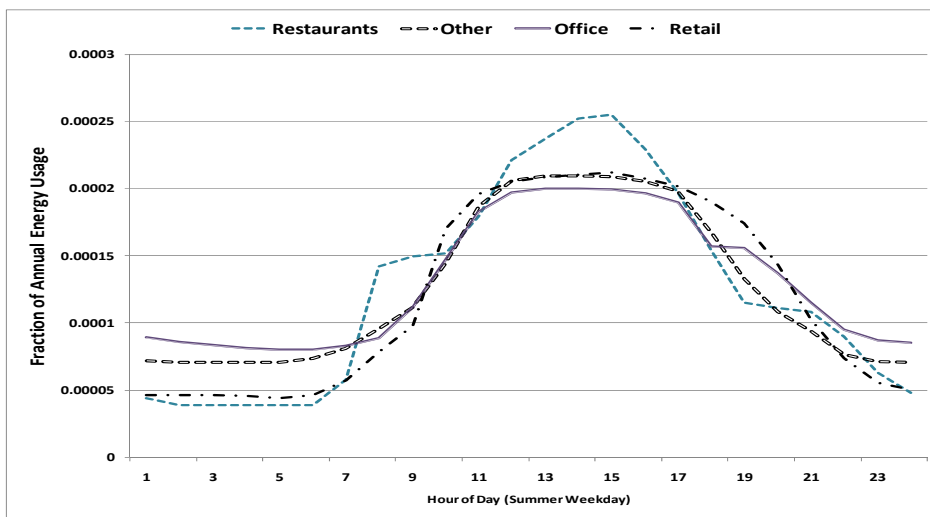


Figure 3-7: Load shapes for hot water in four commercial building types

<sup>415</sup> One reason for the close agreement is that the factor is a ratio of the energy usage to peak demand for the same location. Even though the energy usages may vary significantly in different climate zones, the hot water usage patterns may be driven by underlying practices that carry over well from state to state (e.g. dishwashing after lunch or dinner in restaurants).

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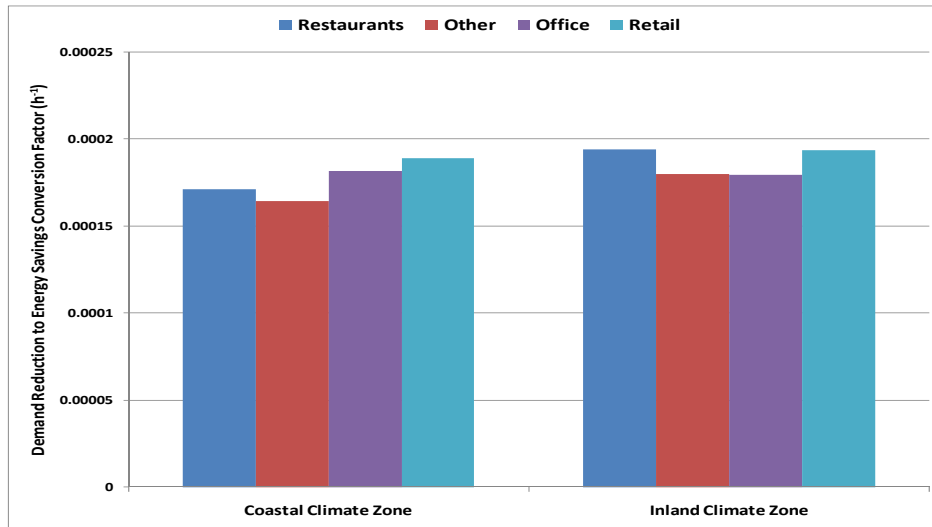


Figure 3-8: Energy to demand factors for four commercial building types.

### 3.31.2 Definition of Terms

The parameters in the above equation are listed in [Table 3-103](#)~~Table 3-97101~~ below. The values for all parameters except incoming water temperature are taken from impact evaluation of the 2004-2005 California Urban Water council Pre-Rinse Spray Valve Installation Program.

$F_{BNG}$	= Baseline Flow Rate of Sprayer for Non-Grocery Applications
$F_{PNG}$	= Post Measure Flow Rate of Sprayer for Non-Grocery Applications
$U_{BNG}$	= Baseline Water Usage Duration for Non-Grocery Applications
$U_{PNG}$	= Post Measure Water Usage Duration for Non-Grocery Applications
$F_{BG}$	= Baseline Flow Rate of Sprayer for Grocery Applications
$F_{PG}$	= Post Measure Flow Rate of Sprayer for Grocery Applications
$U_{BG}$	= Baseline Water Usage Duration for Grocery Applications
$U_{PG}$	= Post Measure Water Usage Duration for Grocery Applications
$T_{HNG}$	= Temperature of hot water coming from the spray nozzle for Non-Grocery Application
$T_C$	= Incoming cold water temperature for Grocery and Non-Grocery Application

$T_{HG}$  = Temperature of hot water coming from the spray nozzle for Grocery Application

$EF_{electric}$  = Energy Factor of existing Electric Water Heater System

Table 3-10397103: Low Flow Pre-Rinse Sprayer Calculations Assumptions

Description	Type	Value	Source
F <sub>BNG</sub>	Fixed	Retrofit: 2.25 gpm	1, 7
F <sub>PNG</sub>	Fixed	Default: 1.12 gpm	1
	Variable	EDC Data Gathering	EDC Data Gathering
U <sub>BNG</sub>	Fixed	32.4min/day	2
U <sub>PNG</sub>	Fixed	43.8 min/day	2
F <sub>BG</sub>	Fixed	Retrofit: 2.15 gpm	1, 7
F <sub>PG</sub>	Fixed	1.12 gpm	1
	Variable	EDC Data Gathering	EDC Data Gathering
U <sub>BG</sub>	Fixed	4.8 min/day	2
U <sub>PG</sub>	Fixed	6 min/day	2
T <sub>HNG</sub>	Fixed	107°F	3
T <sub>C</sub>	Fixed	55°F	6
T <sub>HG</sub>	Fixed	97.6°F	3
EF <sub>electric</sub>	Fixed	0.904	4
	Variable	EDC Data Gathering	EDC Data Gathering
EnergyToDemandFactor	Fixed	0.0001916	5

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**Sources:**

1. *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2)*, SBW Consulting, 2007, Table 3-4, p. 23
2. *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2)*, SBW Consulting, 2007, Table 3-6, p. 24

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3. *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2)*, SBW Consulting, 2007, Table 3-5, p. 23
4. Federal Standards are  $0.97 - 0.00132 \times \text{Rated Storage in Gallons}$ . For a 50-gallon tank this is approximately 0.90. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept. of Energy Docket Number: EE-2006-BT-STD-0129, p. 30
5. The load shapes can be accessed online:  
<http://www.ethree.com/CPUC/PG&ENonResViewer.zip>
6. Mid-Atlantic TRM, footnote #24
7. The Energy Policy Act (EPAct) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 GPM at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006.

### 3.31.3 Deemed Savings

The deemed savings for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer is 151 kWh/year for pre-rinse sprayers installed in grocery stores and 1,222 kWh/year for pre-rinse sprayers installed in non-groceries building types such as restaurants. The deemed demand reductions for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer is 0.03 kW for pre-rinse sprayers installed in grocery stores and 0.23 kW for pre-rinse sprayers installed in non-groceries building types such as restaurants.

### 3.31.4 Measure Life

The effective life for this measure is 5 years<sup>416</sup>.

### 3.31.5 Evaluation Protocol

The most appropriate evaluation protocol for this measure is verification of installation coupled with [EDC data gathering](#) or assignment of stipulated energy savings.

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<sup>416</sup> *Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2)*, SBW Consulting, 2007, p. 30

### 3.32 Low Flow Pre-Rinse Sprayers for Time of Sale / Retail Programs

Measure Name	Low Flow Pre-Rinse Sprayers for Time of Sale / Retail Programs
Target Sector	Commercial Kitchens
Measure Unit	Pre Rinse Sprayer
Unit Energy Savings	See <a href="#">Table 3-105: Low Flow Pre-Rinse Sprayer Deemed Savings</a> <a href="#">Table 3-99: Low Flow Pre-Rinse Sprayer Deemed Savings</a> <a href="#">105</a>
Unit Peak Demand Reduction	See <a href="#">Table 3-105: Low Flow Pre-Rinse Sprayer Deemed Savings</a> <a href="#">Table 3-99: Low Flow Pre-Rinse Sprayer Deemed Savings</a> <a href="#">105</a>
Measure Life	5 years

This protocol documents the energy savings and demand reductions attributed to efficient low flow pre-rinse sprayers in small quick service restaurants, medium-sized casual dining restaurants, and large institutional establishments with cafeteria. Low flow pre-rinse sprayers reduce hot water usage and save energy associated with water heating. Only premises with electric water heating may qualify for this incentive. In addition, the new pre-rinse spray nozzle must have a cleanability performance of 26 seconds per plate or less.

This protocol is applicable to Time of Sale/Retail programs only. The baseline for Time of Sale / Retail programs is assumed to be 1.52 GPM<sup>417</sup>.

#### 3.32.1 Algorithms

The energy savings and demand reduction are calculated through the protocols documented below.

$$\Delta kWh = (F_B - F_P) \times U \times 60 \times 312 \times 8.33 \times 1 \times (T_H - T_C) / (EF \times 3413 \text{ Btu/kWh})$$

The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage.

$$\Delta kW_{peak} = \text{EnergyToDemandFactor} \times \text{Energy Savings}$$

<sup>417</sup> The Energy Policy Act (EPA) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 GPM at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. The federal baseline is adjusted using a baseline adjustment factor of 0.95 to arrive at 1.52 GPM i.e. 1.6 GPM X 0.95 = 1.52 GPM. This value is derived based on the performance rating results of 29 models listed on the Food Service Technology Center Website which showed that the highest rated flow was 1.51 GPM. Web address: <http://www.fishnick.com/equipment/sprayvalves/>, Accessed September 21, 2012. Sprayer by T&S Brass Model JetSpray B-0108 was rated at 1.48 GPM, and tested at 1.51 GPM.

The Energy to Demand Factor is defined below:

$$\text{EnergyToDemandFactor} = \frac{\text{Average Usage}_{\text{Summer WD Noon-8}}}{\text{Annual Energy Usage}}$$

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA. The usage profiles are shown in [Figure 3-9: Load shapes for hot water in four commercial building types](#). To ensure that the load shape data derived from observations in CA can be applied to PA, we compared the annual energy usage to peak demand factors for two disparate climate zones in CA. The results, shown in [Figure 3-10: Energy to demand factors for four commercial building types](#), indicate that the ratio of peak demand to annual energy usage is not strongly influenced by climate. Also, though the actual usage profiles may be different, the average usage between noon and 8 PM on summer weekdays is quite similar for all building types. The close level of agreement between disparate climate zones and building types suggest that the results will carry over to Pennsylvania.

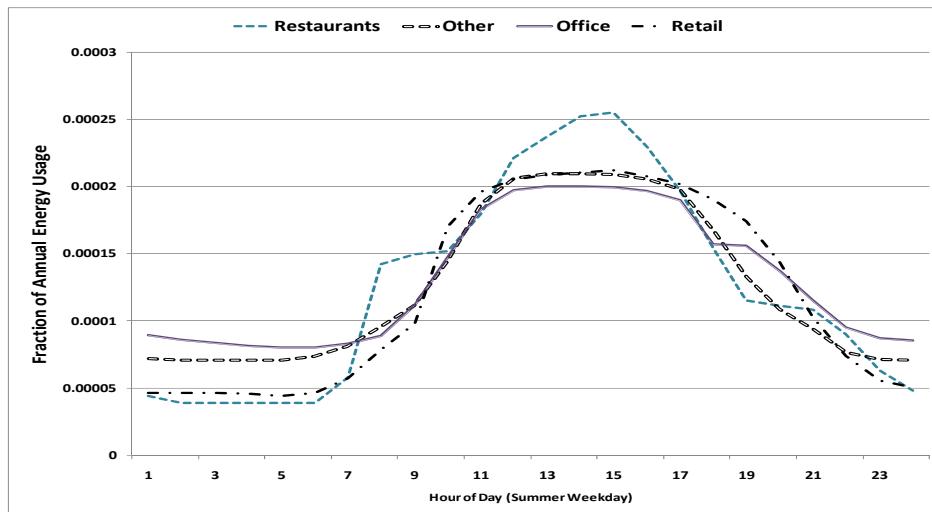


Figure 3-9: Load shapes for hot water in four commercial building types

418 One reason for the close agreement is that the factor is a ratio of the energy usage to peak demand for the same location. Even though the energy usages may vary significantly in different climate zones, the hot water usage patterns may be driven by underlying practices that carry over well from state to state (e.g. dishwashing after lunch or dinner in restaurants).

### SECTION 3: Commercial and Industrial Measures

Low Flow Pre-Rinse Sprayers for Time of Sale / Retail Programs

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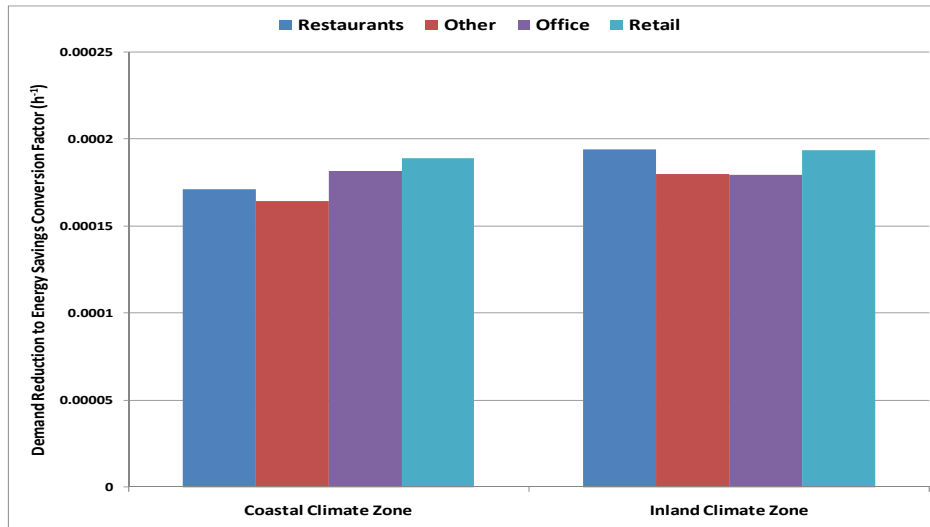


Figure 3-10: Energy to demand factors for four commercial building types.

### 3.32.2 Definition of Terms

The parameters in the above equation are listed in [Table 3-103](#) ~~Table 3-97~~ [Table 3-97](#) below.

$F_B$	= Baseline Flow Rate of Sprayer
$F_P$	= Post Measure Flow Rate of Sprayer
$U$	= Baseline and Post Measure Water Usage Duration based on application.
$T_H$	= Temperature of hot water coming from the spray nozzle
$T_C$	= Incoming cold water temperature
$EF_{electric}$	= Energy Factor of existing Electric Water Heater System
8.33 lbm/gal	= specific mass in pounds of one gallon of water
1 Btu/lbm°F	= Specific heat of water: 1 Btu/lbm°F
312419	= Days per year pre-rinse spray valve is used at the site
60	= Minutes per hour pre-rinse spray valve is used at the site

419 Days per year pre-rinse spray valve is used at the site is assumed to be 312 days/yr derived based on 6 days/wk x 52 wk/yr.

Table 3-10498104: Low Flow Pre-Rinse Sprayer Calculations Assumptions

Description	Type	Value	Source
F <sub>B</sub>	Fixed	Time of Sale/Retail: 1.52 GPM	1, 2
F <sub>P</sub>	Fixed	Default: Time of Sale/Retail: 1.06 GPM	3
	Variable	EDC Data Gathering	EDC Data Gathering
U (hours/day)	Fixed	Default: Small, quick- service restaurants: 0.5 Medium-sized casual dining restaurants: 1.5 Large institutional establishments with cafeteria: 3	4
T <sub>H</sub>	Fixed	120°F	5
T <sub>C</sub>	Fixed	55°F	6
EF <sub>electric</sub>	Fixed	Default: 0.904	7
	Variable	EDC Data Gathering	EDC Data Gathering
EnergyToDemandFactor	Fixed	0.0001916	8

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**Sources:**

1. Verification measurements taken at 195 installations showed average pre and post flowrates of 2.23 and 1.12 gallon per minute, respectively.” from Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2) (PG&E Program # 1198-04; SoCalGas Program 1200-04) (“CUWCC Report”, Feb 2007)
2. The Energy Policy Act (EPA) of 2005 sets the maximum flow rate for pre-rinse spray valves at 1.6 GPM at 60 pounds per square inch of water pressure when tested in accordance with ASTM F2324-03. This performance standard went into effect January 1, 2006. The federal baseline is adjusted using a baseline adjustment factor of 0.95. This value is derived based on the performance rating results of 29 models listed on the Food Service Technology Center Website showed that the highest rated flow was 1.51 GPM. Web address: <http://www.fishnick.com/equipment/sprayvalves/>, Accessed September 21, 2012. Sprayer by T&S Brass Model JetSpray B-0108 was rated at 1.48 GPM, and tested at 1.51 GPM.
3. 1.6 gallons per minute used to be the high efficiency flow, but more efficient spray valves are available ranging down to 0.64 gallons per minute per Federal Energy Management Program which references the Food Services Technology Center web site with the added note that even more efficient models may be available since publishing the data. The average of the nozzles listed on the FSTC website is 1.06.

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4. Hours primarily based on PG& E savings estimates, algorithms, sources (2005), Food Service Pre-Rinse Spray Valves with review of 2010 Ohio Technical Reference Manual and Act on Energy Business Program Technical Resource Manual Rev05.
5. Food Service Technology Center calculator assumptions to account for variations in mixing and water heater efficiencies. In the algorithm,  $T_h = T_c + 70^\circ \text{ F}$  temperature rise from  $T_c$ .
6. Mid-Atlantic TRM, footnote #24
7. Federal Standards are  $0.97 - 0.00132 \times \text{Rated Storage in Gallons}$ . For a 50-gallon tank this is approximately 0.90. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept. of Energy Docket Number: EE-2006-BT-STD-0129, p. 30
8. The load shapes can be accessed online:  
<http://www.ethree.com/CPUC/PG&ENonResViewer.zip>

**3.32.3 Deemed Savings**

The deemed savings for the installation of a low flow pre-rinse sprayer compared to a standard efficiency sprayer for retail programs are listed in [Table 3-105: Low Flow Pre-Rinse Sprayer Deemed Savings](#) below.

Table 3-105: Low Flow Pre-Rinse Sprayer Deemed Savings

Application	Retail	
	kWh	kW
Small quick service restaurants	814	0.156
Medium-sized casual dining restaurants	2,441	0.468
Large institutional establishments with cafeteria	4,882	0.935

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**3.32.4 Measure Life**

The effective life for this measure is 5 years.

**3.32.5 Evaluation Protocol**

The most appropriate evaluation protocol for this measure is verification of installation coupled with [EDC data gathering](#) or assignment of stipulated energy savings.

420 Impact and Process Evaluation Final Report for California Urban Water Conservation Council 2004-5 Pre-Rinse Spray Valve Installation Program (Phase 2), SBW Consulting, 2007, p. 30

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### 3.33 Small C/I HVAC Refrigerant Charge Correction

Measure Name	Refrigerant Charge Correction
Target Sector	Small C/I HVAC
Measure Unit	Tons of Refrigeration Capacity
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	10 years

This protocol describes the assumptions and algorithms used to quantify energy savings for refrigerant charging on packaged AC units and heat pumps operating in small commercial

**SECTION 3: Commercial and Industrial Measures**

Small C/I HVAC Refrigerant Charge Correction

Page 392

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applications. The protocol herein describes a partially deemed energy savings and demand reduction estimation.

### 3.33.1 Eligibility

This protocol is applicable for small commercial and industrial customers, and applies to documented tune-ups for package or split systems up to 20 tons.

### 3.33.2 Algorithms

This section describes the process of creating energy savings and demand reduction calculations.

#### Air Conditioning:

For A/C units < 65,000 BtuH, use SEER instead of EER to calculate  $\Delta kWh$  and convert SEER to EER to calculate  $\Delta kW_{peak}$  using 11.3/13 as the conversion factor.

$$\begin{aligned}\Delta kWh &= (EFLH_C \times CAPY_C / 1000) \times (1/[EER \times RCF] - 1/EER) \\ &= (EFLH_C \times CAPY_C / 1000) \times (1/[SEER \times RCF] - 1/SEER) \\ \Delta kW_{peak} &= (CF \times CAPY_C / 1000) \times (1/[EER \times RCF] - 1/EER)\end{aligned}$$

#### Heat Pumps:

For Heat Pump units < 65,000 BtuH, use SEER instead of EER to calculate  $\Delta kWh_{cool}$  and HSPF instead of COP to calculate  $\Delta kWh_{heat}$ . Convert SEER to EER to calculate  $\Delta kW_{peak}$  using 11.3/13 as the conversion factor.

$$\begin{aligned}\Delta kWh &= \Delta kWh_{cool} + \Delta kWh_{heat} \\ \Delta kWh_{cool} &= (EFLH_C \times CAPY_C / 1000) \times (1/[EER \times RCF] - 1/EER) \\ &= (EFLH_C \times CAPY_C / 1000) \times (1/[SEER \times RCF] - 1/SEER) \\ \Delta kWh_{heat} &= (EFLH_{MH} \times CAPY_H / 1000) / 3.412 \times (1/[COP \times RCF] - 1/COP) \\ &= (EFLH_{MH} \times CAPY_H / 1000) \times (1/[HSPF \times RCF] - 1/HSPF) \\ \Delta kW_{peak} &= (BtuH_{cool} / 1000) \times (1/EER_{base} - 1/EER_{ee}) \times CF\end{aligned}$$

### 3.33.3 Definition of Terms

$CAPY_C$	= Unit Capacity, in Btu/h for cooling
$CAPY_H$	= Unit Capacity, in Btu/h for heating
$EER$	= Energy Efficiency Ratio. For A/C and heat pump units < 65,000 BtuH, SEER should be used for cooling savings.

- SEER** = Seasonal Energy Efficiency Ratio. For A/C and heat pump units > 65,000 BtuH, EER should be used for cooling savings.
- HSPF** = Heating Seasonal Performance Factor. For heat pump units > 65,000 BtuH, COP should be used for heating savings.
- COP** = Coefficient of Performance. For heat pump units < 65,000 BtuH, HSPF should be used for heating savings.
- EFLH<sub>C</sub>** = Equivalent Full-Load Hours for Mechanical Cooling
- EFLH<sub>MH</sub>** = Equivalent Full-Load Hours for Mechanical Heating<sup>421</sup>
- RCF** = COP Degradation Factor for Cooling
- CF** = Demand Coincidence Factor (See Section 4.4)<sup>422</sup>
- 11.3/13** = Conversion factor from SEER to EER, based on average EER of a SEER 13 unit.

The values and sources are listed in [Table 3-106](#)~~Table 3-100~~<sup>106</sup>.

Table 3-~~106~~<sup>100</sup><sup>106</sup>: Refrigerant Charge Correction Calculations Assumptions

Component	Type	Value	Source
CAPY <sub>C</sub>	Variable	Nameplate	EDC Data Gathering
CAPY <sub>H</sub>	Variable	Nameplate	EDC Data Gathering
EER	Variable	Nameplate	EDC Data Gathering
	Fixed	Default: See <a href="#">Table 3-20</a> <a href="#">Table 3-22</a> in <a href="#">20132014</a> PA TRM	<a href="#">20132014</a> PA TRM
HSPF	Variable	Nameplate	EDC Data Gathering
	Fixed	Default: See <a href="#">Table 3-20</a> <a href="#">Table 3-22</a> in <a href="#">20132014</a> PA TRM	<a href="#">20132014</a> PA TRM
EFLH <sub>C</sub>	Variable	<a href="#">Table 3-21</a> <a href="#">Table 3-23</a> in <a href="#">20132014</a> PA TRM	<a href="#">20132014</a> PA TRM
		<a href="#">Based on Logging, BMS data or Modeling</a> <sup>422</sup>	<a href="#">EDC's Data Gathering</a>

<sup>421</sup> Here it is assumed that the compressor provides 70% of the heat, while the fan and supplemental heat strips provide the remaining 30% of the heating. The efficiency gains from refrigerant charging do not apply to the fan or supplemental heat strips.

<sup>422</sup> Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

**SECTION 3: Commercial and Industrial Measures**

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EFLH <sub>MH</sub>	Variable	Take EFLH <sub>HM</sub> as 70% of the listed EFLH <sub>H</sub> in <a href="#">Table 3-22</a> <a href="#">Table 3-24</a> in <a href="#">20132014 PA TRM</a>	2
RCF	Variable	See <a href="#">Table 3-107</a> <a href="#">Table 3-104</a> <a href="#">107</a>	1
CF	Fixed	6780%	<a href="#">Table 3-20</a> <a href="#">Table 3-21</a> in <a href="#">20112014 PA TRM</a>

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**Sources:**

[9-1](#). CA 2003 RTU Survey

Assumes 70% of heating is done by compressor, 30% by fan and supplemental resistive heat

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Table 3-~~107~~~~104~~~~107~~: Refrigerant charge correction COP degradation factor (RCF) for various relative charge adjustments for both TXV metered and non-TXV units.423.

% of nameplate charge added (removed)	RCF (TXV)	RCF (Orifice)	% of nameplate charge added (removed)	RCF (TXV)	RCF (Orifice)	% of nameplate charge added (removed)	RCF (TXV)	RCF (Orifice)
60%	68%	13%	28%	95%	83%	(4%)	100%	100%
59%	70%	16%	27%	96%	84%	(5%)	100%	99%
58%	71%	19%	26%	96%	85%	(6%)	100%	99%
57%	72%	22%	25%	97%	87%	(7%)	99%	99%
56%	73%	25%	24%	97%	88%	(8%)	99%	99%
55%	74%	28%	23%	97%	89%	(9%)	99%	98%
54%	76%	31%	22%	98%	90%	(10%)	99%	98%
53%	77%	33%	21%	98%	91%	(11%)	99%	97%
52%	78%	36%	20%	98%	92%	(12%)	99%	97%
51%	79%	39%	19%	98%	92%	(13%)	99%	96%
50%	80%	41%	18%	99%	93%	(14%)	98%	96%
49%	81%	44%	17%	99%	94%	(15%)	98%	95%
48%	82%	46%	16%	99%	95%	(16%)	98%	95%
47%	83%	48%	15%	99%	95%	(17%)	98%	94%
46%	84%	51%	14%	99%	96%	(18%)	98%	93%

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423 CA 2003 RTU Survey

**SECTION 3: Commercial and Industrial Measures**

Small C/I HVAC Refrigerant Charge Correction

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45%	85%	53%	13%	100%	97%	(19%)	98%	93%
44%	86%	55%	12%	100%	97%	(20%)	97%	92%
43%	86%	57%	11%	100%	98%	(21%)	97%	91%
42%	87%	60%	10%	100%	98%	(22%)	97%	90%
41%	88%	62%	9%	100%	98%	(23%)	97%	90%
40%	89%	64%	8%	100%	99%	(24%)	97%	89%
39%	89%	65%	7%	100%	99%	(25%)	96%	88%
38%	90%	67%	6%	100%	99%	(26%)	96%	87%
37%	91%	69%	5%	100%	100%	(27%)	96%	86%
36%	91%	71%	4%	100%	100%	(28%)	96%	85%
35%	92%	73%	3%	100%	100%	(29%)	95%	84%
34%	92%	74%	2%	100%	100%	(30%)	95%	83%
33%	93%	76%	1%	100%	100%	(31%)	95%	82%
32%	94%	77%	(0%)	100%	100%	(32%)	95%	81%
31%	94%	79%	(1%)	100%	100%	(33%)	95%	80%
30%	95%	80%	(2%)	100%	100%	(34%)	94%	78%
29%	95%	82%	(3%)	100%	100%	(35%)	94%	77%

### 3.33.4 Measure Life

According to the 2008 Database for Energy Efficiency Resources (DEER) EUL listing, the measure life for refrigerant charging is **10 years**<sup>424</sup>.

424 [http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)

## SECTION 3: Commercial and Industrial Measures

### Small C/I HVAC Refrigerant Charge Correction

Page 396

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### 3.34 Refrigeration – Special Doors with Low or No Anti-Sweat Heat for Low Temp Case

Measure Name	Special Doors with Low or No Anti-Sweat Heat for Low Temp Case
Target Sector	Commercial Refrigeration
Measure Unit	Display Cases
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	15 years

Traditional clear glass display case doors consist of two-pane glass (three-pane in low and medium temperature cases), and aluminum doorframes and door rails. Glass heaters may be included to eliminate condensation on the door or glass. The door heaters are traditionally designed to overcome the highest humidity conditions as cases are built for nation-wide applications. New low heat/no heat door designs incorporate heat reflective coatings on the glass, gas inserted between the panes, non-metallic spacers to separate the glass panes, and/or non-metallic frames (such as fiberglass).

This protocol documents the energy savings attributed to the installation of special glass doors w/low/no anti-sweat heaters for low temp cases. The primary focus of this rebate measure is on new cases to incent customers to specify advanced doors when they are purchasing refrigeration cases.

#### 3.34.1 Eligibility

For this measure, a no-heat/low-heat clear glass door must be installed on an upright display case. It is limited to door heights of 57 inches or more. Doors must have either heat reflective treated glass, be gas filled, or both. This measure applies to low temperature cases only—those with a case temperature below 0°F. Doors must have 3 or more panes. Total door rail, glass, and frame heater amperage (@ 120 volt) cannot exceed 0.39425 amps per linear foot for low temperature display cases. Rebate is based on the door width (not including case frame).

#### 3.34.2 Algorithms

The energy savings and demand reduction are obtained through the following calculations adopted from California's Southern California Edison 426.

Assumptions: Indoor Dry-Bulb Temperature of 75°F and Relative Humidity of 55%, (4-minute opening intervals for 16-second), neglect heat conduction through doorframe / assembly.

425 <http://www.energysmartgrocer.org/pdfs/PGE/BridgeEquipment%20SpecificationTandCs.pdf>  
426 Southern California Edison. Non-Residential Express 2003 Refrigeration Work Paper. Pg. 27.

**Compressor Savings (excluding condenser):**

$$\Delta kW_{compressor} = [Q\text{-cooling}_{svg}/EER/1000]$$

$$\Delta kWh_{compressor} = \Delta kW \times EFLH$$

$$Q\text{-cooling}_{svg} = Q\text{-cooling} \times K\text{-ASH}$$

**Anti-Sweat Heater Savings:**

$$\Delta kW_{ASH} = \Delta ASH / 1000$$

$$\Delta kWh_{ASH} = \Delta kW_{ASH} \times t$$

**3.34.3 Definition of Terms**

The variables in the above equation are defined below:

<i>Q-cooling</i>	= Case rating by manufacturer (Btu/hr/door)
<i>Q-cooling<sub>svg</sub></i>	= Cooling savings (Btu/hr/door)
$\Delta kW_{compressor}$	= Compressor power savings (kW/door)
$\Delta kW_{ASH}$	= Reduction due to ASH (kW/door)
<i>K-ASH</i>	= % of cooling load reduction due to low anti-sweat heater (Btu/hr/door reduction)
$\Delta ASH$	= Reduction in ASH power per door (watts/door)
$\Delta kWh_{compressor}$	= Annual compressor energy savings (excluding condenser energy), (kWh/door)
$\Delta kWh_{ASH}$	= Annual Reduction in energy (kWh/door)
<i>EER</i>	= Compressor rating from manufacturer (Btu/hr/Watts)
<i>EFLH</i>	= Equivalent full load annual operating hours
<i>t</i>	= Annual operating hours of Anti-sweat heater

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Table 3-108102108: Special Doors with Low or No Anti-Sweat Heat for Low Temp Case Calculations Assumptions

Parameter	Type	Value	Source
Q-cooling	Variable	Nameplate	EDC Data Gathering
K-ASH	Fixed	1.5%	1
EER	Variable	Nameplate	EDC Data Gathering
EFLH	FixedVariable	Default: 5,700427	1
		Based on Logging, BMS data or Modeling428	EDC's Data Gathering
Δ ASH	Fixed	83429	1
t	Fixed	8,760	1

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Sources:

40.1. Southern California Edison. Non-Residential Express 2003 Refrigeration Work Paper. Pg. 27

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3.34.4 Measure Life

The expected measure life is 15 years430.

427 EFLH was determined by multiplying annual available operation hours of 8,760 by overall duty cycle factors. Duty cycle is a function of compressor capacity, defrost and weather factor. The units are assumed to be operating 24/7, 8760 hrs/yr.

428 Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

429 From Actual Test: 0.250 kW per 3 doors

430 [http://energysmartonline.org/documents/EnergySmart\\_BPA\\_T&Cs.pdf](http://energysmartonline.org/documents/EnergySmart_BPA_T&Cs.pdf)

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SECTION 3: Commercial and Industrial Measures

### 3.35 ENERGY STAR Room Air Conditioner

This protocol is for ENERGY STAR room air conditioner units installed in small commercial spaces. Only ENERGY STAR units qualify for this protocol.

#### 3.35.1 Algorithms

$$\Delta kWh = (BtuH_{cool} / 1000) \times (1/EER_{base} - 1/EER_{ee}) \times EFLH_{cool}$$

$$\Delta kW_{peak} = (BtuH_{cool} / 1000) \times (1/EER_{base} - 1/EER_{ee}) \times CF$$

#### 3.35.2 Definition of Terms

$BtuH_{cool}$  = Rated cooling capacity of the energy efficient unit in  $BtuH_{cool}$

$EER_{base}$  = Efficiency rating of the baseline unit.

$EER_{ee}$  = Efficiency rating of the energy efficiency unit.

$CF$  = Demand Coincidence Factor (See Section 1.4)01.4)

$EFLH_{cool}$  = Equivalent Full Load Hours for the cooling season – The kWh during the entire operating season divided by the kW at design conditions.

Table 3-109103109: Variables for HVAC Systems

Component	Type	Value	Source
BtuH	Variable	Nameplate data (AHRI or AHAM)	EDC's Data Gathering
$EER_{base}$	Variable	Default values from <a href="#">Table 3-110</a> <a href="#">Table 3-104110</a>	See <a href="#">Table 3-110</a> <a href="#">Table 3-104110</a>
$EER_{ee}$	Variable	Nameplate data (AHRI or AHAM)	EDC's Data Gathering
CF	Fixed	80%	2
$EFLH_{cool}$	Variable	Based on Logging, <a href="#">BMS data</a> or Modeling <a href="#">431</a>	EDC's Data Gathering
		Default values from <a href="#">Table 3-111</a> <a href="#">Table 3-105111</a>	See <a href="#">Table 3-111</a> <a href="#">Table 3-105111</a>

#### Sources:

1. Average based on coincidence factors from Ohio, New Jersey, Mid-Atlantic, Massachusetts, Connecticut, Illinois, New York, CEE and Minnesota. (74%, 67%, 81%, 94%, 82%, 72%, 100%, 70% and 76% respectively)

[431 Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data \(pre-retrofit\).](#)

Table 3-~~110404110~~: Room Air Conditioner Baseline Efficiencies432

Equipment Type and Capacity	Cooling Baseline	Heating Baseline
Room AC		
< 8,000 BtuH	9.7 EER	N/A
≥ 8,000 BtuH and <14,000 BtuH	9.8 EER	N/A
≥ 14,000 BtuH and < 20,000 BtuH	9.7 EER	N/A
≥ 20,000 BtuH	8.5 EER	N/A

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Table 3-~~111405111~~: Cooling EFLH for Pennsylvania Cities433

Space and/or Building Type	Allentown	Erie	Harrisburg	Pittsburgh	Williamsport	Philadelphia	Scranton
College: Classes/Administrative	690	380	733	582	520	815	490
Convenience Stores	1,216	671	1,293	1,026	917	1,436	864
Dining: Bar Lounge/Leisure	912	503	969	769	688	1,077	648
Dining: Cafeteria / Fast Food	1,227	677	1,304	1,035	925	1,449	872
Dining: Restaurants	912	503	969	769	688	1,077	648
Lodging: Hotels/Motels/Dormitories	756	418	805	638	571	894	538
Lodging: Residential	757	418	805	638	571	894	538
Multi-Family (Common Areas)	1,395	769	1,482	1,176	1,052	1,647	991
Nursing Homes	1,141	630	1,213	963	861	1,348	811
Office: General/Retail	851	469	905	718	642	1,005	605
Office: Medical/Banks	851	469	905	718	642	1,005	605
Penitentiary	1,091	602	1,160	920	823	1,289	775
Police/Fire Stations (24 Hr)	1,395	769	1,482	1,176	1,052	1,647	991
Post Office/Town Hall/Court House	851	469	905	718	642	1,005	605
Religious Buildings/Church	602	332	640	508	454	711	428
Retail	894	493	950	754	674	1,055	635
Schools/University	634	350	674	535	478	749	451
Warehouses (Not Refrigerated)	692	382	735	583	522	817	492
Warehouses (Refrigerated)	692	382	735	583	522	817	492

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432 Baseline values from IECC 2009, after Jan 1, 2010 or Jan 23, 2010 as applicable.  
433 US Department of Energy. Energy Star Calculator and Bin Analysis Models

### SECTION 3: Commercial and Industrial Measures

#### ENERGY STAR Room Air Conditioner

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## 4 APPENDICES

### 4.1 Appendix A: Measure Lives

#### Measure Lives Used in Cost-Effectiveness Screening February 2008<sup>434</sup>

Program/Measure <small>*For the purpose of calculating the total Resource Cost Test for Act 129, measure cannot claim savings for more than fifteen years.</small>	Measure <small>Life/Floating Head/Pressure Control</small>
<b>RESIDENTIAL PROGRAMS</b>	
<i>ENERGY STAR Appliances</i>	
ENERGY STAR Refrigerator post-2001	13
ENERGY STAR Refrigerator 2001	13
ENERGY STAR Dishwasher	11
ENERGY STAR Clothes Washer	11
ENERGY STAR Dehumidifier	12
ENERGY STAR Room Air Conditioners	10
<i>ENERGY STAR Lighting</i>	
Compact Fluorescent Light Bulb	6.8
Recessed Can Fluorescent Fixture	20*
Torchieres (Residential)	10
Fixtures Other	20*
<i>ENERGY STAR Windows</i>	
WINDOW - heat pump	20*
WINDOW - gas heat with central air conditioning	20*
WINDOW - electric heat without central air conditioning	20*
WINDOW - electric heat with central air conditioning	20*
<i>Refrigerator/Freezer Retirement</i>	
Refrigerator/Freezer retirement	8

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<sup>434</sup> Energy Star Appliances, Energy Star Lighting, and several Residential Electric HVAC measures lives updated February 2008. U.S. Environmental Protection Agency and U.S. Department of Energy, [Energy Star](http://www.energystar.gov/). <<http://www.energystar.gov/>>.

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<i>Residential New Construction</i>	
Single Family – gas heat with central air conditioner	20*
Single Family – oil heat with central air conditioner	20*
Single Family – all electric	20*
Multiple Single Family (Townhouse) – gas heat with central air conditioner	20*
Multiple Single Family (Townhouse) – oil heat with central air conditioner	20*
Multiple Single Family (Townhouse) – all electric	20*
Multi-Family – gas heat with central air conditioner	20*
Multi-Family – oil heat with central air conditioner	20*
Multi-Family – all electric	20*
ENERGY STAR Clothes Washer	11
Recessed Can Fluorescent Fixture	20*
Fixtures Other	20*
Efficient Ventilation Fans with Timer	10
<i>Residential Electric HVAC</i>	
Central Air Conditioner SEER 13	14
Central Air Conditioner SEER 14	14
Air Source Heat Pump SEER 13	12
Air Source Heat Pump SEER 14	12
Central Air Conditioner proper sizing/install	14
Central Air Conditioner Quality Installation Verification	14
Central Air Conditioner Maintenance	7
Central Air Conditioner duct sealing	14
Air Source Heat Pump proper sizing/install	12
ENERGY STAR Thermostat (Central Air Conditioner)	15
ENERGY STAR Thermostat (Heat Pump)	15
Ground Source Heat Pump	30*
Central Air Conditioner SEER 15	14
Air Source Heat Pump SEER 15	12
Room Air Conditioner Retirement	4
<i>Home Performance with ENERGY STAR</i>	
Blue Line Innovations – PowerCost Monitor™	5

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<b>NON-RESIDENTIAL PROGRAMS</b>	
<i>C&amp;I Construction</i>	
<b>Target Sector</b> Commercial Lighting (Non-SSL) — New	15 Commercial Refrigeration
<b>Measure Unit</b> Commercial Lighting (Non-SSL) — Remodel/Replacement	15 Floating Head Pressure Controls
Commercial Lighting (SSL — 25,000 hours) — New	6 Deemed by location, kWh
Commercial Lighting (SSL — 30,000 hours) — New	70 kW
Commercial Lighting (SSL — 35,000 hours) — New	8
Commercial Lighting (SSL — 40,000 hours) — New	10
Commercial Lighting (SSL — 45,000 hours) — New	11
Commercial Lighting (SSL — 50,000 hours) — New	12
Commercial Lighting (SSL — 55,000 hours) — New	13
Commercial Lighting (SSL — 60,000 hours) — New	14
Commercial Lighting (SSL — ≥60,000 hours) — New	15*
Commercial Lighting (SSL — 25,000 hours) — Remodel/Replacement	6
Commercial Lighting (SSL — 30,000 hours) — Remodel/Replacement	7
Commercial Lighting (SSL — 35,000 hours) — Remodel/Replacement	8
Commercial Lighting (SSL — 40,000 hours) — Remodel/Replacement	10
Commercial Lighting (SSL — 45,000 hours) — Remodel/Replacement	11
Commercial Lighting (SSL — 50,000 hours) — Remodel/Replacement	12
Commercial Lighting (SSL — 55,000 hours) — Remodel/Replacement	13
Commercial Lighting (SSL — 60,000 hours) — Remodel/Replacement	14
Commercial Lighting (SSL — ≥60,000 hours) — Remodel/Replacement	15*
Commercial Custom — New	18*
Commercial Chiller Optimization	18*
Commercial Unitary HVAC — New — Tier 1	15
Commercial Unitary HVAC — Replacement — Tier 1	15
Commercial Unitary HVAC — New — Tier 2	15
Commercial Unitary HVAC — Replacement — Tier 2	15
Commercial Chillers — New	20*
Commercial Chillers — Replacement	20*
Commercial Small Motors (1-10 horsepower) — New or Replacement	20*
Commercial Medium Motors (11-75 horsepower) — New or Replacement	20*

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Commercial Large Motors (76-200 horsepower) — New or Replacement	20*
Commercial Variable Speed Drive — New	15
Commercial Variable Speed Drive — Retrofit	15
Commercial Comprehensive New Construction Design	18*
Commercial Custom — Replacement	18*
Industrial Lighting — New	15
Industrial Lighting — Remodel/Replacement	15
Industrial Unitary HVAC — New — Tier 1	15
Industrial Unitary HVAC — Replacement — Tier 1	15
Industrial Unitary HVAC — New — Tier 2	15
Industrial Unitary HVAC — Replacement Tier 2	15
Industrial Chillers — New	20*
Industrial Chillers — Replacement	20*
Industrial Small Motors (1-10 horsepower) — New or Replacement	20*
Industrial Medium Motors (11-75 horsepower) — New or Replacement	20*
Industrial Large Motors (76-200 horsepower) — New or Replacement	20*
Industrial Variable Speed Drive — New	15
Industrial Variable Speed Drive — Retrofit	15
Industrial Custom — Non-Process	18*
Industrial Custom — Process	10
<i>Building O&amp;M</i>	
O&M savings	3

### **3.36 Refrigeration – Floating Head Pressure Controls**

Installers conventionally design a refrigeration system to condense at a set pressure-temperature setpoint, typically 90° F. By installing a floating head pressure control<sup>435</sup> (FHPCs) condenser system, the refrigeration system can change condensing temperatures in response to different outdoor temperatures. This means that the minimum condensing head pressure from a fixed setting (180 psig for R-22) is lowered to a saturated pressure equivalent at 70° F or less. Either a balanced-port or electronic expansion valve that is sized to meet the load requirement at a 70° F condensing temperature must be installed. Alternatively, a device may be installed to supplement the refrigeration feed to each evaporator attached to a condenser that is reducing head pressure.

#### **3.36.1 Eligibility**

This protocol documents the energy savings attributed to FHPCs applied to a single-compressor refrigeration system in commercial applications. The baseline case is a refrigeration system without FHPC whereas the efficient case is a refrigeration system with FHPC. FHPCs must have a minimum Saturated Condensing Temperature (SCT) programmed for the floating head pressure control of ≤ 70°F. The use of FHPC would require balanced-port expansion valves, allowing satisfactory refrigerant flow over a range of head pressures. Compressor must be 1HP or larger.

#### **3.36.2 Algorithms**

The savings are primarily dependent on the following factors:

- Load factor of compressor motor horsepower (HP)
- Climate zone
- Refrigeration system temperature application

The savings algorithm is as follows:

$$\Delta kWh = HP_{compressor} \times kWh/HP$$

If the refrigeration system is rated in tonnage:

$$\Delta kWh = (4.715 / COP) \times Tons \times kWh/HP$$

$$\Delta kW_{peak} = 0$$

#### **3.36.3 Definition of Terms**

$HP_{compressor}$  = Rated horsepower (HP) per compressor

$kWh/HP$  = Annual savings per HP

$COP$  = Coefficient of Performance

$Tons$  = Refrigeration tonnage of the system

<sup>435</sup> Also called as flood back control

4.715 = Conversion factor to convert from tons to HP

**Table 1-1442: Floating Head Pressure Controls – Values and References**

Component	Type	Values	Sources
HP <sub>compressor</sub>	Variable	<a href="#">EDC Data Gathering</a>	<a href="#">EDC Data Gathering</a>
kWh/HP	Fixed	<a href="#">Table 1-2Table 3-113</a>	1
COP	Variable	<a href="#">Based on design conditions</a>	<a href="#">EDC Data Gathering</a>
		Default: Condensing Unit: Refrigerator (Medium Temp: 28 °F – 40 °F): 2.55 COP Freezer (Low Temp: -20 °F – 0 °F): 1.32 COP Remote Condenser: Refrigerator (Medium Temp: 28 °F – 40 °F): 2.49 COP Freezer (Low Temp: -20 °F – 0 °F): 1.45 COP	2
Tons	Variable	<a href="#">EDC Data Gathering</a>	<a href="#">EDC Data Gathering</a>
4.715	Fixed	<a href="#">Engineering Estimate</a>	3

**Sources:**

1. [The deemed savings values were derived from the Regional Technical Forum \(RTF\) as part of the Northwest Power & Conservation Council, Deemed Measures List, Grocery Floating Head Pressure Controls for Single Compressor Systems, FY2010, V1. Using RTF Deemed saving estimates for the NW climate zone, data was extrapolated to Pennsylvania climate zones by using cooling degree days comparison based on the locale.](#)
2. [The given COP values are averaged based on the data from: Regional Technical Forum \(RTF\) as part of the Northwest Power & Conservation Council, Deemed Measures List, Grocery Floating Head Pressure Controls for Single Compressor Systems, FY2010, V1.](#)
3. [Conversion factor for compressor horsepower per ton:   
http://www.engineeringtoolbox.com/refrigeration-formulas-d\\_1695.html](#)

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**Table 1-2443: Annual Savings kWh/HP by Location**

Climate Zone	Condensing Unit (kWh/HP)			Remote Condenser (kWh/HP)		
	Refrigerator (Medium Temp)	Freezer (Low Temp)	Default436 (Temp Unknown)	Refrigerator (Medium Temp)	Freezer (Low Temp)	Default437 (Temp Unknown)
Allentown	630	767	674	380	639	463
Erie	681	802	720	438	657	508
Harrisburg	585	737	634	330	623	424
Philadelphia	546	710	598	286	609	390
Pittsburgh	617	759	662	366	634	452
Scranton	686	806	724	443	659	512
Williamsport	663	790	703	417	651	492

**Table 1-3444: Default Condenser Type Annual Savings kWh/HP by Location**

Climate Zone	Unknown Condenser Type Default438 (kWh/HP)		
	Refrigerator (Medium Temp)	Freezer (Low Temp)	Temp Unknown
Allentown	505	703	568
Erie	559	730	614
Harrisburg	458	680	529
Philadelphia	416	660	494
Pittsburgh	491	697	557
Scranton	564	732	618
Williamsport	540	720	598

### 3.36.4 Measure Life

The measure life is 15 years<sup>439</sup> as per the Regional Technical Forum (RTF) of the Northwest Power & Conservation Council.

436 Default based on: 2010 ASHRAE Refrigeration Handbook, page 15.1 "Medium- and low-temperature display refrigerator line-ups account for roughly 68% and 32%, respectively, of a typical supermarket's total display refrigerators."  
437 Ibid.

438 No data available to predict if condensing units or remote condensers will be more prevalent, assumed 50/50 split, based on discussion with Portland Energy Conservation, Inc. (PECI) GrocerySmart staff.

439 Grocery Floating Head Pressure Controls for Single Compressor Systems, FY2010, V1. Accessed from RTF website <http://www.nwcouncil.org/rtf/measures/Default.asp> on September 06, 2011.

**3.36.5 Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installed refrigeration capacity coupled with EDC data gathering or assignment of stipulated energy savings.

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### 3.37 Variable Speed Refrigeration Compressor

Measure Name	VSD Refrigeration Compressor
Target Sector	Commercial Refrigeration Establishments
Measure Unit	VSD Refrigeration Compressor
Unit Energy Savings	Variable
Unit Peak Demand Reduction	Variable
Measure Life	10

Variable speed drive (VSD) compressors are used to control and reduce the speed of the compressor during times when the refrigeration system does not require the motor to run at full capacity. VSD control is an economical and efficient retrofit option for existing compressor installations. The performance of variable speed compressors can more closely match the variable refrigeration load requirements thus minimizing energy consumption.

#### 3.37.1 Eligibility

This measure, VSD control for refrigeration systems and its eligibility targets applies to retrofit construction in the commercial and industrial building sectors; it is most applicable to grocery stores or food processing applications with refrigeration systems. This protocol is for a VSD control system replacing a slide valve control system.

#### 3.37.2 Algorithms

The savings algorithm is as follows:

If the refrigeration system is rated in tonnage:

$$\Delta kWh = Tons \times ES_{Value}$$

$$\Delta kW_{peak} = Tons \times DS_{Value}$$

If the refrigeration system is rated in horsepower:

$$\Delta kWh = 0.445 * HP_{compressor} \times ES_{Value}$$

$$\Delta kW_{peak} = 0.445 * HP_{compressor} \times DS_{Value}$$

#### 3.37.3 Definition of Terms

$$HP_{compressor} = \text{Rated horsepower per compressor}$$

$$ES_{Value} = \text{Energy savings value in kWh per compressor HP}$$

$$DS_{Value} = \text{Demand savings value in kW per compressor HP}$$

$$Tons = \text{Refrigeration tonnage of the system}$$

$$0.445 = \text{Conversion factor to convert from tons to HP}$$

**Table 1-4145: VSD Compressor – Values and References**

<b>Component</b>	<b>Type</b>	<b>Values</b>	<b>Sources</b>
<u>Tons</u>	<u>Variable</u>	<u>EDC Data Gathering</u>	<u>EDC Data Gathering</u>
<u>HP<sub>compressor</sub></u>	<u>Variable</u>	<u>EDC Data Gathering</u>	<u>EDC Data Gathering</u>
<u>ES<sub>value</sub></u>	<u>Fixed</u>	<u>1,696 kWh/ton</u>	<u>1</u>
<u>DS<sub>value</sub></u>	<u>Fixed</u>	<u>0.22 kW/ton</u>	<u>1</u>
<u>0.445</u>	<u>Fixed</u>	<u>Engineering Estimate</u>	<u>2,3</u>

**Sources:**

1. Deemed savings values of 1696 kWh/ton and 0.22 kW/ton were obtained from the 2005 DEER (Database for Energy Efficiency Resources). This measure considered the associated savings by vintage and by climate zone for compressors. The deemed value was an average across all climate zones440 and all vintages (excluding new construction).
2. PSC of Wisconsin, Focus on Energy Evaluation, Business Programs: Deemed Savings Manual V1.0, p. 4-103 to 4-106. Where refrigerator (medium temp: 28 °F – 40 °F) COP equals 2.5 and freezer COP (low temp: -20 °F – 0 °F) equals 1.3. The weighted average COP equals 2.1, based on 2010 ASHRAE Refrigeration Handbook, page 15.1 “Medium- and low-temperature display refrigerator line-ups account for roughly 68% and 32%, respectively, of a typical supermarket’s total display refrigerators.”
3. Conversion factor for compressor horsepower per ton is HP/ton = 4.715/COP, using weighted average COP of 2.1. From [http://www.engineeringtoolbox.com/refrigeration-formulas-d\\_1695.html](http://www.engineeringtoolbox.com/refrigeration-formulas-d_1695.html)

**3.37.4 Measure Life**

According to the 2005 DEER, a VFD compressor has a measure life of 10 years.

**3.37.5 Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installed refrigeration capacity affected by the retrofit coupled with EDC data gathering or assignment of stipulated energy savings.

440 The deemed savings was averaged across all climate zones since the variance between all cases was less than 5%.



### 3.38 Fuel Switching: Domestic Hot Water Electric to Gas / Oil / Propane

<b>Measure Name</b>	<b>Fuel Switching: DHW Electric to Gas/Oil/Propane</b>
<b>Target Sector</b>	Small Commercial
<b>Measure Unit</b>	Water Heater
<b>Unit Energy Savings</b>	Varies
<b>Unit Peak Demand Reduction</b>	Varies
<b>Fossil Fuel Consumption Increase</b>	Varies
<b>Measure Life</b>	13 years for natural gas or propane 8 years for oil

Natural gas, propane, and oil water heaters generally offer the customer lower costs compared to standard electric water heaters. Additionally, they typically see an overall energy savings when looking at the source energy of the electric unit versus the fossil fuel unit. Federal standard electric water heaters have energy factors of  $\geq 0.904$  and a federal standard efficiency gas and propane-fired water heater have an energy factor of 0.575 for a 50 gal unit and 0.495 for an oil-fired 50 gal unit. This protocol does not apply for units  $>55$  gal.

#### 3.38.1 Eligibility

This protocol documents the energy savings attributed to converting from a standard electric water heater with Energy Factor of 0.904 or greater to a standard natural gas/propane-fired water heater with Energy Factor of 0.575 or greater and 0.495 or greater for an oil-fired water heater. The target sector primarily consists of motels, small office, and small retail establishments.

#### 3.38.2 Algorithms

The energy savings calculation utilizes average performance data for available small commercial standard electric and natural gas water heaters and typical water usage. Because there is little electric energy associated with a natural gas or propane water heater, the energy savings are the full energy utilization of the electric water heater. The energy savings are obtained through the following formula:

$$\Delta kWh = \frac{\left\{ \left( \frac{1}{EF_{elec,bl}} \right) \times \left( HW \times 1 \frac{BTU}{lb-F} \times 8.3 \frac{lb}{gal} \times (T_{hot}-T_{cold}) \right) \right\}}{3413 \frac{Btu}{kWh}}$$

Although there is a significant electric savings, there is an associated increase in fossil fuel energy consumption. While this fossil fuel consumption does not count against PA Act 129 energy savings, it is expected to be used in the program TRC test. The increased fossil fuel usage is obtained through the following formula:

$$\text{Fuel Consumption (MMBtu)} = \frac{\left\{ \left( \frac{1}{EF_{fuel,inst}} \right) \times \left( HW \times 1 \frac{BTU}{lb-F} \times 8.3 \frac{lb}{gal} \times (T_{hot}-T_{cold}) \right) \right\}}{1,000,000 \frac{Btu}{MMBtu}}$$

**SECTION 1: Appendices**

Fuel Switching: Domestic Hot Water Electric to Gas / Oil / Propane

Page 413

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Where  $EF_{fuel}$  changes depending on the fossil fuel used by the water heater.

For resistive water heaters, the demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage.

$$\frac{\Delta kW_{peak}}{ResistiveDiscountFactor} = EnergyToDemandFactor \times Energy Savings \times$$

The Energy to Demand Factor is defined below:

$$EnergyToDemandFactor = \frac{Average Usage_{Summer WD Noon-8}}{Annual Energy Usage}$$

**Loads**

The annual loads are taken from data from the DEER database<sup>441</sup>. The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The loads are averaged over all 16 climate zones and all six vintage types in the DEER database. Finally, the loads are converted to average annual gallons of use using the algorithm below. The loads are summarized in [Table 1-5](#)~~Table 3-116~~ below, assuming a 40 gal natural gas water heater with a standard efficiency of 0.594.

$$HW (Gallons) = \frac{Load \times EF_{NG, Base} \times 1000 \frac{Btu}{kBTU} \times Typical SF}{1 \frac{BTU}{lb} \times 8.3 \frac{lb}{gal} \times (T_{hot} - T_{cold}) \times 1000 SF}$$

Table 1-5~~116~~: Typical water heating loads.

Building Type	Typical Square Footage	Average Annual Load In kBTU/1000 sq ft	Average Annual Use, Gallons
Motel	30,000	2,963	97,870
Small Office	10,000	2,214	24,377
Small Retail	7,000	1,451	11,183

**Energy to Demand Factor**

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in CA<sup>442</sup>. The usage profiles are shown in [Figure 1-1](#)~~Figure 3-14~~. To ensure that the load shape data derived from observations in CA can be applied to PA, we compared the annual energy usage to peak demand factors for two disparate climate zones in CA. The results, shown in

<sup>441</sup> <http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe>  
<sup>442</sup> [ibid](#)

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Figure 1-2 and Figure 3-12 indicate that the ratio of peak demand to annual energy usage is not strongly influenced by climate. Also, though the actual usage profiles may be different, the average usage between noon and 8 PM on summer weekdays is quite similar for all building types. The close level of agreement between disparate climate zones and building types suggest that the results will carry over to Pennsylvania<sup>443</sup>.



Figure 1-141: Load shapes for hot water in four commercial building types

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<sup>443</sup> One reason for the close agreement is that the factor is a ratio of the energy usage to peak demand for the same location. Even though the energy usages may vary significantly in different climate zones, the hot water usage patterns may be driven by underlying practices that carry over well from state to state (e.g., dishwashing after lunch or dinner in restaurants).

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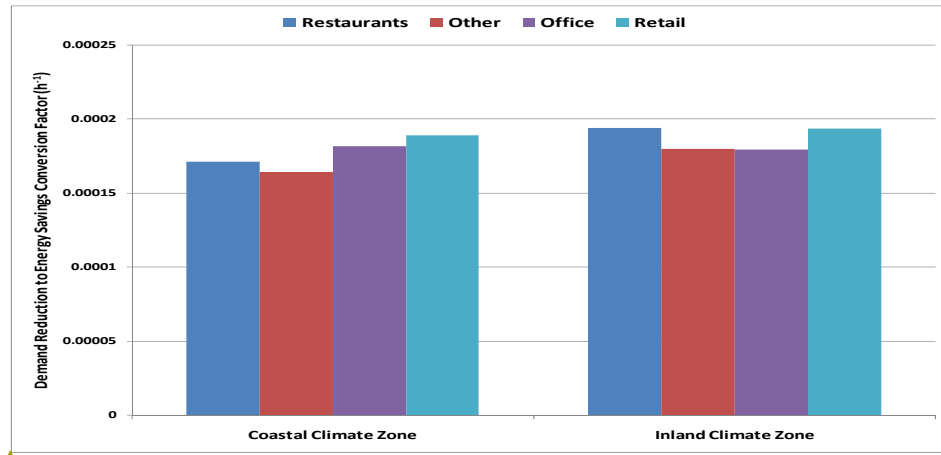


Figure 1-242: Energy to demand factors for four commercial building types

3.38.3 Definition of Terms

The parameters in the above equation are listed in Table 1-6Table 3-117.

Table 1-6117: Commercial Water Heater Fuel Switch Calculation Assumptions

Component	Type	Values	Source
EF <sub>base</sub> , Energy Factor of baseline water heater	Variable	Default: 0.904	1
		Nameplate	EDC Data Gathering
EF <sub>fuel</sub> 444, Energy Factor of installed fossil fuel water heater*	Variable	>=0.575 for Natural Gas and Propane >=0.495 for Oil	5, EDC Data Gathering
Load, Average annual Load in kBTU	Fixed	Varies	DEER Database
T <sub>hot</sub> , Temperature of hot water	Fixed	120 °F	2
T <sub>cold</sub> , Temperature of cold water supply	Fixed	55 °F	3
HW, Average annual gallons of Use	Variable	Default: See Table 1-5Table 3-116	Calculation
		EDC Data Gathering	EDC Data Gathering
EnergyToDemandFactor	Fixed	0.0001916	4
445EF <sub>NG, base</sub> , Energy Factor of baseline gas water heater	Fixed	0.594	5

444 Note that the federal minimum energy efficiency standards for electric and fossil fuel water heaters will increase starting April 16, 2015. These new standards will be included in the 2015 TRM.

445 The protocol assumes a 40 gal natural gas water heater with a standard efficiency of 0.594 to calculate the loads summarized in Table 3-92: Typical water heating loads. Table 3-92: Typical water heating loads.

SECTION 1: Appendices

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<u>ResistiveDiscountFactor</u>	<u>Fixed</u>	<u>1.0</u>	<u>6</u>
--------------------------------	--------------	------------	----------

\* For tankless water heaters, the EF should be at least 0.82

**Sources:**

2. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. For a 50-gallon tank this is approximately 0.90. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE-2006-BT-STD-0129, p. 30
- 40-3. Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.
4. Mid-Atlantic TRM, footnote #24
5. The load shapes can be accessed online:  
<http://www.ethree.com/CPUC/PG&ENonResViewer.zip>
6. Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons for natural gas/propane and 0.59 – 0.0019 x Rated Storage in Gallons for oil. For a 50-gallon tank this is 0.575 for natural gas/propane and 0.495 for oil. For a 40-gallon tank, this is 0.594 for natural gas. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE-2006-BT-STD-0129, p. 30
7. Engineering Estimate. No discount factor is needed because the baseline is already an electric resistance water heater system.

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**3.38.4 Deemed Savings**

The deemed savings for the replacement of 50 gal electric water heater with a 50 gal fossil fuel units in various applications are listed below.

Table 1-7118: Water Heating Fuel Switch Energy Savings and Demand Reductions

<u>Building Type</u>	<u>Average Annual Use, Gallons</u>	<u>Energy Savings (kWh)</u>	<u>Demand Reduction (kW)</u>	<u>Natural Gas/Propane Usage (MMBtu)</u>	<u>Oil Usage (MMBtu)</u>
<u>Motel</u>	<u>97,870</u>	<u>17,113</u>	<u>3.28</u>	<u>91.8</u>	<u>106.7</u>
<u>Small Office</u>	<u>24,377</u>	<u>4,263</u>	<u>0.82</u>	<u>22.9</u>	<u>26.6</u>
<u>Small Retail</u>	<u>11,183</u>	<u>1,955</u>	<u>0.37</u>	<u>10.5</u>	<u>12.2</u>

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**3.38.5 Measure Life**

A natural gas or propane water heater’s lifespan is 13 years<sup>446</sup> and an oil-fired water heater has an 8 year lifetime.<sup>447</sup>

**3.38.6 Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installation coupled with EDC data gathering or assignment of stipulated energy savings.

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<sup>446</sup> From ENERGY STAR

[https://www.energystar.gov/index.cfm?fuseaction=find\\_a\\_product.showProductGroup&pgw\\_code=WGS](https://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=WGS)

<sup>447</sup> <http://www.aceee.org/consumer/water-heating>

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### 3.39 Fuel Switching: Heat Pump Water Heaters to Gas / Oil / Propane

Measure Name	Heat Pump Water Heaters
Target Sector	Commercial Establishments
Measure Unit	Water Heater
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Fossil Fuel Consumption Increase	Varies
Measure Life	13 years for natural gas/propane 8 years for oil

Natural gas, propane, and oil water heaters generally offer the customer lower costs compared to heat pump water heaters. Additionally, they typically see an overall energy savings when looking at the source energy of the electric unit versus the gas unit. Heat pump water heaters have energy factors of 2 or greater and a federal standard efficiency gas and propane water heater have an energy factor of 0.575 for a 50 gal unit and 0.495 for an oil-fired 50 gal unit. This protocol does not apply for units >55 gal.

#### 3.39.1 Eligibility

This protocol documents the energy savings attributed to converting heat pump water heaters with Energy Factors of 2 or greater to fossil fuel water heaters. The target sector includes domestic hot water applications in small commercial settings such as small retail establishments, small offices, small clinics, and small lodging establishments such as small motels. The measure described here involves a direct retrofit of a heat pump water heater with a fossil fuel water heater. It does not cover systems where the heat pump is a pre-heater or is combined with other water heating sources. More complicated installations can be treated as custom projects.

#### 3.39.2 Algorithms

The energy savings calculation utilizes average performance data for available heat pump water heaters and typical hot water usages. The energy savings are obtained through the following formula:

$$\Delta kWh = \frac{\left\{ \left( \frac{1}{EF_{base}} \times \frac{1}{F_{Adjust}} \right) \times HW \times 8.3 \frac{lb}{gal} \times 1.0 \frac{Btu}{lb-F} \times (T_{hot} - T_{cold}) \right\}}{3413 \frac{Btu}{kWh}}$$

Although there is a significant electric savings, there is an associated increase in fossil fuel energy consumption. While this fossil fuel consumption does not count against PA Act 129 energy savings, it is expected to be used in the program TRC test. The increased fossil fuel usage is obtained through the following formula:

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$$\text{Fuel Consumption (MMBtu)} = \frac{\left\{ \left( \frac{1}{EF_{\text{fuel,inst}}} \right) \times \left( \text{HW} \times 1 \frac{\text{BTU}}{\text{lb} - F} \times 8.3 \frac{\text{lb}}{\text{gal}} \times (T_{\text{hot}} - T_{\text{cold}}) \right) \right\}}{1,000,000 \frac{\text{Btu}}{\text{MMBtu}}}$$

Where  $EF_{\text{fuel}}$  changes depending on the fossil fuel used by the water heater.

For replacement of heat pump water heaters with fossil fuel units, demand savings result primarily from a reduced connected load. The demand reduction is taken as the annual energy savings multiplied by the ratio of the average energy usage during noon and 8PM on summer weekdays to the total annual energy usage.

$$\frac{\Delta kW_{\text{peak}}}{\text{ResistiveDiscountFactor}} = \text{EnergyToDemandFactor} \times \text{Energy Savings} \times$$

The Energy to Demand Factor is defined below:

$$\text{EnergyToDemandFactor} = \frac{\text{Average Usage}_{\text{Summer WD Noon-8}}}{\text{Annual Energy Usage}}$$

**Loads**

The annual loads are taken from data from the DEER database448. The DEER database has data for gas energy usage for the domestic hot water end use for various small commercial buildings. The loads are averaged over all 16 climate zones and all six vintage types in the DEER database. Finally, the loads are converted to average annual gallons of use using the algorithm below. The loads are summarized in [Table 3-96: Typical water heating loads](#) [Table 1-8](#) [Table 3-119](#) below, assuming a 40 gal natural gas water heater with a standard efficiency of 0.594.

$$\text{HW (Gallons)} = \frac{\text{Load} \times EF_{\text{NG, Base}} \times 1000 \frac{\text{Btu}}{\text{kBTU}} \times \text{Typical SF}}{1 \frac{\text{BTU}}{\text{lb} - F} \times 8.3 \frac{\text{lb}}{\text{gal}} \times (T_{\text{hot}} - T_{\text{cold}}) \times 1000 \text{ SF}}$$

Table 1-8119: Typical water heating loads

Building Type	Typical Square Footage	Average Annual Load In kBTU/1000 sq ft	Average Annual Use, Gallons
Motel	30,000	2,963	97,870
Small Office	10,000	2,214	24,377
Small Retail	7,000	1,451	11,183

**Energy to Demand Factor**

The ratio of the average energy usage during noon and 8 PM on summer weekdays to the total annual energy usage is taken from usage profile data collected for commercial water heaters in

448 <http://www.deeresources.com/deer0911planning/downloads/DEER2008-CommercialResultsReview-NonUpdatedMeasures.exe>

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CA449. The usage profiles are shown in [Figure 1-3](#)~~Figure 3-13~~. To ensure that the load shape data derived from observations in CA can be applied to PA, we compared the annual energy usage to peak demand factors for two disparate climate zones in CA. The results, shown in [Figure 1-4](#)~~Figure 3-14~~, indicate that the ratio of peak demand to annual energy usage is not strongly influenced by climate. Also, though the actual usage profiles may be different, the average usage between noon and 8 PM on summer weekdays is quite similar for all building types. The close level of agreement between disparate climate zones and building types suggest that the results will carry over to Pennsylvania<sup>450</sup>.



[Figure 1-313](#): Load shapes for hot water in four commercial building types

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<sup>449</sup> [ibid](#)

<sup>450</sup> One reason for the close agreement is that the factor is a ratio of the energy usage to peak demand for the same location. Even though the energy usages may vary significantly in different climate zones, the hot water usage patterns may be driven by underlying practices that carry over well from state to state (e.g. dishwashing after lunch or dinner in restaurants).

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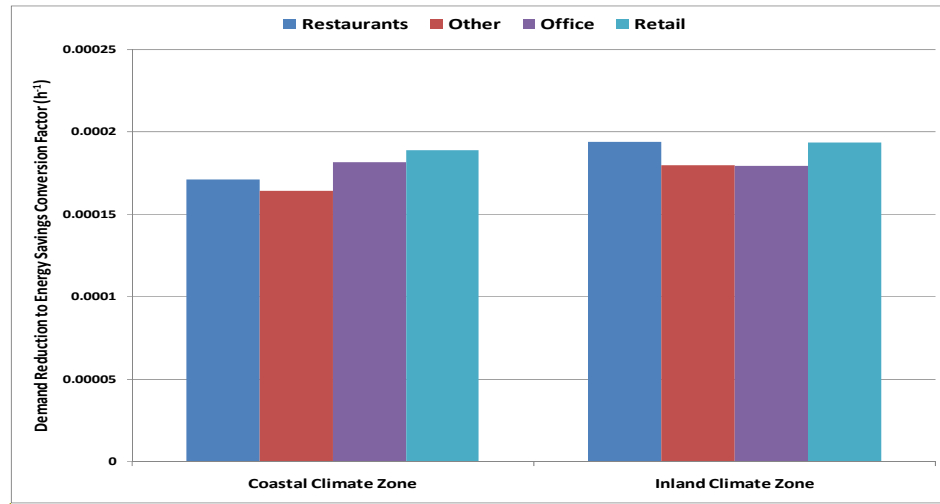


Figure 1-414: Energy to demand factors for four commercial building types

#### Resistive Heating Discount Factor

The resistive heating discount factor is an attempt to account for possible increased reliance on back-up resistive heating elements during peak usage conditions. Although a brief literature review failed to find data that may lead to a quantitative adjustment, two elements of the demand reduction calculation are worth considering.

- The hot water temperature in this calculation is somewhat conservative at 120 °F.
- The peak usage window is eight hours long.
- In conditioned space, heat pump capacity is somewhat higher in the peak summer window.
- In unconditioned space, heat pump capacity is dramatically higher in the peak summer window.

Under these operating conditions, one would expect a properly sized heat pump water heater with adequate storage capacity to require minimal reliance on resistive heating elements. A resistive heating discount factor of 0.9, corresponding to a 10% reduction in COP during peak times, is therefore taken as a conservative estimation for this adjustment.

#### Heat Pump COP Adjustment Factor

The Energy Factors are determined from a DOE testing procedure that is carried out at 56 °F wetbulb temperature. However, the average wetbulb temperature in PA is closer to 45 °F<sup>451</sup>, while the average wetbulb temperature in conditioned typically ranges from 50 °F to 80 °F. The

<sup>451</sup> Based on TMY2 weather files from DOE2.com for Erie, Harrisburg, Pittsburgh, Wilkes-Barre, and Williamsport, the average annual wetbulb temperature is 45 ± 1.3 °F. The wetbulb temperature in garages or attics, where the heat pumps are likely to be installed, are likely to be two or three degrees higher, but for simplicity, 45 °F is assumed to be the annual average wetbulb temperature.

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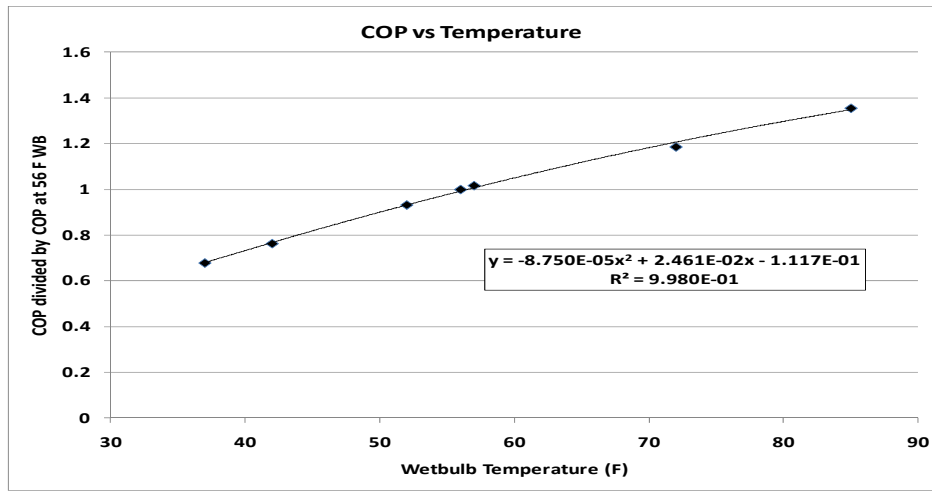
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heat pump performance is temperature dependent. [Figure 1-5](#)[Figure 3-15](#) below shows relative coefficient of performance (COP) compared to the COP at rated conditions<sup>452</sup>. According to the plotted profile, the following adjustments are recommended.

**Table 1-9120: COP Adjustment Factors**

Heat Pump Placement	Typical WB Temperature °F	COP Adjustment Factor
Unconditioned Space	44	0.80
Conditioned Space	63	1.09
Kitchen	80	1.30



[Figure 1-515: Dependence of COP on outdoor wetbulb temperature.](#)

**3.39.3 Definition of Terms**

The parameters in the above equation are listed in [Table 1-10](#)[Table 3-121](#).

<sup>452</sup> The performance curve is adapted from Table 1 in <http://wescorhvac.com/HPWH%20design%20details.htm#Single-stage%20HPWHs>. The performance curve depends on other factors, such as hot water set point. Our adjustment factor of 0.84 is a first order approximation based on the information available in literature.

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Table 1-10121: Heat Pump Water Heater Fuel Switch Calculation Assumptions

Component	Type	Values	Source
EF <sub>base</sub> , Energy Factor of baseline water heater	Variable	Default: 2	1
		Nameplate	EDC Data Gathering
EF <sub>fuel</sub> 453, Energy Factor of installed fossil fuel water heater*	Variable	>=0.575 for Natural Gas and Propane >=0.495 for Oil	7, EDC Data Gathering
Load, Average annual Load in kBtu	Fixed	Varies	5
T <sub>hot</sub> , Temperature of hot water	Fixed	120 °F	2
T <sub>cold</sub> , Temperature of cold water supply	Fixed	55 °F	3
EnergyToDemandFactor	Fixed	0.0001916	4
F <sub>Adjust</sub> , COP Adjustment factor	Fixed	0.80 if outdoor 1.09 if indoor 1.30 if in kitchen	4
HW, Average annual gallons of Use	Variable	Default: See Table 1-8Table 3-119	Calculation
		EDC Data Gathering	EDC Data Gathering
ResistiveDiscountFactor	Fixed	0.90	6
454EF <sub>NG, base</sub> , Energy Factor of baseline gas water heater	Fixed	0.594	7

\* For tankless water heaters, the EF should be at least 0.82

#### Sources:

1. Federal Standards are 0.97 -0.00132 x Rated Storage in Gallons. Heat pump water heaters require an EF of at least 2.0. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: EE-2006-BT-STD-0129, p. 30
2. [Many states have plumbing codes that limit shower and bathtub water temperature to 120 °F.](#)
3. Mid-Atlantic TRM, footnote #24
4. The load shapes can be accessed online:  
<http://www.ethree.com/CPUC/PG&ENonResViewer.zip>

453 Note that the federal minimum energy efficiency standards for electric and fossil fuel water heaters will increase starting April 16, 2015. These new standards will be included in the 2015 TRM.

454 The protocol assumes a 40 gal natural gas water heater with a standard efficiency of 0.594 to calculate the loads summarized in Table 3-96: Typical water heating loads Table 3-95: Typical water heating loads.

#### SECTION 1: Appendices

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5. DEER Database6. Engineering Estimate

7. Federal Standards are 0.67 -0.0019 x Rated Storage in Gallons. For a 50-gallon tank this is 0.575 for natural gas/propane and 0.495 for oil. For a 40-gallon tank this is 0.594 for natural gas. "Energy Conservation Program: Energy Conservation Standards for Residential Water Heaters, Direct Heating Equipment, and Pool Heaters" US Dept of Energy Docket Number: **EE-2006-BT-STD-0129**, p. 30

**3.39.4 Deemed Savings**

The deemed savings for the replacement of heat pump electric water heaters with fossil fuel units in various applications are listed below.

Table 1-1122: Energy Savings and Demand Reductions

<u>Building Type</u>	<u>Location Installed</u>	<u>Average Annual Use, Gallons</u>	<u>EF</u>	<u>COP Adjustme nt Factor</u>	<u>Energy Savings (kWh)</u>	<u>Demand Reduction (kW)</u>	<u>Natural Gas/Pro pane Usage (MMBtu)</u>	<u>Oil Usage (MMBtu )</u>
Motel	Uncondition ed Space	97,870	2	0.8	9,669	1.85	91.8	106.7
Motel	Conditioned Space	97,870	2	1.09	7,097	1.36	91.8	106.7
Motel	Kitchen	97,870	2	1.3	5,950	1.14	91.8	106.7
Small Office	Uncondition ed Space	24,377	2	0.8	2,408	0.46	22.9	26.6
Small Office	Conditioned Space	24,377	2	1.09	1,768	0.34	22.9	26.6
Small Office	Kitchen	24,377	2	1.3	1,482	0.28	22.9	26.6
Small Retail	Uncondition ed Space	11,183	2	0.8	1,105	0.21	10.5	12.2
Small Retail	Conditioned Space	11,183	2	1.09	811	0.16	10.5	12.2
Small Retail	Kitchen	11,183	2	1.3	680	0.13	10.5	12.2

### **3.39.5 Measure Life**

A natural gas or propane water heater's lifespan is 13 years<sup>455</sup> and an oil-fired water heater has an 8 year lifetime.<sup>456</sup>

### **3.39.6 Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installation coupled with EDC data gathering or assignment of stipulated energy savings.

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<sup>455</sup> From ENERGY STAR.

[https://www.energystar.gov/index.cfm?fuseaction=find\\_a\\_product.showProductGroup&pgw\\_code=WGS](https://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=WGS)

<sup>456</sup> <http://www.aceee.org/consumer/water-heating>

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### **3.40 Fuel Switching: Commercial Electric Heat to Natural gas / Propane / Oil Heat**

The energy and demand savings for Commercial fuel switching for heating systems is determined from the algorithms listed below. This protocol excludes water source, ground source, and groundwater source heat pumps.

The baseline for this measure is an existing commercial facility with an electric primary heating source. The heating source can be electric baseboards, packaged terminal heat pump (PTHP) units, electric furnace, or electric air source heat pump. The retrofit condition for this measure is the installation of a new standard efficiency natural gas, propane, or oil furnace or boiler. This algorithm does not apply to combination space and water heating units.

#### **3.40.1 Algorithms**

The energy savings are the full energy consumption of the electric heating source minus the energy consumption of the fossil fuel furnace blower motor. The energy savings are obtained through the following formulas:

##### **Electric furnace or air source heat pump**

For ASHP units < 65,000 BtuH, use HSPF instead of COP to calculate  $\Delta kWh_{heat}$ .

$$\begin{aligned} \Delta kWh_{heat} &= (BtuH_{heat} / 1000) / 3.412 \times 1/COP_{base} \times EFLH_{heat} \\ &= (BtuH_{heat} / 1000) \times 1/HSPF_{base} \times EFLH_{heat} \end{aligned}$$

##### **Baseboard heating, packaged terminal heat pump**

$$\Delta kWh_{heat} = \frac{BtuH_{heat} \times EFLH_{heat}}{3413 \frac{Btu}{kWh} \times COP_{base}} - \frac{HP_{motor} \times \left(746 \frac{W}{HP}\right) \times EFLH_{heat}}{\eta_{motor} \times 1000 \frac{W}{kW}}$$

The motor consumption of a gas furnace is subtracted from the savings for a baseboard or PTHP heating system, as these existing systems do not require a fan motor while the replacement furnace does (the electric furnace and air source heat pumps require fan motors with similar consumption as a gas furnace and thus there is no significant change in motor load). For boilers, the annual pump energy consumption is negligible (<50 kWh per year) and not included in this calculation.<sup>457</sup>

There are no peak demand savings as it is a heating only measure.

Although there is a significant electric savings, there is also an associated increase in fossil fuel energy consumption. While this fuel consumption does not count against PA Act 129 energy savings, it is expected to be used in the program TRC test. The increased fossil fuel energy is obtained through the following formula:

<sup>457</sup> Pump motors are typically 1/25 HP. With 1,000 hour runtime and 80% assumed efficiency, this translates to 37 kWh.

**Fuel consumption with fossil fuel furnace or boiler:**

$$\text{Fuel Consumption (MMBtu)} = \frac{\text{BtuH}_{\text{fuel}} \times \text{EFLH}_{\text{heat}}}{\text{AFUE}_{\text{fuel}} \times 1,000,000} \frac{\text{Btu}}{\text{MMBtu}}$$

**3.40.2 Definition of Terms**

BtuH<sub>heat</sub> = Rated heating capacity of the existing electric unit in BtuH<sub>heat</sub>

BtuH<sub>fuel</sub> = Rated heating capacity of the new fossil fuel unit in BtuH<sub>fuel</sub>

COP<sub>base</sub> = Efficiency rating of the baseline unit. For ASHP units < 65,000 BtuH, HSPF should be used for heating savings.

HSPF<sub>base</sub> = Heating seasonal performance factor of the baseline unit. For units > 65,000 BtuH, COP should be used for heating savings.

AFUE<sub>fuel</sub> = Annual Fuel Utilization Efficiency rating of the fossil fuel unit.

EFLH<sub>heat</sub> = Equivalent Full Load Hours for the heating season – The kWh during the entire operating season divided by the kW at design conditions.

HP<sub>motor</sub> = Gas furnace blower motor horsepower (hp)

η<sub>motor</sub> = Efficiency of furnace blower motor

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Table 1-12123: Variables for HVAC Systems

<u>Component</u>	<u>Type</u>	<u>Value</u>	<u>Source</u>
$BtuH_{fuel}$	Variable	Nameplate data (AHRI or AHAM)	EDC Data Gathering
$BtuH_{heat}$	Variable	Nameplate data (AHRI or AHAM) Default: set equal to $BtuH_{fuel}$	EDC Data Gathering
$COP_{base}$	Variable	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 1-13Table 3-124	See Table 1-13Table 3-124
$HSPF_{base}$	Variable	Early Replacement: Nameplate data	EDC Data Gathering
		New Construction or Replace on Burnout: Default values from Table 1-13Table 3-124	See Table 1-13Table 3-124
$AFUE_{fuel}$	Variable	Default = 80% (natural gas/propane furnace) 79% (natural gas/propane steam boiler) 80% (natural gas/propane hot water boiler) 81% (oil furnace) 81% (oil steam boiler) 82% (oil hot water boiler)	Code of Federal Regulations 10 CFR 431.87, for Less than 2,500,000 Btu/h
		Nameplate data (AHRI or AHAM)	EDC Data Gathering
$EFLH_{heat}$	Variable	Based on Logging, EMS data or Modeling458	EDC Data Gathering
		Default values from Table 1-14Table 3-125	See Table 1-14Table 3-125
$HP_{motor}$	Variable	Default = ½ hp for furnace	Average blower motor capacity for gas furnace (typical range = ¼ hp to ¾ hp)
		Nameplate	EDC Data Gathering
$\eta_{motor}$	Variable	Default = 0.50 for furnace	Typical efficiency of ½ hp blower motor for gas furnace
		Nameplate	EDC Data Gathering

**Sources:**

458 Modeling is an acceptable substitute to metering and BMS data if modeling is conducted using building- and equipment-specific information at the site and the facility consumption is calibrated using 12 months of billing data (pre-retrofit).

**SECTION 1: Appendices**

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1. The Equivalent Full Load Hours (ELFH) for Pennsylvania are calculated based on the degree day scaling methodology. The EFLH values reported in the Connecticut Program Savings Documentation were adjusted using full load hours (FLH) from the US DOE ENERGY STAR Calculator to account for differences in weather conditions. Degree day scaling ratios were calculated using heating degree day and cooling degree day values for seven Pennsylvania cities: Allentown, Erie, Harrisburg, Philadelphia, Pittsburgh, Scranton, and Williamsport.

a. US Department of Energy, ENERGY STAR Calculator and Bin Analysis Models

b. UI and CL&P Program Savings Documentation for 2012 Program Year, United Illuminating Company, September 2011, Pages 219-220.

Table 1-13124: HVAC Baseline Efficiencies<sup>459</sup>

<u>Equipment Type and Capacity</u>	<u>Heating Baseline</u>
<u>Air-Source Heat Pumps</u>	
<u>&lt; 65,000 BtuH</u>	<u>7.7 HSPF</u>
<u>&gt; 65,000 BtuH and &lt;135,000 BtuH</u>	<u>3.3 COP</u>
<u>&gt; 135,000 BtuH and &lt; 240,000 BtuH</u>	<u>3.2 COP</u>
<u>&gt; 240,000 BtuH (IPLV for units with capacity-modulation only)</u>	<u>3.2 COP</u>
<u>Electric Resistance Heat (Electric Furnace or Baseboard)</u>	
<u>All sizes</u>	<u>1.0 COP</u>
<u>Packaged Terminal Systems (Replacements)<sup>460</sup></u>	
<u>PTHP</u>	<u>2.9 - (0.026 x Cap / 1000) COP</u>

<sup>459</sup> Baseline values from IECC 2009, after Jan 1, 2010 or Jan 23, 2010 as applicable.

<sup>460</sup> Cap represents the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7,000 Btu/h, 7,000 Btu/h is used in the calculation. If the unit's capacity is greater than 15,000 Btu/h, 15,000 Btu/h is used in the calculation.

## **SECTION 1: Appendices**

Fuel Switching: Commercial Electric Heat to Natural gas / Propane / Oil Heat

Page 430

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**Table 1-14125: Heating EFLH for Pennsylvania Cities 461-462**

<b>Space and/or Building Type</b>	<b>Allentown</b>	<b>Erie</b>	<b>Harrisburg</b>	<b>Pittsburgh</b>	<b>Williamsport</b>	<b>Philadelphia</b>	<b>Scranton</b>
<u>Arena/Auditorium/Convention Center</u>	<u>1,719</u>	<u>2,002</u>	<u>1,636</u>	<u>1,642</u>	<u>1,726</u>	<u>1,606</u>	<u>1,747</u>
<u>College: Classes/Administrative</u>	<u>1,559</u>	<u>1,815</u>	<u>1,484</u>	<u>1,489</u>	<u>1,565</u>	<u>1,457</u>	<u>1,584</u>
<u>Convenience Stores</u>	<u>603</u>	<u>701</u>	<u>573</u>	<u>576</u>	<u>605</u>	<u>563</u>	<u>612</u>
<u>Dining: Bar Lounge/Leisure</u>	<u>1,156</u>	<u>1,346</u>	<u>1,100</u>	<u>1,104</u>	<u>1,161</u>	<u>1,080</u>	<u>1,175</u>
<u>Dining: Cafeteria / Fast Food</u>	<u>582</u>	<u>678</u>	<u>554</u>	<u>556</u>	<u>585</u>	<u>544</u>	<u>592</u>
<u>Dining: Restaurants</u>	<u>1,156</u>	<u>1,346</u>	<u>1,100</u>	<u>1,104</u>	<u>1,161</u>	<u>1,080</u>	<u>1,175</u>
<u>Gymnasium/Performing Arts Theatre</u>	<u>1,559</u>	<u>1,815</u>	<u>1,484</u>	<u>1,489</u>	<u>1,565</u>	<u>1,457</u>	<u>1,584</u>
<u>Hospitals/Health care</u>	<u>276</u>	<u>321</u>	<u>263</u>	<u>264</u>	<u>277</u>	<u>258</u>	<u>280</u>
<u>Industrial: 1 Shift/Light Manufacturing</u>	<u>1,491</u>	<u>1,737</u>	<u>1,420</u>	<u>1,425</u>	<u>1,498</u>	<u>1,394</u>	<u>1,516</u>
<u>Industrial: 2 Shift</u>	<u>1,017</u>	<u>1,184</u>	<u>968</u>	<u>972</u>	<u>1,022</u>	<u>951</u>	<u>1,034</u>
<u>Industrial: 3 Shift</u>	<u>538</u>	<u>626</u>	<u>512</u>	<u>513</u>	<u>540</u>	<u>502</u>	<u>546</u>
<u>Lodging: Hotels/Motels/Dormitories</u>	<u>1,438</u>	<u>1,675</u>	<u>1,369</u>	<u>1,374</u>	<u>1,444</u>	<u>1,344</u>	<u>1,462</u>
<u>Lodging: Residential</u>	<u>1,438</u>	<u>1,675</u>	<u>1,369</u>	<u>1,374</u>	<u>1,444</u>	<u>1,344</u>	<u>1,462</u>
<u>Multi-Family (Common Areas)</u>	<u>277</u>	<u>322</u>	<u>263</u>	<u>264</u>	<u>278</u>	<u>259</u>	<u>281</u>
<u>Museum/Library</u>	<u>1,266</u>	<u>1,474</u>	<u>1,205</u>	<u>1,209</u>	<u>1,271</u>	<u>1,183</u>	<u>1,286</u>
<u>Nursing Homes</u>	<u>738</u>	<u>859</u>	<u>702</u>	<u>704</u>	<u>740</u>	<u>689</u>	<u>749</u>
<u>Office: General/Retail</u>	<u>1,266</u>	<u>1,474</u>	<u>1,205</u>	<u>1,209</u>	<u>1,271</u>	<u>1,183</u>	<u>1,286</u>
<u>Office: Medical/Banks</u>	<u>1,266</u>	<u>1,474</u>	<u>1,205</u>	<u>1,209</u>	<u>1,271</u>	<u>1,183</u>	<u>1,286</u>
<u>Parking Garages &amp; Lots</u>	<u>1,110</u>	<u>1,292</u>	<u>1,056</u>	<u>1,060</u>	<u>1,114</u>	<u>1,037</u>	<u>1,128</u>
<u>Penitentiary</u>	<u>829</u>	<u>965</u>	<u>789</u>	<u>792</u>	<u>832</u>	<u>774</u>	<u>842</u>
<u>Police/Fire Stations (24 Hr)</u>	<u>277</u>	<u>322</u>	<u>263</u>	<u>264</u>	<u>278</u>	<u>259</u>	<u>281</u>
<u>Post Office/Town Hall/Court House</u>	<u>1,266</u>	<u>1,474</u>	<u>1,205</u>	<u>1,209</u>	<u>1,271</u>	<u>1,183</u>	<u>1,286</u>
<u>Religious Buildings/Church</u>	<u>1,718</u>	<u>2,001</u>	<u>1,635</u>	<u>1,641</u>	<u>1,725</u>	<u>1,605</u>	<u>1,746</u>
<u>Retail</u>	<u>1,188</u>	<u>1,383</u>	<u>1,130</u>	<u>1,135</u>	<u>1,193</u>	<u>1,110</u>	<u>1,207</u>
<u>Schools/University</u>	<u>1,661</u>	<u>1,933</u>	<u>1,580</u>	<u>1,586</u>	<u>1,667</u>	<u>1,551</u>	<u>1,687</u>
<u>Warehouses (Not Refrigerated)</u>	<u>1,555</u>	<u>1,810</u>	<u>1,480</u>	<u>1,485</u>	<u>1,561</u>	<u>1,453</u>	<u>1,580</u>
<u>Warehouses (Refrigerated)</u>	<u>1,555</u>	<u>1,810</u>	<u>1,480</u>	<u>1,485</u>	<u>1,561</u>	<u>1,453</u>	<u>1,580</u>
<u>Waste Water Treatment Plant</u>	<u>538</u>	<u>626</u>	<u>512</u>	<u>513</u>	<u>540</u>	<u>502</u>	<u>546</u>

461 US Department of Energy. Energy Star Calculator and Bin Analysis Models

462 The Equivalent Full Load Hours (EFLH) for Pennsylvania are calculated based on the degree day scaling methodology. The EFLH values reported in the Connecticut Program Savings Documentation were adjusted using full load hours (FLH) from the US DOE ENERGY STAR Calculator to account for differences in weather conditions.

## SECTION 1: Appendices

Fuel Switching: Commercial Electric Heat to Natural gas / Propane / Oil Heat

Page 431

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**3.40.3 Measure Life**

Measure life = 20 years463

463 DEER 2008 for nonresidential high efficiency furnace  
([http://www.deeresources.com/deer0911planning/downloads/EUL\\_Summary\\_10-1-08.xls](http://www.deeresources.com/deer0911planning/downloads/EUL_Summary_10-1-08.xls)) PA 2013 TRM Appendix A:  
Measure Lives. Note that PA Act 129 savings can be claimed for no more than 15 years.

**SECTION 1: Appendices**

**Fuel Switching: Commercial Electric Heat to Natural gas / Propane / Oil Heat**

**Page 432**

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## **4 AGRICULTURAL MEASURES**

The following section of the TRM contains savings protocols for agricultural measures that apply to both residential and commercial & industrial sector.

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## 4.1 Automatic Milker Takeoffs

Measure Name	Automatic Milker Takeoffs
Target Sector	Agriculture (includes Small Commercial, Residential)
Measure Unit	Per project
Unit Energy Savings	Varies, partially deemed
Unit Peak Demand Reduction	Varies, partially deemed
Measure Life	10

The following protocol for the calculation of energy and demand savings applies to the installation of automatic milker takeoffs on dairy milking vacuum pump systems. Automatic milker takeoffs shut off the suction on teats once a minimum flow rate is achieved. This reduces the load on the vacuum pump.

### 4.1.1 Eligibility

This measure requires the installation of automatic milker takeoffs to replace pre-existing manual takeoffs on dairy milking vacuum pump systems. Equipment with existing automatic milker takeoffs is not eligible. In addition, the vacuum pump system serving the affected milking units must be equipped with a variable speed drive (VSD) to qualify for incentives. Without a VSD, little or no savings will be realized.

### 4.1.2 Algorithms

The annual energy savings are obtained through the following formula:

$$\Delta kWh / yr = COWS \times \frac{MPD}{2 \frac{avg. milkings}{day}} \times ESC$$

$$\Delta kW_{peak} = \Delta kWh \times CF$$

### 4.1.3 Definition of Terms

COWS = Number of cows milked per day

MPD = Number of milkings per day per cow

ESC = Energy Savings per cow per year.

CF = Demand Coincidence factor

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#### 4.1.4 Description of Calculation Method

Table 4-1: Variables for Automatic Milker Takeoffs

<u>Component</u>	<u>Type</u>	<u>Value</u>	<u>Source</u>
<u>COWS</u>	<u>Variable</u>	<u>Based on customer application</u>	<u>EDC Data Gathering</u>
<u>MPD</u>	<u>Variable</u>	<u>Based on customer application</u>	<u>EDC Data Gathering</u>
		<u>Default = 2</u>	<u>1</u>
<u>ESC</u>	<u>Fixed</u>	<u>7.5 kWh/cow/yr</u>	<u>1, 2, 3, 4, 5,6</u>
<u>CF</u>	<u>Fixed</u>	<u>0.00014</u>	<u>2</u>

#### Sources:

1. The ESC was calculated based on the following assumptions:
  - Average herd size is 75 cows in PA
  - The typical dairy vacuum pump size is 10 horsepower
  - Based on the herd size, average pump operating hours are estimated at 8 hours per day
  - A 12.5% annual energy saving factor
2. Average Pennsylvania Herd Size information came from: Hoard's Dairyman: The National Dairy Farm Magazine, March 2013. U.S. Industry Dairy Statistics, 2007-2013
3. Average dairy vacuum pump size was estimated based on the Minnesota Dairy Project literature. <http://www.mnproject.org/resourcecenter/Vacuum%20System%20options.pdf>
4. Annual pump operating hours were based on the assumption that 15-20 cows are milked per hour and two milkings occur per day.
5. Savings are based on the assumption that automatic milker take-offs eliminate open vacuum pump time associated with milker take-offs separating from the cow or falling off during the milking process. The following conservative assumptions were made to determine energy savings associated with the automatic milker take-offs:
  - There is 30 seconds of open vacuum pump time for every 8 cows milked
  - The vacuum pump has the ability to turn down during these open-vacuum pump times from a 90% VFD speed to a 40% VFD speed

Additionally, several case studies from the Minnesota Dairy Project include dairy pump VFD and automatic milker take-off energy savings and are estimated at 50-70% pump savings. It is assumed that the pump VFD savings are 46% (see Vacuum Pump VFD IMP), therefore the average remaining savings can be attributed to automatic milker take-offs.

<http://www.mnproject.org/resourcecenter/Vacuum%20System%20options.pdf>

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6. Because this measure results in vacuum pump energy savings, the load profile and coincidence factor described in the VSD Controller on Dairy Vacuum Pump TRM protocol also apply to this measure.

**4.1.5 Measure Life**

The measure life for automatic milker takeoffs is 10 years. 464

464 Idaho Power Demand Side Management Potential Study – Volume II Appendices, Nexant, 2009.

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## 4.2 Dairy Scroll Compressors

<b>Measure Name</b>	<b>Dairy Scroll Compressors</b>
<b>Target Sector</b>	Agriculture (includes Small Commercial, Residential)
<b>Measure Unit</b>	Per compressor
<b>Unit Energy Savings</b>	Varies
<b>Unit Peak Demand Reduction</b>	Varies
<b>Measure Life</b>	15 years

The following protocol for the calculation of energy and demand savings applies to the installation of a scroll compressor to replace an existing reciprocating compressor or the installation of a scroll compressor in a new construction application. The milk cooling equipment can consume 20 percent to 25 percent of all electrical energy use on a dairy farm. The compressor is used to cool milk for preservation and packaging. The energy and demand savings per cow will depend on the installed scroll compressor energy efficiency ratio (EER), operating days per year and the presence of a pre cooler in the refrigeration system.

### 4.2.1 Eligibility

This measure requires the installation of a scroll compressor to replace an existing reciprocating compressor or to be installed in a new construction application. Existing farms replacing scroll compressors are not eligible.

### 4.2.2 Algorithms

The energy and peak demand savings are dependent on the presence of a pre cooler in the system, and are obtained through the following formulas:

#### Annual Savings without a Pre cooler

$$\Delta kWh_{no\ precool} / yr \times COWS = \left( \frac{CBTU_{no\ precool}}{EER_{base}} - \frac{CBTU_{no\ precool}}{EER_{eff}} \right) \times \frac{1\ kW}{1000\ W} \times HRS \times DAYS$$

$$\Delta kW_{peak, no\ precool} = \Delta kWh_{no\ precool} \times CF$$

#### Annual Savings with a Pre cooler

$$\Delta kWh_{precool} / yr \times COWS = \left( \frac{CBTU_{precool}}{EER_{base}} - \frac{CBTU_{precool}}{EER_{eff}} \right) \times \frac{1\ kW}{1000\ W} \times HRS \times DAYS$$

$$\Delta kW_{peak, precool} = \Delta kWh_{precool} \times CF$$

### 4.2.3 Definition of Terms

$$EER_{base} = \text{Baseline compressor efficiency}$$

$$EER_{eff} = \text{Installed compressor efficiency}$$

## SECTION 4: Agricultural Measures

### Dairy Scroll Compressors

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$CBTU_{no\ precool}$  = Heat load of milk per cow per day for a refrigeration system with no pre-cooler in Btu/Cow/day.

$CBTU_{precool}$  = Heat load of milk per cow per day for a refrigeration system with a pre-cooler in Btu/Cow/day.

DAYS = Milking days per year

HRS = Operating hours per day

COWS = Average number of cows milked per day

CF = Demand Coincidence factor

#### 4.2.4 Description of Calculation Method

Table 4-2: Variables for Dairy Scroll Compressors

Component	Type	Value	Source
<u>EER<sub>base</sub></u>	Variable	<u>Baseline compressor nameplate, customer application</u>	<u>EDC Data Gathering</u>
	Default	<u>5.85</u>	<u>1</u>
<u>EER<sub>eff</sub></u>	Variable	<u>Nameplate</u>	<u>EDC Data Gathering</u>
<u>CBTU<sub>no precool</sub></u>	Fixed	<u>2,864 Btu/Cow/day</u>	<u>2, 3</u>
<u>CBTU<sub>precool</sub></u>	Fixed	<u>922 Btu/Cow/day</u>	<u>2, 3</u>
<u>HRS</u>	Variable	<u>Customer application</u>	<u>EDC Data Gathering</u>
	Default	<u>8 hours</u>	<u>4</u>
<u>DAYS</u>	Variable	<u>Based on customer application</u>	<u>EDC Data Gathering</u>
	Default	<u>365 days/year</u>	<u>3, 4</u>
<u>COWS</u>	Variable	<u>Based on customer application</u>	<u>EDC Data Gathering</u>
<u>CF</u>	Fixed	<u>0.00014</u>	<u>5</u>

#### Sources:

1. Based on the average EER data for a variety of reciprocating compressors from Emerson Climate Technologies. <http://www.emersonclimate.com/en-us/Pages/default.aspx>
2. Based on a specific heat value of 0.93 Btu/lb deg F and density of 8.7 lb/gallon for whole milk. American Society of Heating Refrigeration and Air-conditioning Engineers Refrigeration Handbook, 2010, Ch.19.5.
3. Based on delta T (between cow temperature milk cooled milk) of 59°F for a system with no pre-cooler and 19°F for a system with a pre-cooler. It was also assumed that an average cow produces 6 gallons of milk per day. Evaluation of Alliant Energy Agriculture Program, Appendix F, 2008.

4. Based on typical dairy parlor operating hours referenced for agriculture measures in California. California Public Utility Commission. Database for Energy Efficiency Resources (DEER) 2005. The DEER database assumes 20 hours of operation per day, but is based on much larger dairy farms (e.g. herd sizes > 300 cows). Therefore, the DEER default value was lowered to 8 hours per day, as the average heard size in 75 cows in Pennsylvania.
5. Because the scroll compressor operates on the same operating schedule as the dairy vacuum pump equipment, the load profile and coincidence factor described in the VSD Controller on Dairy Vacuum Pump TRM protocol can be applied to this measure. However, it should be noted that the compressor and refrigeration system are thermostatically controlled and will cycle on and off during the peak demand period.

#### **4.2.5 Measure Life**

The measure life for dairy scroll compressors is 15 years<sup>465</sup>.

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465 PA Consulting Group for the State of Wisconsin Public Service Commission, Focus on Energy Evaluation. Business Programs: Measure Life Study. August 25, 2009. Appendix B

### 4.3 High Efficiency Ventilation Fans with and without Thermostats

Measure Name	High Efficiency Ventilation Fans
Target Sector	Agriculture, Large Commercial, Small Commercial, Residential
Measure Unit	Per fan
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	10 years

The following protocol for the calculation of energy and demand savings applies to the installation of ventilation fans to replace standard efficiency ventilation fans or in new construction. The high efficiency fans move more cubic feet of air per watt than compared to standard efficiency ventilation fans. Adding a thermostat control will reduce the number of hours that the ventilation fans operate.

This protocol does not apply to circulation fans.

#### 4.3.1 Eligibility

This protocol applies to: (1) the installation of high efficiency ventilation fans in either new construction or retrofit applications where standard efficiency ventilation fans are replaced, and/or (2) the installation of a thermostat controlling either new efficient fans or existing fans. Default values are provided for dairy and swine applications. Other facility types are eligible, however, data must be collected for all default values.

#### 4.3.2 Algorithms

The annual energy savings are obtained through the following formula:

$$\Delta kWh_{fan}/yr = Qty_{std} \left( \frac{1}{Eff_{std}} \right) \times CFM \times hours \times \frac{1}{1000} - Qty_{high} \left( \frac{1}{Eff_{high}} \right) \times CFM \times hours \times \frac{1}{1000}$$

$$\Delta kWh_{tstat}/yr = \left( \frac{1}{Eff_{installeds}} \right) \times CFM \times hours_{tstat} \times 1/1000$$

$$\Delta kWh_{total}/yr = \Delta kWh_{fan} + \Delta kWh_{tstat}$$

$$\Delta kW_{peak} = \Delta kWh_{fan} \times CF$$

#### 4.3.3 Definition of Terms

$Qty_{std}$  = Quantity of the baseline standard efficiency fans

$Qty_{high}$  = Quantity of high efficiency fans that were installed

$Eff_{high}$  = Efficiency in cfm/W of the high efficiency fan at a static pressure of 0.1 inches water

*Eff<sub>std</sub>* = *Efficiency in cfm/W of the standard efficiency fan at a static pressure of 0.1 inches water*

*Eff<sub>installed</sub>* = *Efficiency in cfm/W at a static pressure of 0.1 inches water for the installed fans controlled by the thermostat*

*CFM* = *cubic feet per minute of air movement*

*hours* = *operating hours per year of the fan without thermostat*

*hours<sub>stat</sub>* = *reduction in operating hours of the fan due to the thermostat*

*1000* = *conversion of watts to kilowatts*

*CF* = *demand coincidence factor*

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#### 4.3.4 Description of Calculation Method

Table 4-3: Variables for Ventilation Fans

Component	Type	Value	Source
Qty <sub>std</sub>	Variable	Based on customer application	EDC Data Gathering
Qty <sub>high</sub>	Variable	Based on customer application	EDC Data Gathering
Eff <sub>std</sub>	Variable	Based on customer application	EDC Data Gathering
	Variable	Default values in Table 4-4Table 4-4	1
Eff <sub>high</sub>	Variable	Based on customer application. Collect the efficiency at static pressure of 0.1 inches water	EDC Data Gathering, 2, 3
		Default values in Table 4-4Table 4-4	1, 2, 3
Eff <sub>installed</sub>	Variable	Based on customer application. Collect the efficiency at 0.1 inches water	EDC Data Gathering, 2, 3
		Default values in Table 4-4Table 4-4. If fans were not replaced, use the default values for Eff <sub>std</sub> . If fans were replaced, use the default values for Eff <sub>high</sub> .	1, 2, 3
hours	Variable	Based on customer application	EDC Data Gathering
		Default use values in Table 4-5	1, 4
CFM	Variable	Based on customer application. This can vary for pre- and post-installation if the information is known for the pre-installation case.	EDC Data Gathering
	Variable	Default values in Table 4-4Table 4-4	1
hours <sub>stat</sub>	Variable	Default values in Table 4-6	4
CF	Fixed	0.000197	5

#### Sources:

9. [KEMA Evaluation of Alliant Energy Agriculture Program, Appendix F, 2008. See Table H-5.](#)
1. [Pennsylvania State University. Tunnel Ventilation for Tie Stall Dairy Barns. 2004. Downloaded from <http://pubs.cas.psu.edu/freepubs/pdfs/g78.pdf>. Static pressure reference point for dairy barns comes from page 3. The recommended static pressure is 0.125 to 0.1 inches water](#)
2. [Iowa State University. Mechanical Ventilation Design Worksheet for Swine Housing. 1999. Downloaded from <http://www.extension.iastate.edu/Publications/PM1780.pdf>. Static pressure reference point for swine housing comes from page 2. The](#)

#### SECTION 4: Agricultural Measures

##### High Efficiency Ventilation Fans with and without Thermostats

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recommended static pressure is 0.125 to 0.1 inches water for winter fans and 0.05 to 0.08 inches water for summer fans. A static pressure of 0.1 inches water was assumed for dairy barns and swine houses as it is a midpoint for the recommended values.

3. Based on the methodology in KEMA's evaluation of the Alliant Energy Agriculture Program (reference 1). Updated the hours for dairies and thermostats using TMY3 temperature data for PA, as fan run time is dependent on ambient dry-bulb temperature. For a stall barn, it was assumed 33% of fans are on 8,760 hours per year, 67% of fans are on when the temperature is above 50 degrees Fahrenheit, and 100% of the fans are on when the temperature is above 70 degrees Fahrenheit. For a cross-ventilated or free-stall barn, it was assumed 10% of fans are on 8,760 hours per year, 40% of fans are on when the temperature is above 50 degrees Fahrenheit, and 100% of the fans are on when the temperature is above 70 degrees Fahrenheit. The hours for hog facilities are based on humidity. These hours were not updated as the methodology and temperatures for determining these hours was not described in KEMA's evaluation report and could not be found elsewhere. However, Pennsylvania and Iowa are in the same ASHRAE climate zone (5A) and so the Iowa hours provide a good estimate for hog facilities in Pennsylvania.
4. The coincident peak demand factor was calculated by dividing the average peak coincident demand kW reduction by  $\Delta$ kWh savings for the fans. There are no peak demand savings for thermostats.

**Table 4-4: Default values for standard and high efficiency ventilation fans for dairy and swine facilities**

<u>Fan Size (inches)</u>	<u>High Efficiency Fan (cfm/W at 0.1 inches water)</u>	<u>Standard Efficiency Fan (cfm/W at 0.1 inches water)</u>	<u>CFM</u>
<u>14-23</u>	<u>12.4</u>	<u>9.2</u>	<u>3,600</u>
<u>24-35</u>	<u>15.3</u>	<u>11.2</u>	<u>6,274</u>
<u>36-47</u>	<u>19.2</u>	<u>15.0</u>	<u>10,837</u>
<u>48 - 61</u>	<u>22.7</u>	<u>17.8</u>	<u>22,626</u>

**Table 4-5: Default Hours for Ventilation Fans by Facility Type by Location (No Thermostat)**

<u>Facility Type</u>	<u>Allentown</u>	<u>Erie</u>	<u>Harrisburg</u>	<u>Philadelphia</u>	<u>Pittsburgh</u>	<u>Scranton</u>	<u>Williamsport</u>
<u>Dairy - Stall Barn</u>	<u>5,071</u>	<u>4,807</u>	<u>5,163</u>	<u>5,390</u>	<u>5,010</u>	<u>4,843</u>	<u>5,020</u>
<u>Dairy – Free-Stall or Cross-Ventilated Barn</u>	<u>3,299</u>	<u>2,984</u>	<u>3,436</u>	<u>3,732</u>	<u>3,231</u>	<u>2,985</u>	<u>3,241</u>
<u>Hog Nursery or Sow House</u>	<u>5,864</u>						
<u>Hog Finishing House</u>	<u>4,729</u>						

**Table 4-6. Default Hours Reduced by Thermostats by Facility Type and Location**

Facility Type	Allentown	Erie	Harrisburg	Philadelphia	Pittsburgh	Scranton	Williamsport
Dairy - Stall Barn	3,457	3,458	3,367	3,285	3,441	3,594	3,448
Dairy - Free-Stall or Cross-Ventilated Barn	1,685	1,635	1,640	1,627	1,662	1,736	1,669
Hog Nursery or Sow House	2,629	2,985	2,323	2,179	2,732	2,885	2,666
Hog Finishing House*	0	0	0	0	0	0	0

\*Hog finishing houses base ventilation needs on humidity, therefore a thermostat will not reduce the number of hours the fans operate.

#### **4.3.5 Measure Life**

The measure life for high efficiency ventilation fans is 10 years. The measure life for the thermostat is 11 years.<sup>466</sup>

#### **4.3.6 Evaluation Protocols**

The most appropriate evaluation protocol for this measure is verification of installation coupled with assignment of stipulated energy savings. For building types which are not covered under this protocol, operating hours should also be verified.

<sup>466</sup> New York Standard Approach for Estimating Energy Savings from Energy Efficiency Measures in Commercial and Industrial Programs, September 1, 2009, based on DEER.



## 4.4 Heat Reclaimers

Measure Name	Heat Reclaimers
Target Sector	Agriculture (includes Small Commercial, Residential)
Measure Unit	Per heat reclaimer
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	15 years

The following protocol for the calculation of energy and demand savings applies to the installation of heat recovery equipment on dairy parlor milk refrigeration systems. The heat reclaimers recover heat from the refrigeration system and use it to pre-heat water used for sanitation, sterilization and cow washing.

### 4.4.1 Eligibility

This measure requires the installation of heat recovery equipment on dairy parlor milk refrigeration systems to heat hot water. This measure only applies to dairy parlors with electric water heating equipment.

The equipment installed must be one of the following pre-approved brands or equivalent: Century-Therm, Fre-Heater, Heat Bank, Sunset, Superheater and Therma- Stor.

### 4.4.2 Algorithms

The energy and peak demand savings are dependent on the presence of a precooler in the refrigeration system, and are obtained through the following formulas:

#### Annual Savings without a precooler

$$\Delta kWh_{\text{no precool}} / \text{yr} = \frac{ES_{\text{no precool}}}{\eta_{\text{water heater}}} \times \text{DAYS} \times \text{COWS} \times \text{HEF}$$

$$\Delta kW_{\text{peak, no precool}} = \Delta kWh_{\text{no precool}} \times \text{CF}$$

#### Annual Savings with a precooler

$$\Delta kWh_{\text{precool}} / \text{yr} = \frac{ES_{\text{precool}}}{\eta_{\text{water heater}}} \times \text{DAYS} \times \text{COWS} \times \text{HEF}$$

$$\Delta kW_{\text{peak, precool}} = \Delta kWh_{\text{precool}} \times \text{CF}$$

### 4.4.3 Definition of Terms

$ES_{\text{no precool}}$  = Energy savings for systems with no precooler in kWh/cow/day.

$ES_{\text{precool}}$  = Energy savings for systems with a precooler in kWh/cow/day.

$\text{DAYS}$  = Milking days per year

$\eta_{\text{water heater}}$  = *Electric water heater efficiency*

COWS = *Average number of cows milked per day*

HEF = *Heating element factor*

CF = *Demand Coincidence factor*

#### 4.4.4 Description of Calculation Method

Table 4-7: Variables for Heat Reclaimers

Component	Type	Value	Source
ES <sub>no precool</sub>	Fixed	0.38 kWh/cow/day	1,2
ES <sub>precool</sub>	Fixed	0.29 kWh/cow/day	1,2
DAYS	Variable	Based on customer application	EDC Data Gathering
	Default	365 days/year	2
COWS	Variable	Based on customer application	EDC Data Gathering
HEF	Variable	Heat reclaimers with no back-up heat = 1.0 Heat reclaimers with back-up heating elements = 0.50	3
$\eta_{\text{water heater}}$	Variable	Standard electric tank water heater = 0.908 High efficiency electric tank water heater = 0.93 Heat pump water heater = 2.0	4, 5
CF	Fixed	0.00014	6

#### Sources:

1. Based on a specific heat value of 0.93 Btu/lb deg F and density of 8.7 lb/gallon for whole milk. American Society of Heating Refrigeration and Air-conditioning Engineers Refrigeration Handbook, 2010, Ch.19.5.
2. Based on a delta T (between cow temperature milk and cooled milk) of 59°F for a system without a pre-cooler and 19°F for a system with a pre-cooler. It was also assumed that a cow produces 6.5 gallons of milk per day (based on two milkings per day), requires 2.2 gallons of hot water per day, and the water heater delta T (between ground water and hot water) is 70°F. Evaluation of Alliant Energy Agriculture Program, Appendix F, 2008.
3. Some smaller dairy farms may not have enough space for an additional water storage tank, and will opt to install a heat reclaimer with a back-up electric resistance element. The HEF used in the savings algorithm is a conservative savings de-ration factor to account for the presence of back-up electric resistance heat. The HEF is based on the assumption that the electric resistance element in a heat reclaimer will increase the

incoming ground water temperature by 40-50 °F before the water is heated by the heat reclaim coil.

4. Standard water heater based on minimum electric water heater efficiencies defined in Table 504.2 of the 2009 International Energy Efficiency Code (IEEC). High efficiency water heater based on water heater efficiencies defined in Table 3-90 of the TRM.
5. Based on minimum heat pump water efficiencies defined by ENERGY STAR, 2009. [https://www.energystar.gov/index.cfm?fuseaction=find\\_a\\_product.showProductGroup&gw\\_code=WHH](https://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&gw_code=WHH)
6. Because the water heater operates on the same operating schedule as the dairy vacuum pump equipment and refrigeration equipment, the load profile and coincidence factor described in the VSD Controller on Dairy Vacuum Pump TRM protocol can be applied to this measure.

#### **4.4.5 Measure Life**

The measure life for a heat reclaimer is 14467 years.

467 California Public Utility Commission. Database for Energy Efficiency Resources 2008.

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## 4.5 High Volume Low Speed Fans

Measure Name	High Volume Low Speed Fans
Target Sector	Agriculture, Large Commercial, Small Commercial, Residential
Measure Unit	Per fan
Unit Energy Savings	Varies
Unit Peak Demand Reduction	Varies
Measure Life	15 years

The following protocol for the calculation of energy and demand savings applies to the installation of High Volume Low Speed (HVLS) fans to replace conventional circulating fans. HVLS fans are a minimum of 16 feet long in diameter and move more cubic feet of air per watt than conventional circulating fans. Default values are provided for dairy, poultry, and swine applications. Other facility types are eligible, however, the operating hours assumptions should be reviewed and modified as appropriate.

### 4.5.1 Eligibility

This measure requires the installation of HVLS fans in either new construction or retrofit applications where conventional circulating fans are replaced.

### 4.5.2 Algorithms

The annual energy savings are obtained through the following formula:

$$\Delta kWh / yr = (W_{conventional} - W_{HVLS}) / 1000 \times hours$$

$$\Delta kW_{peak} = \Delta kWh \times CF$$

$$CF = (W_{conventional} - W_{HVLS}) / 1000 \text{ (or use default CF value in Table 4-8)}$$

### 4.5.3 Definition of Terms

$$W_{conventional} = \text{Watts of the conventional fans}$$

$$W_{HVLS} = \text{Watts of the HVLS fan}$$

$$hours = \text{operating hours per year of the fans}$$

$$1000 = \text{conversion of watts to kilowatts}$$

$$CF = \text{Demand coincidence factor}$$

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#### 4.5.4 Description of Calculation Method

Table 4-8: Variables for HVLS Fans

Component	Type	Value	Source
$W_{\text{conventional}}$	Variable	Based on customer application	EDC Data Gathering
	Variable	Default values in Table 4-4	1, 2
$W_{\text{HVLS}}$	Variable	Based on customer application	EDC Data Gathering
		Default values in Table 4-4	2
hours	Variable	Based on customer application	EDC Data Gathering
		Default values in Table 4-10	3
CF	Variable	$(W_{\text{conventional}} - W_{\text{HVLS}}) / 1000$	EDC Data Gathering, Engineering calculations
	Fixed	Default value is 0.000500	4

#### Sources:

- Bioenvironmental and Structural Systems Laboratory database for circulating fans.
- KEMA. 2009 Evaluation of IPL Energy Efficiency Programs, Appendix F Group I Programs Volume 2. See Table H-17.
- Number of hours above 65 degrees Fahrenheit. Based on TMY3 data.
- The coincident peak demand factor is calculated by dividing the peak coincident demand kW reduction by  $\Delta$ kWh savings. The peak coincident demand kW reduction is calculated by  $(W_{\text{conventional}} - W_{\text{HVLS}}) / 1000$ .

Table 4-9: Default Values for Conventional and HVLS Fan Wattages

Fan Size (ft)	$W_{\text{HVLS}}$	$W_{\text{conventional}}$
$\geq 16$ and $< 18$	761	4,497
$\geq 18$ and $< 20$	850	5,026
$\geq 20$ and $< 24$	940	5,555
$\geq 24$	1,119	6,613

Table 4-10. Default Hours by Location for Dairy/Poultry/Swine Applications

Location	Hours/year
Allentown	2,446
Erie	2,107
Harrisburg	2,717
Philadelphia	2,914
Pittsburgh	2,292
Scranton	2,145
Williamsport	2,371

**4.5.5 Measure Life**

The measure life for HVLS fans is 15 years.

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## 4.6 Livestock Waterer

<b>Measure Name</b>	<b>Livestock Waterer</b>
<b>Target Sector</b>	Agriculture (includes Small Commercial, Residential)
<b>Measure Unit</b>	Per project
<b>Unit Energy Savings</b>	Varies
<b>Unit Peak Demand Reduction</b>	0 kW
<b>Measure Life</b>	10 years

The following protocol for the calculation of energy and demand savings applies to the installation of energy-efficient livestock waterers. In freezing climates low energy livestock waterers are used to prevent livestock water from freezing. These waterers are closed insulated watering containers which typically use super insulation, the relatively warmer ground water temperature, and the livestock's use of the waterer to keep water from freezing and thereby capable of watering the livestock.

### 4.6.1 Eligibility

This measure requires the installation of an energy efficient livestock waterer that is thermostatically controlled and has a minimum of two inches of factory-installed insulation.

### 4.6.2 Algorithms

The annual energy savings are obtained through the following formula:

$$\Delta kWh/yr = QTY \times OPRHS \times ESW \times HRT$$

No demand savings are expected for this measure, as the energy savings occur during the winter months.

### 4.6.3 Definition of Terms

QTY = Number of livestock waterers installed

OPRHS = Annual operating hours

ESW = Energy Demand Savings per waterer (deemed).

HRT = % heater run time

#### 4.6.4 Description of Calculation Method

Table 4-11: Variables for Livestock Waterers

Component	Type	Value	Source
QTY	Variable	Based on customer application	EDC Data Gathering
OPRHS	Fixed	Allentown = 1,489 Erie = 1,768 Harrisburg = 1,302 Philadelphia = 1,090 Pittsburgh = 1,360 Scranton = 1,718 Williamsport = 1,574	1
ESW	Fixed	0.50 kW per livestock waterer	2, 3, 4
HRT	Fixed	80%	5

#### Sources:

1. Based on TMY3 data for various climate zones in Pennsylvania. The annual operating hours represent the annual hours when the outdoor air dry-bulb temperature is less than 32 deg F, and it is assumed that the livestock waterer electric resistance heaters are required below this temperature to prevent water freezing.
2. Field Study of Electrically Heated and Energy Free Automated Livestock Water Fountains - Prairie Agricultural Machinery Institute, Alberta and Manitoba, 1994.
3. Facts Automatic Livestock Waterers Fact Sheet, December 2008.  
[http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/agdex5421/\\$file/716c52.pdf](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex5421/$file/716c52.pdf)
4. Connecticut Farm Energy Program: Energy Best Management Practices Guide, 2010.  
[http://www.ctfarmenergy.org/Pdfs/CT\\_Energy\\_BMPGuide.pdf](http://www.ctfarmenergy.org/Pdfs/CT_Energy_BMPGuide.pdf)
5. The Regional Technical Forum (RTF) analyzed metered data from three baseline livestock waterers and found the average run time of electric resistance heaters in the waterers to be approximately 80% for average monthly temperatures similar to Pennsylvania climate zones. This run time factor accounts for warmer make-up water being introduced to the tank as livestock drinking occurs.  
Downloaded on May 30<sup>th</sup>, 2013: <http://rtf.nwcouncil.org/measures/measure.asp?id=87>

#### 4.6.5 Measure Life

The measure life for a livestock waterer is 10 years. 468

468 California Public Utility Commission. Database for Energy Efficiency Resources 2005.



## 4.7 Variable Speed Drive (VSD) Controller on Dairy Vacuum Pumps

<b>Measure Name</b>	<b>VSD Controller on Dairy Pumps Vacuum Pumps</b>
<b>Target Sector</b>	Agriculture (includes Small Commercial, Residential)
<b>Measure Unit</b>	Per dairy vacuum pump VSD
<b>Unit Energy Savings</b>	Varies
<b>Unit Peak Demand Reduction</b>	Varies
<b>Measure Life</b>	15

The following protocol for the calculation of energy and demand savings applies to the installation of a variable speed drive (VSD) and controls on a dairy vacuum pump. The vacuum pump operates during the milk harvest and equipment washing and can consume 20 percent to 25 percent of all electrical energy use on a dairy farm. The vacuum pump creates negative air pressure that draws milk from the cow and assists in the milk flow from the milk receiver to either the bulk tank or the receiver bowl.

Dairy vacuum pumps are more efficient with VSDs since it enables the motor to speed up or slow down depending on the pressure demand. The energy savings for this measure is based on pump capacity and hours of use of the pump.

### 4.7.1 Eligibility

This measure requires the installation of a VSD and controls on dairy vacuum pumps, or the purchase of dairy vacuum pumps with variable speed capability. Pre-existing pumps with VSD's are not eligible for this measure.

### 4.7.2 Algorithms

The annual energy savings are obtained through the following formula:

$$\Delta kWh / yr = HP \times LF \times \eta_{MOTOR} \times ESF \times DHRS \times ADAYS$$

$$\Delta kW_{peak} = \Delta kWh \times CF$$

### Coincidence Factor

An average of pre and post kW vacuum pump power meter data from five dairy farms in the Pacific Northwest 469 are used to create the vacuum pump demand load profile in [Figure 6](#) [Figure 26](#). Because dairy vacuum pump operation does not vary based on geographical location, the average peak demand reduction obtained from these five sites can be applied to Pennsylvania. There are no seasonal variations in cow milking times, as dairy farms milk cows year round, so the load profile

469 Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. Accessed from RTF website <http://rtf.nwcouncil.org/measures/Default.asp> on February 27, 2013. Pre and post power meter data for five sites were used to establish RTF energy savings for this measure, and raw data used to generate the load profile referenced in this protocol can be found in the zip file on the "BPA Case Studies" tab.

## SECTION 4: Agricultural Measures

### Variable Speed Drive (VSD) Controller on Dairy Vacuum Pumps

Page 453

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below applies to 365 days of operation. The average percent demand reduction for these five sites during the coincident peak demand period of June through September between noon and 8 pm is 46%, which is consistent with the energy savings factors and demand savings estimated for the sources cited in this protocol.

Based on this data, the demand coincidence factor is estimated by dividing the average peak coincident demand kW reduction by  $\Delta$ kWh savings for a 1 horsepower motor. The result is a coincidence factor equal to 0.00014.

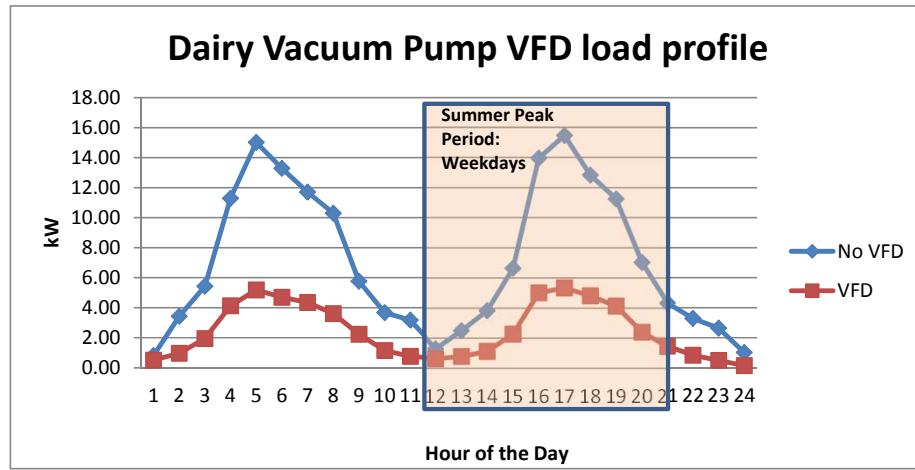


Figure 626: Typical Dairy Vacuum Pump Coincident Peak Demand Reduction

4.7.3 Definition of Terms

- HP = Rated horsepower of the motor
- LF = Load Factor. Ratio between the actual load and the rated load. The default value is 0.90.
- $\eta_{motor}$  = Motor efficiency at the full-rated load. For VFD installations, this can be either an energy efficient motor or standard efficiency motor.
- ESF = Energy Savings Factor. Percent of baseline energy consumption saved by installing VFD.
- DHRS = Daily run hours of the motor
- ADAYS = Annual operating days
- CF = Demand Coincidence factor

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#### 4.7.4 Description of Calculation Method

Table 4-12: Variables for VSD Controller on Dairy Vacuum Pump

Component	Type	Value	Source
Motor HP	Variable	Nameplate	EDC Data Gathering
LF	Variable	Based on spot metering and nameplate	EDC Data Gathering
		Default 90%470	1
Efficiency - $\eta_{\text{motor}}$	Variable	Nameplate	EDC Data Gathering
ESF	Fixed	46%	2, 3
DHRS	Variable	Based on customer application	EDC Data Gathering
		Default 8 hours/day	2, 3
ADAYS	Variable	Based on customer application	EDC Data Gathering
		Default 365 days/year	2, 3
CF	Fixed	0.00014	4

#### Sources:

1. Southern California Edison, Dairy Farm Energy Management Guide: California, p. 11, 2004.
2. California Public Utility Commission. *Database for Energy Efficiency Resources (DEER)* 2005. The DEER database assumes 20 hours of operation per day, but is based on much larger dairy farms (e.g. herd sizes > 300 cows). Therefore, the DEER default value was lowered to 8 hours per day, as the average heard size in 75 cows in Pennsylvania.
3. Regional Technical Forum (RTF) as part of the Northwest Power & Conservation Council, Deemed Measures List. Agricultural: Variable Frequency Drives-Dairy, FY2012, V1.2. Accessed from RTF website <http://rtf.nwcouncil.org/measures/Default.asp> on February 27, 2013.
4. The coincident peak demand factor is calculated by dividing the average peak coincident demand kW reduction by  $\Delta\text{kWh}$  savings for a 1 horsepower, 90% efficient motor. The motor efficiency was determined by averaging the efficiencies of NEMA premium efficiency motors for motor sizes between 1 and 50 horsepower.

#### 4.7.5 Measure Life

The measure life for VSD Controllers is 15 years. 471

470 Default Value can be used by EDC but is subject to metering and adjustment by evaluators or SWE

471 California Public Utility Commission. *Database for Energy Efficiency Resources* 2008.

## 4.8 Low Pressure Irrigation System

<b>Measure Name</b>	<b>Low Pressure Irrigation System</b>
<b>Target Sector</b>	Agriculture and Golf Courses(includes Small Commercial, Residential)
<b>Measure Unit</b>	Per project
<b>Unit Energy Savings</b>	Varies
<b>Unit Peak Demand Reduction</b>	Varies by application
<b>Measure Life</b>	5 years

The following protocol for the measurements of energy and demand savings applies to the installation of a low-pressure irrigation system, thus reducing the amount of energy required to apply the same amount of water.

The amount of energy saved per acre will depend on the actual operating pressure decrease, the pumping plant efficiency, the amount of water applied, and the number of nozzle, sprinkler or micro irrigation system conversions made to the system.

### 4.8.1 Eligibility

This measure requires a minimum of 50% reduction in irrigation pumping pressure is achieved through the installation of a low-pressure irrigation system in agriculture or golf course applications. The pressure reduction can be achieved in several ways, such as nozzle or valve replacement, sprinkler head replacement, or drip irrigation system installation, and is left up to the discretion of the owner. Pre and post retrofit pump pressure measurements are required.

### 4.8.2 Algorithms

The annual energy savings are obtained through the following formula:

*Agriculture applications:*

$$\Delta kWh/yr = \frac{\{ACRES \times (PSI_{base} - PSI_{eff}) \times GPM1\}}{1,714 \frac{gpm \text{ psi}}{HP} \times \eta_{MOTOR}} \times 0.746 \frac{kW}{HP} \times \frac{OPRHS}{\text{Growing Season}}$$

$$\Delta kW_{peak} = \Delta kWh/yr \times CF$$

*Golf Course applications:*

$$\Delta kWh/yr = \frac{\{(PSI_{base} - PSI_{eff}) \times GPM2\}}{1,714 \frac{gpm \text{ psi}}{HP} \times \eta_{MOTOR}} \times 0.746 \frac{kW}{HP} \times DHRHS \times MONTHS \times 30 \frac{\text{Avg. days}}{\text{month}}$$

No peak demand savings may be claimed for golf course applications as watering typically occurs during non-peak demand hours.

### 4.8.3 Definition of Terms

**ACRES** = Number of acres irrigated

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<u><math>PSI_{base}</math></u>	<u>= Baseline pump pressure in pounds per square inch (psi). Baseline pump pressure must be measured and recorded prior to installing low-pressure irrigation equipment.</u>
<u><math>PSI_{eff}</math></u>	<u>= Installed pump pressure in psi. Installed pump pressure must be measured and recorded after the installation of low-pressure irrigation equipment by the installer.</u>
<u>GPM1</u>	<u>= Pump flow rate in gallons per minute (gpm) per acre for agriculture applications.</u>
<u>GPM2</u>	<u>= Pump flow rate in gallons per minute (gpm) for pumping system for golf courses.</u>
<u>OPHRS</u>	<u>= Average irrigation hours per growing season for agriculture</u>
<u>DHRS</u>	<u>= Hours of watering per day for golf courses</u>
<u>MONTHS</u>	<u>= Number of months of irrigation for golf courses</u>
<u><math>\eta_{MOTOR}</math></u>	<u>= Pump motor efficiency (%)</u>
<u>CF</u>	<u>= Demand coincidence factor for agriculture</u>

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#### 4.8.4 Description of Calculation Method

Table 4-13: Variables for Low Pressure Irrigation Systems

Component	Type	Value	Source
ACRES	Variable	Based on customer application	EDC Data Gathering, 1
PSI <sub>base</sub>	Variable	Based on pre retrofit pressure measurements taken by the installer	EDC Data Gathering, 1
PSI <sub>eff</sub>	Variable	Based on post retrofit pressure measurements taken by the installer	EDC Data Gathering, 1
GPM1	Variable	Based on pre retrofit flow measurements taken by the installer	EDC Data Gathering, 1
GPM2	Variable	Based on pre retrofit flow measurements taken by the installer	EDC Data Gathering, 1
DHRS	Variable	Based on customer application	EDC Data Gathering
MONTHS	Variable	Based on customer application	EDC Data Gathering
η <sub>MOTOR</sub>	Variable	Based on customer application	EDC Data Gathering
	Default	Look up pump motor efficiency based on the pump nameplate horsepower (hp) from customer application and nominal efficiencies defined in Table 3-14.	2
CF	Fixed	0.0026	3, 4

#### Sources:

1. Based on Alliant Energy program evaluation assumptions for low-flow pressure irrigation systems. Evaluation of Alliant Energy Agriculture Program, Appendix F, 2008.
2. Table 3-14 contains motor efficiency values from NEMA EPACT efficiency motor standards by motor size and type. If existing motor nameplate data is not available, these tables will be used to establish motor efficiencies.
3. The coincidence factor was only estimated for agricultural applications, and was determined by using the following formula:  $CF = \frac{\Delta kW \text{ savings per acre}}{\Delta kWh/yr \text{ savings per acre}}$ . Pennsylvania census data was used to estimate an average  $\Delta kW$  savings/acre and  $\Delta kWh/yr$  savings/acre values.
4. Pennsylvania Census data:  
[http://www.nass.usda.gov/Statistics\\_by\\_State/Pennsylvania/Publications/Annual\\_Statistical\\_Bulletin/2009\\_2010/fris.pdf](http://www.nass.usda.gov/Statistics_by_State/Pennsylvania/Publications/Annual_Statistical_Bulletin/2009_2010/fris.pdf)  
<http://pubs.usgs.gov/circ/2004/circ1268/htdocs/table07.html>

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**4.8.5 Measure Life**

The measure life for low pressure irrigation systems is 5 years. 472

472 California Public Utility Commission. Database for Energy Efficiency Resources 2008.

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## 5 APPENDICES

### 5.1 Appendix A: Measure Lives

#### Measure Lives Used in Cost-Effectiveness Screening

August 2013

\*For the purpose of calculating the total Resource Cost Test for Act 129, measure cannot claim savings for more than fifteen years.

<u>Measure</u>	<u>Measure Life</u>
<b>RESIDENTIAL SECTOR</b>	
<b><u>Lighting End-Use</u></b>	
<u>Electroluminescent Nightlight</u>	<u>8</u>
<u>LED Nightlight</u>	<u>8</u>
<u>Compact Fluorescent Light Bulb</u>	<u>6.8</u>
<u>Recessed Can Fluorescent Fixture</u>	<u>20*</u>
<u>Torchieres</u>	<u>10</u>
<u>Fixtures Other</u>	<u>20*</u>
<u>ENERGY STAR LEDs</u>	<u>14.7</u>
<u>Residential Occupancy Sensors</u>	<u>10</u>
<u>Holiday Lights</u>	<u>10</u>
<b><u>HVAC End-Use</u></b>	
<u>Central Air Conditioner (CAC)</u>	<u>14</u>
<u>Air Source Heat Pump</u>	<u>12</u>
<u>Central Air Conditioner proper sizing/install</u>	<u>14</u>
<u>Central Air Conditioner Quality Installation Verification</u>	<u>14</u>
<u>Central Air Conditioner Maintenance</u>	<u>7</u>
<u>Central Air Conditioner duct sealing</u>	<u>14</u>
<u>Air Source Heat Pump proper sizing/install</u>	<u>12</u>
<u>ENERGY STAR Thermostat (Central Air Conditioner)</u>	<u>15</u>
<u>ENERGY STAR Thermostat (Heat Pump)</u>	<u>15</u>
<u>Ground Source Heat Pump</u>	<u>30*</u>
<u>Room Air Conditioner Retirement</u>	<u>4</u>
<u>Furnace Whistle</u>	<u>15</u>
<u>Programmable Thermostat</u>	<u>11</u>
<u>Room AC (RAC) Retirement</u>	<u>4</u>
<u>Residential Whole House Fans</u>	<u>15</u>
<u>Ductless Mini-Split Heat Pumps</u>	<u>15</u>
<u>Fuel Switching: Electric Heat to Gas Heat</u>	<u>20*</u>
<u>Efficient Ventilation Fans with Timer</u>	<u>10</u>
<u>New Construction (NC): Single Family - gas heat with CAC</u>	<u>20*</u>
<u>NC: Single Family - oil heat with CAC</u>	<u>20*</u>

**SECTION 5:** Appendices

Appendix A: Measure Lives

Page 460

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<u>NC: Single Family - all electric</u>	<u>20*</u>
<u>NC: Multiple Single Family (Townhouse) – oil heat with CAC</u>	<u>20*</u>
<u>NC: Multiple Single Family (Townhouse) - all electric</u>	<u>20*</u>
<u>NC: Multi-Family – gas heat with CAC</u>	<u>20*</u>
<u>NC: Multi-Family - oil heat with CAC</u>	<u>20*</u>
<u>NC: Multi-Family - all electric</u>	<u>20*</u>
<b><u>Hot Water End-Use</u></b>	
<u>Efficient Electric Water Heaters</u>	<u>14</u>
<u>Heat Pump Water Heaters</u>	<u>14</u>
<u>Low Flow Faucet Aerators</u>	<u>12</u>
<u>Low Flow Showerheads</u>	<u>9</u>
<u>Solar Water Heaters</u>	<u>15</u>
<u>Electric Water Heater Pipe Insulation</u>	<u>13</u>
<u>Fuel Switching: Domestic Hot Water Electric to Gas or Propane Water Heater</u>	<u>13</u>
<u>Fuel Switching: Domestic Hot Water Electric to Oil Water Heater</u>	<u>8</u>
<u>Fuel Switching: Heat Pump Water Heater to Gas or Propane Water Heater</u>	<u>13</u>
<u>Fuel Switching: Heat Pump Water Heater to Oil Water Heater</u>	<u>8</u>
<u>Water Heater Tank Wrap</u>	<u>7</u>
<b><u>Appliances End-Use</u></b>	
<u>Electric Clothes Dryer with Moisture Sensor</u>	<u>11</u>
<u>Refrigerator / Freezer Recycling without replacement</u>	<u>8</u>
<u>Refrigerator / Freezer Recycling with replacement</u>	<u>7</u>
<u>ENERGY STAR Refrigerators</u>	<u>12</u>
<u>ENERGY STAR Freezers</u>	<u>12</u>
<u>ENERGY STAR Clothes Washers</u>	<u>11</u>
<u>ENERGY STAR Dishwashers</u>	<u>11</u>
<u>ENERGY STAR Dehumidifiers</u>	<u>12</u>
<u>ENERGY STAR Room Air Conditioners</u>	<u>9</u>
<u>ENERGY STAR Televisions</u>	<u>15</u>
<u>ENERGY STAR Water Coolers</u>	<u>10</u>
<b><u>Office Equipment / Electronics End-Use</u></b>	
<u>Smart Strip Plug Outlets</u>	<u>5</u>
<u>ENERGY STAR Computer</u>	<u>4</u>
<u>ENERGY STAR Monitor</u>	<u>5</u>
<u>ENERGY STAR Fax</u>	<u>4</u>
<u>ENERGY STAR Multifunction Device</u>	<u>6</u>
<u>ENERGY STAR Printer</u>	<u>5</u>

**SECTION 5: Appendices**

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<u>ENERGY STAR Copier</u>	<u>6</u>
<b><u>Building Shell End-Use</u></b>	
<u>Ceiling / Attic and Wall Insulation</u>	<u>25*</u>
<u>Window -heat pump</u>	<u>20*</u>
<u>Window -gas heat with central air conditioning</u>	<u>20*</u>
<u>Window – electric heat without central air conditioning</u>	<u>20*</u>
<u>Window – electric heat with central air conditioning</u>	<u>20*</u>
<b><u>Agricultural End-Use</u></b>	
<u>Automatic Milker Takeoffs</u>	<u>10</u>
<u>Dairy Scroll Compressors</u>	<u>15</u>
<u>High Efficiency Ventilation Fans with or without Thermostats</u>	<u>10</u>
<u>Heat Reclaimers</u>	<u>15</u>
<u>High Volume Low Speed Fans</u>	<u>15</u>
<u>Livestock Waterer</u>	<u>10</u>
<u>Variable Speed Drive (VSD) Controller on Dairy Vacuum Pumps</u>	<u>15</u>
<u>Low Pressure Irrigation System</u>	<u>5</u>
<b><u>Miscellaneous</u></b>	
<u>Home Audit Conservation Kits</u>	<u>8.1</u>
<u>Home Performance with ENERGY STAR</u>	<u>5</u>
<u>Pool Pump Load Shifting</u>	<u>1</u>
<u>High Efficiency Two-Speed Pool Pump</u>	<u>10</u>
<u>Variable Speed Pool Pumps (with Load Shifting Option)</u>	<u>10</u>
<b>COMMERCIAL &amp; INDUSTRIAL SECTOR</b>	
<b><u>Lighting End-Use</u></b>	
<u>Lighting (Non-SSL) — New/Remodel/Replacement</u>	<u>15</u>
<u>Lighting (SSL – 25,000 hours) — New/Remodel/Replacement</u>	<u>6</u>
<u>Lighting (SSL – 30,000 hours) — New/Remodel/Replacement</u>	<u>7</u>
<u>Lighting (SSL – 35,000 hours) — New/Remodel/Replacement</u>	<u>8</u>
<u>Lighting (SSL – 40,000 hours) — New/Remodel/Replacement</u>	<u>10</u>
<u>Lighting (SSL – 45,000 hours) — New/Remodel/Replacement</u>	<u>11</u>
<u>Lighting (SSL – 50,000 hours) — New/Remodel/Replacement</u>	<u>12</u>
<u>Lighting (SSL – 55,000 hours) — New/Remodel/Replacement</u>	<u>13</u>
<u>Lighting (SSL – 60,000 hours) — New/Remodel/Replacement</u>	<u>14</u>
<u>Lighting (SSL – ≥60,000 hours) — New/Remodel/Replacement</u>	<u>15*</u>
<u>LED Channel Signage</u>	<u>15</u>
<b><u>Motors &amp; VFDs End-Use</u></b>	

**SECTION 5: Appendices**

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Premium Efficiency Motors — New or Replacement	20*
Variable Frequency Drive (VFD) Improvements — New / Retrofit	15
Variable Frequency Drive (VFD) Improvement for Industrial Air Compressors	20*
<b>HVAC End-Use</b>	
HVAC Systems — New or Replacement	15
Electric Chillers — New or Replacement	20*
Water Source and Geothermal Heat Pumps	15
Ductless Mini-Split Heat Pumps - Commercial < 5.4 tons	15
Commercial Chiller Optimization	18*
Fuel Switching: Electric Heat to Gas Heat	20*
Small C/I HVAC Refrigerant Charge Correction	10
<b>Hot Water End-Use</b>	
Electric Resistance Water Heaters	15
Heat Pump Water Heaters	10
Low Flow Pre-Rinse Sprayers for Retrofit Programs	5
Low Flow Pre-Rinse Sprayers for Time of Sale / Retail Programs	5
Fuel Switching: Domestic Hot Water Electric to Gas or Propane Water Heater	13
Fuel Switching: Domestic Hot Water Electric to Oil Water Heater	8
Fuel Switching: Heat Pump Water Heater to Gas or Propane Water Heater	13
Fuel Switching: Heat Pump Water Heater to Oil Water Heater	8
<b>Refrigeration End-Use</b>	
Anti-Sweat Heater Controls	12
High-Efficiency Refrigeration/Freezer Cases	12
High-Efficiency Evaporator Fan Motors for Reach-In Refrigerated Cases	15
High-Efficiency Evaporator Fan Motors for Walk-In Refrigerated Cases	15
Strip Curtains for Walk-In Freezers and Coolers	4
Refrigeration - Night Covers for Display Cases	5
Refrigeration - Auto Closers	8
Refrigeration - Door Gaskets for Walk-in Coolers and Freezers	4
Refrigeration - Suction Pipes Insulation	11
Refrigeration - Evaporator Fan Controllers	10
Refrigeration - Special Doors with Low or No Anti-Sweat Heat for Low Temp Case	15
Refrigeration - Floating Head Pressure Controls	15
Refrigeration - VFD Compressor	10

**SECTION 5: Appendices**

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<b><u>Office Equipment / Electronics End-Use</u></b>	
<u>ENERGY STAR Computer</u>	<u>4</u>
<u>ENERGY STAR Monitor</u>	<u>4</u>
<u>ENERGY STAR Fax</u>	<u>4</u>
<u>ENERGY STAR Multifunction Device</u>	<u>6</u>
<u>ENERGY STAR Printer</u>	<u>5</u>
<u>ENERGY STAR Copier</u>	<u>6</u>
<u>Office Equipment - Network Power Management Enabling</u>	<u>5</u>
<u>Smart Strip Plug Outlets</u>	<u>5</u>
<b><u>Food Service Equipment End-Use</u></b>	
<u>Beverage Machine Controls</u>	<u>5</u>
<u>High-Efficiency Ice Machines</u>	<u>10</u>
<u>ENERGY STAR Electric Steam Cooker</u>	<u>12</u>
<b><u>Appliances End-Use</u></b>	
<u>ENERGY STAR Clothes Washer Multifamily</u>	<u>11.3</u>
<u>ENERGY STAR Clothes Washer Laundromats</u>	<u>7.1</u>
<b><u>Building Shell End-Use</u></b>	
<u>Wall and Ceiling Insulation</u>	<u>15</u>
<b><u>Agricultural End-Use</u></b>	
<u>Automatic Milker Takeoffs</u>	<u>10</u>
<u>Dairy Scroll Compressors</u>	<u>15</u>
<u>High Efficiency Ventilation Fans with or without Thermostats</u>	<u>10</u>
<u>Heat Reclaimers</u>	<u>15</u>
<u>High Volume Low Speed Fans</u>	<u>15</u>
<u>Livestock Waterer</u>	<u>10</u>
<u>Variable Speed Drive (VSD) Controller on Dairy Vacuum Pumps</u>	<u>15</u>
<u>Low Pressure Irrigation System</u>	<u>5</u>
<b><u>Miscellaneous</u></b>	
<u>Commercial Custom — New/Replacement</u>	<u>18*</u>
<u>Commercial Comprehensive New Construction Design</u>	<u>18*</u>
<u>Industrial Custom — Non-Process</u>	<u>18*</u>
<u>Industrial Custom — Process</u>	<u>10</u>

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## 5.2 Appendix B: Relationship between Program Savings and Evaluation Savings

There is a distinction between activities required to conduct measurement and verification of savings at the program participant level and the activities conducted by program evaluators and the SWE to validate those savings. However, the underlying standard for the measurement of the savings for both of these activities is the measurement and verification protocols approved by the PA PUC. These protocols are of ~~three~~two different types:

1. TRM specified protocols for standard measures, originally approved in the May 2009 order adopting the TRM, and updated annually thereafter
2. Interim Protocols for standard measures, reviewed and recommended by the SWE and approved for use by the Director of the CEEP, subject to modification and incorporation into succeeding TRM versions to be approved by the PA PUC
- ~~3. There could occasionally be a need for EDCs to draft Custom Measure Protocols for measures that are not covered by TRM specified protocols or Interim protocols for standard measures.~~

These protocols are to be uniform and used to measure and calculate savings throughout Pennsylvania. The TRM protocols are comprised of Deemed Measures and Partially Deemed Measures. Deemed Measures specify saving per energy efficiency measure and require verifying that the measure has been installed, or in cases where that is not feasible, that the measure has been purchased by a utility customer. Partially Deemed Measures require both verification of installation and the measurement or quantification of open variables in the protocol.

Stipulated and deemed numbers are valid relative to a particular classification of “standard” measures. In the determination of these values, a normal distribution of values should have been incorporated. Therefore, during the measurement and verification process, participant savings measures cannot be arbitrarily treated as “custom measures” if the category allocation is appropriate.

Custom measures are outside the scope of the TRM. The EDCs are not required to submit savings protocols for custom measures to the Commission or the SWE for each measure/technology type prior to implementing the custom measure. The Commission recommends that these protocols be established in general conformity to the IPMVP or Federal Energy Management Program M&V Guidelines. The SWE reserves the right to audit and review claimed and verified impacts of all custom measures as part of its role to perform EM&V services for the Commission.

Utility evaluators and the SWE will adjust the savings reported by program staff based on the application of the PA PUC approved protocols to a sample population and realization rates will be based on the application of these same standards. To the extent that the protocols or deemed values included in these protocols require modification, the appropriate statewide approval process will be utilized. These changes will be prospective.

### 5.3 Appendix C: Lighting Audit and Design Tool

The Lighting Audit and Design Tool is located on the Public Utility Commission's website at: [http://www.puc.state.pa.us/filing\\_resources/issues\\_laws\\_regulations/act\\_129\\_information/technical\\_reference\\_manual.aspx](http://www.puc.state.pa.us/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx).

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#### 5.4 Appendix D: Motor & VFD Audit and Design Tool

The Motor and VFD Inventory Form is located on the Public Utility Commission's website at: [http://www.puc.state.pa.us/filing\\_resources/issues\\_laws\\_regulations/act\\_129\\_information/technical\\_reference\\_manual.aspx](http://www.puc.state.pa.us/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx).

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## 5.5 Appendix E: Lighting Audit and Design Tool for New Construction Projects

The Lighting Audit and Design Tool is located on the Public Utility Commission's website at: [http://www.puc.state.pa.us/filing\\_resources/issues\\_laws\\_regulations/act\\_129\\_information/technical\\_reference\\_manual.aspx](http://www.puc.state.pa.us/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx).

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## 5.6 Appendix F: Eligibility Requirements for Solid State Lighting Products in Commercial and Industrial Applications

The SSL market, still setting up its foundations, has been inundated with a great variety of products, including those that do not live up to manufacturers' claims. Several organizations, such as ENERGY STAR and Design Lights Consortium have responded by following standardized testing procedures and setting minimum requirements to be identified as a qualified product under those organizations.

### 5.6.1 Solid State Lighting

Due to the immaturity of the SSL market, diversity of product technologies and quality, and current lack of uniform industry standards, it is impossible to point to one source as the complete list of qualifying SSL products for inclusion in Act 129 efficiency programs. A combination of industry-accepted references have been collected to generate minimum criteria for the most complete list of products while not sacrificing quality and legitimacy of savings. The following states the minimum requirements for SSL products that qualify under the TRM:

For Act 129 energy efficiency measure savings qualification, for SSL products for which there is an ENERGY STAR commercial product category<sup>473</sup>, the product shall meet the minimum ENERGY STAR requirements<sup>474 475</sup> for the given product category. Products are not required to be on the ENERGY STAR Qualified Product List<sup>476</sup>, however, if a product is on the list it shall qualify for Act 129 energy efficiency programs and no additional supporting documentation shall be required. ENERGY STAR qualified commercial/non-residential product categories include:

- Omni-directional: A, BT, P, PS, S, T
- Decorative: B, BA, C, CA, DC, F, G
- Directional: BR, ER, K, MR, PAR, R
- Non-standard
- Recessed, surface and pendant-mounted down-lights
- Under-cabinet shelf-mounted task lighting
- Portable desk task lights
- Wall wash luminaires
- Bollards

473 ENERGY STAR website for Commercial LED Lighting:

[http://www.energystar.gov/index.cfm?fuseaction=find\\_a\\_product.showProductGroup&pgw\\_code=LTG](http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=LTG)

474 "ENERGY STAR® Program Requirements for Integral LED Lamps

Partner Commitments." *LED Lamp Specification V1.1*, modified 03/22/10. Accessed from the ENERGY STAR website on September 28, 2010. [http://www.energystar.gov/ia/partners/manuf\\_res/downloads/IntegrallampsFINAL.pdf](http://www.energystar.gov/ia/partners/manuf_res/downloads/IntegrallampsFINAL.pdf)

475 "ENERGY STAR® Program Requirements for Solid State Lighting Luminaires" *Eligibility Criteria V1.1*, Final 12/19/08. Accessed from the ENERGY STAR website on September 28, 2010.

[http://www.energystar.gov/ia/partners/product\\_specs/program\\_reqs/SSL\\_prog\\_req\\_V1.1.pdf](http://www.energystar.gov/ia/partners/product_specs/program_reqs/SSL_prog_req_V1.1.pdf)

476 ENERGY STAR Qualified LED Lighting list

[http://www.energystar.gov/index.cfm?fuseaction=ssl.display\\_products\\_res\\_html](http://www.energystar.gov/index.cfm?fuseaction=ssl.display_products_res_html)

#### SECTION 5: Appendices

Appendix F: Eligibility Requirements for Solid State Lighting Products in Commercial and Industrial Applications

Page 469

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For SSL products for which there is not an ENERGY STAR commercial product category, but for which there is a DLC commercial product category<sup>477</sup>, the product shall meet the minimum DLC requirements<sup>478</sup> for the given product category. Products are not required to be on the DLC Qualified Product List<sup>479</sup>, however, if a product is on the list it shall qualify for Act 129 energy efficiency programs and no additional supporting documentation shall be required. DLC qualified commercial product categories include:

- Outdoor Pole or Arm mounted Area and Roadway Luminaires
- Outdoor Pole or arm mounted Decorative Luminaires
- Outdoor Wall-Mounted Area Luminaires
- Parking Garage Luminaires
- Track or Mono-point Directional Lighting Fixtures
- Refrigerated Case Lighting
- Display Case Lighting
- 2x2 Luminaires
- High-bay and Low-bay fixtures for Commercial and Industrial buildings

For SSL products that are not on either of the listed qualified products lists, they can still be considered for inclusion in Act 129 energy efficiency programs by submitting the following documentation to show compliance with the minimum product category criteria as described above:

- Manufacturer's product information sheet
- LED package/fixture specification sheet
- List the ENERGY STAR or DLC product category for which the luminaire qualifies
- Summary table listing the minimum reference criteria and the corresponding product values for the following variables:
  - Light output in lumens
  - Luminaire efficacy (lm/W)
  - Color rendering index (CRI)

477 DesignLights Consortium (DLC) Technical Requirements Table v1.4. Accessed from the DLC website on September 24, 2010. <http://www.designlights.org/solidstate.manufacturer.requirements.php>

478 Ibid.

479 DesignLights Consortium (DLC) Qualified Product List.

[http://www.designlights.org/solidstate.about.QualifiedProductsList\\_Publicv2.php](http://www.designlights.org/solidstate.about.QualifiedProductsList_Publicv2.php)

"This Qualified Products List (QPL) of LED luminaires signifies that the proper documentation has been submitted to DesignLights (DLC) and the luminaire has met the criteria noted in the technical requirements table shown on the DesignLights website ([www.designlights.org](http://www.designlights.org)). This list is exclusively used and owned by DesignLights Members. Manufacturers, vendors and other non DesignLights members may use the QPL as displayed herein subject to the DLC Terms of Use, and are prohibited from tampering with any portion or all of its contents. For information on becoming a member please go to [DesignLights.org](http://DesignLights.org)."

## SECTION 5: Appendices

### Appendix F: Eligibility Requirements for Solid State Lighting Products in Commercial and Industrial Applications

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- Correlated color temperature (CCT)
- LED lumen maintenance at 6000 hrs
- Manufacturer's estimated lifetime for L<sub>70</sub> (70% lumen maintenance at end of useful life) (manufacturer should provide methodology for calculation and justification of product lifetime estimates)
- Operating frequency of the lamp
- IESNA LM-79-08 test report(s) (from approved labs specified in DOE Manufacturers' Guide) containing:
  - Photometric measurements (i.e. light output and efficacy)
  - Colorimetry report (i.e. CCT and CRI)
  - Electrical measurements (i.e. input voltage and current, power, power factor, etc.)
- Lumen maintenance report (select one of the two options and submit all of its corresponding required documents):
  - Option 1: Compliance through component performance (for the corresponding LED package)
    - IESNA LM-80 test report
    - In-situ temperature measurements test (ISTMT) report.
    - Schematic/photograph from LED package manufacturer that shows the specified temperature measurement point (TMP)
  - Option 2: Compliance through luminaire performance
    - IESNA LM-79-08 report at 0 hours (same file as point c)
    - IESNA LM-79-08 report at 6000 hours after continuous operation in the appropriate ANSI/UL 1598 environment (use ANSI/UL 1574 for track lighting systems).

All supporting documentation must include a specific, relevant model or part number.

## 5.7 Appendix G: Zip Code Mapping

Per Section ~~1.174-1617~~, the following table is to be used to determine the appropriate reference city for each Pennsylvania zip code.

Zip	Reference City	Zip	Reference City	Zip	Reference City
15001	Pittsburgh	15054	Pittsburgh	15116	Pittsburgh
15003	Pittsburgh	15055	Pittsburgh	15120	Pittsburgh
15004	Pittsburgh	15056	Pittsburgh	15122	Pittsburgh
15005	Pittsburgh	15057	Pittsburgh	15123	Pittsburgh
15006	Pittsburgh	15059	Pittsburgh	15126	Pittsburgh
15007	Pittsburgh	15060	Pittsburgh	15127	Pittsburgh
15009	Pittsburgh	15061	Pittsburgh	15129	Pittsburgh
15010	Pittsburgh	15062	Pittsburgh	15130	Pittsburgh
15012	Pittsburgh	15063	Pittsburgh	15131	Pittsburgh
15014	Pittsburgh	15064	Pittsburgh	15132	Pittsburgh
15015	Pittsburgh	15065	Pittsburgh	15133	Pittsburgh
15017	Pittsburgh	15066	Pittsburgh	15134	Pittsburgh
15018	Pittsburgh	15067	Pittsburgh	15135	Pittsburgh
15019	Pittsburgh	15068	Pittsburgh	15136	Pittsburgh
15020	Pittsburgh	15069	Pittsburgh	15137	Pittsburgh
15021	Pittsburgh	15071	Pittsburgh	15139	Pittsburgh
15022	Pittsburgh	15072	Pittsburgh	15140	Pittsburgh
15024	Pittsburgh	15074	Pittsburgh	15142	Pittsburgh
15025	Pittsburgh	15075	Pittsburgh	15143	Pittsburgh
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15027	Pittsburgh	15077	Pittsburgh	15145	Pittsburgh
15028	Pittsburgh	15078	Pittsburgh	15146	Pittsburgh
15030	Pittsburgh	15081	Pittsburgh	15147	Pittsburgh
15031	Pittsburgh	15082	Pittsburgh	15148	Pittsburgh
15032	Pittsburgh	15083	Pittsburgh	15189	Pittsburgh
15033	Pittsburgh	15084	Pittsburgh	15201	Pittsburgh
15034	Pittsburgh	15085	Pittsburgh	15202	Pittsburgh
15035	Pittsburgh	15086	Pittsburgh	15203	Pittsburgh
15036	Pittsburgh	15087	Pittsburgh	15204	Pittsburgh
15037	Pittsburgh	15088	Pittsburgh	15205	Pittsburgh
15038	Pittsburgh	15089	Pittsburgh	15206	Pittsburgh
15042	Pittsburgh	15090	Pittsburgh	15207	Pittsburgh
15043	Pittsburgh	15091	Pittsburgh	15208	Pittsburgh
15044	Pittsburgh	15095	Pittsburgh	15209	Pittsburgh
15045	Pittsburgh	15096	Pittsburgh	15210	Pittsburgh
15046	Pittsburgh	15101	Pittsburgh	15211	Pittsburgh
15047	Pittsburgh	15102	Pittsburgh	15212	Pittsburgh
15049	Pittsburgh	15104	Pittsburgh	15213	Pittsburgh
15050	Pittsburgh	15106	Pittsburgh	15214	Pittsburgh
15051	Pittsburgh	15108	Pittsburgh	15215	Pittsburgh
15052	Pittsburgh	15110	Pittsburgh	15216	Pittsburgh
15053	Pittsburgh	15112	Pittsburgh	15217	Pittsburgh

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Zip	Reference City
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## SECTION 5: Appendices

## Appendix G: Zip Code Mapping

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## SECTION 5: Appendices

## Appendix G: Zip Code Mapping

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15860	Erie
15861	Williamsport
15863	Pittsburgh
15864	Pittsburgh
15865	Pittsburgh
15866	Pittsburgh
15868	Williamsport
15870	Erie
15901	Pittsburgh
15902	Pittsburgh
15904	Pittsburgh
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15928	Pittsburgh
15929	Pittsburgh
15930	Pittsburgh

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Zip	Reference City
15931	Pittsburgh
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16027	Pittsburgh
16028	Pittsburgh
16029	Pittsburgh
16030	Pittsburgh
16033	Pittsburgh
16034	Pittsburgh
16035	Pittsburgh
16036	Pittsburgh

Zip	Reference City
16037	Pittsburgh
16038	Pittsburgh
16039	Pittsburgh
16040	Pittsburgh
16041	Pittsburgh
16045	Pittsburgh
16046	Pittsburgh
16048	Pittsburgh
16049	Pittsburgh
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16101	Pittsburgh
16102	Pittsburgh
16103	Pittsburgh
16105	Pittsburgh
16107	Pittsburgh
16108	Pittsburgh
16110	Erie
16111	Erie
16112	Pittsburgh
16113	Erie
16114	Erie
16115	Pittsburgh
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16120	Pittsburgh
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16123	Pittsburgh
16124	Erie
16125	Erie
16127	Pittsburgh
16130	Erie
16131	Erie
16132	Pittsburgh
16133	Pittsburgh
16134	Erie

Zip	Reference City
16136	Pittsburgh
16137	Pittsburgh
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16141	Pittsburgh
16142	Pittsburgh
16143	Pittsburgh
16145	Erie
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16150	Pittsburgh
16151	Erie
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16159	Pittsburgh
16160	Pittsburgh
16161	Pittsburgh
16172	Pittsburgh
16201	Pittsburgh
16210	Pittsburgh
16211	Pittsburgh
16212	Pittsburgh
16213	Pittsburgh
16214	Pittsburgh
16215	Pittsburgh
16217	Erie
16218	Pittsburgh
16220	Erie
16221	Pittsburgh
16222	Pittsburgh
16223	Pittsburgh
16224	Pittsburgh
16225	Pittsburgh
16226	Pittsburgh
16228	Pittsburgh
16229	Pittsburgh
16230	Pittsburgh
16232	Pittsburgh
16233	Erie
16234	Pittsburgh
16235	Erie
16236	Pittsburgh
16238	Pittsburgh
16239	Erie
16240	Pittsburgh

## SECTION 5: Appendices

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Zip	Reference City
16242	Pittsburgh
16244	Pittsburgh
16245	Pittsburgh
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16249	Pittsburgh
16250	Pittsburgh
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16254	Pittsburgh
16255	Pittsburgh
16256	Pittsburgh
16257	Erie
16258	Pittsburgh
16259	Pittsburgh
16260	Erie
16261	Pittsburgh
16262	Pittsburgh
16263	Pittsburgh
16301	Erie
16311	Erie
16312	Erie
16313	Erie
16314	Erie
16316	Erie
16317	Erie
16319	Erie
16321	Erie
16322	Erie
16323	Erie
16326	Erie
16327	Erie
16328	Erie
16329	Erie
16331	Pittsburgh
16332	Erie
16333	Erie
16334	Erie
16335	Erie
16340	Erie
16341	Erie
16342	Erie
16343	Erie
16344	Erie
16345	Erie
16346	Erie
16347	Erie
16350	Erie

Zip	Reference City
16351	Erie
16352	Erie
16353	Erie
16354	Erie
16360	Erie
16361	Erie
16362	Erie
16364	Erie
16365	Erie
16366	Erie
16367	Erie
16368	Erie
16369	Erie
16370	Erie
16371	Erie
16372	Pittsburgh
16373	Pittsburgh
16374	Pittsburgh
16375	Pittsburgh
16388	Erie
16401	Erie
16402	Erie
16403	Erie
16404	Erie
16405	Erie
16406	Erie
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16410	Erie
16411	Erie
16412	Erie
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16423	Erie
16424	Erie
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16428	Erie
16430	Erie
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16433	Erie
16434	Erie
16435	Erie

Zip	Reference City
16436	Erie
16438	Erie
16440	Erie
16441	Erie
16442	Erie
16443	Erie
16444	Erie
16475	Erie
16501	Erie
16502	Erie
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16534	Erie
16538	Erie
16541	Erie
16544	Erie
16546	Erie
16550	Erie
16553	Erie
16554	Erie
16563	Erie
16565	Erie
16601	Pittsburgh
16602	Pittsburgh
16603	Pittsburgh
16611	Harrisburg
16613	Pittsburgh
16616	Pittsburgh
16617	Williamsport
16619	Pittsburgh
16620	Williamsport
16621	Harrisburg

## SECTION 5: Appendices

## Appendix G: Zip Code Mapping

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Zip	Reference City
16622	Harrisburg
16623	Harrisburg
16624	Pittsburgh
16625	Pittsburgh
16627	Pittsburgh
16629	Pittsburgh
16630	Pittsburgh
16631	Harrisburg
16633	Harrisburg
16634	Harrisburg
16635	Pittsburgh
16636	Pittsburgh
16637	Pittsburgh
16638	Harrisburg
16639	Pittsburgh
16640	Pittsburgh
16641	Pittsburgh
16644	Pittsburgh
16645	Pittsburgh
16646	Pittsburgh
16647	Harrisburg
16648	Pittsburgh
16650	Harrisburg
16651	Williamsport
16652	Harrisburg
16654	Harrisburg
16655	Pittsburgh
16656	Pittsburgh
16657	Harrisburg
16659	Harrisburg
16660	Harrisburg
16661	Williamsport
16662	Harrisburg
16663	Williamsport
16664	Pittsburgh
16665	Pittsburgh
16666	Williamsport
16667	Pittsburgh
16668	Pittsburgh
16669	Harrisburg
16670	Pittsburgh
16671	Williamsport
16672	Harrisburg
16673	Pittsburgh
16674	Harrisburg
16675	Pittsburgh
16677	Williamsport

Zip	Reference City
16678	Harrisburg
16679	Harrisburg
16680	Williamsport
16681	Williamsport
16682	Pittsburgh
16683	Williamsport
16684	Williamsport
16685	Harrisburg
16686	Williamsport
16689	Harrisburg
16691	Harrisburg
16692	Pittsburgh
16693	Harrisburg
16694	Harrisburg
16695	Harrisburg
16698	Williamsport
16699	Pittsburgh
16701	Erie
16720	Williamsport
16724	Williamsport
16725	Erie
16726	Erie
16727	Erie
16728	Erie
16729	Erie
16730	Williamsport
16731	Williamsport
16732	Erie
16733	Erie
16734	Erie
16735	Erie
16738	Erie
16740	Erie
16743	Williamsport
16744	Erie
16745	Erie
16746	Williamsport
16748	Williamsport
16749	Williamsport
16750	Williamsport
16801	Williamsport
16802	Williamsport
16803	Williamsport
16804	Williamsport
16805	Williamsport
16820	Williamsport
16821	Williamsport

Zip	Reference City
16822	Williamsport
16823	Williamsport
16825	Williamsport
16826	Williamsport
16827	Williamsport
16828	Williamsport
16829	Williamsport
16830	Williamsport
16832	Williamsport
16833	Williamsport
16834	Williamsport
16835	Williamsport
16836	Williamsport
16837	Williamsport
16838	Pittsburgh
16839	Williamsport
16840	Williamsport
16841	Williamsport
16843	Williamsport
16844	Williamsport
16845	Williamsport
16847	Williamsport
16848	Williamsport
16849	Williamsport
16850	Williamsport
16851	Williamsport
16852	Williamsport
16853	Williamsport
16854	Williamsport
16855	Williamsport
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16863	Williamsport
16864	Williamsport
16865	Williamsport
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16871	Williamsport
16872	Williamsport
16873	Williamsport
16874	Williamsport
16875	Williamsport
16876	Williamsport

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Zip	Reference City
16877	Williamsport
16878	Williamsport
16879	Williamsport
16881	Williamsport
16882	Williamsport
16901	Williamsport
16910	Williamsport
16911	Williamsport
16912	Williamsport
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16921	Williamsport
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16941	Williamsport
16942	Williamsport
16943	Williamsport
16945	Williamsport
16946	Williamsport
16947	Williamsport
16948	Williamsport
16950	Williamsport
17001	Harrisburg
17002	Harrisburg
17003	Harrisburg
17004	Harrisburg
17005	Harrisburg
17006	Harrisburg
17007	Harrisburg
17008	Harrisburg

Zip	Reference City
17009	Harrisburg
17010	Harrisburg
17011	Harrisburg
17012	Harrisburg
17013	Harrisburg
17014	Harrisburg
17015	Harrisburg
17016	Harrisburg
17017	Harrisburg
17018	Harrisburg
17019	Philadelphia
17020	Harrisburg
17021	Harrisburg
17022	Harrisburg
17023	Harrisburg
17024	Harrisburg
17025	Harrisburg
17026	Harrisburg
17027	Harrisburg
17028	Harrisburg
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17047	Harrisburg
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17049	Harrisburg
17050	Harrisburg
17051	Harrisburg
17052	Harrisburg
17053	Harrisburg
17054	Harrisburg
17055	Harrisburg
17056	Harrisburg

Zip	Reference City
17057	Harrisburg
17058	Harrisburg
17059	Harrisburg
17060	Harrisburg
17061	Harrisburg
17062	Harrisburg
17063	Williamsport
17064	Harrisburg
17065	Harrisburg
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17067	Harrisburg
17068	Harrisburg
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17070	Harrisburg
17071	Harrisburg
17072	Harrisburg
17073	Harrisburg
17074	Harrisburg
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17076	Harrisburg
17077	Harrisburg
17078	Harrisburg
17080	Harrisburg
17081	Harrisburg
17082	Harrisburg
17083	Harrisburg
17084	Williamsport
17085	Harrisburg
17086	Harrisburg
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17088	Harrisburg
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17093	Harrisburg
17094	Harrisburg
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17099	Harrisburg
17101	Harrisburg
17102	Harrisburg
17103	Harrisburg
17104	Harrisburg
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17106	Harrisburg
17107	Harrisburg
17108	Harrisburg

## SECTION 5: Appendices

## Appendix G: Zip Code Mapping

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Zip	Reference City
17109	Harrisburg
17110	Harrisburg
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17122	Harrisburg
17123	Harrisburg
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17128	Harrisburg
17129	Harrisburg
17130	Harrisburg
17140	Harrisburg
17177	Harrisburg
17201	Harrisburg
17202	Harrisburg
17210	Harrisburg
17211	Harrisburg
17212	Harrisburg
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17237	Harrisburg
17238	Harrisburg
17239	Harrisburg
17240	Harrisburg
17241	Harrisburg
17243	Harrisburg

Zip	Reference City
17244	Harrisburg
17246	Harrisburg
17247	Harrisburg
17249	Harrisburg
17250	Harrisburg
17251	Harrisburg
17252	Harrisburg
17253	Harrisburg
17254	Harrisburg
17255	Harrisburg
17256	Harrisburg
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17266	Harrisburg
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17271	Harrisburg
17272	Harrisburg
17301	Harrisburg
17302	Philadelphia
17303	Harrisburg
17304	Harrisburg
17306	Harrisburg
17307	Harrisburg
17309	Philadelphia
17310	Harrisburg
17311	Philadelphia
17312	Philadelphia
17313	Philadelphia
17314	Philadelphia
17315	Philadelphia
17316	Harrisburg
17317	Philadelphia
17318	Philadelphia
17319	Philadelphia
17320	Harrisburg
17321	Philadelphia
17322	Philadelphia
17323	Philadelphia
17324	Harrisburg
17325	Harrisburg

Zip	Reference City
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17327	Philadelphia
17329	Philadelphia
17331	Philadelphia
17332	Philadelphia
17333	Philadelphia
17334	Philadelphia
17337	Harrisburg
17339	Philadelphia
17340	Harrisburg
17342	Philadelphia
17343	Harrisburg
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17347	Philadelphia
17349	Philadelphia
17350	Harrisburg
17352	Philadelphia
17353	Harrisburg
17354	Philadelphia
17355	Philadelphia
17356	Philadelphia
17358	Philadelphia
17360	Philadelphia
17361	Philadelphia
17362	Philadelphia
17363	Philadelphia
17364	Philadelphia
17365	Philadelphia
17366	Philadelphia
17368	Philadelphia
17370	Philadelphia
17371	Philadelphia
17372	Harrisburg
17375	Harrisburg
17401	Philadelphia
17402	Philadelphia
17403	Philadelphia
17404	Philadelphia
17405	Philadelphia
17406	Philadelphia
17407	Philadelphia
17408	Philadelphia
17415	Philadelphia
17501	Harrisburg
17502	Harrisburg
17503	Harrisburg

## SECTION 5: Appendices

## Appendix G: Zip Code Mapping

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Zip	Reference City
17504	Harrisburg
17505	Harrisburg
17506	Harrisburg
17507	Allentown
17508	Harrisburg
17509	Harrisburg
17512	Harrisburg
17516	Harrisburg
17517	Harrisburg
17518	Harrisburg
17519	Allentown
17520	Harrisburg
17521	Harrisburg
17522	Harrisburg
17527	Harrisburg
17528	Allentown
17529	Harrisburg
17532	Harrisburg
17533	Harrisburg
17534	Harrisburg
17535	Harrisburg
17536	Harrisburg
17537	Harrisburg
17538	Harrisburg
17540	Harrisburg
17543	Harrisburg
17545	Harrisburg
17547	Harrisburg
17549	Harrisburg
17550	Harrisburg
17551	Harrisburg
17552	Harrisburg
17554	Harrisburg
17555	Allentown
17557	Harrisburg
17560	Harrisburg
17562	Harrisburg
17563	Harrisburg
17564	Harrisburg
17565	Harrisburg
17566	Harrisburg
17567	Harrisburg
17568	Harrisburg
17569	Harrisburg
17570	Harrisburg
17572	Harrisburg
17573	Harrisburg

Zip	Reference City
17575	Harrisburg
17576	Harrisburg
17577	Harrisburg
17578	Harrisburg
17579	Harrisburg
17580	Harrisburg
17581	Allentown
17582	Harrisburg
17583	Harrisburg
17584	Harrisburg
17585	Harrisburg
17601	Harrisburg
17602	Harrisburg
17603	Harrisburg
17604	Harrisburg
17605	Harrisburg
17606	Harrisburg
17607	Harrisburg
17608	Harrisburg
17611	Harrisburg
17622	Harrisburg
17699	Harrisburg
17701	Williamsport
17702	Williamsport
17703	Williamsport
17705	Williamsport
17720	Williamsport
17721	Williamsport
17722	Williamsport
17723	Williamsport
17724	Williamsport
17726	Williamsport
17727	Williamsport
17728	Williamsport
17729	Williamsport
17730	Williamsport
17731	Williamsport
17735	Williamsport
17737	Williamsport
17738	Williamsport
17739	Williamsport
17740	Williamsport
17742	Williamsport
17744	Williamsport
17745	Williamsport
17747	Williamsport
17748	Williamsport

Zip	Reference City
17749	Williamsport
17750	Williamsport
17751	Williamsport
17752	Williamsport
17754	Williamsport
17756	Williamsport
17758	Williamsport
17759	Williamsport
17760	Williamsport
17762	Williamsport
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17779	Williamsport
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17823	Harrisburg
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17827	Williamsport
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17831	Williamsport
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17836	Harrisburg
17837	Williamsport
17839	Williamsport
17840	Harrisburg

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Zip	Reference City
17841	Williamsport
17842	Williamsport
17843	Williamsport
17844	Williamsport
17845	Williamsport
17846	Williamsport
17847	Williamsport
17850	Williamsport
17851	Harrisburg
17853	Harrisburg
17855	Williamsport
17856	Williamsport
17857	Williamsport
17858	Williamsport
17859	Williamsport
17860	Williamsport
17861	Williamsport
17862	Williamsport
17864	Harrisburg
17865	Williamsport
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17868	Williamsport
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17872	Harrisburg
17876	Williamsport
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17882	Williamsport
17883	Williamsport
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17885	Williamsport
17886	Williamsport
17887	Williamsport
17888	Williamsport
17889	Williamsport
17901	Allentown
17920	Williamsport
17921	Harrisburg
17922	Allentown
17923	Harrisburg
17925	Allentown
17929	Allentown
17930	Allentown
17931	Allentown

Zip	Reference City
17932	Allentown
17933	Allentown
17934	Allentown
17935	Allentown
17936	Harrisburg
17938	Harrisburg
17941	Harrisburg
17942	Allentown
17943	Harrisburg
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17945	Allentown
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17957	Harrisburg
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17964	Harrisburg
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17967	Allentown
17968	Harrisburg
17970	Allentown
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17974	Allentown
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17978	Harrisburg
17979	Allentown
17980	Harrisburg
17981	Harrisburg
17982	Allentown
17983	Harrisburg
17985	Allentown
18001	Allentown
18002	Allentown
18003	Allentown
18010	Allentown
18011	Allentown
18012	Allentown
18013	Allentown
18014	Allentown

Zip	Reference City
18015	Allentown
18016	Allentown
18017	Allentown
18018	Allentown
18020	Allentown
18025	Allentown
18030	Allentown
18031	Allentown
18032	Allentown
18034	Allentown
18035	Allentown
18036	Allentown
18037	Allentown
18038	Allentown
18039	Philadelphia
18040	Allentown
18041	Philadelphia
18042	Allentown
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18045	Allentown
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18049	Allentown
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18065	Allentown
18066	Allentown
18067	Allentown
18068	Allentown
18069	Allentown
18070	Philadelphia
18071	Allentown
18072	Allentown
18073	Philadelphia
18074	Philadelphia
18076	Philadelphia

## SECTION 5: Appendices

## Appendix G: Zip Code Mapping

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Zip	Reference City
18077	Philadelphia
18078	Allentown
18079	Allentown
18080	Allentown
18081	Philadelphia
18083	Allentown
18084	Philadelphia
18085	Allentown
18086	Allentown
18087	Allentown
18088	Allentown
18091	Allentown
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Zip	Reference City
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Zip	Reference City
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18445	Scranton
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18451	Scranton

## SECTION 5: Appendices

## Appendix G: Zip Code Mapping

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18472	Scranton
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18522	Scranton
18540	Scranton
18577	Scranton
18601	Scranton
18602	Scranton
18603	Scranton
18610	Scranton
18611	Williamsport
18612	Scranton
18614	Williamsport
18615	Scranton
18616	Williamsport

Zip	Reference City
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Zip	Reference City
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18842	Scranton
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18847	Scranton
18848	Williamsport
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18851	Scranton
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18854	Scranton
18901	Philadelphia
18902	Philadelphia
18910	Philadelphia

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Zip	Reference City
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Zip	Reference City
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Zip	Reference City
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19401	Philadelphia

## SECTION 5: Appendices

## Appendix G: Zip Code Mapping

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Zip	Reference City
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19462	Philadelphia
19464	Philadelphia
19465	Philadelphia
19468	Philadelphia
19470	Philadelphia

Zip	Reference City
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19496	Philadelphia
19501	Allentown
19503	Allentown
19504	Allentown
19505	Allentown
19506	Allentown
19507	Harrisburg
19508	Allentown
19510	Allentown
19511	Allentown
19512	Allentown
19516	Allentown
19518	Allentown
19519	Allentown
19520	Philadelphia
19522	Allentown
19523	Allentown
19525	Philadelphia
19526	Allentown
19529	Allentown
19530	Allentown

Zip	Reference City
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19534	Allentown
19535	Allentown
19536	Allentown
19538	Allentown
19539	Allentown
19540	Allentown
19541	Allentown
19542	Allentown
19543	Allentown
19544	Harrisburg
19545	Allentown
19547	Allentown
19548	Allentown
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19550	Harrisburg
19551	Allentown
19554	Allentown
19555	Allentown
19557	Allentown
19559	Allentown
19560	Allentown
19562	Allentown
19564	Allentown
19565	Allentown
19567	Harrisburg
19601	Allentown
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19603	Allentown
19604	Allentown
19605	Allentown
19606	Allentown
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19608	Allentown
19609	Allentown
19610	Allentown
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19640	Allentown

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