Legal Department

American Electric Power
1 Riverside Plaza
Columbus, OH 43215-2373
AEP.com

January 24, 2013

Barcy F. McNeal
Docketing Division Chief
Public Utilities Commission of Ohio
180 East Broad Street
Columbus, OH 43215-3793

Yazen Alami
Regulatory Services
(614) 716-2920 (P)
(614) 716-2950 (F)
yalami@aep.com

Re: In the Matter of the Motions to Protect Confidential Information and Waive Certain Requirements of O.A.C. 4901:1-24 by Ohio Power Company, Case No. 10-1599-EL-EEC

Dear Ms. McNeal,

Enclosed please find Ohio Power Company's (dba AEP Ohio) updated Prescriptive Protocol Workpapers for the 2013 program year to be filed in the above referenced docket.

Thank you for your attention to this matter. Should you have any questions, please do not hesitate to contact me.

Respectfully submitted,

/s/ Yazen Alami__________
Yazen Alami

Attachments

AEP Ohio Business Incentives

DNV KEMA Savings Workpaper

Appendix A — AEP Ohio Prescriptive Measures Protocols

A unit of American Electric Power

Table of Contents

This appendix provides DNV KEMA's workpapers that document the deemed savings used within the Business Incentives prescriptive program tracking system. DNV KEMA uses the "State of Ohio Energy Efficiency Technical Reference Manual: Including Predetermined Savings Values and Protocols for Determining Energy and Demand Savings" draft date of 8/6/10, (referenced as "Ohio TRM" throughout this appendix) for many of the measures described within this document. In cases where the TRM is not comprehensive, other sources are referenced or our own estimations are provided. For example, it is understood that interactive effects for lighting measures should be based on data or prototypical building models for Ohio weather. HVAC savings should also be building-specific. The current draft of the Ohio TRM presents both HVAC savings and interactive effects as independent of building type. Due to the interim nature of the TRM, DNV KEMA does not update the savings or assumptions for certain measures with the expectation that the future iteration of the Ohio TRM will include a more comprehensive approach for measures as indicated in DNV KEMA's comments in regards to the Ohio TRM.

All energy savings are presented on an annual basis and all demand savings are presented on an average of coincident peak basis for both Ohio peak periods June 1st and August 31st on weekday, non-holidays, between the hours of 3:00 PM and 6:00 PM and PJM peak period, which is 2:00 PM – 6:00PM. In most cases, the same savings are assumed for Ohio and PJM peak period, unless noted differently (for lighting and some HVAC measures).

Note: In February 2012, Oslo-based Det Norske Veritas (DNV) acquired KEMA's parent company, KEMA NV, to form a new subsidiary, DNV KEMA Energy & Sustainability (DNV KEMA). Together as one company, DNV KEMA is committed to driving the global transition toward a safe, reliable efficient and clean energy future. As DNV KEMA, KEMA Services, Inc. continues to deliver the same quality services to AEP Ohio.

Lighting

The following provides the assumptions and methods used for calculating energy savings. Most lighting measures presented in these work papers use the same methodology.

Baseline and retrofit equipment assumptions, i.e. wattages, are specific to the measure. Most lighting retrofits assume an early replacement of existing technologies where the baseline represents the equipment removed. This type of measure is considered a retrofit, not replace on burnout.

The lighting portion of this workpaper includes the documentation provided here, as well as the accompanying workbook.

All the lighting measures discussed here are applicable for the self-direct prescriptive lighting measures since lighting is consider as a retrofit measure that is consistent with the “as-found” protocol. Unless otherwise noted, none of these measures are applicable for new construction.

Savings Calculation Methodology

DNV KEMA calculated annual energy savings and the peak coincident demand savings using the equations below:

Non-coincident kW reduction = kW of existing equipment - kW of replacement equipment

Energy savings are based on the difference between baseline and efficient equipment connected wattage and annual operating hours, according to the following formula:

*kWh Reduction = non-coincident kW reduction * (Annual operating hours)*(Energy Interactive Effects)*

Coincident demand savings are calculated by applying the coincidence factor and the demand interactive effect, according to the following formula:

*Coincident kW savings = non-coincident kW reduction * Coincidence Factor * Demand interactive effect*

Interactive factors account for savings that the measures achieve through avoided air conditioning load because of reduced internal heat gains from energy-efficient lighting. The interactive effects do not apply to exterior or garage lighting.

Non-coincident Demand Reduction

Baseline and retrofit equipment assumptions are based on what DNV KEMA believes to be standard for the measure. Using this approach simplifies the default savings values. The baseline and retrofit fixtures are selected and the wattage assumptions are from a standard fixture wattage table found in the accompanying workbook. DNV KEMA assembled this table from multiple sources including the Pennsylvania TRM and California statewide non-residential retrofit program.

2008 DEER Data

Most lighting measure input parameters comes from the 2008 Database for Energy Efficiency Resources (DEER) Study[1] Savings are calculated by appyling operating hours and other parameters that define the energy savings. These workpapers base the energy savings methodology on the California 2008 DEER Study assumptions. The DEER database is a tool that was jointly developed by the California Public Utilities Commission (CPUC) and the California Energy Commission with support and input from the Investor-Owned Utilities and other interested stakeholders. DEER provides operating hours, interactive effects and coincidence factors by building type and California weather zone. It is clear that California and Ohio climate are not similar, but these values will be considered relevant until a clear direction is provided via the Ohio TRM for HVAC interactive effects. Many states, other than California, use the DEER Study as its resource for deemed savings.

DNV KEMA extracted required data elements from the DEER, as well as other sources, to use in calculating measure energy savings and to provide a simple, comprehensive list of lighting retrofit measures. The annual operating hours, the coincidence factors, and the interactive effect factors are all derived from 2008 DEER figures.

Compact fluorescent lamps (CFLs), LED lighting (unless otherwise noted), cold cathode lamps, and integrated ballast ceramic metal halides use CFL lighting operating hours. Other lighting categories have different operating hours as shown below. Operating hour values for the three different Manufacturing/Industrial shifts, exterior and garage are taken from the Ohio TRM.

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[1] 2008 Database for Energy Efficiency Resources (DEER), www.deeresources.com

Ohio TRM, IL TRM and 2008 DEER building types are grouped as shown below. Lighting measure data is derived from DEER 2008. For DNV KEMA Building Types which are a combination of more than one DEER 2008 building type, measure data is averaged across the combined building types.

Table 1. Mapping Building Types

KEMA Workpaper Building Type	2008 DEER	Ohio TRM	IL TRM
Large Office	Office - Large	Office	Office
Small Office	Office - Small		
School	Education – Primary School	School	High School/Middle School
	Education – Secondary School		Elementary School
Small Retail/Service	Retail – Small	Retail	Retail/Service
Large Retail/Service	Retail – 3-Story Large		
	Retail – Single-Story Large		
Hotel/Motel	Lodging – Hotel	Hotel/Motel	Hotel/Motel Common Areas
	Lodging – Motel		Hotel/Motel Guest Rooms
Medical – Hospital	Health/Medical – Hospital	Health Care	Hospital
Medical - Nursing Home	Health/Medical – Nursing Home		Healthcare Clinic
Restaurant	Restaurant – Fast-Food	Food Service	Restaurant
	Restaurant – Sit-Down		
Grocery	Grocery	Food Sales	Grocery
Conditioned Warehouse	Storage - Conditioned	Warehouse	Warehouse
Unconditioned Warehouse	Storage - Unconditioned		Uncooled Building
Manufacturing – Light Industrial (1 shift)	*Ohio TRM	*Ohio TRM	Heavy or Light Industry
Manufacturing – Light Industrial (2 shift)	*Ohio TRM	*Ohio TRM	Heavy or Light Industry
Manufacturing – Light Industrial (3 shift)	*Ohio TRM	*Ohio TRM	Heavy or Light Industry
College/University	Education – Community College	College	College/University
	Education – University		
Government/Municipal	Ave of Assembly & Large Office	Public Assembly	Ave of Assembly & Office
Assembly	Assembly	Public Assembly	Miscellaneous

Miscellaneous	*Average across all bldg types (including garage and exterior)	*Average across all bldg types (including garage and exterior)	Miscellaneous
Garage (Ohio)	*Ohio TRM	*Ohio TRM	Garage
Exterior (Ohio)	*Ohio TRM	*Ohio TRM	Exterior

Table 2. Annual Operating Hours by Building Type[2]

Building Type	Non-CFL	CFL
Large Office	2651	3151
Small Office	2594	3082
School	2245	2442
Small Retail/Service	3253	3721
Large Retail/Service	3401	3758
Hotel/Motel	6834	5572
Guest Rooms	NA	799
Medical - Hospital	4881	4084
Medical - Nursing Home	4260	3576
Restaurant	4825	4825
Grocery	4886	3876
Conditioned Warehouse	3441	2780
Unconditioned Warehouse	3441	2780
Manufacturing – Light Industrial (1 shift)	2857	2857
Manufacturing – Light Industrial (2 shift)	4730	4730
Manufacturing – Light Industrial (3 shift)	6631	6631
College/University	2523	2540
Government/Municipal	2547	2719
Assembly	2443	2286
Miscellaneous	4075	3775
Garage (Ohio)	8760	8760
Exterior (Ohio)	4300	4300

The following table provides the interactive effects per the IL TRM. The values were developed using EQuest models for various building types averaged across 5 climate zones for Illinois for

[2] Manufacturing/Industrial, Garage hours are taken from the Ohio TRM. Exterior operating hours are from Vermont Energy Investment Corporation's replies to the Ohio Utilities joint objections, dated Nov 15, 2010 and filed with the PUCO, 09-512-GE-UNC.

the following building types: office, grocery, healthcare/clinic, manufacturing, motel, high school, hospital, elementary school, restaurant, retail, college and warehouse. Exterior and garage values are 1, miscellaneous is an average of all indoor spaces. The above mapping was used to determine the values.

Table 3. Interactive Effects by Building Type

Building Type	Demand	Energy
Assembly	1.46	1.24
Education – Primary School	1.33	1.21
Education – Secondary School	0.74	1.23
Education – Community College	1.5	1.14
Education – University	1.5	1.14
Grocery	1.52	1.43
Health/Medical – Hospital	1.69	1.35
Health/Medical – Nursing Home	1.57	1.34
Lodging – Hotel	1.51	1.15
Lodging – Motel	1.51	1.15
Lodging – Guest Room*	1.51	1.15
Manufacturing – Light Industrial	1.06	1.03
Manufacturing – Light Industrial (1 shift)	1.06	1.03
Manufacturing – Light Industrial (2 shift)	1.06	1.03
Manufacturing – Light Industrial (3 shift)	1.06	1.03
Miscellaneous	1.26	1.15
Office – Large	1.3	1.25
Office – Small	1.3	1.25
Restaurant – Fast-Food	1.65	1.34
Restaurant – Sit-Down	1.65	1.34
Retail – 3-Story Large	1.44	1.24
Retail – Single-Story Large	1.44	1.24
Retail – Small	1.44	1.24
Storage – Conditioned	1.17	1.16
Storage – Unconditioned	varies	1
Garage	1	1
Exterior	1	1

Table 4. Coincident Diversity Factors[3]

Building Type	OH Peak - Non-CFL	OH Peak - CFL	PJM Peak
Large Office	0.71	0.63	0.78
Small Office	0.69	0.67	0.72
School	0.64	0.65	0.46
Small Retail/Service	0.88	0.70	0.78
Large Retail/Service	0.81	0.66	0.82
Hotel/Motel	0.21	0.17	0.63
Guest Rooms	0.21	0.17	0.63
Medical - Hospital	0.82	0.72	0.77
Medical - Nursing Home	0.68	0.56	0.77
Restaurant	0.81	0.81	0.93
Grocery	0.69	0.50	1.12
Conditioned Warehouse	0.70	0.58	0.70
Unconditioned Warehouse	0.70	0.58	0.62
Manufacturing – Light Industrial (1 shift)	0.92	0.78	0.76
Manufacturing – Light Industrial (2 shift)	0.92	0.78	0.76
Manufacturing – Light Industrial (3 shift)	0.92	0.78	0.76
College/University	0.76	0.67	0.67
Government/Municipal	0.62	0.52	0.50
Garage (Ohio)	1.00	1.00	1.00
Exterior (Ohio)	0.00	0.00	0.00
Assembly	0.530	0.410	0.66
Miscellaneous	0.68	0.59	0.72

Measure Life and Incremental Measure Cost

[3] These load shapes are based on results of previous evaluation studies, including metering, that were conducted for various programadministrators in the NEEP EMV Forum region. The data was sourced from interval lighting meter data collected for evaluating energy efficiency impacts. Data were mined from existing data that consisted of short-term (typically 3-4 weeks) metered data of interior C&I lighting equipment that was installed through an energy efficiency program. The data were collected primarily by KEMA as part of energy efficiency program evaluation work conducted from 2000 through the present. http://neep.org/uploads/EMV%20Forum/EMV%20Products/NEEP%20CI%20Lighting%20LS%20FINAL%20Report_ver%205_7-19-11.pdf

The 2008 DEER provides measure life for several lighting measures, which vary by building type (operating hours) and ballast-rated hours. DNV KEMA used the 2005 DEER measure life for this report as a single number that is based on an average life.[4]

We have assumed an EUL of 5 years for T-12 to T-8 conversions. There has been discussion in the evaluation industry of different numbers ranging from 1 to 15 years. Reconsideration might be warranted going forward as by statute, the manufacture of T-12s ends in 2012.

Incremental costs are taken from a number of sources. The AEP Ohio 2009-2028 Energy Efficiency/Peak Demand Reduction Potential Study conducted in August of 2009 provides costs for some measures. Since this study was prepared specifically for AEP, the utility's costs are used whenever applicable. Because some measures listed or measure units in the study do not match with that of the program, costs are derived from other sources as well including DEER, DNV KEMA, and the Commonwealth Edison Company's 2008-10 Energy Efficiency and Demand Response Plan prepared by ICF International, referred to as the" ICF Portfolio Plan."

Incremental cost is cost difference between the energy efficient equipment and the less efficient option. In retrofit cases, the IMC is equal to the full measure cost since the cost of the less efficient option, i.e., not conducting the retrofit, is $0.

[4] The 2008 DEER uses 15 years as standard life if not using rated equipment life (such as the ballast) and actual operating hours.

T5 Lamp and Ballast

Measure Description	This measure consists of replacing 4 foot T12 lamps and magnetic ballasts with T5 lamps and electronic ballast. The T5 lamps must have a color rendering index (CRI) ≥ 80 and be 4 ft. The electronic ballast must be high frequency (≥20 kHz), UL listed, and warranted against defects for 5 years. Ballasts must have a power factor (PF) ≥ 0.90 and a total harmonic distortion (THD) ≤20 percent at full light output.
Units	Per Lamp
Base Case Description	T12 lamps with magnetic ballasts

Measure Savings

The savings are presented in the following table. The annual operating hours, the coincidence factors, and the interactive effect factors are obtained from Tables 1-3.

Table 5. T12 to T5 Fluorescent Fixture Measure Savings, per lamp

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	24.1	0.005	0.006
College/University	24.4	0.010	0.006
Conditioned Warehouse	33.9	0.007	0.006
Government/Municipal	27.0	0.007	0.004
Grocery	59.4	0.009	0.010
Hotel/Motel	66.8	0.003	0.005
Guest Rooms	7.8	0.002	0.005
Large Office	28.2	0.008	0.007
Large Retail/Service	35.8	0.010	0.007
Manufacturing – Light Industrial (1 shift)	25.0	0.008	0.006
Manufacturing – Light Industrial (2 shift)	41.4	0.008	0.006
Manufacturing – Light Industrial (3 shift)	58.1	0.008	0.006
Medical - Hospital	56.0	0.012	0.007

Building Type	kWh	OH peak kW	PJM peak kW
Medical - Nursing Home	48.5	0.009	0.007
Miscellaneous	41.0	0.008	0.006
Restaurant	55.0	0.011	0.008
School	23.3	0.006	0.004
Small Office	27.6	0.008	0.006
Small Retail/Service	34.3	0.011	0.007
Unconditioned Warehouse	29.2	0.006	0.005
Garage (Ohio)	74.5	0.009	0.009
Exterior (Ohio)	36.6	0.000	0.000

Measure Savings Analysis
Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Baseline and retrofit equipment assumptions are listed in the table below.

Table 6. Baseline and Retrofit Wattages for T12 to T5 Fixture Retrofit

	Pre	Post
Measure Code	F42ES	F42GL
Description	Fluorescent, (2) 48", ES T12 lamp	Fluorescent, (2) 48", STD T5 lamp
Watts/Fixture	80	63

Measure Life and Incremental Measure Cost
The measure life is 5 years. The IMC is $18.54 per DNV KEMA research/experience.

High Performance 4-foot T8 Lamps and Ballast – T12 Base

Measure Description	This measure consists of replacing existing T12 lamps and magnetic ballasts with high-performance T8 lamps. This measure is based on the Consortium for Energy Efficiency (CEE) high-performance T8 (www.cee1.org). A list of qualified lamps and ballasts can be found on the same website. Both the lamp and ballast must meet the specification to qualify for an incentive. The incentive is calculated based on the number of lamps installed.
Units	Per lamp
Base Case Description	T12 lamp and magnetic ballasts

Measure Savings
The savings are presented in the following table.

Table 7. High-Performance 4-foot Lamp and Ballast Measure Savings – T12 Base (per lamp)

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	36.9	0.008	0.009
College/University	37.4	0.015	0.009
Conditioned Warehouse	51.9	0.011	0.009
Government/Municipal	41.2	0.011	0.007
Grocery	90.8	0.014	0.015
Hotel/Motel	102.2	0.004	0.008
Guest Rooms	11.9	0.003	0.008
Large Office	43.1	0.012	0.010
Large Retail/Service	54.8	0.015	0.011
Manufacturing – Light Industrial (1 shift)	38.3	0.013	0.010
Manufacturing – Light Industrial (2 shift)	63.3	0.013	0.010
Manufacturing – Light Industrial (3 shift)	88.8	0.013	0.010
Medical - Hospital	85.7	0.018	0.010
Medical - Nursing Home	74.2	0.014	0.010
Miscellaneous	62.7	0.012	0.009
Restaurant	84.1	0.017	0.012
School	35.6	0.009	0.006
Small Office	42.2	0.012	0.009

Building Type	kWh	OH peak kW	PJM peak kW
Small Retail/Service	52.4	0.016	0.010
Unconditioned Warehouse	44.7	0.009	0.008
Garage (Ohio)	113.9	0.013	0.013
Exterior (Ohio)	55.9	0.000	0.000

Measure Savings Analysis
Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Baseline and retrofit equipment assumptions are listed in the table below.

Table 8. Baseline and Retrofit Wattages for High-Performance Fixture Retrofits

	Pre	Post
Measure Code	F42ES	F42LL-R
Description	Fluorescent, (2) 48", ES T12 lamp	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)
Watts/Fixture	80	54

Measure Life and Incremental Measure Cost
The measure life is 5 years. The IMC is $13.14 per AEP Ohio Potential Study.

Reduced Wattage 4-foot T8 Lamps and Ballast – T12 Base

Measure Description	This measure consists of replacing existing T12 lamps and magnetic ballasts with reduced wattage (28 or 25W) T8 lamps and electronic ballasts. For reduced wattage 4-foot T8 lamps, the nominal wattage must be 28 W (≥2,585 Lumens) or 25 W (≥2,400 Lumens) to qualify. This measure is based on the Consortium for Energy Efficiency (CEE) reduced wattage specification (www.cee1.org). A list of qualified lamps and ballasts can be found on the CEE website. Both the lamp and ballast must meet the specification to qualify for an incentive. The incentive is calculated based on the number of lamps installed.
Units	Per lamp
Base Case Description	T12 lamp and magnetic ballasts

Measure Savings
Savings are summarized by the following table.

Table 9. Reduced Wattage 4-foot Lamp and Ballast – T12 Base Measure Savings (per lamp)

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	49.6	0.010	0.011
College/University	50.3	0.020	0.012
Conditioned Warehouse	69.9	0.014	0.012
Government/Municipal	55.5	0.015	0.009
Grocery	122.3	0.018	0.020
Hotel/Motel	137.5	0.005	0.011
Guest Rooms	16.1	0.005	0.011
Large Office	58.0	0.016	0.014
Large Retail/Service	73.8	0.020	0.014
Manufacturing – Light Industrial (1 shift)	51.5	0.017	0.013
Manufacturing – Light Industrial (2 shift)	85.3	0.017	0.013
Manufacturing – Light Industrial (3 shift)	119.5	0.017	0.013
Medical - Hospital	115.3	0.024	0.013
Medical - Nursing Home	99.9	0.019	0.013
Miscellaneous	84.3	0.016	0.013
Restaurant	113.1	0.023	0.016
School	47.9	0.012	0.008
Small Office	56.7	0.016	0.013
Small Retail/Service	70.6	0.022	0.014
Unconditioned Warehouse	60.2	0.012	0.011
Garage (Ohio)	153.3	0.018	0.018
Exterior (Ohio)	75.3	0.000	0.000

Measure Savings Analysis
Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Baseline and retrofit equipment assumptions are listed in the table below.

Table 10. Baseline and Retrofit Wattages for Reduced Wattage Fixture Retrofits

	Pre	Post

Measure Code	F42ES	F42SSILL-R
Description	Fluorescent, (2) 48", ES T12 lamp	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)
Watts/Fixture	80	45

Measure Life and Incremental Measure Cost
The measure life is 5 years. The IMC is $13.14 per AEP Ohio Potential Study.

1-Lamp 8-foot T12 to 2-Lamp High Performance/Reduced Wattage 4-foot T8 Lamps and Ballast

Measure Description	This measure consists of replacing existing one 8-foot T12 lamp and magnetic ballast with high performance 32W or reduced wattage 4-foot T8 and electronic ballasts. Both the lamp and ballast must meet the Consortium for Energy Efficiency (CEE) high performance or reduced wattage T8 specification (www.cee1.org). The incentive is calculated based on the number of 4-foot lamps installed. Typically, this measure retrofit is in conjunction with a one 8-foot lamp removed (in a 2-lamp, 8-foot T12 to 2 –lamp, 4-foot T8 retrofit).
Units	Per 4-foot lamp
Base Case Description	T12 lamp and magnetic ballasts

Measure Savings
The savings are presented in the following table.

Table 11. Measure Savings for 1-Lamp 4-foot Lamp and Ballast (per lamp)

Building Type	High Performance			Reduced Wattage		
	kWh	OH peak kW	PJM peak kW	kWh	OH peak kW	PJM peak kW
Assembly	52.4	0.011	0.012	65.2	0.014	0.015
College/University	53.2	0.021	0.012	66.2	0.026	0.015
Conditioned Warehouse	73.8	0.015	0.013	91.8	0.019	0.016
Government/Municipal	58.7	0.016	0.009	72.9	0.020	0.012
Grocery	129.3	0.019	0.021	160.7	0.024	0.026
Hotel/Motel	145.4	0.006	0.012	180.8	0.007	0.015

Building Type	High Performance			Reduced Wattage		
	kWh	OH peak kW	PJM peak kW	kWh	OH peak kW	PJM peak kW
Guest Rooms	17.0	0.005	0.012	21.1	0.006	0.015
Large Office	61.3	0.017	0.014	76.2	0.021	0.018
Large Retail/Service	78.0	0.022	0.015	97.0	0.027	0.019
Manufacturing – Light Industrial (1 shift)	54.4	0.018	0.014	67.7	0.022	0.018
Manufacturing – Light Industrial (2 shift)	90.1	0.018	0.014	112.1	0.022	0.018
Manufacturing – Light Industrial (3 shift)	126.4	0.018	0.014	157.1	0.022	0.018
Medical - Hospital	121.9	0.025	0.014	151.6	0.032	0.018
Medical - Nursing Home	105.6	0.020	0.014	131.3	0.024	0.018
Miscellaneous	89.2	0.016	0.013	110.8	0.020	0.017
Restaurant	119.6	0.025	0.017	148.7	0.031	0.021
School	50.7	0.012	0.009	63.0	0.015	0.011
Small Office	60.0	0.017	0.013	74.6	0.021	0.016
Small Retail/Service	74.6	0.023	0.014	92.8	0.029	0.018
Unconditioned Warehouse	63.7	0.013	0.011	79.1	0.016	0.014
Garage (Ohio)	162.1	0.019	0.019	201.5	0.023	0.023
Exterior (Ohio)	79.6	0.000	0.000	98.9	0.000	0.000

Measure Savings Analysis

Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Baseline and retrofit equipment assumptions are listed in the table below.

Table 12. Baseline and Retrofit Wattages for 1-Lamp 8-foot T12 to 2-Lamp 4-foot T8 Fixture Retrofits

	Pre	High Performance Post	Reduced Wattage Post
Measure Code	F81SE	F42LL-R	F42SSILL-R
Description	Fluorescent, (1) 96", STD lamp	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)
Watts/Fixture	91	54	45

Demand reduction per 4-foot lamp installed is calculated as follows:

*(Pre-Watt/Fixture * 0.5) – (Post-Watt/Fixture * 0.5)*

Measure Life and Incremental Measure Cost

The measure life is 5 years.(assuming 20,000 hours rated lamp life for average operating hours per year). The IMC is $13.14 per AEP Ohio Potential Study.

Reduced Wattage 8-foot Lamp and Ballast

Measure Description	This measure consists of replacing existing T12 8' lamps and magnetic ballasts with reduced wattage T8 lamps and electronic ballasts. Eight foot lamps must have a minimum MLPW of 90 and must have a nominal wattage of 57W or less.
Units	Per lamp
Base Case Description	T12 lamp and magnetic ballasts or high watt T8 fixtures (for reduced wattage lamp only replacements).

Measure Savings

Savings are summarized by the following table.

Table 13. Measure Savings for Reduced-Wattage 8-foot Lamp and Ballast

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	69.4	0.015	0.016
College/University	70.5	0.028	0.016
Conditioned Warehouse	97.8	0.020	0.017
Government/Municipal	77.7	0.021	0.012
Grocery	171.2	0.026	0.028
Hotel/Motel	192.5	0.008	0.016
Guest Rooms	22.5	0.006	0.016
Large Office	81.2	0.023	0.019
Large Retail/Service	103.3	0.029	0.020
Manufacturing – Light Industrial (1 shift)	72.1	0.024	0.019
Manufacturing – Light Industrial (2 shift)	119.4	0.024	0.019
Manufacturing – Light Industrial (3 shift)	167.3	0.024	0.019
Medical - Hospital	161.4	0.034	0.019
Medical - Nursing Home	139.9	0.026	0.019
Miscellaneous	118.1	0.022	0.018
Restaurant	158.4	0.033	0.023
School	67.1	0.016	0.011
Small Office	79.4	0.022	0.018
Small Retail/Service	98.8	0.031	0.019
Unconditioned Warehouse	84.3	0.017	0.015
Garage (Ohio)	214.6	0.025	0.025
Exterior (Ohio)	105.4	0.000	0.000

Measure Savings Analysis

Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Baseline and retrofit equipment assumptions are listed in the table below.

Table 14. Baseline and Retrofit Wattages for 8-foot T8 Lamp and Ballast

	Pre	Post
Measure Code	F82SE	F82ILL
Description	Fluorescent, (2) 96", STD lamp	Fluorescent, (2) 96", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)
Watts/Fixture	158	109

Measure Life and Incremental Measure Cost
The measure life is 5 years. The IMC is $36.91 per DEER 2008.

2-foot & 3-foot T8 Lamps and Ballast

Measure Description	This measure consists of replacing existing T12 lamps and magnetic ballasts with T8 lamps and electronic ballasts. The lamp must have a color rendering index (CRI) ≥ 80 and the ballast must have a total harmonic distortion (THD) ≤ 32% at full light output and power factor (PF) ≥ 0.90. Ballasts must also be warranted against defects for 5 years.
Units	Per lamp
Base Case Description	T12 lamps and magnetic ballast

Measure Savings
The coincident kW and kWh savings are provided in the following table.

Table 15. Measure Savings for 2-foot and 3- foot Lamp and Ballast (per lamp)

Building Type	2-foot			3-foot		
	kWh	OH peak kW	PJM peak kW	kWh	OH peak kW	PJM peak kW
Assembly	32.6	0.007	0.008	39.7	0.008	0.009
College/University	33.1	0.013	0.008	40.3	0.016	0.009
Conditioned Warehouse	45.9	0.009	0.008	55.9	0.011	0.010
Government/Municipal	36.5	0.010	0.006	44.4	0.012	0.007
Grocery	80.4	0.012	0.013	97.8	0.015	0.016
Hotel/Motel	90.4	0.004	0.007	110.0	0.004	0.009
Guest Rooms	10.6	0.003	0.007	12.9	0.004	0.009
Large Office	38.1	0.011	0.009	46.4	0.013	0.011

Large Retail/Service	48.5	0.013	0.009	59.0	0.016	0.011
Manufacturing – Light Industrial (1 shift)	33.8	0.011	0.009	41.2	0.014	0.011
Manufacturing – Light Industrial (2 shift)	56.0	0.011	0.009	68.2	0.014	0.011
Manufacturing – Light Industrial (3 shift)	78.5	0.011	0.009	95.6	0.014	0.011
Medical - Hospital	75.8	0.016	0.009	92.3	0.019	0.011
Medical - Nursing Home	65.6	0.012	0.009	79.9	0.015	0.011
Miscellaneous	55.4	0.010	0.008	67.5	0.012	0.010
Restaurant	74.4	0.015	0.011	90.5	0.019	0.013
School	31.5	0.008	0.005	38.3	0.009	0.006
Small Office	37.3	0.010	0.008	45.4	0.013	0.010
Small Retail/Service	46.4	0.014	0.009	56.5	0.018	0.011
Unconditioned Warehouse	39.6	0.008	0.007	48.2	0.010	0.009
Garage (Ohio)	100.7	0.012	0.012	122.6	0.014	0.014
Exterior (Ohio)	49.5	0.000	0.000	60.2	0.000	0.000

Measure Savings Analysis

Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Baseline and retrofit equipment assumptions are listed in the table below.

Table 16. Baseline and Retrofit Wattages for 2-foot Lamps – T12 Base

	Pre	Post
Measure Code	F22SS	F22ILL
Description	Fluorescent, (2) 24", STD lamp	Fluorescent, (2) 24", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)
Watts/Fixture	56	33

Table 17. Baseline and Retrofit Wattages for 3-foot Lamps – T12 Base

	Pre	Post
Measure Code	F32SE	F32ILL
Description	Fluorescent, (2) 36", STD lamp	Fluorescent, (2) 36", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)
Watts/Fixture	74	46

Measure Life and Incremental Measure Cost
The measure life is 11 years per DEER 2005. The IMC is $10.50 for 2-foot lamp and $21.00 for 3-foot lamp per PG&E 2006 workpapers.

Permanent Lamp Removal

Measure Description	Incentives are paid for the permanent removal of existing 8', 4', 3' and 2' fluorescent lamps. Unused lamps, lamp holders, and ballasts must be permanently removed from the fixture. This measure is applicable when retrofitting from T12 lamps to T8 lamps. Removing lamps from a T12 fixture that is not being retrofitted with T8 lamps are not eligible for this incentive.
Units	Per lamp
Base Case Description	T12 fluorescent fixtures before removal of lamps.

Incentives are paid for the removal of fluorescent lamps from existing fixtures. Permanent lamp removal is the net reduction in the total quantity of *lamps* after a project is completed, regardless of the number of fixtures. This measure is applicable when retrofitting from T12 lamps to T8 or T5 lamps. Removing lamps from a T12 fixture that is not being retrofitted with T8 or T5 lamps does not qualify for this credit.

Customers are responsible for determining whether or not to use reflectors in combination with lamp removal in order to maintain adequate lighting levels. Lighting levels are expected to meet the Illuminating Engineering Society of North America (IESNA) recommended light levels. Unused lamps, lamp holders, and ballasts must be permanently removed from the fixture and disposed of in accordance with local regulations. A pre-approval application is required for lamp removal projects.

Measure Savings
Savings are summarized by the following table. There are no PJM savings since lamp removal does not qualify.

Table 18. Measure Savings for T12 Lamp Removal, per lamp

	8-foot T12			4-foot T12			3-foot T12			2-foot T12		
Building Type	**kWh**	**OH peak kW**	**PJM peak kW**	**kWh**	**OH peak kW**	**PJM peak kW**	**kWh**	**OH peak kW**	**PJM peak kW**	**kWh**	**OH peak kW**	**PJM peak kW**
Assembly	195.6	0.041	0.045	113.4	0.024	0.026	104.9	0.022	0.024	72.3	0.015	0.017

College/University	198.5	0.079	0.046	115.0	0.046	0.027	106.4	0.042	0.025	73.3	0.029	0.017
Conditioned Warehouse	275.4	0.057	0.048	159.7	0.033	0.028	147.7	0.030	0.026	101.8	0.021	0.018
Government/Municipal	218.8	0.059	0.035	126.8	0.034	0.020	117.3	0.032	0.019	80.9	0.022	0.013
Grocery	482.1	0.072	0.078	279.5	0.042	0.045	258.5	0.039	0.042	178.2	0.027	0.029
Hotel/Motel	542.3	0.021	0.044	314.4	0.012	0.025	290.8	0.011	0.023	200.4	0.008	0.016
Guest Rooms	63.4	0.018	0.044	36.8	0.010	0.025	34.0	0.010	0.023	23.4	0.007	0.016
Large Office	228.6	0.064	0.054	132.6	0.037	0.031	122.6	0.034	0.029	84.5	0.024	0.020
Large Retail/Service	291.0	0.081	0.057	168.7	0.047	0.033	156.0	0.043	0.030	107.5	0.030	0.021
Manufacturing – Light Industrial (1 shift)	203.0	0.067	0.053	117.7	0.039	0.031	108.9	0.036	0.028	75.0	0.025	0.019
Manufacturing – Light Industrial (2 shift)	336.2	0.067	0.053	194.9	0.039	0.031	180.3	0.036	0.028	124.2	0.025	0.019
Manufacturing – Light Industrial (3 shift)	471.3	0.067	0.053	273.2	0.039	0.031	252.7	0.036	0.028	174.2	0.025	0.019
Medical - Hospital	454.7	0.095	0.053	263.6	0.055	0.031	243.8	0.051	0.028	168.0	0.035	0.020
Medical - Nursing Home	393.9	0.073	0.053	228.3	0.042	0.031	211.2	0.039	0.028	145.6	0.027	0.020
Miscellaneous	332.5	0.061	0.050	192.8	0.036	0.029	178.3	0.033	0.027	122.9	0.023	0.018
Restaurant	446.1	0.092	0.064	258.6	0.053	0.037	239.2	0.049	0.034	164.9	0.034	0.024
School	188.9	0.046	0.032	109.5	0.027	0.019	101.3	0.025	0.017	69.8	0.017	0.012
Small Office	223.7	0.062	0.049	129.7	0.036	0.029	120.0	0.033	0.027	82.7	0.023	0.018
Small Retail/Service	278.3	0.087	0.054	161.3	0.050	0.031	149.2	0.047	0.029	102.9	0.032	0.020
Unconditioned Warehouse	237.4	0.048	0.043	137.6	0.028	0.025	127.3	0.026	0.023	87.7	0.018	0.016
Garage (Ohio)	604.4	0.069	0.069	350.4	0.040	0.040	324.1	0.037	0.037	223.4	0.026	0.026
Exterior (Ohio)	296.7	0.000	0.000	172.0	0.000	0.000	159.1	0.000	0.000	109.7	0.000	0.000

Measure Savings Analysis

Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Baseline equipment assumptions are listed in the table below. Each lamp type wattage reduction is converted to a per lamp basis for savings analysis. The retrofit wattage is assumed to be zero (post measure code, “removed”. This measure only considers the lamp removed. The lamp installed/retrofit is captured in another measure

Table 19. Baseline Wattages for T12 Lamp Removal

Lamp Removed	Pre Measure Code	Pre Fixture Description	Watts/Fixture (PRE)
8-ft T12	F82ES	Fluorescent, (2) 96", ES lamp	138
4-ft T12	F42ES	Fluorescent, (2) 48", ES lamp	80

3-ft T12	F32SE	Fluorescent, (2) 36", STD lamp	74
2-ft T12	F22SE	Fluorescent, (2) 24", STD lamp	51

Measure Life and Incremental Measure Cost
The measure life is 5 years per DEER 2005. The cost is $25 per lamp removed per a DNV KEMA assumption.

Other Lighting

Measure Description	This measure is for lighting projects that do not fall into one of the measures offered elsewhere in the application. The new equipment must have a higher mean efficacy (lumens per watt) than the existing equipment. The following are not eligible under this measure: retrofitting to standard 32W T8 and electronic ballast, retrofit to lower wattage lamp of the same technology, and retrofits with a measure life of less than 3 years. Examples of what is eligible are: high intensity discharge to compact fluorescent fixtures, high wattage CFL retrofits, delamping T8 lamps from T8 fixtures. Projects will be approved on a case by case basis, based on currently available industry standards. The following are specific requirements per certain lighting categories: New T5/T8 Fluorescent Fixtures Metal Halide Retrofits T8 to T8 Retrofits
Units	Per Watt reduced
Base Case Description	Varies, Less efficient lamp or fixture

New T5/T8 Fluorescent Fixtures
This measure consists of replacing one or more existing fixtures with new fixtures containing T8 or T5 lamps and electronic ballasts. The T8 or T5 lamps must have a color rendering index (CRI) ≥ 80. The electronic ballast must be high frequency (≥20 kHz), UL listed, and warranted against defects for 5 years. Ballasts must have a power factor (PF) ≥ 0.90. Ballasts for 4-foot lamps must have total harmonic distortion (THD) ≤20 percent at full light output. For 2- and 3-foot lamps, ballasts must have THD ≤32% at full light output. High output T5/T8 lamps also qualify for this credit. Specifications of the new fixtures, lamps and ballasts must accompany the final application.

Standard T8 to High Peformance or Reduced Wattage T8 Retrofit

Retrofitting an existing T8 fixture with standard T8 lamps with CEE qualified T8 lamps. CEE qualified electronic ballasts must be installed. New, higher efficiency lamps and ballasts may allow for de-lamping within the fixture, or ballast factor reduction, resulting in energy savings. U-bend lamps also qualify. A list of qualified lamps and ballasts can be found at http://www.cee1.org/.

Customers are responsible for determining whether or not to use reflectors in combination with lamp removal in order to maintain adequate lighting levels. Lighting levels are expected to meet the IESNA recommended light levels. Unused lamps, lamp holders, and ballasts must be permanently removed from the fixture and disposed of in accordance with local regulations.

Metal Halide Fixtures

Total replacement wattage must be lower than existing wattage to insure energy savings.

Pulse Start or Ceramic - This measure is for replacing mercury vapor, high pressure sodium, standard metal halide, incandescent or T12 fixtures[5] with either new or retrofit kit pulse start metal halide or ceramic metal halide fixtures. Retrofit kits may be used on existing mercury vapor, standard metal halide or high pressure sodium fixtures only.
Probe Start HID to Ceramic Discharge Metal Halide Lamp - Retrofits of probe start high intensity discharge fixtures with ceramic discharge metal halide lamps. New lamps must be compatible with existing ballast and socket.
Integrated Ballast Ceramic Metal Halide Lamps - Replace incandescent lamps or high intensity discharge fixtures with qualifying integrated ballast ceramic metal halide PAR lamps that are 25 watt or less with a rated life of 12,000 hours or greater.

Measure Savings

Table 20. Measure Savings for Other Lighting (per Watt reduced)

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	2.83	0.000599	0.000655
College/University	2.88	0.001142	0.000672
Conditioned Warehouse	3.99	0.000819	0.000695
Government/Municipal	3.17	0.000856	0.000500
Grocery	6.99	0.001049	0.001124

[5] Only eligible until June 1, 2013.

Building Type	kWh	OH peak kW	PJM peak kW
Hotel/Motel	7.86	0.000310	0.000634
Guest Rooms	0.92	0.000262	0.000634
Large Office	3.31	0.000923	0.000779
Large Retail/Service	4.22	0.001169	0.000821
Manufacturing – Light Industrial (1 shift)	2.94	0.000978	0.000764
Manufacturing – Light Industrial (2 shift)	4.87	0.000978	0.000764
Manufacturing – Light Industrial (3 shift)	6.83	0.000978	0.000764
Medical - Hospital	6.59	0.001378	0.000766
Medical - Nursing Home	5.71	0.001062	0.000766
Miscellaneous	4.82	0.000891	0.000720
Restaurant	6.47	0.001331	0.000929
School	2.74	0.000665	0.000464
Small Office	3.24	0.000901	0.000717
Small Retail/Service	4.03	0.001260	0.000780
Unconditioned Warehouse	3.44	0.000700	0.000616
Garage (Ohio)	8.76	0.001000	0.001000
Exterior (Ohio)	4.30	0.000000	0.000000

Measure Savings Analysis

Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. LED lighting is assumed to follow the operating hours and use the coincidence and energy factors of CFL lighting.

Measure Life and Incremental Measure Cost

This measure includes a mix of options and therefore an estimate of 8 years for other lighting, 11 years for new T8/T5 fixture and metal halide retrofis are used for the EUL. The IMC is assumed to be $1.10 per Watt reduced based on DNV KEMA analysis of previous projects.

Exit Signs

Measure Description	High-efficiency exit signs must replace or retrofit an existing incandescent exit sign. Electroluminescent, photoluminescent, T1 and light-emitting diode (LED) exit signs are eligible under this category. Non-electrified and remote exit signs are not eligible. All new exit signs or retrofit exit signs must be UL924 listed, have a minimum lifetime of 10 years, and have an input wattage ≤ 5 Watts per face.
Units	Per Sign
Base Case Description	Incandescent Exit Signs

Measure Savings

The coincident kW and kWh savings are provided in the following table.

Table 21. Measure Savings for LED Exit Signs (per sign)

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	339.5	0.019	0.020
College/University	312.1	0.047	0.021
Conditioned Warehouse	317.6	0.037	0.022
Government/Municipal	340.8	0.043	0.016
Grocery	391.5	0.048	0.035
Hotel/Motel	314.8	0.047	0.020
Guest Rooms	314.8	0.008	0.020
Large Office	342.2	0.041	0.024
Large Retail/Service	339.5	0.045	0.026
Manufacturing – Light Industrial (1 shift)	282.0	0.033	0.024
Manufacturing – Light Industrial (2 shift)	282.0	0.033	0.024
Manufacturing – Light Industrial (3 shift)	282.0	0.033	0.024
Medical - Hospital	369.6	0.053	0.024
Medical - Nursing Home	366.8	0.049	0.024
Miscellaneous	323.7	0.041	0.022
Restaurant	366.8	0.052	0.029
School	334.0	0.032	0.015
Small Office	342.2	0.041	0.022
Small Retail/Service	339.5	0.045	0.024
Unconditioned Warehouse	273.8	0.031	0.019

Building Type	kWh	OH peak kW	PJM peak kW
Garage (Ohio)	273.8	0.031	0.031
Exterior (Ohio)	273.8	0.031	0.000

Measure Savings Analysis
Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Baseline and retrofit equipment assumptions are listed in the table below. It is assumed that the CFL basecase accounts for 25% of installations, while the Incandescent basecase accounts for 75% of installations. This results in a weighted basecase average wattage of 35.25 W.

Table 22. Baseline and Retrofit Wattages Exit Signs

	Pre (Incandescent)	Pre (CFL)	Post
Measure Code	EI20/2	ECF7/2	ELED2/2
Description	EXIT Incandescent, (2) 20W lamp	EXIT Compact Fluorescent, (2) 7W lamp	EXIT Light Emitting Diode, (2) 2W lamp, Dual Sided
Watts/Fixture	40	21	4

Measure Life and Incremental Measure Cost
The measure life is 16 years per DEER 2008. The IMC is $82.54 per AEP Potential Study.

ENERGY STAR® and DesignLights Consortium (DLC) LED Lamp or Fixture

Measure Description	The LED lamp or fixuture must appear on either the ENERGY STAR qualified products list, or the Design Lights Consortium qualified products list.
Units	Per Watt reduced
Base Case Description	Less efficient lamp or fixture

Measure Savings
The coincident kW and kWh savings are provided in the following table.

Table 23. Measure Savings for LED lamp or fixture (per Watts reduced)

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	2.83	0.000599	0.000655
College/University	2.88	0.001142	0.000672

Building Type	kWh	OH peak kW	PJM peak kW
Conditioned Warehouse	3.99	0.000819	0.000695
Government/Municipal	3.17	0.000856	0.000500
Grocery	6.99	0.001049	0.001124
Hotel/Motel	7.86	0.000310	0.000634
Guest Rooms	0.92	0.000262	0.000634
Large Office	3.31	0.000923	0.000779
Large Retail/Service	4.22	0.001169	0.000821
Manufacturing – Light Industrial (1 shift)	2.94	0.000978	0.000764
Manufacturing – Light Industrial (2 shift)	4.87	0.000978	0.000764
Manufacturing – Light Industrial (3 shift)	6.83	0.000978	0.000764
Medical - Hospital	6.59	0.001378	0.000766
Medical - Nursing Home	5.71	0.001062	0.000766
Miscellaneous	4.82	0.000891	0.000720
Restaurant	6.47	0.001331	0.000929
School	2.74	0.000665	0.000464
Small Office	3.24	0.000901	0.000717
Small Retail/Service	4.03	0.001260	0.000780
Unconditioned Warehouse	3.44	0.000700	0.000616
Garage (Ohio)	8.76	0.001000	0.001000
Exterior (Ohio)	4.30	0.000000	0.000000

Measure Savings Analysis
Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. LED lighting is assumed to follow the operating hours and use the coincidence and energy factors of CFL lighting. The wattage reduction are inputsfrom the applicant.

Measure Life and Incremental Measure Cost
The measure life for the LED bulbs is taken from the ENERGY STAR® website, which lists most of LED fixtures as having an average rated lifetime of 35,000 hours. Using an average operating hours from across the building types, the estimated useful of LED fixtures is 7.7 years. The IMC is $2.97 per watt reduced based on DNV KEMA analysis of previous projects.

Non-standard LED or Induction Equipment

Measure Description	The non-standard LED measure is for LED equipment which is not yet listed by ENERGY STAR or DesignLights Consortium. LM-79 sheets must be provided for general illumination projects, and LM-80 sheets if available. Eligibility will be determined at the discretion of the program. The induction fixture must have a CRI of 80 or above and a mean efficacy of 50 or above.
Units	Per Watt reduced
Base Case Description	Less efficient lamp or fixture

Measure Savings
The coincident kW and kWh savings are provided in the following table.

Table 24. Measure Savings for Non-Standard LED or Induction Equipment (per Watt reduced)

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	2.83	0.000599	0.000655
College/University	2.88	0.001142	0.000672
Conditioned Warehouse	3.99	0.000819	0.000695
Government/Municipal	3.17	0.000856	0.000500
Grocery	6.99	0.001049	0.001124
Hotel/Motel	7.86	0.000310	0.000634
Guest Rooms	0.92	0.000262	0.000634
Large Office	3.31	0.000923	0.000779
Large Retail/Service	4.22	0.001169	0.000821
Manufacturing – Light Industrial (1 shift)	2.94	0.000978	0.000764
Manufacturing – Light Industrial (2 shift)	4.87	0.000978	0.000764
Manufacturing – Light Industrial (3 shift)	6.83	0.000978	0.000764
Medical - Hospital	6.59	0.001378	0.000766
Medical - Nursing Home	5.71	0.001062	0.000766
Miscellaneous	4.82	0.000891	0.000720
Restaurant	6.47	0.001331	0.000929
School	2.74	0.000665	0.000464
Small Office	3.24	0.000901	0.000717

Building Type	kWh	OH peak kW	PJM peak kW
Small Retail/Service	4.03	0.001260	0.000780
Unconditioned Warehouse	3.44	0.000700	0.000616
Garage (Ohio)	8.76	0.001000	0.001000
Exterior (Ohio)	4.30	0.000000	0.000000

Measure Savings Analysis
Annual energy savings and the peak coincident demand savings arewere calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. LED lighting is assumed to follow the operating hours and use the coincidence and energy factors of CFL lighting. The wattage reduction are inputsfrom the applicant.

Measure Life and Incremental Measure Cost
The measure life for the LEDs is taken from the ENERGY STAR website, which lists most of LED fixtures as having an average rated lifetime of 35,000 hours. Using an average operating hours from across the building types, the estimated useful of LED fixtures is 7.7 years. The IMC is $2.97 per watt reduced based on DNV KEMA analysis of previous projects.

Compact Fluorescent Fixtures, Hardwired

Measure Description	Hardwired CFL incentives apply only to complete new fixtures or modular (pin-based) retrofits with hardwired electronic ballasts. The CFL ballast must be programmed start or programmed rapid start with a PF ≥90 and THD ≤20%.
Units	Per fixture
Base Case Description	Non-compact fluorescent lamps or fixtures

Measure Savings
The following tables provide the measure savings using the above wattage reduction assumptions outlined in the Measure Savings analysis section.

Table 25. Measure Savings for Hardwired Compact Fluorescent Fixtures, per lamp

Building Type	29W or less			30W to 60 W			61W to 120W		
	kWh	OH peak kW	PJM peak kW	kWh	OH peak kW	PJM peak kW	kWh	OH peak kW	PJM peak kW
Assembly	155.9	0.033	0.036	258.0	0.054	0.060	260.8	0.055	0.060
College/University	159.2	0.055	0.037	263.4	0.091	0.061	266.3	0.092	0.062
Conditioned Warehouse	177.4	0.037	0.038	293.5	0.061	0.063	296.7	0.062	0.064
Government/Municipal	186.1	0.039	0.028	308.0	0.065	0.046	311.4	0.066	0.046
Grocery	304.8	0.041	0.062	504.4	0.068	0.102	509.9	0.069	0.103
Hotel/Motel	352.4	0.014	0.035	583.1	0.024	0.058	589.5	0.024	0.058
Guest Rooms	50.5	0.014	0.035	83.6	0.024	0.058	84.5	0.024	0.058
Large Office	216.6	0.045	0.043	358.4	0.074	0.071	362.4	0.075	0.072
Large Retail/Service	256.3	0.053	0.045	424.1	0.087	0.075	428.7	0.088	0.076
Manufacturing – Light Industrial (1 shift)	161.8	0.045	0.042	267.8	0.075	0.070	270.7	0.076	0.070
Manufacturing – Light Industrial (2 shift)	268.0	0.045	0.042	443.3	0.075	0.070	448.2	0.076	0.070
Manufacturing – Light Industrial (3 shift)	375.6	0.045	0.042	621.5	0.075	0.070	628.4	0.076	0.070
Medical - Hospital	303.2	0.067	0.042	501.7	0.111	0.070	507.2	0.112	0.070
Medical - Nursing Home	263.6	0.049	0.042	436.1	0.081	0.070	440.8	0.082	0.070
Miscellaneous	245.5	0.043	0.040	406.2	0.070	0.065	410.7	0.071	0.066
Restaurant	355.6	0.073	0.051	588.4	0.121	0.085	594.8	0.122	0.085
School	163.9	0.037	0.026	271.1	0.061	0.042	274.1	0.062	0.043
Small Office	211.9	0.048	0.039	350.6	0.080	0.065	354.4	0.081	0.066
Small Retail/Service	253.8	0.055	0.043	419.9	0.092	0.071	424.5	0.093	0.072
Unconditioned Warehouse	152.9	0.032	0.034	253.0	0.052	0.056	255.8	0.053	0.057
Garage (Ohio)	481.8	0.055	0.055	797.2	0.091	0.091	805.9	0.092	0.092
Exterior (Ohio)	236.5	0.000	0.000	391.3	0.000	0.000	395.6	0.000	0.000

Measure Savings Analysis

Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Baseline and retrofit equipment assumptions are listed in the table below.

Table 26. Baseline and Retrofit Wattages for Hardwired Compact Fluorescent Fixtures

Measure Name	Pre Measure Code	Pre Fixture Description	Watts/Fixture (PRE)	Post Measure Code	Post Fixture Description	Watts/Fixture (POST)
Interior HW CFL - 29W or Less	I75/1	Incandescent, (1) 75W lamp	75	CFM18/1-L	Compact Fluorescent, Multi, 4-pin, (1) 18W lamp	20
Interior HW CFL - 30W to 60W	I150/1	Incandescent, (1) 150W lamp	150	CFM57/1-L	CFL, Multi, 4-pin, (1) 57 W Lamp	59
Interior HW CFL - 61W to 120 W	I200/1	Incandescent, (1) 200W lamp	200	CFT50/2-BX	Compact Fluorescent, Biax, (2) 50W lamp	108

Measure Life and Incremental Measure Cost
The measure life is 12 years per DEER 2008. The IMC is $95 for ≤29 W and $132 for >30W per fixture per DNV KEMA's research/experience.

Cold Cathode

Measure Description	All cold cathode fluorescent lamps (CCFLs) must replace incandescent lamps of at least 10 W. Cold cathode lamps may be medium (Edison) or candelabra base. Product must be rated for at least 18,000 average life hours.
Units	Per lamp
Base Case Description	Incandescent

Measure Savings
Baseline and retrofit equipment assumptions are presented in table below.

Table 27. Cold Cathode Measure Savings, per lamp

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	56.7	0.012	0.013
College/University	57.9	0.020	0.013
Conditioned Warehouse	64.5	0.013	0.014
Government/Municipal	67.7	0.014	0.010
Grocery	110.9	0.015	0.022
Hotel/Motel	128.2	0.005	0.013
Guest Rooms	18.4	0.005	0.013
Large Office	78.8	0.016	0.016

Building Type	kWh	OH peak kW	PJM peak kW
Large Retail/Service	93.2	0.019	0.016
Manufacturing – Light Industrial (1 shift)	58.9	0.016	0.015
Manufacturing – Light Industrial (2 shift)	97.4	0.016	0.015
Manufacturing – Light Industrial (3 shift)	136.6	0.016	0.015
Medical – Hospital	110.3	0.024	0.015
Medical - Nursing Home	95.8	0.018	0.015
Miscellaneous	89.3	0.015	0.014
Restaurant	129.3	0.027	0.019
School	59.6	0.013	0.009
Small Office	77.1	0.018	0.014
Small Retail/Service	92.3	0.020	0.016
Unconditioned Warehouse	55.6	0.012	0.012
Garage (Ohio)	175.2	0.020	0.020
Exterior (Ohio)	86.0	0.000	0.000

Measure Savings Analysis
Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Cold cathode lighting is assumed to follow the operating hours and use the coincidence and energy factors of CFL lighting. Baseline and retrofit equipment assumptions are listed in the table below.

Table 28. Baseline and Retrofit Wattages for Cold Cathode Lamps

	Pre	Post
Measure Code	I25/1	CFC5/1-SCRW
Description	Incandescent, (1) 25W lamp	CFL Cold Cathode (1) 5W screw-in Lamp, any bulb shape
Watts/Fixture	25	5

Measure Life and Incremental Measure Cost

The measure life is 5 years per SCE workpapers[6]. The IMC is $9.68 per PG&E workpapers[7].

Specialty Screw-in CFL

Measure Description	Replacing existing incandescent, metal halide, induction or other non-CFL lamps with specialty CFLs, such as PAR, 3-way or dimmable lamps. These lamps must meet ENERGY STAR® criteria, if available for the type of lamp. Maximum replacement wattage lamp is 40W. Lamps must have an efficacy ≥40 LPW.
Units	Per lamp
Base Case Description	Non-compact fluorescent lamp

Measure Savings
The savings are presented in the following table. Measure life of less than 3 years does not qualify for the PJM market and hence no PJM peak kW savings are claimed.

Table 29. Specialty Screw-in CFL Measure Savings, per lamp

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	155.9	0.033	0.036
College/University	159.2	0.055	0.037
Conditioned Warehouse	177.4	0.037	0.038
Government/Municipal	186.1	0.039	0.028
Grocery	304.8	0.041	0.062
Hotel/Motel	352.4	0.014	0.035
Guest Rooms	50.5	0.014	0.035
Large Office	216.6	0.045	0.043
Large Retail/Service	256.3	0.053	0.045
Manufacturing – Light Industrial (1 shift)	161.8	0.045	0.042
Manufacturing – Light Industrial (2 shift)	268.0	0.045	0.042
Manufacturing – Light Industrial (3 shift)	375.6	0.045	0.042
Medical - Hospital	303.2	0.067	0.042
Medical - Nursing Home	263.6	0.049	0.042

[6] Southern California Edison Company, Cold Cathode Fluorescent Lamp Workpaper WPSCNRLG0063. 2007.
[7] Pacific Gas & Electric, Lighting WP.doc, 2006.

Building Type	kWh	OH peak kW	PJM peak kW
Miscellaneous	245.5	0.043	0.040
Restaurant	355.6	0.073	0.051
School	163.9	0.037	0.026
Small Office	211.9	0.048	0.039
Small Retail/Service	253.8	0.055	0.043
Unconditioned Warehouse	152.9	0.032	0.034
Garage (Ohio)	481.8	0.055	0.055
Exterior (Ohio)	236.5	0.000	0.000

Measure Savings Analysis
Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Specialty screw-in CFL lighting is assumed to follow the operating hours and use the coincidence and energy factors of CFL lighting. Baseline and retrofit equipment assumptions are listed in the table below.

Table 30. Baseline and Retrofit Wattages for Specialty Screw-in Compact Fluorescent Lamps

	Pre	Post
Measure Code	I75/1	CFS20/1
Description	Incandescent, (1) 75W lamp	Compact Fluorescent, spiral, (1) 20W lamp
Watts/Fixture	75	20

Measure Life and Incremental Measure Cost
The measure life is 2.5 years per DEER 2008. The IMC is $47 per DNV KEMA's research/experience.

Compact Fluorescent Lamps, Screw-in

Measure Description	This incentive applies to screw-in lamps and applies only if an incandescent or high-intensity discharge (HID) lamp is being replaced. All screw-in CFLs must be ENERGY STAR® rated. The lamp/ballast combination must have an efficacy ≥40 lumens per Watt (LPW). For screw-in CFLs, electronic ballasts are required for lamps ≥18 Watts.
Units	Per lamp
Base Case Description	Non-compact fluorescent lamps.

Measure Savings

The savings are presented in the following table. All wattage categories refer to retrofit wattage and not baseline wattage. Measure life of less than 3 years does not qualify for the PJM market and hence no PJM peak kW savings are claimed.

Table 31. Measure Savings for Screw-in CFL, per lamp

Building Type	≤15W			16-26W			27-40W		
	kWh	OH peak kW	PJM peak kW	kWh	OH peak kW	PJM peak kW	kWh	OH peak kW	PJM peak kW
Assembly	90.7	0.019	0.021	170.1	0.036	0.039	209.8	0.044	0.048
College/University	92.6	0.032	0.022	173.7	0.060	0.040	214.2	0.074	0.050
Conditioned Warehouse	103.2	0.022	0.022	193.5	0.040	0.042	238.6	0.050	0.051
Government/Municipal	108.3	0.023	0.016	203.1	0.043	0.030	250.5	0.053	0.037
Grocery	177.4	0.024	0.036	332.6	0.045	0.067	410.2	0.056	0.083
Hotel/Motel	205.0	0.008	0.020	384.5	0.016	0.038	474.2	0.019	0.047
Guest Rooms	29.4	0.008	0.020	55.1	0.016	0.038	68.0	0.019	0.047
Large Office	126.0	0.026	0.025	236.3	0.049	0.047	291.5	0.060	0.058
Large Retail/Service	149.1	0.031	0.026	279.6	0.057	0.049	344.8	0.071	0.061
Manufacturing – Light Industrial (1 shift)	94.2	0.026	0.024	176.6	0.049	0.046	217.8	0.061	0.057
Manufacturing – Light Industrial (2 shift)	155.9	0.026	0.024	292.3	0.049	0.046	360.5	0.061	0.057
Manufacturing – Light Industrial (3 shift)	218.6	0.026	0.024	409.8	0.049	0.046	505.4	0.061	0.057
Medical - Hospital	176.4	0.039	0.025	330.8	0.073	0.046	408.0	0.090	0.057
Medical - Nursing Home	153.3	0.028	0.025	287.5	0.053	0.046	354.6	0.066	0.057
Miscellaneous	142.8	0.025	0.023	267.8	0.046	0.043	330.3	0.057	0.053
Restaurant	206.9	0.043	0.030	387.9	0.080	0.056	478.4	0.098	0.069

School	95.3	0.022	0.015	178.8	0.040	0.028	220.5	0.050	0.034
Small Office	123.3	0.028	0.023	231.2	0.053	0.043	285.1	0.065	0.053
Small Retail/Service	147.6	0.032	0.025	276.8	0.060	0.047	341.4	0.075	0.058
Unconditioned Warehouse	89.0	0.018	0.020	166.8	0.035	0.037	205.7	0.043	0.046
Garage (Ohio)	280.3	0.032	0.032	525.6	0.060	0.060	648.2	0.074	0.074
Exterior (Ohio)	137.6	0.000	0.000	258.0	0.000	0.000	318.2	0.000	0.000

Measure Savings Analysis
Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Baseline and retrofit equipment assumptions are presented in the next table. Most lighting retrofits assume an early replacement of existing technologies where the baseline represents the equipment removed. The table shows the wattages used for the savings calculations.

Table 32. Baseline and Retrofit Wattages for Screw-in CFLs

Measure Name	Pre Measure Code	Pre Fixture Description	Watts/Fixture (PRE)	Post Measure Code	Post Fixture Description	Watts/Fixture (POST)
Interior CFL - Screw-in (15W or less)	I40/1	Incandescent, (1) 40W lamp	40	CF8/1-SCRW	CFL, (1) 8 W screw-in Lamp, any bulb shape	8
Interior CFL - Screw-in (16W to 26W)	I75/1	Incandescent, (1) 75W lamp	75	CF15/1-SCRW	CFL, (1) 15 W screw-in Lamp, any bulb shape	15
Interior CFL - Screw-in (27W to 40W)	I100/1	Incandescent, (1) 100W lamp	100	CF26/1-SCRW	CFL, (1) 26 W screw-in Lamp, any bulb shape	26

Measure Life and Incremental Measure Cost
The measure life is 2.5 years per DEER 2008. The IMC is $4.13 per AEP Ohio Potential Study.

Occupancy Sensors

Measure Description	Passive infrared, ultrasonic detectors and fixture-integrated sensors or sensors with a combination thereof are eligible. All sensors must be hard-wired and control interior lighting fixtures. The incentive is per Watt controlled.
Units	Per Connected Watt

Base Case Description	No Sensor

Measure Savings

The following table summarizes the measure savings.

Table 33. Measure Savings for Occupancy Sensor per Connected Watt

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	0.85	0.00007	0
College/University	0.86	0.00007	0
Conditioned Warehouse	1.20	0.00005	0
Government/Municipal	0.95	0.00006	0
Grocery	2.10	0.00007	0
Hotel/Motel	2.36	0.00007	0
Guest Rooms	0.28	0.00007	0
Large Office	0.99	0.00006	0
Large Retail/Service	1.27	0.00006	0
Manufacturing – Light Industrial (1 shift)	0.88	0.00005	0
Manufacturing – Light Industrial (2 shift)	1.46	0.00005	0
Manufacturing – Light Industrial (3 shift)	2.05	0.00005	0
Medical - Hospital	1.98	0.00008	0
Medical - Nursing Home	1.71	0.00007	0
Miscellaneous	1.45	0.00006	0
Restaurant	1.94	0.00007	0
School	0.82	0.00005	0
Small Office	0.97	0.00006	0
Small Retail/Service	1.21	0.00006	0
Unconditioned Warehouse	1.03	0.00005	0

Measure Savings Analysis

Annual energy savings and the peak coincident demand savings are calculated using the Operating hours, energy, and demand factors outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Baseline and retrofit equipment assumptions are variable. Because we define this measure with the number of watts reduced, the non-coincident demand savings will be one watt by definition.

Energy savings are calculated by applying the annual operating hours and the energy interactive effect, according to the following formula:

*kWh Reduction = Connected wattage/1000 * Annual operating hours * Energy interactive effect*Energy Savings Factor*

Coincident demand savings are calculated by applying the coincidence factor and the demand interactive effect, according to the following formula:

*Coincident kW savings = Connected wattage/1000 * Energy Savings Factor * Coincidence Factor * Demand interactive effect*

The Ohio TRM defines the Energy Savings Factor for Occupancy Sensors as 30%. The Ohio TRM also defines the summer peak coincidence factor for occupancy sensors as 0.15.[8] The baseline for this measure is fixtures that do not include any automatic controls, i.e., manual switches. Since the unit is defined as per connected Watt, the baseline demand is one watt. The PJM does not recognize peak kW savings for controls.

Measure Life and Incremental Measure Cost
The measure life is 8 years per DEER 2008. The IMC is $0.38 per Ohio TRM, if it is assumed that 4, 2-lamp T8 fixtures are controlled per sensor and one 4-lamp T5 high output for integrated fixture.

Daylighting Controls

Measure Description	This measure consists of the installation of daylighting controls in spaces with reasonable amounts of sunlight exposure and areas where task lighting is not critical.
Units	Per watt controlled
Base Case Description	No lighting controls

This measure consists of the installation of daylighting controls. These systems use photoelectric controls to take advantage of available daylight in interior building spaces. These controls can be used to turn lights off/on, A-B switching, or stepped or continuous dimming. The on/off controller should turn off artificial lighting when the interior illuminance meets the desired

[8] Ohio TRM, Page 151. This value is consistent with the " Coincidence Factor Study Residential and Commercial Industrial Lighting Measures", Spring 2007, prepared for the New England State Program Working Group, prepared by RLW Analytics.

indoor lighting level. Daylight sensor controls are required to be commissioned in order to ensure proper sensor calibration and energy savings.

Measure Savings

The following table summarizes the measure savings.

Table 34. Measure Savings for Daylighting Controls per Watt Controlled

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	0.85	0.000066	0
College/University	0.86	0.000068	0
Conditioned Warehouse	1.20	0.000053	0
Government/Municipal	0.95	0.000062	0
Grocery	2.10	0.000068	0
Hotel/Motel	2.36	0.000068	0
Guest Rooms	0.28	0.000068	0
Large Office	0.99	0.000059	0
Large Retail/Service	1.27	0.000065	0
Manufacturing – Light Industrial (1 shift)	0.88	0.000048	0
Manufacturing – Light Industrial (2 shift)	1.46	0.000048	0
Manufacturing – Light Industrial (3 shift)	2.05	0.000048	0
Medical - Hospital	1.98	0.000076	0
Medical - Nursing Home	1.71	0.000071	0
Miscellaneous	1.45	0.000059	0
Restaurant	1.94	0.000074	0
School	0.82	0.000047	0
Small Office	0.97	0.000059	0
Small Retail/Service	1.21	0.000065	0
Unconditioned Warehouse	1.03	0.000045	0

Measure Savings Analysis

Annual energy savings and the peak coincident demand savings are calculated using the operating hours, energy, and demand factors outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Baseline and retrofit equipment assumptions are variable. Because we define this measure with the number of watts reduced, the non-coincident demand savings will be one watt by definition.

Energy savings are calculated by applying the annual operating hours and the energy interactive effect, according to the following formula:

*kWh Reduction = Connected wattage/1000 * Annual operating hours * Energy interactive effect*Energy Savings Factor*

Coincident demand savings are calculated by applying the coincidence factor and the demand interactive effect, according to the following formula:

*Coincident kW savings = Connected wattage/1000 * Energy Savings Factor * Coincidence Factor * Demand interactive effect*

The Ohio TRM defines the energy savings factor for daylighting as 30%. The Ohio TRM also defines the summer peak coincidence factor for daylighting sensors as 0.9[9] The baseline for this measure is fixtures that do not include any automatic controls, i.e., manual switches. The PJM does not recognize peak kW savings for controls.

Measure Life and Incremental Measure Cost

The measure life is 8 years per DEER 2008. The IMC is $0.28 per the Ohio TRM, if it is assumed that 4, 2-lamp T8 fixtures are controlled per sensor (at $65 per sensor).

Daylighting Controls with Occupancy Sensors

Measure Description	This measure consists of the installation of both occupancy sensors daylighting controls to control the same fixture(s). These systems use photoelectric controls to take advantage of available daylight in interior building spaces, as well as occupancy controls to shut off the light when the ambient light from outdoors is low, and no one is using the space. These controls can be used to turn lights off/on, A-B switching, or stepped or continuous dimming. The on/off controller should turn off artificial lighting when the interior illuminance meets the desired indoor lighting level. Daylight sensor controls are required to be commissioned in order to ensure proper sensor calibration and energy savings.
Units	Per watt controlled
Base Case	No lighting controls

[9] Ohio TRM, Page 151

Description	

Measure Savings

The following table summarizes the measure savings.

Table 35. Measure Savings for Daylighting Controls with Occupancy Sensors per Watt Controlled

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	0.91	0.00042	0
College/University	0.93	0.00043	0
Conditioned Warehouse	1.29	0.00034	0
Government/Municipal	1.02	0.00040	0
Grocery	2.25	0.00044	0
Hotel/Motel	2.53	0.00044	0
Guest Rooms	0.30	0.00044	0
Large Office	1.07	0.00038	0
Large Retail/Service	1.36	0.00042	0
Manufacturing – Light Industrial (1 shift)	0.95	0.00031	0
Manufacturing – Light Industrial (2 shift)	1.57	0.00031	0
Manufacturing – Light Industrial (3 shift)	2.20	0.00031	0
Medical - Hospital	2.12	0.00049	0
Medical - Nursing Home	1.84	0.00045	0
Miscellaneous	1.55	0.00038	0
Restaurant	2.08	0.00048	0
School	0.88	0.00030	0
Small Office	1.04	0.00038	0
Small Retail/Service	1.30	0.00042	0
Unconditioned Warehouse	1.11	0.00029	0

Measure Savings Analysis

Annual energy savings and the peak coincident demand savings are calculated using the operating hours, energy, and demand factors outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Baseline and retrofit equipment assumptions are variable. Because we define this measure with the number of watts reduced, the non-coincident demand savings will be one watt by definition.

Energy savings are calculated by applying the annual operating hours and the energy interactive effect, according to the following formula:

*kWh Reduction = Connected wattage/1000 * Annual operating hours * Energy interactive effect*Energy Savings Factor*

Coincident demand savings are calculated by applying the coincidence factor and the demand interactive effect, according to the following formula:

*Coincident kW savings = Connected wattage/1000 * Energy Savings Factor * Coincidence Factor * Demand interactive effect*

The Ohio TRM defines the energy savings factor for daylighting as 30%, and from occupancy sensors as 30%. A model of a typical day in an office was created, to estimate how much of these savings might have overlapped, and the combined energy savings factor was calculated to be 0.322. The Ohio TRM also defines the summer peak coincidence factor for daylighting sensors as 0.9[10] The baseline for this measure is fixtures that do not include any automatic controls, i.e., manual switches. Since the unit is defined as per connected Watt, the baseline demand is one watt. The PJM does not recognize peak kW savings for controls.

Measure Life and Incremental Measure Cost
The measure life is 8 years per DEER 2008. The IMC is $0.66 per Watt controlled based on DNV KEMA estimations informed by the Ohio TRM.

Bi-level Exterior or Garage Lighting Fixtures

Measure Description	The lighting system must have stepped-dimming occupancy controls that operates at full power and full light output when the space is occupied and at reduced power level and reduced light output (at least 50%) when unoccupied. The sensors must control exterior or parking garage lighting fixtures, must be hard-wired, and can be passive-infrared occupancy sensor or microwave occupancy sensor.
Units	Total Watts controlled of fixture at full light output
Base Case Description	Fixture at full level output

[10] Ohio TRM, Page 151

Measure Savings

Table 36. Measure Savings for Bi-level Exterior or Garage Lighting Fixtures

Building Type	kWh	OH peak kW	PJM peak kW
Garage (Ohio)	1.31	0.00014	0.0000
Exterior (Ohio)	0.65	0.00000	0.0000

Measure Savings Analysis
This measure assumes that the sensor would be able to dim down the bi-level fixture 50% at least 30% of the time. Operating hours for garage and exterior are from the lighting calculation section near the beginning of this document. Equations for the energy and demand savings are provided below:

Energy Savings = Watts Controlled x Operating Hours x 50% x 30% / 1000

Demand Savings = Watts Controlled x 50% x 30% x DIF x CF

Measure Life and Incremental Measure Cost
The measure life is 8 years per DEER 2005. The IMC is $0.19 per watt controlled based on DNV KEMA analysis.

Photocells

Measure Description	Installing photo cells on exterior lighting They switch outdoor lights on at dusk and off at dawn.
Units	Per Watt Controlled
Base Case Description	Existing controls are with time clock, only.

Photocells control lighting fixtures by sensing the amount of sunlight in the area and switching lights off when enough sunlight is present. The measure assumes that the existing exterior lights are controlled by a time clock and the measure retrofits those with a new photocell. Photo cells must control the on/off schedule of lighting equipment based upon the safety guidelines that determine the appropriate footcandle requirements for the area being controlled by photo cell.

Measure Savings
The coincident peak kW is 0 and kWh savings is 0.47 kWh/year per controlled wattage.

Measure Savings Analysis
Without, exterior lights are assumed to operate approximately 4,300 hours per year, based on approximately 12 hours per day. With a photocell, the lights would operate approximately 10.5 hours per day according to the Ohio TRM. The energy savings factor is calculated using the following expression:

ESF = (4300 – 3833) / 4300 = 0.109

Energy savings are calculated by applying the annual operating hours and the energy interactive factor, i.e. 1.0, according to the following formula:

*kWh Reduction = Connected wattage/1000 * ESF * EIF * 4300 = 0.47 kWh per watt controlled*

Coincident peak demand savings are zero, since the savings occur off peak.

Measure Life and Incremental Measure Cost
The measure life is 8 years per DEER 2008. The IMC is $0.18 per DEER 2005, if it is assumed that (4) 70W metal halide fixtures are controlled per sensor (at $60 per sensor).

Time Clocks for Lighting

Measure Description	Time clocks are an electrical device that control lighting equipment by turning the equipment on and off according to a set schedule. This measure applies to both internal and external lighting. These clocks can program lights to switch off during weekends, for example. The time clocks must be installed with a 3 hour battery pack so that schedule information will not be lost during any power outages. Astronomical time clocks (where on-off times are in accordance with sunrise and sunset) are required for outdoor lighting when photocells are not in use.
Units	Per Watt Controlled
Base Case Description	No control system

Measure Savings

Table 37. Measure Savings for TimeClock Lighting Controls per Watt Controlled

Building Type	kWh	Peak kW

Building Type	kWh	Peak kW
Assembly	0.283	0
College/University	0.288	0
Conditioned Warehouse	0.399	0
Government/Municipal	0.317	0
Grocery	0.699	0
Hotel/Motel	0.786	0
Guest Rooms	0.092	0
Large Office	0.331	0
Large Retail/Service	0.422	0
Manufacturing – Light Industrial (1 shift)	0.294	0
Manufacturing – Light Industrial (2 shift)	0.487	0
Manufacturing – Light Industrial (3 shift)	0.683	0
Medical - Hospital	0.659	0
Medical - Nursing Home	0.571	0
Miscellaneous	0.482	0
Restaurant	0.647	0
School	0.274	0
Small Office	0.324	0
Small Retail/Service	0.403	0
Unconditioned Warehouse	0.344	0
Garage (Ohio)	0.876	0
Exterior (Ohio)	0.430	0

Measure Savings Analysis
Energy savings are calculated by applying the annual operating hours, energy savings factor, and the energy interactive factor, according to the following formula:

*kWh Reduction = Connected wattage/1000 * Annual operating hours * Energy Savings Factor * Energy Interactive Factor*

Coincident demand savings are calculated by applying the coincidence factor and the demand interactive effect, according to the following formula:

*Coincident kW savings = Controlled wattage/1000 * Energy Savings Factor * Coincidence Factor * Demand interactive factor*

The Ohio TRM defines the energy savings factor for timeclocks is 10%. The Ohio TRM also defines the summer peak coincidence factor for occupancy sensors as 0.[11]

Measure Life and Incremental Measure Cost
The measure life is 8 years per DEER 2008. The IMC is $0.15 per the Ohio TRM, if it is assumed that 8, 70W metal halide fixtures are controlled per sensor (at $103 per sensor).

Photocells Plus Time Clocks for Lighting

Measure Description	Installing photocells and time clocks on exterior lighting. They switch outdoor lights on at dusk and off at dawn as well as on and off during periods of non-use typically 2am – 6am. See photocells and timeclocks for their specifications.
Units	Per Watt Controlled
Base Case Description	No control system

Measure Savings

Table 38. Measure Savings for Daylighting Controls per Connected Watt

Building Type	kWh	Coincident peak kW
Exterior (Ohio)	1.74	0

Measure Savings Analysis

It is assumed that the baseline is manual control, and adding a time clock will allow the customer to turn off their lights an additional 4 hours a night for 365 days/year, while the photocell saves 3 hours per day for 3 months, or 280 hours.

4 hours/day x 365 days/year x 1kW/1000W = 1.46 kWh/year
3 hours/day x 31 days x 3 months/year x 1kW/1000W=0.28 kWh/year.

[11] Ohio TRM, Page 151

1.46 kWh/year +0.28 kWh/year = 1.76 kWh/year.

Measure Life and Incremental Measure Cost
The measure life is 8 years per DEER 2008.

The IMC for photocell is $0.18 per DEER 2005, if it is assumed that (4) 70W metal halide fixtures are controlled per sensor (at $60 per sensor).

The IMC for timeclock is based on $103 per unit per the draft Ohio TRM. If a timeclock controls six 250W PS metal halide at 295W per fixture, then the cost is $0.06 per watt controlled.

Therefore, the combined incremental measure cost is $0.24 per watt controlled.

LED Traffic Signals

Measure Description	Signals shall have a maximum LED module wattage of 17. Credits are offered for LED traffic lights on a per-signal basis (including arrows) that replace or retrofit an existing incandescent traffic signal. At minimum, red and green lamps must be retrofitted to qualify for the signal credit. Lights must be hard-wired, with the exception of pedestrian hand signals. Credits are not available for spare lights.
Units	Per Signal
Base Case Description	Incandescent fixtures

LED traffic signals can save 80-90 percent of the energy typically consumed by incandescent traffic signals and LED signals generally last 5-10 times longer. Since traffic signals operate 24 hours a day, 365 days a year, the opportunity for energy savings is significant, particularly in the peak demand. LED Traffic signals perform better than incandescent models and are a better value. They also have lower maintenance costs because they need to be replaced less frequently.

Measure Savings
The energy savings vary for red, green and yellow signals. Savings also vary for round lamps, arrows and pedestrian signals (per the OH TRM).

Table 39. Measure Savings Traffic and Pedestrian Signals, per signal

Measure Name	kWh	Coincident Peak kW
Green 8 inch ROUND	226.0	0.026
Green 12 inch ROUND	519.8	0.059
Yellow 8 inch ROUND	10.3	0.001
Yellow 12 inch ROUND	24.0	0.003
Red 8 inch ROUND	298.7	0.034
Red 12 inch ROUND	693.8	0.079
Green 8 inch ARROW	76.4	0.011
Green 12 inch ARROW	76.4	0.011
Yellow 8 inch ARROW	76.4	0.002
Yellow 12 inch ARROW	75.0	0.002
Red 8 inch ARROW	76.4	0.098
Red 12 inch ARROW	76.4	0.098
Walk/Don't Walk - 9 inch	946.1	0.108
Walk/Don't Walk - 12 inch	946.1	0.108

Measure Savings Analysis
Operating hours, coincident factors, and baseline and refrofit wattages are from values found in the Ohio TRM (pg 187). Reference for savings for Red Turn Arrows do not appear in the Ohio TRM, so specifications for Green Turn Arrows are used.

Measure Life and Incremental Measure Cost
The measure life is assumed to be 6 for traffic and 8 years for pedestrian signals. The IMC is $90 and $140 for traffic and pedestrian signal, respectively. Data is from the Michigan Statewide database 2010.

New Construction – Lighting Power Density

Measure Description	This measure consists of lighting retrofits exceeding ASHRAE 90.1-2007 lighting power density (LPD) requirements by at least 10% (maximum 50%).
Units	Per Watt Reduced
Base Case Description	ASHRAE 90.1 LPD - 2007

Measure Savings

The savings are presented in the following table.

Table 40. Lighting Power Density, per Watt Reduced

Building Type	kWh	OH peak kW	PJM peak kW
Assembly	2.83	0.000599	0.000655
College/University	2.88	0.001142	0.000672
Conditioned Warehouse	3.99	0.000819	0.000695
Government/Municipal	3.17	0.000856	0.000500
Grocery	6.99	0.001049	0.001124
Hotel/Motel	7.86	0.000310	0.000634
Guest Rooms	0.92	0.000262	0.000634
Large Office	3.31	0.000923	0.000779
Large Retail/Service	4.22	0.001169	0.000821
Manufacturing – Light Industrial (1 shift)	2.94	0.000978	0.000764
Manufacturing – Light Industrial (2 shift)	4.87	0.000978	0.000764
Manufacturing – Light Industrial (3 shift)	6.83	0.000978	0.000764
Medical - Hospital	6.59	0.001378	0.000766
Medical - Nursing Home	5.71	0.001062	0.000766
Miscellaneous	4.82	0.000891	0.000720
Restaurant	6.47	0.001331	0.000929
School	2.74	0.000665	0.000464
Small Office	3.24	0.000901	0.000717
Small Retail/Service	4.03	0.001260	0.000780
Unconditioned Warehouse	3.44	0.000700	0.000616
Garage (Ohio)	8.76	0.001000	0.001000
Exterior (Ohio)	4.30	0.000000	0.000000

Measure Savings Analysis

Annual energy savings and the peak coincident demand savings are calculated using the equations outlined in the Savings Calculation Methodology section at the beginning of the Lighting section.

Measure Life

The measure life is 11 years per DEER 2005, assuming that most are linear fluorscent. The IMC is $1.10 similar to new T5/T8 fixture retrofits.

Cooling

Cooling measures are eligible for prescriptive incentives. Most savings values stated here apply to both retrofit and new construction cases. Control measures, however, are only applicable under new construction if they not required by code. For example, variable speed drives are required under some conditions and therefore can not claim savings under those conditions.

Measures under the Self Direct program can also use this set of workpapers, however, unit replacement measures, such as package units, heat pumps, chillers, room air conditioners, or package terminal air conditioners, will require a different baseline to comply with the Ohio PUC's order for savings claimed to be based on an "as found" condition. Whereas building codes dictate the baseline for non-Self Direct replacement measures, the actual existing unit efficiency is used for the savings calculation in the Self Direct program. The savings calculation methodology, equivalent full load hours, and coincidence factors may be used for Self Direct claimed savings.

Unitary or Split Air Conditioning Systems and Air Source Heat Pumps

Measure Description	New unitary air conditioning units or air source heat pumps that meet or exceed the qualifying cooling efficiency shown in the table below are eligible for an incentive. They can be either split systems or single package units. Efficiencies of split systems are based on ARI reference numbers. Water-cooled systems, evaporative coolers, and water source heat pumps do not qualify under this program but may qualify under the Custom Incentive Program. All unitary and split-system cooling equipment must meet Air Conditioning, Heating and Refrigeration Institute (AHRI) standards (210/240, 320 or 340/360), be UL listed, and utilize a minimum ozone-depleting refrigerant (e.g., HCFC or HFC). A manufacturer's specification sheet indicating the system efficiency must accompany the application. Disposal of the existing unit must comply with local codes and ordinances.
Units	Ton
Base Case Description	IECC 2009 Efficiency Level

The following table are the program qualifying efficiencies.

Table 41. Program Qualifying Efficiencies

Unit Size (tons)	Unit Size (Btuh)	Minimum Efficiency (Cooling Mode)
≤ 5.4 tons	< 65,000 Btuh	14 SEER
5.4 - 20 tons	≥ 65,000 Btuh and <240,000 Btuh	12 EER/13 IEER
20-63 tons	≥240,000 Btuh and <760,000 Btuh	10.6 EER/12.1 IEER
≥ 63 tons	≥ 760,000 Btuh	10.2 EER/11.4 IEER

Measure Savings
The coincident kW and the annual kWh savings per ton of installed cooling system are provided below. Note that coincident kW savings do not vary with building type while kWh savings do.

Table 42. kWh Savings for Unitary or Split Air Conditioning Systems (per ton)

Business Type	< 5.4 tons	(5.4 - 11.24 tons	11.25 - 19.9 tons	20 - 63.2 tons	≥ 63.3 tons
Large Office	40.02	43.35	55.18	41.23	36.81
Small Office	34.24	37.10	47.21	35.28	31.50
School	30.34	32.87	41.83	31.25	27.90
Small Retail/Service	55.94	60.60	77.13	57.63	51.45
Large Retail/Service	59.40	64.35	81.90	61.19	54.63
Hotel/Motel	55.02	59.61	75.87	56.69	50.61
Medical - Hospital	77.45	83.91	106.79	79.79	71.24
Medical - Nursing Home	62.19	67.37	85.74	64.06	57.20
Assembly/Meeting Place	50.38	54.58	69.47	51.90	46.34
Restaurant	56.32	61.02	77.66	58.02	51.80
Grocery	64.68	70.07	89.18	66.63	59.49
Conditioned Warehouse	33.41	36.20	46.07	34.42	30.73
Unconditioned Warehouse	-	-	-	-	-
Industrial/Manufacturing	31.59	34.22	43.55	32.54	29.05
College/University	62.86	68.09	86.67	64.75	57.81
Government/Municipal	45.20	48.97	62.32	46.57	41.57
Other/Miscellaneous	51.26	55.54	70.68	52.81	47.15

Table 43. Ohio Peak kW Savings for Unitary or Split Air Conditioning Systems (per ton)

Business Type	< 5.4 tons	(5.4 - 11.24 tons	11.25 - 19.9 tons	20 - 63.2 tons	≥ 63.3 tons
Large Office	0.0342	0.0371	0.0472	0.0353	0.0315
Small Office	0.0298	0.0322	0.0410	0.0307	0.0274
School	0.0214	0.0231	0.0294	0.0220	0.0196
Small Retail/Service	0.0369	0.0400	0.0509	0.0381	0.0340
Large Retail/Service	0.0334	0.0362	0.0460	0.0344	0.0307
Hotel/Motel	0.0194	0.0210	0.0267	0.0200	0.0178
Medical - Hospital	0.0273	0.0296	0.0377	0.0282	0.0251
Medical - Nursing Home	0.0229	0.0248	0.0315	0.0235	0.0210
Assembly/Meeting Place	0.0318	0.0344	0.0438	0.0327	0.0292
Restaurant	0.0328	0.0355	0.0452	0.0338	0.0302
Grocery	0.0352	0.0381	0.0485	0.0363	0.0324
Conditioned Warehouse	0.0263	0.0285	0.0363	0.0271	0.0242
Unconditioned Warehouse	-	-	-	-	-

Industrial/Manufacturing	0.0251	0.0272	0.0346	0.0259	0.0231
College/University	0.0311	0.0337	0.0429	0.0321	0.0286
Government/Municipal	0.0330	0.0358	0.0455	0.0340	0.0304
Other/Miscellaneous	0.0292	0.0317	0.0403	0.0301	0.0269

Table 44. PJM Peak kW Savings for Unitary or Split Air Conditioning Systems (per ton)

Business Type	< 5.4 tons	(5.4 - 11.24 tons	11.25 - 19.9 tons	20 - 63.2 tons	≥ 63.3 tons
Large Office	0.0339	0.0367	0.0467	0.0349	0.0312
Small Office	0.0293	0.0318	0.0404	0.0302	0.0270
School	0.0218	0.0236	0.0301	0.0225	0.0201
Small Retail/Service	0.0365	0.0395	0.0503	0.0376	0.0336
Large Retail/Service	0.0331	0.0359	0.0456	0.0341	0.0304
Hotel/Motel	0.0192	0.0208	0.0265	0.0198	0.0176
Medical - Hospital	0.0271	0.0293	0.0374	0.0279	0.0249
Medical - Nursing Home	0.0226	0.0244	0.0311	0.0232	0.0208
Assembly/Meeting Place	0.0320	0.0347	0.0442	0.0330	0.0295
Restaurant	0.0328	0.0355	0.0452	0.0338	0.0302
Grocery	0.0349	0.0378	0.0482	0.0360	0.0321
Conditioned Warehouse	0.0260	0.0282	0.0359	0.0268	0.0239
Unconditioned Warehouse	-	-	-	-	-
Industrial/Manufacturing	0.0249	0.0270	0.0344	0.0257	0.0229
College/University	0.0318	0.0344	0.0438	0.0327	0.0292
Government/Municipal	0.0330	0.0357	0.0455	0.0340	0.0303
Other/Miscellaneous	0.0292	0.0316	0.0402	0.0301	0.0268

Savings are also provided on a per unit efficiency (SEER or EER/ IEER) increment over the Qualifying Program efficiency. Units are per unit SEER/EER/IEER efficiency improvement per ton.

Table 45. Incremental kWh Savings for Unitary or Split Air Conditioning Systems (per unit efficiency over Qualifying Efficiency per ton)

Business Type	< 5.4 tons	(5.4 - 11.24 tons	11.25 - 19.9 tons	20 - 63.2 tons	≥ 63.3 tons
Large Office	40.02	54.19	55.18	68.71	73.61
Small Office	34.24	46.37	47.21	58.80	62.99
School	30.34	41.08	41.83	52.09	55.80

Small Retail/Service	55.94	75.75	77.13	96.05	102.90
Large Retail/Service	59.40	80.44	81.90	101.99	109.26
Hotel/Motel	55.02	74.51	75.87	94.48	101.22
Medical - Hospital	77.45	104.89	106.79	132.99	142.48
Medical - Nursing Home	62.19	84.21	85.74	106.77	114.39
Assembly/Meeting Place	50.38	68.23	69.47	86.51	92.68
Restaurant	56.32	76.27	77.66	96.71	103.61
Grocery	64.68	87.59	89.18	111.06	118.98
Conditioned Warehouse	33.41	45.24	46.07	57.37	61.46
Unconditioned Warehouse	-	-	-	-	-
Industrial/Manufacturing	31.59	42.77	43.55	54.23	58.10
College/University	62.86	85.12	86.67	107.92	115.62
Government/Municipal	45.20	61.21	62.32	77.61	83.15
Other/Miscellaneous	51.26	69.42	70.68	88.02	94.30

Table 46. Incremental Ohio Peak kW Measure Savings for Unitary or Split Air Conditioning Systems (per unit efficiency over Qualifying Efficiency per ton)

Business Type	< 5.4 tons	(5.4 - 11.24 tons	11.25 - 19.9 tons	20 - 63.2 tons	≥ 63.3 tons
Large Office	0.03424	0.04637	0.04721	0.05879	0.06298
Small Office	0.02975	0.04029	0.04102	0.05108	0.05473
School	0.02136	0.02892	0.02945	0.03667	0.03929
Small Retail/Service	0.03694	0.05002	0.05093	0.06342	0.06795
Large Retail/Service	0.03339	0.04522	0.04604	0.05734	0.06143
Hotel/Motel	0.01937	0.02623	0.02671	0.03326	0.03563
Medical - Hospital	0.02734	0.03702	0.03769	0.04694	0.05029
Medical - Nursing Home	0.02285	0.03095	0.03151	0.03924	0.04204
Assembly/Meeting Place	0.03177	0.04303	0.04381	0.05456	0.05845
Restaurant	0.03280	0.04442	0.04523	0.05632	0.06034
Grocery	0.03521	0.04768	0.04855	0.06045	0.06477
Conditioned Warehouse	0.02634	0.03567	0.03632	0.04523	0.04846
Unconditioned Warehouse	-	-	-	-	-
Industrial/Manufacturing	0.02511	0.03400	0.03462	0.04311	0.04619
College/University	0.03112	0.04214	0.04291	0.05344	0.05725
Government/Municipal	0.03301	0.04470	0.04551	0.05667	0.06072
Other/Miscellaneous	0.02924	0.03959	0.04031	0.05020	0.05378

Table 47. Incremental PJM Peak kW Measure Savings for Unitary or Split Air Conditioning Systems (per unit efficiency over Qualifying Efficiency per ton)

Business Type	< 5.4 tons	(5.4 - 11.24 tons	11.25 - 19.9 tons	20 - 63.2 tons	≥ 63.3 tons
Large Office	0.03389	0.04589	0.04673	0.05819	0.06234
Small Office	0.02933	0.03972	0.04044	0.05036	0.05396
School	0.02181	0.02953	0.03007	0.03744	0.04011
Small Retail/Service	0.03651	0.04943	0.05033	0.06268	0.06715
Large Retail/Service	0.03310	0.04482	0.04563	0.05683	0.06088
Hotel/Motel	0.01919	0.02599	0.02646	0.03295	0.03530
Medical - Hospital	0.02709	0.03668	0.03735	0.04651	0.04983
Medical - Nursing Home	0.02256	0.03055	0.03111	0.03874	0.04151
Assembly/Meeting Place	0.03204	0.04339	0.04418	0.05501	0.05894
Restaurant	0.03279	0.04441	0.04521	0.05631	0.06032
Grocery	0.03494	0.04731	0.04817	0.05998	0.06426
Conditioned Warehouse	0.02602	0.03523	0.03587	0.04467	0.04786
Unconditioned Warehouse	-	-	-	-	-
Industrial/Manufacturing	0.02492	0.03375	0.03437	0.04280	0.04585
College/University	0.03176	0.04301	0.04380	0.05454	0.05843
Government/Municipal	0.03297	0.04464	0.04545	0.05660	0.06064
Other/Miscellaneous	0.02919	0.03953	0.04025	0.05012	0.05369

Measure Savings Analysis

Savings values are determined for units with efficiency levels listed which exceed IECC 2009 (or ASHRAE 2007) efficiency levels which is the existing state of Ohio code.

Table 48. Demand Savings and Efficiency Assumptions

Size (Tons)	IECC 2009	Program Qualifying	SEER or EER
≤ 5.4	13	14	SEER
5.4 – 11.25	11.2	12, 13	EER, IEER
11.25 – 20	11	12, 13	EER, IEER
20-63	10	10.6, 12.1	EER, IEER
≥ 63	9.7	10.2, 11.4	EER, IEER

Equivalent Full Load Cooling Hours (EFLCH) were determined by utilizing DOE-2 models generated with eQUEST software for chillers, using Columbus Ohio weather data. See the section on water cooled chillers for more information on those models. The EFLHs were determined by taking the annual MBTUH, and dividing by the rated full load capacity of the chiller, MBTU, both of which can be found in the PV-A and PS-A eQuest reports using Columbus, OH TMY3 data. The equation below describes how the EFLHs were determined:

EFLH = Total Annual Cooling Load (MBTU) / Rated Chiller Loop Capacity (MBTU/HR)

The EFLHs for the different chiller models were averaged by building types and are shown in the table below.

Table 49. Equivalent Full Load Cooling Hours, Columbus, OH

Business Type	Centrifugal	Scroll or Helical Rotary	Recipro-cating	Air Cooled	Average
Large Office	591.7	595.1	594.5	646.6	607.0
Small Office	506.1	510.0	508.9	552.5	519.4
School	448.2	449.9	448.5	493.9	460.1
Small Retail/Service	835.9	839.0	835.2	883.5	848.4
Large Retail/Service	887.1	890.9	888.4	937.2	900.9
Hotel/Motel	832.9	836.1	833.5	835.6	834.5
Medical - Hospital	1,158.7	1,164.6	1,163.8	1,211.8	1,174.7
Medical - Nursing Home	931.5	936.0	934.3	970.8	943.1
Assembly/Meeting Place	755.1	757.0	752.5	791.9	764.1
Restaurant	845.7	847.6	842.5	881.2	854.2
Grocery	981.6	983.0	975.0	984.4	981.0
Conditioned Warehouse	548.7	549.5	545.0	383.8	506.7
Unconditioned Warehouse					-
Industrial/Manufacturing	479.5	480.5	477.3	479.0	479.1
College/University	926.3	929.8	927.6	1,029.6	953.3
Government/Municipal	673.4	676.0	673.5	719.2	685.5
Other/Miscellaneous	768.7	771.5	768.5	801.3	777.5

The annual kWh savings/ton were determined using the following equation:

kWh Savings/ton = (12/Baseline EER/SEER -12/Post Case EER/SEER) x EFLH

The incremental kWh savings/ton were determined using the following equation:

Incremental kWh Savings/ton = kWh Savings/ton / (Post Case EER/SEER - Baseline EER/SEER)

The peak AEP and PJM kW savings were determined by first finding out the peak AEP and peak PJM coincidence factors for the AEP building types, using the Columbus, Ohio chiller models 8760 hourly data outputs. Baseline and efficiency case kW values were tabulated for the 8760 hours in the TMY3 year for each chiller model and building type. The average kW savings which occurred during the peak periods (3:00 – 6:00 PM for AEP, 2:00 – 6:00 PM for PJM, both June 1 – August 31st excluding weekends and federal holidays) were divided by the non coincident kW savings from the efficiency gain, to determine the CFs. The peak kW savings were simply determined by multiplying the non-coincident kW savings/ton for air conditioning by the coincidence factors determined from the models, per the equation shown below.

Peak kW savings = (12/Baseline (S)EER -12/Post Case (S)EER) x CF

Table 50. AEP Coincidence Factors AEP Building Types, Determined from Columbus Ohio Chiller Models

Business Type	Water cooled, electrically operated, centrifugal	Water cooled, electrically operated, positive displacement	Air Cooled	Average
Large Office	0.5224	0.5025	0.5331	0.5193
Small Office	0.4561	0.4322	0.4654	0.4512
School	0.3365	0.3071	0.3283	0.3239
Small Retail/Service	0.5880	0.5407	0.5521	0.5602
Large Retail/Service	0.5294	0.4871	0.5030	0.5065
Hotel/Motel	0.3125	0.2868	0.2820	0.2938
Medical - Hospital	0.4276	0.3976	0.4186	0.4146
Medical - Nursing Home	0.3574	0.3290	0.3534	0.3466
Assembly/Meeting Place	0.5211	0.4564	0.4683	0.4819
Restaurant	0.5369	0.4735	0.4821	0.4975
Grocery	0.5832	0.5412	0.4776	0.5340
Conditioned Warehouse	0.4101	0.3862	0.4024	0.3995
Unconditioned Warehouse				
Industrial/Manufacturing	0.4078	0.3605	0.3743	0.3808
College/University	0.4848	0.4484	0.4828	0.4720

Government/Municipal	0.5217	0.4794	0.5007	0.5006
Other/Miscellaneous	0.4645	0.4258	0.4400	0.4434

Table 51. PJM Coincidence Factors AEP Building Types, Determined from Columbus Ohio Chiller Models

Business Type	Water cooled, electrically operated, centrifugal	Water cooled, electrically operated, positive displacement	Air Cooled	Average
Large Office	0.5176	0.4970	0.5274	0.5140
Small Office	0.4497	0.4258	0.4592	0.4449
School	0.3439	0.3134	0.3349	0.3307
Small Retail/Service	0.5823	0.5337	0.5450	0.5537
Large Retail/Service	0.5250	0.4826	0.4983	0.5020
Hotel/Motel	0.3101	0.2839	0.2791	0.2910
Medical - Hospital	0.4238	0.3942	0.4145	0.4109
Medical - Nursing Home	0.3534	0.3245	0.3487	0.3422
Assembly/Meeting Place	0.5250	0.4605	0.4723	0.4860
Restaurant	0.5370	0.4734	0.4816	0.4974
Grocery	0.5799	0.5366	0.4731	0.5299
Conditioned Warehouse	0.4053	0.3813	0.3971	0.3946
Unconditioned Warehouse				
Industrial/Manufacturing	0.4053	0.3573	0.3715	0.3780
College/University	0.4935	0.4583	0.4935	0.4818
Government/Municipal	0.5213	0.4788	0.4999	0.5000
Other/Miscellaneous	0.4640	0.4250	0.4391	0.4427

Table 52. Building Type Mapping From eQuest to AEP Ohio Building Types

Program Building Type	eQuest Building Type
Large Office	Large Office
Small Office	Small Office
School	Primary School
	High School
Small Retail/Service	Small Retail
Large Retail/Service	Large Retail

Program Building Type	eQuest Building Type
	Large 3-Story Retail
Hotel/Motel	Hotel
Medical - Hospital	Hospital
Medical - Nursing Home	Nursing Home
Assembly/Meeting Place	Assembly
Restaurant	Fast Food Restaurant
	Full Service Restaurant
Grocery	Grocery
Conditioned Warehouse	Conditioned Storage
Unconditioned Warehouse	NA - No Cooling by Definition
Industrial/Manufacturing	Light Manufacturing
College/University	Community College
	University
Government/Municipal	Assembly
	Large Office
Other/Miscellaneous	Average of All

For AEP building types for which there are multiple eQuest building types are listed, a simple average of the results from those eQuest building types was taken.

Measure Life and Incremental Measure Cost
The measure life for packaged units is 15 years according to DEER 2005.

The next table provides incremental measure cost (IMC) documented for this measure.

Table 53. Package Units Incremental Measure Cost[12]

Measure	Minimum Qualifying	Delta 1.0 SEER/EER Improvement
65,000 Btuh or less	\$113	\$113
65,000 to 120,000 Btuh	\$59	\$74
120,000 to 240,000 Btuh	\$53	\$53
240,000 to 760,000 Btuh	\$76	\$95
760,000 Btuh or more	\$106	\$212

[12] Survey of (3) packaged unit distributors who provide service in Illinois.

Ground Source and Water Source Heat Pumps

Measure Description	New ground source heat pumps that meet or exceed the qualifying 17 Energy Efficiency Ratio (EER) are eligible for an incentive. EER is the efficiency at standard (ARI/ISO) conditions of 77°F entering water for closed-loop models and 59°F entering water for open-loop systems. A manufacturer's specification sheet indicating the system efficiency for cooling and heating must accompany the application. Disposal of the existing unit must comply with local codes and ordinances. New water source heat pumps that meet or exceed the qualifying 17 Energy Efficiency Ratio (EER) are eligible for an incentive. EER is the efficiency at standard (ARI/ISO) conditions of 86°F entering water. A manufacturer's specification sheet indicating the system efficiency for cooling and heating must accompany the application. Disposal of the existing unit must comply with local codes and ordinances.
Units	Per Ton
Base Case Description	IECC 2009 minimum standard air source air conditioners, water source, and ground source heat pumps.

Measure Savings

The following is the savings for ground source heat pumps.

Table 54. Measure kWh Savings for Ground Source Heat Pumps (per ton)

AEP Building Type	AC to GS < 65,000 Btuh	AC to GS ≥ 65,000 Btu/h and < 135,000 Btu/h	GS to GS < 135,000 Btu/h
Large Office	223.03	221.87	115.10
Small Office	190.85	189.85	98.49
School	169.07	168.19	87.26
Small Retail/Service	311.76	310.14	160.90
Large Retail/Service	331.04	329.31	170.84
Hotel/Motel	306.66	305.06	158.26
Medical - Hospital	431.66	429.41	222.77
Medical - Nursing Home	346.57	344.76	178.86
Assembly/Meeting Place	280.79	279.33	144.91

Restaurant	313.90	312.26	162.00
Grocery	360.48	358.60	186.03
Conditioned Warehouse	186.21	185.23	96.10
Unconditioned Warehouse	-	-	-
Industrial/Manufacturing	176.04	175.12	90.85
College/University	350.31	348.49	180.79
Government/Municipal	251.91	250.60	130.01
Other/Miscellaneous	285.71	284.22	147.45

Table 55. Measure Peak AEP kW Savings for Ground Source Heat Pumps (per ton)

AEP Building Type	AC to GS < 65,000 Btuh	AC to GS ≥ 65,000 Btu/h and < 135,000 Btu/h	GS to GS < 135,000 Btu/h
Large Office	0.1908	0.1898	0.0985
Small Office	0.1658	0.1649	0.0856
School	0.1190	0.1184	0.0614
Small Retail/Service	0.2059	0.2048	0.1062
Large Retail/Service	0.1861	0.1851	0.0961
Hotel/Motel	0.1080	0.1074	0.0557
Medical - Hospital	0.1524	0.1516	0.0786
Medical - Nursing Home	0.1274	0.1267	0.0657
Assembly/Meeting Place	0.1771	0.1762	0.0914
Restaurant	0.1828	0.1819	0.0943
Grocery	0.1962	0.1952	0.1013
Conditioned Warehouse	0.1468	0.1461	0.0758
Unconditioned Warehouse	-	-	-
Industrial/Manufacturing	0.1399	0.1392	0.0722
College/University	0.1734	0.1725	0.0895
Government/Municipal	0.1840	0.1830	0.0949
Other/Miscellaneous	0.1629	0.1621	0.0841

Table 56. Measure Peak PJM kW Savings for Ground Source Heat Pumps (per ton)

AEP Building Type	AC to GS < 65,000 Btuh	AC to GS ≥ 65,000 Btu/h and < 135,000 Btu/h	GS to GS < 135,000 Btu/h
Large Office	0.1889	0.1879	0.0975

Small Office	0.1635	0.1626	0.0844
School	0.1215	0.1209	0.0627
Small Retail/Service	0.2035	0.2024	0.1050
Large Retail/Service	0.1845	0.1835	0.0952
Hotel/Motel	0.1069	0.1064	0.0552
Medical - Hospital	0.1510	0.1502	0.0779
Medical - Nursing Home	0.1258	0.1251	0.0649
Assembly/Meeting Place	0.1786	0.1776	0.0922
Restaurant	0.1828	0.1818	0.0943
Grocery	0.1947	0.1937	0.1005
Conditioned Warehouse	0.1450	0.1442	0.0748
Unconditioned Warehouse	-	-	-
Industrial/Manufacturing	0.1389	0.1382	0.0717
College/University	0.1770	0.1761	0.0914
Government/Municipal	0.1837	0.1828	0.0948
Other/Miscellaneous	0.1627	0.1618	0.0840

Table 57. Measure kWh Savings for Water Source Heat Pumps (per ton)

AEP Building Type	AC to WS < 65,000 Btu/h	AC to WS ≥ 65,000 Btu/h and < 135,000 Btu/h	WS to WS < 17,000 Btu/h	WS to WS ≥ 17,000 Btu/h and < 135,000 Btu/h
Large Office	223.03	221.87	221.87	178.51
Small Office	190.85	189.85	189.85	152.75
School	169.07	168.19	168.19	135.33
Small Retail/Service	311.76	310.14	310.14	249.54
Large Retail/Service	331.04	329.31	329.31	264.97
Hotel/Motel	306.66	305.06	305.06	245.45
Medical - Hospital	431.66	429.41	429.41	345.50
Medical - Nursing Home	346.57	344.76	344.76	277.40
Assembly/Meeting Place	280.79	279.33	279.33	224.75
Restaurant	313.90	312.26	312.26	251.24
Grocery	360.48	358.60	358.60	288.53
Conditioned Warehouse	186.21	185.23	185.23	149.04
Unconditioned Warehouse	-	-	-	-

Industrial/Manufacturing	176.04	175.12	175.12	140.90
College/University	350.31	348.49	348.49	280.39
Government/Municipal	251.91	250.60	250.60	201.63
Other/Miscellaneous	285.71	284.22	284.22	228.68

Table 58. Measure Peak AEP kW Savings for Water Source Heat Pumps (per ton)

AEP Building Type	AC to WS < 65,000 Btu/h	AC to WS ≥ 65,000 Btu/h and < 135,000 Btu/h	WS to WS < 17,000 Btu/h	WS to WS ≥ 17,000 Btu/h and < 135,000 Btu/h
Large Office	0.1908	0.1898	0.1898	0.1527
Small Office	0.1658	0.1649	0.1649	0.1327
School	0.1190	0.1184	0.1184	0.0953
Small Retail/Service	0.2059	0.2048	0.2048	0.1648
Large Retail/Service	0.1861	0.1851	0.1851	0.1490
Hotel/Motel	0.1080	0.1074	0.1074	0.0864
Medical - Hospital	0.1524	0.1516	0.1516	0.1219
Medical - Nursing Home	0.1274	0.1267	0.1267	0.1019
Assembly/Meeting Place	0.1771	0.1762	0.1762	0.1417
Restaurant	0.1828	0.1819	0.1819	0.1463
Grocery	0.1962	0.1952	0.1952	0.1571
Conditioned Warehouse	0.1468	0.1461	0.1461	0.1175
Unconditioned Warehouse	-	-	-	-
Industrial/Manufacturing	0.1399	0.1392	0.1392	0.1120
College/University	0.1734	0.1725	0.1725	0.1388
Government/Municipal	0.1840	0.1830	0.1830	0.1472
Other/Miscellaneous	0.1629	0.1621	0.1621	0.1304

Table 59. Measure Peak PJM kW Savings for Water Source Heat Pumps (per ton)

AEP Building Type	AC to WS < 65,000 Btu/h	AC to WS ≥ 65,000 Btu/h and < 135,000 Btu/h	WS to WS < 17,000 Btu/h	WS to WS ≥ 17,000 Btu/h and < 135,000 Btu/h
Large Office	0.1889	0.1879	0.1879	0.1512

Small Office	0.1635	0.1626	0.1626	0.1309
School	0.1215	0.1209	0.1209	0.0973
Small Retail/Service	0.2035	0.2024	0.2024	0.1628
Large Retail/Service	0.1845	0.1835	0.1835	0.1476
Hotel/Motel	0.1069	0.1064	0.1064	0.0856
Medical - Hospital	0.1510	0.1502	0.1502	0.1208
Medical - Nursing Home	0.1258	0.1251	0.1251	0.1007
Assembly/Meeting Place	0.1786	0.1776	0.1776	0.1429
Restaurant	0.1828	0.1818	0.1818	0.1463
Grocery	0.1947	0.1937	0.1937	0.1558
Conditioned Warehouse	0.1450	0.1442	0.1442	0.1161
Unconditioned Warehouse	-	-	-	-
Industrial/Manufacturing	0.1389	0.1382	0.1382	0.1112
College/University	0.1770	0.1761	0.1761	0.1417
Government/Municipal	0.1837	0.1828	0.1828	0.1471
Other/Miscellaneous	0.1627	0.1618	0.1618	0.1302

Measure Savings Analysis

The same calculation methodology used for “Unitary or Split Air Conditioning Systems and Air Source Heat Pumps” was used. The same EFLHs and CFs from the eQUEST models for chillers were used, and the same calculations were used as well. Baseline and efficient case efficiencies are provided in the table below. Baseline efficiencies are based off of the IECC 2009.

Table 60. Baseline and Program Qualifying Effiiciencies

Baseline Equipment Type	Post-retrofit Equipment Type	Size Category	Baseline Efficiency	Program Qualifying Efficiency	Efficiency Unit Type
Air conditioners, Air cooled	Ground Source Heat Pump	< 65,000 Btu/h	11.18	17	EER
		≥ 65,000 Btu/h and < 135,000 Btu/h	11.2		EER
Ground Source Heat Pump		< 135,000 Btu/h	13.4		EER
Air conditioners, Air cooled	Water Source Heat	< 65,000 Btu/h	11.18	17	EER
		≥ 65,000 Btu/h	11.2		EER

	Pump	and < 135,000 Btu/h			
Water Source Heat Pump		< 17,000 Btu/h	11.2		EER
		≥ 17,000 Btu/h and < 135,000 Btu/h	12		EER

Measure Life and Incremental Measure Cost
The measure life for packaged units which assumed to be the same for GSHP is 15 years according to DEER[13]. The same is assumed for WSHP.

The following table provides the incremental measure cost (IMC) documented for this measure. The cost is from the Michigan Database, and a reportdone by the Oregon Institute of Technology for the DOE. The incremental cost data provided below is based on cost data for ground source heat pump systems and until further information is collected, it is is assumed that water source heat pumps have the same incremental costs.

Table 61. Incremental Measure Cost (per ton)

Measure Name	Cost	Source
GSHP to GSHP and WSHP to WSHP	$179.79	Michigan Databse
ASHP to GSHP and ASHP to WSHP	$800	Oregon Institute of Technology, US DOE[14]

[13] 2008 DEER, www.deeresources.com
[14] http://geoheat.oit.edu/pdf/hp1.pdf

Water-cooled Chillers and Air-cooled Chillers

Measure Description	Chillers are eligible for an incentive if they have a rated kW/ton for the Integrated Part Load Value (IPLV) that is 90 percent of the IECC 2009 value. The chiller efficiency rating must be based on AHRI Standard 550/590-2011 for IPLV conditions and not based on full-load conditions. The chillers must meet AHRI standards 550/590-2011, be NRTL listed, and use a minimum ozone-depleting refrigerant (e.g., HCFC or HFC). The AHRI net capacity value should be used to determine the chiller tons. A manufacturer's specification sheet with the kW/Ton-IPLV, COP-IPLV, or EER-IIPLV must accompany the application.
Units	Per Ton
Base Case Description	Chillers at IECC 2009 IPLV standards

Qualifying efficiencies for chillers are summarized below.

Table 62. Efficiency Levels for Chillers

Chiller Type	Size (tons)	IECC 2009 kW/ton- IPLV	Qualifying kW/ton- IPLV
Water cooled, electrically operated, positive displacement	< 75	0.63	0.567
	75 - 149	0.615	0.554
	150 - 299	0.58	0.522
	≥ 300	0.54	0.486
Water cooled, electrically operated, centrifugal	< 300	0.596	0.536
	300 to 599	0.549	0.494
	≥ 600	0.539	0.485
Air Cooled Chiller	< 150	0.960	0.864
	≥ 150	0.941	0.847

Measure Savings

The peak AEP kW, peak PJM kW and the annual kWh savings per ton of installed chiller are provided below, in addition to the incremental savings for chillers with efficiency improvements that exceed the qualifying kW/ton-IPLV level.

Table 63. Measure kWh Savings for Chillers (per ton)

AEP Building Type	Air-cooled		Water cooled, electrically operated, centrifugal			Water cooled, electrically operated, positive displacement			
	< 150	≥ 150	< 300	300 - 599	≥600	< 75	75-149	150-299	≥300

Large Office	45.41	89.85	31.33	62.15	49.82	37.46	32.06	71.55	52.35
Small Office	48.74	96.71	27.44	28.86	57.25	48.91	30.79	31.29	67.48
School	45.15	107.59	31.70	33.62	26.57	44.27	50.00	36.90	28.93
Small Retail/Service	26.39	58.76	64.43	16.44	41.20	27.48	31.56	53.90	41.24
Large Retail/Service	42.86	76.17	58.88	63.42	37.20	26.28	31.99	27.53	39.27
Hotel/Motel	61.98	109.74	53.32	40.99	66.25	52.53	14.14	35.04	23.55
Medical - Hospital	53.47	60.76	61.90	49.12	40.24	59.65	51.28	13.34	32.63
Medical - Nursing Home	73.20	52.42	53.60	57.02	48.22	44.53	58.23	48.36	12.42
Assembly/Meeting Place	29.84	71.77	63.87	49.38	55.98	43.33	43.47	54.91	45.03
Restaurant	103.50	62.24	73.90	65.45	53.12	53.92	50.63	40.44	44.65
Grocery	83.77	107.72	90.13	64.08	70.75	48.27	46.31	55.60	37.14
Conditioned Warehouse	79.30	82.13	35.12	83.03	62.91	52.98	47.12	43.67	51.77
Unconditioned Warehouse	-	-	-	-	-	-	-	-	-
Industrial/Manufacturing	112.31	77.74	41.42	32.35	81.51	56.87	51.72	44.44	40.66
College/University	91.11	100.33	58.12	43.99	34.61	52.68	63.53	50.56	43.39
Government/Municipal	37.63	80.81	47.60	55.76	52.90	40.40	37.76	63.23	48.69
Other/Miscellaneous	65.54	83.35	53.76	49.80	48.73	45.90	44.39	42.39	39.82

Table 64. Incremental Measure kWhSavings for Chillers (per unit efficiency over Qualifying Efficiency per ton)

AEP Building Type	Air-cooled		Water cooled, electrically operated, centrifugal			Water cooled, electrically operated, positive displacement			
	< 150	≥ 150	< 300	300 - 599	≥600	< 75	75-149	150-299	≥300
Large Office	8.41	9.36	5.26	10.43	9.07	6.95	5.09	11.63	9.03
Small Office	9.03	10.07	4.60	5.26	10.43	9.07	4.89	5.09	11.63
School	8.36	11.21	5.32	6.12	4.93	7.78	7.94	6.00	4.99
Small Retail/Service	4.89	6.12	10.81	2.99	7.64	4.36	5.13	8.76	7.11
Large Retail/Service	7.94	7.93	9.88	11.55	6.90	4.17	6.04	4.75	6.95
Hotel/Motel	6.46	11.43	8.95	7.47	12.29	8.34	2.30	6.04	4.36
Medical - Hospital	5.57	6.46	10.39	8.95	7.47	9.47	8.34	2.30	6.04
Medical - Nursing Home	7.63	5.57	8.99	10.39	8.95	7.07	9.47	8.34	2.30
Assembly/Meeting Place	3.11	7.63	10.72	8.99	10.39	6.88	7.07	9.47	8.34
Restaurant	10.78	6.61	12.40	11.92	9.85	8.56	8.23	6.97	8.27

Grocery	8.73	11.44	15.12	11.67	13.13	7.66	7.53	9.59	6.88
Conditioned Warehouse	8.26	8.73	5.89	15.12	11.67	8.41	7.66	7.53	9.59
Unconditioned Warehouse	-	-	-	-	-	-	-	-	-
Industrial/Manufacturing	11.70	8.26	6.95	5.89	15.12	9.03	8.41	7.66	7.53
College/University	9.49	10.66	9.75	8.01	6.42	8.36	10.33	8.72	8.04
Government/Municipal	5.76	8.49	7.99	9.71	9.73	6.91	6.08	10.55	8.68
Other/Miscellaneous	8.16	8.77	9.02	9.02	9.02	7.50	7.35	7.18	7.18

Table 65. AEP Peak kW Savings for Chillers (per ton)

AEP Building Type	Air-cooled		Water cooled, electrically operated, centrifugal			Water cooled, electrically operated, positive displacement			
	< 150	≥ 150	< 300	300 - 599	≥600	< 75	75-149	150-299	≥300
Large Office	0.0251	0.0588	0.0331	0.0311	0.0276	0.0232	0.0301	0.0419	0.0369
Small Office	0.0336	0.0516	0.0289	0.0301	0.0282	0.0273	0.0281	0.0299	0.0368
School	0.0287	0.0647	0.0213	0.0287	0.0279	0.0336	0.0350	0.0310	0.0254
Small Retail/Service	0.0223	0.0505	0.0373	0.0077	0.0308	0.0337	0.0389	0.0355	0.0298
Large Retail/Service	0.0278	0.0536	0.0336	0.0331	0.0206	0.0240	0.0358	0.0318	0.0312
Hotel/Motel	0.0669	0.0611	0.0198	0.0287	0.0320	0.0422	0.0096	0.0334	0.0268
Medical - Hospital	0.0584	0.0669	0.0271	0.0180	0.0284	0.0397	0.0419	0.0084	0.0304
Medical - Nursing Home	0.0657	0.0584	0.0227	0.0246	0.0178	0.0363	0.0395	0.0368	0.0076
Assembly/Meeting Place	0.0167	0.0657	0.0330	0.0206	0.0244	0.0224	0.0360	0.0346	0.0335
Restaurant	0.0674	0.0430	0.0340	0.0288	0.0250	0.0283	0.0265	0.0256	0.0302
Grocery	0.0608	0.0655	0.0370	0.0343	0.0273	0.0356	0.0255	0.0270	0.0178
Conditioned Warehouse	0.0354	0.0608	0.0260	0.0336	0.0339	0.0315	0.0354	0.0224	0.0247
Unconditioned Warehouse	-	-	-	-	-	-	-	-	-
Industrial/Manufacturing	0.0525	0.0354	0.0259	0.0236	0.0332	0.0423	0.0313	0.0310	0.0204
College/University	0.0516	0.0484	0.0307	0.0256	0.0233	0.0362	0.0420	0.0322	0.0267
Government/Municipal	0.0209	0.0622	0.0331	0.0258	0.0260	0.0228	0.0331	0.0383	0.0352
Other/Miscellaneous	0.0438	0.0552	0.0295	0.0269	0.0265	0.0321	0.0330	0.0301	0.0273

Table 66. Incremental AEP Peak kW Savings for Chillers (per 0.01 kW/ton Efficiency Improvement over Qualifying Efficiency per Ton)

AEP Building Type	Air-cooled		Water cooled, electrically operated, centrifugal			Water cooled, electrically operated, positive displacement			
	< 150	≥ 150	< 300	300 - 599	≥600	< 75	75-149	150-299	≥300
Large Office	0.0040	0.0047	0.0052	0.0049	0.0048	0.0041	0.0039	0.0054	0.0054
Small Office	0.0054	0.0041	0.0046	0.0052	0.0049	0.0048	0.0036	0.0039	0.0054
School	0.0046	0.0052	0.0034	0.0050	0.0049	0.0050	0.0045	0.0040	0.0037
Small Retail/Service	0.0036	0.0040	0.0059	0.0013	0.0054	0.0043	0.0050	0.0046	0.0044
Large Retail/Service	0.0045	0.0043	0.0053	0.0057	0.0036	0.0031	0.0046	0.0047	0.0048
Hotel/Motel	0.0053	0.0049	0.0031	0.0050	0.0056	0.0054	0.0012	0.0049	0.0043
Medical - Hospital	0.0047	0.0053	0.0043	0.0031	0.0050	0.0051	0.0054	0.0012	0.0049
Medical - Nursing Home	0.0052	0.0047	0.0036	0.0043	0.0031	0.0047	0.0051	0.0054	0.0012
Assembly/Meeting Place	0.0013	0.0052	0.0052	0.0036	0.0043	0.0029	0.0047	0.0051	0.0054
Restaurant	0.0054	0.0034	0.0054	0.0050	0.0044	0.0036	0.0034	0.0038	0.0049
Grocery	0.0048	0.0052	0.0058	0.0059	0.0048	0.0046	0.0033	0.0040	0.0029
Conditioned Warehouse	0.0028	0.0048	0.0041	0.0058	0.0059	0.0040	0.0046	0.0033	0.0040
Unconditioned Warehouse	-	-	-	-	-	-	-	-	-
Industrial/Manufacturing	0.0042	0.0028	0.0041	0.0041	0.0058	0.0054	0.0040	0.0046	0.0033
College/University	0.0041	0.0039	0.0048	0.0044	0.0041	0.0046	0.0054	0.0047	0.0043
Government/Municipal	0.0027	0.0050	0.0052	0.0042	0.0045	0.0035	0.0043	0.0053	0.0054
Other/Miscellaneous	0.0044	0.0044	0.0046	0.0046	0.0046	0.0043	0.0043	0.0043	0.0043

Table 67. PJM Peak kW Savings for Chillers (per ton)

AEP Building Type	Air-cooled		Water cooled, electrically operated, centrifugal			Water cooled, electrically operated, positive displacement			
	< 150	≥ 150	< 300	300 - 599	≥600	< 75	75-149	150-299	≥300
Large Office	0.0251	0.0593	0.0328	0.0312	0.0285	0.0231	0.0297	0.0416	0.0369
Small Office	0.0336	0.0516	0.0285	0.0298	0.0284	0.0282	0.0279	0.0296	0.0365
School	0.0285	0.0643	0.0218	0.0288	0.0276	0.0334	0.0357	0.0315	0.0251
Small Retail/Service	0.0222	0.0498	0.0369	0.0079	0.0314	0.0332	0.0385	0.0357	0.0310
Large Retail/Service	0.0284	0.0546	0.0333	0.0329	0.0205	0.0244	0.0359	0.0314	0.0311
Hotel/Motel	0.0662	0.0614	0.0197	0.0283	0.0318	0.0416	0.0099	0.0340	0.0264
Medical - Hospital	0.0576	0.0662	0.0269	0.0179	0.0280	0.0395	0.0414	0.0086	0.0310

Medical - Nursing Home	0.0669	0.0576	0.0224	0.0244	0.0177	0.0358	0.0392	0.0363	0.0079
Assembly/Meeting Place	0.0172	0.0669	0.0333	0.0204	0.0242	0.0221	0.0356	0.0344	0.0331
Restaurant	0.0667	0.0428	0.0340	0.0289	0.0250	0.0280	0.0263	0.0253	0.0299
Grocery	0.0600	0.0651	0.0368	0.0342	0.0273	0.0359	0.0252	0.0268	0.0176
Conditioned Warehouse	0.0350	0.0600	0.0257	0.0334	0.0339	0.0316	0.0357	0.0221	0.0244
Unconditioned Warehouse	-	-	-	-	-	-	-	-	-
Industrial/Manufacturing	0.0520	0.0350	0.0257	0.0233	0.0331	0.0423	0.0314	0.0313	0.0201
College/University	0.0515	0.0479	0.0313	0.0259	0.0231	0.0358	0.0418	0.0322	0.0268
Government/Municipal	0.0211	0.0631	0.0330	0.0258	0.0263	0.0226	0.0327	0.0380	0.0350
Other/Miscellaneous	0.0437	0.0551	0.0294	0.0269	0.0265	0.0320	0.0330	0.0301	0.0273

Table 68. Incremental PJM Peak kW Savings for Chillers (per 0.01 kW/ton Efficiency Improvement over Qualifying Efficiency per Ton)

AEP Building Type	Air-cooled		Water cooled, electrically operated, centrifugal			Water cooled, electrically operated, positive displacement			
	< 150	≥ 150	< 300	300 - 599	≥600	< 75	75-149	150-299	≥300
Large Office	0.0040	0.0047	0.0052	0.0049	0.0049	0.0041	0.0038	0.0054	0.0054
Small Office	0.0054	0.0041	0.0045	0.0052	0.0049	0.0049	0.0036	0.0038	0.0054
School	0.0046	0.0051	0.0034	0.0050	0.0048	0.0049	0.0046	0.0041	0.0037
Small Retail/Service	0.0036	0.0040	0.0058	0.0014	0.0055	0.0043	0.0050	0.0046	0.0046
Large Retail/Service	0.0046	0.0043	0.0052	0.0057	0.0036	0.0031	0.0046	0.0046	0.0048
Hotel/Motel	0.0053	0.0049	0.0031	0.0049	0.0056	0.0053	0.0013	0.0050	0.0043
Medical - Hospital	0.0046	0.0053	0.0042	0.0031	0.0049	0.0051	0.0053	0.0013	0.0050
Medical - Nursing Home	0.0053	0.0046	0.0035	0.0042	0.0031	0.0046	0.0051	0.0053	0.0013
Assembly/Meeting Place	0.0014	0.0053	0.0053	0.0035	0.0042	0.0028	0.0046	0.0051	0.0053
Restaurant	0.0053	0.0034	0.0054	0.0050	0.0044	0.0036	0.0034	0.0037	0.0048
Grocery	0.0048	0.0052	0.0058	0.0059	0.0048	0.0046	0.0032	0.0039	0.0028
Conditioned Warehouse	0.0028	0.0048	0.0041	0.0058	0.0059	0.0040	0.0046	0.0032	0.0039
Unconditioned Warehouse	-	-	-	-	-	-	-	-	-
Industrial/Manufacturing	0.0041	0.0028	0.0041	0.0041	0.0058	0.0054	0.0040	0.0046	0.0032
College/University	0.0041	0.0038	0.0049	0.0045	0.0041	0.0046	0.0054	0.0047	0.0043
Government/Municipal	0.0027	0.0050	0.0052	0.0042	0.0046	0.0034	0.0042	0.0052	0.0054

Other/Miscellaneous	0.0044	0.0044	0.0046	0.0046	0.0046	0.0043	0.0043	0.0043	0.0043

Measure Savings Analysis

Savings values are determined for units with efficiency levels listed which exceed IECC 2009 efficiency levels which is the existing state of Ohio code.

Savings calculations were performed by utilizing DOE-2 models generated with eQUEST software. The models are the same used to generate California's DEER with modifications pertinent to Columbus Ohio, regarding climate zone and building construction, as outlined below. The same calculation methodology used for "Unitary or Split Air Conditioning Systems and Air Source Heat Pumps" was used with the following additional assumptions:

1) Air handler units were assumed to be Variable Air Volume (VAV) systems with hot water reheat.
2) VAV units include economizers and supply temperature reset controls based on outside air.
3) Condenser water temperature was set to 75° F.
4) All chillers for pre and post cases were assumed to be constant speed.
5) All measure cases assumed the same type of chiller (screw, centrifugal, etc.) pre and post.

The savings values presented here are direct outputs from eQuest for the 300 ton chiller size pre and post efficiency values, but are scaled for sizes with different pre and post efficiency values. The scaling is done based on a ratio of the efficiency values between the modeled, and non-modeled sizes.

$$kWhSavings_{NEWSize} = \frac{\Delta IPLVEfficiency_{NEW\,Size}}{\Delta IPLVEfficiency_{MODELEDSize}} kWhSavings_{MODELED\,Size}$$

$$kWSavings_{NEWSize} = \frac{\Delta Full\_Load\_Efficiency_{NEW\,Size}}{\Delta Full\_Load\_Efficiency_{MODELEDSize}} kWSavings_{MODELED\,Size}$$

Incremental savings per 0.01 kW/ton efficiency improvements are calculated by taking the difference between the program savings, and dividing those by the in efficiency improvements.

$$IncrementalSavings = \frac{\Delta Savings}{\Delta Efficiency} / 100$$

The results from eQuest were mapped to the AEP OH building types as described below:

Table 69. Building Type Mapping From eQuest to AEP Ohio Building Types

AEP Ohio Building Types (on application)	Building Types from eQuest Models
Large Office	Large Office
Small Office	Small Office
School	Primary School
	High School
Small Retail/Service	Small Retail
Large Retail/Service	Large Retail
	Large 3-Story Retail
Hotel/Motel	Hotel
Medical - Hospital	Hospital
Medical - Nursing Home	Nursing Home
Assembly/Meeting Place	Assembly
Restaurant	Fast Food Restaurant
	Full Service Restaurant
Grocery	Grocery
Conditioned Warehouse	Conditioned Storage
Unconditioned Warehouse	NA - No Cooling by Definition
Industrial/Manufacturing	Light Manufacturing
College/University	Community College
	University
Government/Municipal	Assembly
	Large Office
Other/Miscellaneous	Average of All

For AEP OH building types for which there are multiple eQuest building types are listed, a simple average of the results from those eQuest building types was taken.

Measure Life and Incremental Measure Cost

The measure life for packaged units is 20 years according to DEER[15].

The following table provides IMC documented for this measure. The costs are based on DEER 2008 data adjusted for different IPLV efficiency improvements between DEER data and efficiency gains required by the program. The adjustment is based on a simple linear scaling relationship described in the equation below:

$$IMC_{program} = \frac{\Delta IPLVEffici\,ency_{program}}{\Delta IPLVEffici\,ency_{DEER}} IMC_{DEER}$$

Incremental IMCs were determined with the following equation:

$$Incrementa\ lIMC = \frac{BaseIMC}{\Delta Efficiency} / 100$$

For situations where DEER did not have cost estimates for certain size categories, the closest size category was used. This is an area recommended for further investigation.

Table 70. Chiller Incremental Measure Cost

Chiller Type	Size (tons)	Base Incremental Measure Cost	Incremental IMC (per 0.01 efficiency improvement)
Water cooled, electrically operated, positive displacement	<75	$51.09	$8.11
	75 to 149	$49.47	$8.11
	150 to 299	$28.20	$4.86
	≥ 300	$20.25	$3.75
Water cooled, electrically operated, centrifugal	< 300	$79.52	$13.25
	300 to 599	$72.89	$13.25
	≥ 600	$71.57	$13.25
Air Cooled Chiller	<150	$56.81	$5.03
	≥ 150	$187.54	$5.03

[15] 2008 Database for Energy Efficiency Resources (DEER) Update Study Final Report

Room Air Conditioners

Measure Description	Room air conditioning units are through-the-wall (or built-in), self-contained units that are 2 tons or less. This measure consists of the installation of a Room Air Conditioner that falls under Super Efficient Home Appliance (SEHA) Tier 1 standards. The minimum requirements and eligible equipment are listed CEE high-efficiency room air conditioning specifications (www.cee1.org)[16]. These units are with and without louvered sides, without reverse cycle (i.e., heating), and casements. Disposal of existing unit must comply with local codes and ordinances.
Units	Per Ton
Base Case Description	Federal standard baseline

The qualifying efficiencies for both levels are provided below.

Table 71. Qualifying Efficiencies[17]

Size (Btuh)	October 2000 Federal Standard (EER) Baseline	SEHA Tier 1 Retrofit (EER)
< 8,000	9.7	11.2
8000 to 13,999	9.8	11.3
14,000 to 19,999	9.7	11.2
>= 20,000	8.5	9.8

Measure Savings

Below are the coincident kW and the annual kWh savings per ton of installed cooling system.

Table 72. Room A/C kWh Savings (per ton)

Size (Btu/h)	kWh Savings/ton	kW_{AEP} Savings per Ton	kW_{PJM} Savings per Ton
< 8,000	127.3	0.07379	0.07352
8,000 - 13,999	124.8	0.07239	0.07212

[16] This website also has a list of eligible units.
[17] These efficiency levels are for units with louvered sides, whereas units without louvered sides or casement-only or casement-slider tend to have lower efficiency thresholds.

14,000 - 19,999	127.3	0.07379	0.07352
>= 20,000	143.8	0.08341	0.08310
Average	**130.8**	**0.07585**	**0.07557**

Measure Savings Analysis
Savings values are calculated with the baseline efficiencies shown above, since efficiency levels depend on the size of the unit. The average equivalent full load hours for Columbus is 768.1 and the AEP coincident factor is 0.435, and the PJM peak coincident factor is 0.458 from the models run for the chiller workpapers.

The energy and demand savings are calculated using the following formulas, where size is in BTUh, EER is in BTUh/Watt, and EFLH are in hours:

Energy savings = Size x $(1/EER_{base} – 1/EER_{EE})$ x EFLH / 1000

Demand Savings = Size x $(1/EER_{base} – 1/EER_{EE})$ x CF

Measure Life and Incremental Measure Cost
The measure life is 12 years from the Ohio TRM.

The incremental measure cost for this measure is from the OH TRM at $80 for a CEE TIER 1 (or SEHA Tier 1) unit.

Package Terminal Air Conditioners/Heat Pumps

Measure Description	Package terminal air conditioners and heat pumps are through-the-wall self contained units that are 2 tons (24,000 Btuh) or less. Only units that have an EER greater than or equal to 13.08 – (0.2556 * Capacity in Btuh/ 1000), where capacity is in Btuh, qualify for the incentive. All EER values must be rated at 95 °F outdoor dry-bulb temperature.
Units	Per Ton
Base Case Description	IECC 2009 EER Efficiencies

Measure Savings
Below are the coincident kW and the annual kWh savings per ton of installed cooling system. The savings are based on efficiencies 20 percent higher than the IECC 2009 minimum efficiency.

Table 73. Measure Savings for PTAC/HP (per ton)

kWh Savings	kW_{PJM} Savings	kW_{AEP} Savings
186.4	0.1061	0.1063

Measure Savings Analysis
Savings values are calculated for qualifying PTAC/HPs with IECC 2009 efficiency standards as the baseline. Both qualifying efficiency levels and baseline efficiencies are based on the capacity of the unit, but, for purposes of calculating savings, we have assumed a baseline of 8.3 EER and a replacement efficiency of 10 EER on average, the efficiencies for a 12,000 Btuh (one ton) unit. The following table provides the efficiencies for a range of PTAC/HP sizes.

Table 74. PTAC/HP Efficiencies

PTAC size	IECC 2009	Qualifying EER
6000	9.6	11.5
7000	9.4	11.3
8000	9.2	11.0
9000	9.0	10.8
10000	8.8	10.5
11000	8.6	10.3
12000	8.3	10.0
13000	8.1	9.8
14000	7.9	9.5
15000	7.7	9.2
16000	7.5	9.0
17000	7.3	8.7
18000	7.1	8.5

The EFLH values were derived from the eQuest chiller models run for the Columbus weather, and are provided in the table below.

Table 75. PTAC EFLH by Business Type

Business Type	EFLCH
Large Office	606.95
Small Office	519.36
School	460.11
Small Retail/Service	848.42
Large Retail/Service	900.88
Hotel/Motel	834.54
Medical - Hospital	1,174.71
Medical - Nursing Home	943.15
Assembly/Meeting Place	764.14
Restaurant	854.23

Grocery	980.99
Conditioned Warehouse	506.73
Unconditioned Warehouse	
Industrial/Manufacturing	479.07
College/University	953.33
Government/Municipal	685.54
Other/Miscellaneous	777.51

The coincident kW savings is calculated using the following equation:

kW Savings per ton = (12/Baseline EER – 12/Replacement EER) / 1,000

Coincident kW Savings = kW Savings x Coincidence Factor

kWh Savings per ton = kW Savings per ton x EFLH

Measure Life and Incremental Measure Cost

The measure life for packaged units is 15 years according to DEER[18] and is assumed to be the same for package terminal units. The IMC documented for this measure is $84 per ton[19].

Variable Refrigerant Flow (VRF) Multi-Split Air-Conditioners and Heat Pumps

Measure Description	New variable refrigerant flow (VRF) multi-split air conditioning or heat pump units that meet or exceed the qualifying cooling efficiencies are eligible for an incentive. Water-cooled systems and water source heat pumps do not qualify under this program but may qualify under the Custom Incentive Program. A manufacturer's specification sheet indicating the system efficiency must accompany the application. Disposal of the existing unit must comply with local codes and ordinances.
Units	Ton
Base Case Description	ASHRAE 90.1-2010 Minimum Standard for VRF Multi-Split System Air Conditioners

The following table are the program qualifying efficiencies.

[18] 2008 DEER, www.deeresources.com
[19] 2008 DEER, www.deeresources.com

Table 76. Program Qualifying Efficiencies

Unit Size (tons)	Unit Size (Btuh)	Minimum Efficiency (Cooling Mode)
≤ 5.4 tons	< 65,000 Btuh	14 SEER
5.4 – 11.24 tons	≥ 65,000 Btuh and <135,000 Btuh	12 EER/13 IEER
11.25 – 19.9 tons	≥ 135,000 < 240,000 Btuh	12 EER/13 IEER
≥ 20 tons	≥240,000 Btuh	10.8 EER/12.1 IEER

Measure Savings

The coincident kW and the annual kWh savings per ton of installed cooling system are provided below.

Table 77. Measure kWh Savings for VRF Air Conditioning Systems (per ton)

Business Type	5 or less	5 to 10	10 to 20	≥ 20
Large Office	40.02	43.35	55.18	53.95
Small Office	34.24	37.10	47.21	46.17
School	30.34	32.87	41.83	40.90
Small Retail/Service	55.94	60.60	77.13	75.42
Large Retail/Service	59.40	64.35	81.90	80.08
Hotel/Motel	55.02	59.61	75.87	74.18
Medical - Hospital	77.45	83.91	106.79	104.42
Medical - Nursing Home	62.19	67.37	85.74	83.84
Assembly/Meeting Place	50.38	54.58	69.47	67.92
Restaurant	56.32	61.02	77.66	75.93
Grocery	64.68	70.07	89.18	87.20
Conditioned Warehouse	33.41	36.20	46.07	45.04
Unconditioned Warehouse	-	-	-	
Industrial/Manufacturing	31.59	34.22	43.55	42.58
College/University	62.86	68.09	86.67	84.74
Government/Municipal	45.20	48.97	62.32	60.94
Other/Miscellaneous	51.26	55.54	70.68	69.11

Table 78. Measure AEP Peak kW Savings for VRF Air Conditioning Systems (per ton)

Business Type	5 or less	5 to 10	10 to 20	≥ 20
Large Office	0.0342	0.0371	0.0472	0.0462
Small Office	0.0298	0.0322	0.0410	0.0401
School	0.0214	0.0231	0.0294	0.0288
Small Retail/Service	0.0369	0.0400	0.0509	0.0498
Large Retail/Service	0.0334	0.0362	0.0460	0.0450
Hotel/Motel	0.0194	0.0210	0.0267	0.0261
Medical - Hospital	0.0273	0.0296	0.0377	0.0369
Medical - Nursing Home	0.0229	0.0248	0.0315	0.0308
Assembly/Meeting Place	0.0318	0.0344	0.0438	0.0428
Restaurant	0.0328	0.0355	0.0452	0.0442
Grocery	0.0352	0.0381	0.0485	0.0475
Conditioned Warehouse	0.0263	0.0285	0.0363	0.0355
Unconditioned Warehouse	-	-	-	-
Industrial/Manufacturing	0.0251	0.0272	0.0346	0.0339
College/University	0.0311	0.0337	0.0429	0.0420
Government/Municipal	0.0330	0.0358	0.0455	0.0445
Other/Miscellaneous	0.0292	0.0317	0.0403	0.0394

Table 79. Measure PJM Peak kW Savings for VRF Air Conditioning Systems (per ton)

Business Type	5 or less	5 to 10	10 to 20	≥ 20
Large Office	0.0339	0.0367	0.0467	0.0457
Small Office	0.0293	0.0318	0.0404	0.0395
School	0.0218	0.0236	0.0301	0.0294
Small Retail/Service	0.0365	0.0395	0.0503	0.0492
Large Retail/Service	0.0331	0.0359	0.0456	0.0446
Hotel/Motel	0.0192	0.0208	0.0265	0.0259
Medical - Hospital	0.0271	0.0293	0.0374	0.0365
Medical - Nursing Home	0.0226	0.0244	0.0311	0.0304
Assembly/Meeting Place	0.0320	0.0347	0.0442	0.0432
Restaurant	0.0328	0.0355	0.0452	0.0442
Grocery	0.0349	0.0378	0.0482	0.0471

Conditioned Warehouse	0.0260	0.0282	0.0359	0.0351
Unconditioned Warehouse	-	-	-	-
Industrial/Manufacturing	0.0249	0.0270	0.0344	0.0336
College/University	0.0318	0.0344	0.0438	0.0428
Government/Municipal	0.0330	0.0357	0.0455	0.0444
Other/Miscellaneous	0.0292	0.0316	0.0402	0.0394

Measure Savings Analysis

Savings values are determined for units with efficiency levels listed which exceed IECC 2009 efficiency levels which is the existing state of Ohio code.

Table 80. Demand Savings and Efficiency Assumptions

Size (Tons)	IECC 2009	Program Qualifying	SEER or EER
≤ 5.4	13	14	SEER
5.4 – 11.25	11.2	12, 13	EER, IEER
11.25 – 20	11	12, 13	EER, IEER
≥ 20	10	10.6, 12.1	EER, IEER

Equivalent Full Load Cooling Hours (EFLCH) were determined by utilizing DOE-2 models generated with eQUEST software for chillers, using Columbus Ohio weather data. See the section on water cooled chillers for more information on those models. The EFLHs were determined by taking the annual MBTUH, and dividing by the rated full load capacity of the chiller, MBTU, both of which can be found in eQuest reports.

The EFLHs for the different chiller models were averaged by building types.

Table 81. Equivalent Full Load Hours for Columbus, OH

Business Type	Average EFLCH
Large Office	607.0
Small Office	519.4
School	460.1
Small Retail/Service	848.4
Large Retail/Service	900.9

Hotel/Motel	834.5
Medical - Hospital	1,174.7
Medical - Nursing Home	943.1
Assembly/Meeting Place	764.1
Restaurant	854.2
Grocery	981.0
Conditioned Warehouse	506.7
Unconditioned Warehouse	-
Industrial/Manufacturing	479.1
College/University	953.3
Government/Municipal	685.5
Other/Miscellaneous	777.5

The annual kWh savings/ton were determined using the following equation:

kWh Savings/ton = (12/Baseline EER/SEER -12/Post Case EER/SEER) x EFLH

The peak AEP and PJM kW savings were determined by first finding out the peak AEP and peak PJM coincidence factors for the AEP building types, using the columbus Ohio chiller models 8760 hourly data outputs. Baseline and efficiency case kW values were tabulated for the 8760 hours in the TMY3 year for each chiller model and building type. The average kW savings which occurred during the peak periods (3:00 – 6:00 PM for AEP, 2:00 – 6:00 PM for PJM, both June 1 – August 31st excluding weekends and federal holidays) were divided by the non coincident kW savings from the efficiency gain, to determine the CFs.

The peak kW savings were simply determined by multiplying the non-coincident kW savings/ton by the coincidence factors. The values are averaged across the chiller types.

Table 82. AEP Coincidence Factors for Columbus, OH

Business Type	Average CF
Large Office	0.5193
Small Office	0.4512
School	0.3239
Small Retail/Service	0.5602
Large Retail/Service	0.5065

Business Type	Average CF
Hotel/Motel	0.2938
Medical - Hospital	0.4146
Medical - Nursing Home	0.3466
Assembly/Meeting Place	0.4819
Restaurant	0.4975
Grocery	0.5340
Conditioned Warehouse	0.3995
Unconditioned Warehouse	
Industrial/Manufacturing	0.3808
College/University	0.4720
Government/Municipal	0.5006
Other/Miscellaneous	0.4434

Table 83. PJM Coincidence Factors for Columbus, OH

Business Type	Average PJM Peak CF
Large Office	0.5140
Small Office	0.4449
School	0.3307
Small Retail/Service	0.5537
Large Retail/Service	0.5020
Hotel/Motel	0.2910
Medical - Hospital	0.4109
Medical - Nursing Home	0.3422
Assembly/Meeting Place	0.4860
Restaurant	0.4974
Grocery	0.5299
Conditioned Warehouse	0.3946
Unconditioned Warehouse	
Industrial/Manufacturing	0.3780
College/University	0.4818
Government/Municipal	0.5000

Other/Miscellaneous	0.4427

Table 84. Building Type Mapping From eQuest to AEP Ohio Building Types

Program Building Type	eQuest Building Type
Large Office	Large Office
Small Office	Small Office
School	Primary School
	High School
Small Retail/Service	Small Retail
Large Retail/Service	Large Retail
	Large 3-Story Retail
Hotel/Motel	Hotel
Medical - Hospital	Hospital
Medical - Nursing Home	Nursing Home
Assembly/Meeting Place	Assembly
Restaurant	Fast Food Restaurant
	Full Service Restaurant
Grocery	Grocery
Conditioned Warehouse	Conditioned Storage
Unconditioned Warehouse	NA - No Cooling by Definition
Industrial/Manufacturing	Light Manufacturing
College/University	Community College
	University
Government/Municipal	Assembly
	Large Office
Other/Miscellaneous	Average of All

For AEP building types for which there are multiple eQuest building types are listed, a simple average of the results from those eQuest building types was taken.

Measure Life and Incremental Measure Cost

The measure life for packaged units is 15 years according to DEER 2005, assumed to be the same for VRF. The VRF costs are assumed to be the same as packaged units.

Table 85. VRF Incremental Measure Cost[20]

Measure	Minimum Qualifying
65,000 Btuh or less	$113
65,000 to 120,000 Btuh	$59
120,000 to 240,000 Btuh	$53
240,000 Btuh and greater	$76

Lodging – Hotel Guest Room Energy Management System (GREM)

Measure Description	GREM is a multi-purpose Direct Digital Control (DDC) device designed to control HVAC unit in hotel guestrooms. Incentives are available for sensors that control HVAC units for individual hotel rooms. Key cards that indicate occupancy also qualify. Sensors controlled by a front desk system are not eligible. Guest room temperature set point or the on/off cycle of the HVAC unit must be controlled by an automatic occupancy sensor or key-card system that indicates the occupancy status of the room. During unoccupied periods the default setting for controlled units must differ from the operating set point by at least 5 degrees (or shut the unit fan and heating or cooling off completely). The control system may also be tied into other electric loads, such as lighting and plug loads to shut them off when occupancy is not sensed. The incentive is per guestroom controlled, rather than per sensor, for multi-room suites. Replacement or upgrades of existing occupancy-based controls are not eligible for an incentive.
Units	Per room HVAC controller
Base Case Description	Manual Heating/Cooling Temperature Setpoint and Fan On/Off/Auto Thermostat

[20] Survey of (3) packaged unit distributors who provide service in Illinois.

The savings are achieved based on GREM's ability to automatically adjust the guest room's set temperatures or reduce the cycle time of the HVAC unit for various occupancy modes.

Measure Savings

The annual kWh savings per HVAC unit controlled are summarized in the following table for different sizes and types of HVAC units. The savings are achieved based on GREM's ability to automatically adjust the guest room's set temperatures and control the HVAC unit to maintain set temperatures under occupied or unoccupied modes of operation.

Key operating assumptions are summarized in the discussion below. These values are from the Michigan savings database using Michigan's 574 annual CDD and 6,676 annual HDD, which are comparable to 925 CDD and 5,546 HDD in Columbus[21].

Table 86. Measure Savings for GREM

Cooling Type	Cooling kWh		Heating (kWh & Therms)		Total kWh	
	3/4 ton	1 ton	3/4 ton	1 ton	3/4 ton	1 ton
PTAC	208	287	1,234 kWh	1,645 kWh	1,441	1,932
PTHP	181	263	721 kWh	988 kWh	902	1,251
FCU with Gas Heat/Elec Cool	407	542	53 Therms	70 Therms	407	542

On average, the annual kWh saving for a 0.75 ton and 1 ton HVAC unit with electric cooling and electric heating is 1,117 kWh per room. For non-electric heating, it is assumed the savings are approximately one third at 334 kWh per room. The average between 0.75 and 1 tons is used for a conservative estimate. However, it is assumed that most PTAC units in hotel rooms are sized to 1 ton.

Measure Savings Analysis

The coincident kW impacts for this measure have not been sufficiently studied or modeled to provide a confident estimate. In the meantime the following kW impacts are estimated for systems that control cooling operation.

kW Savings per ton = (12/HVAC EER) x average on peak uncontrolled load factor of 50% (estimated from anecdotal observations by DNV KEMA) x estimated cycling reduction of 30%

[21] http://www.ncdc.noaa.gov/oa/climate/online/ccd/nrmcdd.html, http://www.ncdc.noaa.gov/oa/climate/online/ccd/nrmhdd.html

(estimated by DNV KEMA from empirical observations and logging from manufacturers for NV Energy).

$$kW = (12/8.344) \times 0.5 \times 0.3 = 0.215 \text{ kW per one-ton unit}$$

where,

HVAC EER = is based on a 1 ton unit at code baseline efficiency of PTAC, defined as EER = 10.9 – (0.213 x 12000 btu/hr/1000) = 8.344

It is estimated as 0.74 as the coincident factor to be consistent with the other HVAC measures.

Coincident kW Savings = 0.215 x 0.74 = 0.159 kW per one-ton unit.

Measure Life and Incremental Measure Cost
The measure life for GREM is 15 years according to CA DEER 2008 value for energy management systems. Cost is $260 based on review of projects in the midwest.

Variable Speed Drive on HVAC Chillers

Measure Description	Variable-speed drives (VSDs) which are installed on existing chillers are eligible for this incentive. New chillers with integrated VSDs are eligible under the chiller incentive. The installation of a VSD must accompany the permanent removal or disabling of any throttling devices. VSDs for non-HVAC applications may be eligible for a custom incentive.
Units	Per HP
Base Case Description	No VSD installed

Measure Savings
Provided below are the coincident kW savings and the annual kWh savings per hp of installed chiller motor. The The annual kWh savings and peak kW savings are dependent on building type.

Table 87. Energy Savings VSD for Chillers (Per HP)

AEP Building Type	kWh Savings	AEP Peak kW Savings	PJM Peak kW Savings
Large Office	160.3	0.06366	0.06301
Small Office	166.7	0.05532	0.05454

School	249.2	0.03971	0.04054
Small Retail/Service	492.2	0.06868	0.06787
Large Retail/Service	413.8	0.06209	0.06153
Hotel/Motel	584.4	0.03601	0.03568
Medical - Hospital	491.8	0.05082	0.05036
Medical - Nursing Home	456.3	0.04249	0.04195
Assembly/Meeting Place	536.9	0.05908	0.05957
Restaurant	648.8	0.06099	0.06097
Grocery	715.9	0.06546	0.06495
Conditioned Warehouse	487.3	0.04898	0.04837
Unconditioned Warehouse			
Industrial/Manufacturing	369.2	0.04669	0.04634
College/University	489.3	0.05786	0.05906
Government/Municipal	348.6	0.06137	0.06129
Other/Miscellaneous	447.9	0.05436	0.05427

Measure Savings Analysis
Savings values are calculated with an estimate of a 19 percent savings[22]. The motors are assumed to have a load factor of 80 percent and an efficiency of 92.5 percent for calculating the equipment kW.

$$\text{kW reduction} = 0.19 \times (\text{ kW of existing equipment})$$

Where kW of equipment is calculated using:

$$\frac{(\text{Motor HP}) \times (0.746 \text{ kW/HP}) \times (\text{Load Factor})}{\text{Motor Efficiency}}.$$

The coincident kW savings are calculated using the following equation. The coincidence factor is derived from the eQUEST models run for the high efficiency chiller measure, using Columbus Ohio weather data.

$$\text{Coincident kW reduction} = \text{kW reduction x coincidence factor}$$

The coincident factors are provided in the table below.

[22] This percentage is a conservative estimate. DEER 2005 on average calculated over 30% savings for installing a VSD for various motor application types.

Table 88. Chiller Coincidence Factors

AEP Building Type	Ohio CF	PJM CF
Large Office	0.5193	0.5140
Small Office	0.4512	0.4449
School	0.3239	0.3307
Small Retail/Service	0.5602	0.5537
Large Retail/Service	0.5065	0.5020
Hotel/Motel	0.2938	0.2910
Medical - Hospital	0.4146	0.4109
Medical - Nursing Home	0.3466	0.3422
Assembly/Meeting Place	0.4819	0.4860
Restaurant	0.4975	0.4974
Grocery	0.5340	0.5299
Conditioned Warehouse	0.3995	0.3946
Unconditioned Warehouse		
Industrial/Manufacturing	0.3808	0.3780
College/University	0.4720	0.4818
Government/Municipal	0.5006	0.5000
Other/Miscellaneous	0.4434	0.4427

Annual energy savings values were calculated based on run hours for each building type as modeled in our chillers section. Here run hours were obtained from building simulation runs for 150-300 ton centrifugal chillers at baseline efficiencies.

Annual kWh Savings = kW Savings x Run Hours

Table 89. Chiller Annual Operating Hours

Building Type	Average Annual Cooling Hours
Large Office	1,308.00
Small Office	1,360.00
School	2,032.50
Small Retail/Service	4,015.00
Large Retail/Service	3,375.50

Hotel/Motel	4,767.00
Medical - Hospital	4,012.00
Medical - Nursing Home	3,722.00
Assembly/Meeting Place	4,380.00
Restaurant	5,292.50
Grocery	5,840.00
Conditioned Warehouse	3,975.00
Unconditioned Warehouse	
Industrial/Manufacturing	3,012.00
College/University	3,991.50
Government/Municipal	2,844.00
Other/Miscellaneous	3,654.17

Measure Life and Incremental Measure Cost
The measure life for packaged units is 15 years according to DEER[23].

The IMC documented for this measure is $90 per horsepower for chiller applications[24].

ECMs for HVAC

Measure Description	This measure consists of the installation of electronically commutated motors (ECMs) on a residential-sized hot air furnace, split A/C system, or an air handler serving both heating and cooling systems.
Units	Motor
Base Case Description	Fan Motor on a residential-sized furnace or air-handler meeting minimum Federal efficiency standards using a low-efficiency split capacitor (PSC) or shaded pole fan motor.

Measure Savings
The non-coincident kW and the annual kWh savings per motor is provided below.

[23] 2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report
[24] 2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report from assessment of several measures that include a VSD retrofit.

Table 90. HVAC ECM Savings[25]

System Type	kWh	Coincident peak kW
Heating only	462	0.462
Cooling only	194	0.2425
Heating and Cooling	656	0.462

Measure Savings Analysis

Measure savings are based on the methodology found in the 2010 Vermont Technical Reference User Manual (TRM). This methodology assumes 1000 equivalent full load hours per year for Heating, and 800 hours per year for Cooling.

Measure Life and Incremental Measure Cost

The measure life for packaged units and motors is 15 years per DEER 2008. The incremental measure cost (IMC) documented for this measure is $200 per the Vermont TRM.

Commercial Kitchen Demand Ventilation Controls

Measure Description	The measure consists of installing a control system that varies the exhaust rate of kitchen ventilation (exhaust and/or makeup air fans) based on the energy and effluent output from the cooking appliances (i.e., the more heat and smoke/vapors generated, the more ventilation needed). This involves installing a temperature sensor in the hood exhaust collar and/or an optic sensor on the end of the hood that sense cooking conditions which allows the system to automatically vary the rate of exhaust to what is needed by adjusting the fan speed accordingly. A VSD must be installed on the exhaust fan, and if applicable, on the make-up air unit.
Units	Per exhaust fan horsepower
Base Case Description	Exhaust and makeup fans that operate at 100% speed

Measure Savings

The savings for this measure is 0.76 kW and 4,486 kWh per exhaust fan horsepower.

[25] Vermont TRM

Measure Savings Analysis
Annual energy use is based on monitoring results from five different types of sites, as summarized in PG&E Food Service Equipment workpaper[26].

Measure Life and Incremental Measure Cost
The measure life is assumed to be the same as that of variable speed drives at 15 years. The incremental cost is cost difference between the energy-efficient equipment and the less efficient option. In the retrofit case, the IMC is equal to the full measure cost since cost of the less efficient option is $0. The cost for the new system is the incremental (difference in) cost of installing ventilation with and without controls. The cost is $1988 for a retrofit system and $1,000 for a new system per the PG&E workpapers.

Toilet Exhaust Occupancy Sensor

Measure Description	This incentive is available for the installation of occupancy sensors in toilet rooms to enable the exhaust fan only when the room is occupied. The existing toilet room exhaust cannot be automatically controlled by any other means, such as scheduled by a building automation system, interlocked with HVAC night setback or interlocked with existing lighting systems. The area served by the controlled exhaust fan must be a conditioned space (electric heated and/or air conditioned) or be taking its makeup air from a conditioned space (electric heated and/or air conditioned). The quantity of air exhausted from the toilet room must not be considered to be any portion of the air quantity exhausted from the building to meet the minimum outside air requirements by local or state codes. The existing exhaust volume flow rate must be a minimum of 75 cfm per toilet room fixture. A toilet room fixture is defined as either a water closet (toilet) or urinal. Manual timers controlling the exhaust system do not qualify for this incentive. Take

[26] Demand Ventilation Controls PGECOFST116 R1 slb4 090517.doc

	measurements to assure that the facility air balance is appropriately maintained.
Units	Per exhaust fan
Base Case Description	Exhaust fan with manual control tied to wall mounted light switch.

This measure is the installation of occupancy sensors on toilet exhaust fans between 0.6 and 2.0 amps.

Measure Savings

The following table summarizes the measure savings.

Table 91. Measure Savings for Toilet Exhaust Fan Occupancy Sensor per Exhaust Fan

Building Type	kWh Savings	kW Savings
Large Office	127	0.0407
Small Office	138	0.0391
School	116	0.0376
Small Retail/Service	168	0.0486
Large Retail/Service	170	0.0453
Hotel/Motel and Guest Rooms	355	0.0128
Medical - Hospital	262	0.0408
Medical - Nursing Home	214	0.0447
Restaurant	219	0.0371
Grocery	225	0.0382
Conditioned Warehouse	145	0.0295
Unconditioned Warehouse	165	0.0463
Manufacturing – Light Industrial (1 shift)	137	0.0463
Manufacturing – Light Industrial (2 shift)	226	0.0463
Manufacturing – Light Industrial (3 shift)	315	0.0399
College/University	124	0.0344
Government/Municipal	129	0.0284
Assembly	120	0.0380
Miscellaneous	160	0.0421
Garage (Ohio)	369	0.0000
Exterior (Ohio)	181	0.0000

Measure Savings Analysis

Annual energy savings and the peak coincident demand savings are calculated using the Operating hours, energy, and demand factors outlined in the Savings Calculation Methodology section at the beginning of the Lighting section. Based on a survey of the Grainger website, the typical amperage draw of toilet exhaust fans ranged from 0.6 to 2.0 amps[27]. A median value of 1.3 amps was used to determine the power draw on a typical 120 volt toilet exhaust fan. Assuming a power factor of 0.90, the connected wattage per exhaust fan would be 1.3 Amps x 120 Volts x x 0.90 = 140.4 Watts controlled.

Energy savings are calculated by applying the annual operating hours and the energy interactive effect, according to the following formula:

*kWh Reduction = Connected wattage/1000 * Annual operating hours * Energy interactive effect*Energy Savings Factor*

Coincident demand savings are calculated by applying the coincidence factor and the demand interactive effect, according to the following formula:

*Coincident kW savings = Connected wattage/1000 * Energy Savings Factor * Coincidence Factor * Demand interactive effect*

The Ohio TRM defines the Energy Savings Factor for Occupancy Sensors as 30%. The Ohio TRM also defines the summer peak coincidence factor for occupancy sensors as 0.15.[28] The baseline for this measure is fixtures that do not include any automatic controls, i.e., manual switches.

Measure Life and Incremental Measure Cost

The incremental cost is assumed to $42, which is the cost of a wall mounted occupancy sensor per the Ohio TRM. The expected measure life for the toilet exhaust control is assumed to be the same as for lighting occupancy sensors, which is 8 years.

Occupancy Sensor Control for HVAC Systems

[27] http://www.grainger.com/Grainger/BROAN-Bathroom-Fan-Finish-kit-2HYB1?Pid=search
[28] Ohio TRM, Page 151

Measure Description	This incentive is available for adding occupancy sensors that automatically switch an AC unit off for specific spaces (i.e., classrooms, large conference rooms, multifunction rooms, etc.) when these areas are not in use. The area served by the proposed HVAC occupancy sensors must be conditioned by a dedicated unitary AC or heat pump unit (i.e., the AC unit controlled by the occupancy sensor must not serve any other spaces that require conditioning when the occupancy sensor dictates unoccupied mode). The installed occupancy control must be capable of turning off the compressor and room fan during unoccupied mode. This incentive is not available for spaces already controlled by outside air demand control ventilation systems.
Units	Square Foot of Conditioned Space
Base Case Description	HVAC system with no occupancy sensors, where 30% of the time a a scheduled occupied space is actually unoccupied.

Measure Savings

The annual kWh savings for this measure is 0.5591 kWh per square foot of conditioned space. There are no coincident demand savings for this measure, since unoccupied periods are assumed to occur during non-peak periods.

Measure Savings Analysis

The heating and cooling energy savings due to this measure are realized by the following:

1) reduced supply air volume flow rate
2) reduced makeup outside air ventilation
3) reduced electrical fan power
4) allowing the space temperature to drift to unoccupied temperature set-point levels.

The energy savings associated with allowing the space temperature to drift is not accounted for in this study. Space with long unoccupied periods (ie: 2-hours) will see more energy savings than spaces with intermittent occupancy (ie: 15-minutes) due to the set-point temperature drift. The energy savings is calculated using heating degree days (HDD) and cooling degree days (CDD) to determine the amount of annual heating and cooling is required annually when the outdoor temperature is above 74°F for cooling and below 70° for heating. For this analysis, it was assumed that 30% of the time a scheduled occupied space is actually unoccupied.[29]

The rate of air conditioned energy consumption savings due to outside air ventilation reduction of cooling energy can be determined by the following:

$$q_{A/C} = (1.08) \cdot V_{OA} \cdot (T_{oC} - T_{iC})$$

Where,

$q_{A/C}$ = rate of conditioned air energy exhausted to the outdoors, Btu/hr
V_{OA} = exhaust volume flow rate, cfm
T_{oC} = average outdoor temperature. This will be the average, yearly temperature during the cooling season for this application, 80.3°F (320-CDD with a base temperature of 74°)
T_{iC} = indoor air temperature during the cooling period, 74°F

The anticipated unit energy rate of conditioned air being exhausted during the heating season can be realized by the following:

$$q_{A/C} = (1.08) \cdot (0.12 cfm/ft^2) \cdot (80.3°F - 74°F) = 0.82\ Btu/hr/ft^2$$

The annual electrical energy savings can be realized by the following to calculate outside air ventilation reduction savings:

$$kWh\ Savings_{ac} = \frac{q_{A/C} \cdot t_{ac} \cdot APO_{occ} \cdot PO_{non-occ}}{C_{1ac} \cdot COP_{ac}}$$

Where,

$kWh\ Savings_{ac}$= annual air conditioning electrical energy savings, kWh/yr/ft^2
t_{ac} = Cooling Degree Day period being unoccupied, 320-hrs/yr
C_{1ac} = conversion constant, 3,413-Btu/kWh
COP_{ac} = air condition system's coefficient of performance, COP of 3.52

$$kWh\ Savings_{ac} = \frac{0.82 \frac{Btu}{hr \cdot ft^2} \cdot 320 \frac{hrs}{yr} \cdot 0.42 \cdot 0.30}{3{,}413 \frac{Btu}{kWh} \cdot 3.52} = 0.002752 \frac{kWh}{yr \cdot ft^2}$$

[29] "An Analysis of the Energy and Cost Savings Potential of Occupancy Sensors for Commercial Lighting Systems". VonNeida, Bill; IES Paper #43; U.S. Environmental Protection Agency, ENERGY STAR Building Program; Aug. 16, 2000.

The reduction in the supply fan motor's electrical energy demand (DC_{motors}) can be realized by the following equation:

$$DC_{motors} = \frac{V \cdot SP_{Exhaust}}{(C_{SP/BHP} \cdot \eta_{Motor} \cdot \eta_{Fan})} \cdot C_{ME}$$

Where,

V_{SA} = supply air unit volume flow rate, 0.80-cfm/ft^2
SP_{SA} = total static pressure drop through the supply air systems, 2.0-inches WC
C_{ME} = conversion constant, 0.746-kW/hp
$C_{SP/BHP}$= conversion constant, 6,356-cfm x inWC/hp
η_{Motor} = efficiency of the fan's electrical motor, 82%
η_{Fan} = mechanical efficiency of the fan, 50%

The expected electrical energy reduction associated with controlling the operation of the exhaust fan motor with occupancy sensors can be realized by the following:

$$DC_{motors} = \frac{0.80 cfm/ft^2 \cdot 2.0"WC}{(6{,}356 cfm \cdot "WC/hp \cdot 0.82 \cdot 0.50)} \cdot \frac{0.746 kW}{hp} = \frac{0.000458 kW}{ft^2}$$

The annual electrical energy reduction can be realized by the following:

$$kWh\ savings_{motor} = DC_{motors} \cdot t_{motors} \cdot PO_{non-occ}$$

Where:

kWh Savings $_{motor}$ = annual electrical energy savings associated with controlling the exhaust fan motor, kWh/yr/ft^2
t_{motors} = annual scheduled hours of operation, 3,680-hrs/yr

$$kWh\ Savings_{motor} = 0.000458 kW/ft^2 \cdot \frac{3{,}680 hrs}{yr} \cdot 0.30 = \frac{0.5056 kWh}{yr \cdot ft^2}$$

The **total annual electrical energy reduction** for this measure can be realized adding the annual electrical energy savings associate with the air conditioning savings, to the reduced fan motor energy saving.

$$kWh\ Savings_{Total} = kWh\ Savings_{ac} + kWh\ Savings_{motor}$$

$$= \frac{0.002752 kWh}{yr \cdot ft^2} + \frac{0.55632 kWh}{yr \cdot ft^2} = \boldsymbol{\frac{0.5591 kWh}{yr \cdot ft^2}}$$

$$= \mathbf{100.8 kWh/yr\ per\ fixture}$$

Measure Life and Incremental Measure Cost

The measure life for occupancy controls is 8 years. The installation cost to add occupancy sensors controls to a building automated system has been estimated at $0.50/ft^2.per DNV KEMA research.

Window Film

Measure Description	This measure applies to window film installed to reduce the solar gain through the affected window. Windows with a northern exposure (+/- 45^o of true north) are not eligible. Film must meet one of the following requirements: • For clear, single-pane glass, the solar heat gain coefficient (SHGC) of the window film must be less than 0.39. • For clear, double paned glass, the SHGC of the window film must be less than 0.25. • For applications that don't meet either of the previous requirements, the film must have a SHGC ≤ 0.47 and visible transmittance/solar heat gain coefficient (VT/SHGC) ratio 1.3.
Units	Per 100 square foot of non-north facing window
Base Case Description	Double paned clear glass windows without any window film, with a U-value of 0.72, and a SHGC of 0.73.

Measure Savings
The average default savings for this measure is 0.12 kW and 274 kWh per 100 square foot of non-north facing window. Savings by building type as provided by the draft Ohio TRM for the Columbus area are provided in the table below.

Table 92. Energy Savings for Window Film

Building Type	Ohio TRM Building Type Mapping	ΔkWh_{100SF}	ΔkW_{100SF}
Large Office	Small Office	271	0.12
Small Office	Small Office	271	0.12
School	Primary School	352	0.17
Small Retail/Service	Small Retail	277	0.14
Large Retail/Service	Big Box Retail	304	0.12
Hotel/Motel and Guest Rooms	Average/Miscellaneous	274	0.12
Medical – Hospital	Average/Miscellaneous	274	0.12

Building Type	Ohio TRM Building Type Mapping	ΔkWh_{100SF}	ΔkW_{100SF}
Medical - Nursing Home	Average/Miscellaneous	274	0.12
Restaurant	Full Service Restaurant	255	0.17
Grocery	Average/Miscellaneous	274	0.12
Conditioned Warehouse	Light Industrial	160	0.14
Unconditioned Warehouse	NA - No Savings	0	0.00
Manufacturing – Light Industrial (1 shift)	Light Industrial	160	0.14
Manufacturing – Light Industrial (2 shift)	Light Industrial	160	0.14
Manufacturing – Light Industrial (3 shift)	Light Industrial	160	0.14
College/University	Average/Miscellaneous	274	0.12
Government/Municipal	Average/Miscellaneous	274	0.12
Assembly	Assembly	316	0.05
Miscellaneous	Average/Miscellaneous	274	0.12
Garage (Ohio)	NA - No Savings	0	0.00
Exterior (Ohio)	NA - No Savings	0	0.00

Measure Savings Analysis
The savings for this measure come from the Ohio Draft TRM.

Measure Life and Incremental Measure Cost
Per the Ohio TRM, the incremental cost for this measure is $267 per 100 square feet of window, and the expected lifetime of the measure is 10 years.

Centralized Energy Management System Controls

Measure Description	Incentives are available for existing buildings that currently have no digital automated HVAC controls or outdated pneumatic control systems with inoperable time control functions. Existing HVAC control systems cannot have time of day scheduling (including 7-day programmable thermostats). Upgrading obsolete EMS HVAC system with inoperable time clock functions will be reviewed on a case-by-case basis for incentive eligibility. Buildings upgrading existing digital EMS systems are not eligible for prescriptive incentives. If incorporated with Demand Control Ventilation, real-time carbon-dioxide monitoring at the operator interface is required. HVAC EMS systems must be new and include (a) central time control, (b) real-time outside air damper positioning, (c) graphic operator interface, (d) whole building real-time power and energy monitoring capability, (e) open-protocol architecture (shall consist of either LonTalk (ANSI/CEA 709.1) or BACNet (ASHRAE/ANSI 135) protocol being used between all controlled and controlling devices and every node on the network), (f) web-based interface with PC based controls, (g) have a minimum setback space temperature of at least 8°F in both heating and air condition mode, (h) minimum setback period must exceed 2,200-hours per year, and (i) at least three "enhanced" control strategies (see Table 2). Buildings with 2,000-ft2 - 50,000 -ft2 of conditioned, controlled space are eligible for this prescriptive incentive.
Units	Per square foot of conditioned space
Base Case Description	No control or only basic electronic or electromechanical time controls.

List of eligible enhanced control strategies:

- Optimal Start
- Economizer Control
- DB or WB Changeover Temperature Setpoint
    - Improved Outside Air Volume Control (other than economizer)
- Morning Warm Up Cycle
- Static Pressure Reset
- Supply Air Temperature Reset
- Unoccupied Temperature Setback
- OA Damper Control
- Summer/Winter Volume Change
- Load Shedding for Demand Control
- Equipment Cycling
- Cooling Lockout on OSAT

- Heating Lockout on OSAT
- Condenser Water Temperature Setpoint Reset
- Chilled Water Temperature Setpoint Reset
- Chiller or Compressor Sequencing
- Distribution Pump Selection/Sequencing
- Distribution Pump Speed Control
- Cooling Tower Fan Staging
- Cooling Tower Fan Speed Control
- Partial Light Shutoff
- Floating Head Pressure Control (Groceries)
- Evaporator Fan Speed Control (Groceries)
- Cold Case Lighting Control (Groceries)
- Variable Light Level Control
- Head Pressure Controls (Groceries)
- Anti Sweat Heater Controls (Groceries)

Note: Enhanced control strategies listed above may not count unless they can be monitored, scheduled, and controlled from a central operator interface.

Measure Savings
The average default savings for this measure is 0.0 kW and 2.31 kWh per square foot of conditioned space. Initial default savings by building type are provided in the table below.

Table 93. Energy Savings for EMS Measure, per square foot

Building Types	kWh
Large Office	2.84
Small Office	2.84
School	1.19
Small Retail/Service	2.15
Large Retail/Service	2.15
Hotel/Motel	2.21
Medical- Hospital	4.19
Medical- Nursing Home	2.88
Assembly/Meeting Place	0.65
Restaurant	5.78
Grocery	2.15
Conditioned Warehouse	1.62
Unconditioned Warehouse	1.62

Industrial/Manufacturing	1.62
College/University	1.19
Government/Municipal	1.85
Miscellaneous	2.31

For larger projects, the numbers shown above may be overwritten in the database after a billing analysis is complete, and more accurate savings for the project can be determined. The values above may be used for initial tracking, and reservation processing as necessary, but are based on general experience from past projects. However, the savings from EMS projects may vary considerably depending on the scope of the project.

Measure Savings Analysis

The Energy Information Administration's Commercial Building Energy Consumption Survey (CBECS) data was used to determine the baseline energy use for the (17) different building types within the program. Specifically, data on the energy intensity (kWh/SF) for the building types within the east north central census region of the US was used.[30] The east north central census region includes Wisconsin, Michigan, Illinois, Indiana, and Ohio.[31] The table below shows the electrical intensities for the EIA space types, along with the closest AEP building type.

Table 94. Electrical Intensities for EIA Space Types and Program Building Type Mapping

EIA Building Type	Electricity Energy Intensity (kWh/square foot) for the East North Central Census Area	Associated Program Building Type
Education	7.9	School
Food Sales	NA	Small Retail/Service and Large Retail/Service
Food Service	38.5	Restaurant
Health Care – Total	24.2	NA
Health Care – Inpatient	27.9	Medical - Hospital
Health Care – Outpatient	NA	Medical - Nursing Home
Lodging	14.7	Hotel/Motel

30 http://www.eia.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set15/2003pdf/c17a.pdf
31 ftp://ftp.abag.ca.gov/pub/mtc/planning/temp/HBrazil/Scoping%20Plan/supmap.pdf

EIA Building Type	Electricity Energy Intensity (kWh/square foot) for the East North Central Census Area	Associated Program Building Type
Mercantile -Total	15.6	Small Retail/Service and Large Retail/Service
Mercantile - Retail (Other than Mall)	12.3	NA
Mercantile - Enclosed and Strip Malls	17.9	NA
Office	18.9	Large Office and Small Office
Public Assembly	12.3	Government/Municipal
Public Order and Safety	NA	NA
Religious Worship	4.3	Assembly/Meeting Place
Service	12	Small Retail/Service and Large Retail/Service
Warehouse and Storage	10.8	Conditioned Warehouse and Unconditioned Warehouse
Other	NA	NA
Vacant	NA	NA

A mapping was done from the (18) CBECS building types to the (17) AEP building types. The energy intensities for the Small Retail, Large Retail and Grocery space types within the AEP program are the weighted average by total square footage of the Service and Mercantile space types within CBECS. The Other/Miscellaneous is the simple average of the other (16) mapped AEP building types.

Data from CBECS, which shows the electric intensities of different building types by end use, is used to determine the baseline energy consumption, as well as to estimate the anticipated energy reduction with the EMS system[32]. Estimates on anticipated energy reductions within building end uses are shown in the table below, for illustrative purposes.

Table 95. Potential Energy Savings Calculation Example

[32] http://www.eia.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set19/2003pdf/e06.pdf

	Electricity Energy Intensity (kWh/square foot)										
	Space Heating	Cooling	Ventilation	Water Heating	Lighting	Cooking	Refrigeration	Office Equipment	Computers	Other	Total
Electricity is Main Heat Source	0.6	2.1	1.8	0.3	5.6	0.1	1.8	0.3	0.7	1.7	15
Potential Savings (Electric Heat)	*2.0%*	*4.0%*	*2.0%*	*0.0%*	*6.0%*	*0.0%*	*1.0%*	*0.0%*	*0.0%*	*0.0%*	**15.0%**

The sum of all of end use savings is 15%, which is the factor applied to the electric intensities in order to come up with the default kWh/SF savings values for each building type.

Measure Life and Incremental Measure Cost

The measure life for this measure is assumed to be 15 years (DEER 2008), and the incremental measure cost is assumed to be $1.5/SF, both values are assumptions based on past experience.

Air –side Economizer

Measure Description	This measure consists of retrofitting Roof-Top Units (RTUs), Air Handling Units (AHUs), Split Direct-Expansion (DX) systems, or Unit Ventilators (UVs), which were designed without economizers. Repairing systems which have inoperable economizer controls are not eligible for this measure. The area served must be air conditioned space. New damper actuators and controls must be installed to the existing system with the proper calibration.
Units	Per ton
Base Case Description	System which was designed without economizers.

Measure Savings

The annual energy savings for this measure is 436.93 kWh per ton.

Measure Savings Analysis

The savings for this measure are based on a simulation using eQUEST version 3.64. For this analysis, a simulation was run for a 10 story, 350,000 ft^2. office building in Columbus, OH. The model simulated HVAC systems with and without economizers to determine the differences in electric energy consumption the cooling loads require to maintain the indoor building temperature at acceptable levels. The specifications of the simulated buildings are defined in the following table.

Table 96. Simulated Building Specifications

Building	Building Area	350,000-ft^2 with 10 floors
	Schedule	Monday to Saturday: 9am to 6pm, and closed on Sunday and holidays
	Lighting density (W/ft^2)	1.55 (perimeter office) and 1.45 (core offices)
	Plug load density (W/ft^2)	1.6 (perimeter office) and 0.7 (core offices)
	Wall construction	Glass curtain wall (R-8)
	Roof construction	Built-up roof (R-14)
	Glazing type	Multipane
HVAC	HVAC system type	Single zone air handler with HW heat
	HVAC system sizing	Based on ASHRAE design day conditions, 10% over sizing assumed
	Chiller type	400 Ton Electric Centrifugal Hermetic, with water cooled condenser, with constant speed compressor
	Boiler type	Hot water, 80% efficiency
	Thermostat setpoints	Occupied hours: 75F (cooling) and 70F (heating) Unoccupied hours: 80F (heating) and 65F (heating)

From the analysis, based on a 10% over-sizing of system size, this building requires a 400 ton unit to maintain comfort and air quality. The modeled cooling system without an economizer mode consumes 5,374,404-kWh/yr. The modeled cooling system with economizer mode consumes 5,199,631-kWh/yr. The model shows that there are energy savings all year. The electrical energy saved from installing an economizer in this building is 174,773-kWh/yr. For this simulation, the energy required to mechanically cool this building is reduced by 3%.

Measure Life and Incremental Measure Cost

The estimated measure life is 10 years[33]. The incremental measure cost is $155/ton based on DEER 2008.

[33] http://www.intel.com/it/pdf/reducing_data_center_cost_with_an_air_economizer.pdf

Demand Control Ventilation - Office[34]

Measure Description	This measure consists of installing ventilation controls on existing buildings to use carbon dioxide levels to measure occupancy and modify the percentage of outside air based on variable levels. Only buildings with space heating and cooling applications are eligible.
Units	Per 1,000 square foot
Base Case Description	Existing building without ventilation controls that modify the percentage of outside air based on carbon dioxide levels

This measure consists of installing ventilation controls on existing buildings to use carbon dioxide levels to measure occupancy and modify the percentage of outside air based on variable levels. Only buildings with space heating and cooling applications are eligible. Conditioned spaces must be kept between 65°F and 75°F during operating hours. The system must have current fresh air requirements ≥ 10% of supply air requirements. Carbon dioxide (CO_2) sensors must be installed in conjunction with fully functioning air-side economizers with zone-level CO_2 sensors for rooftop units qualify, and return system CO_2 sensors are required for built up systems. Controlled space must meet the minimum requirements of the current State Mechanical Building Code, as well as local building code, and manufacturer's recommendations. The incentive is calculated per square foot of area controlled. A floor plan must be submitted with the Final Application.

Measure Savings

The annual electrical energy savings are 511.65 kWh/1,000 ft^2 and the annual gas savings are 115.21 therms/1,000 ft^2.

Measure Savings Analysis

The cooling energy savings due to this measure are realized by reducing the incoming makeup outside air ventilation which results in a decrease in the cooling load.

A study done by the ENERGY STAR program under the direction of the US Environmental Protection Agency, found that most commercial facilities are only occupied seventy percent (70%) of the time. It is nearly impossible to schedule the HVAC equipment to take into account true occupancy of a space without automated feedback. A demand control system measures the carbon dioxide levels in a space which can be correlated into an approximate occupancy load; thus, allowing the HVAC system to modulate down the makeup outside air ventilation rate during period of light occupancy.

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[34] This measures is considered as hybrid-prescriptive. The workpaper documents the default value, however KEMA will report a site-specific value for the final approved project.

The information in the following table is from the ENERGY STAR Building program, within the U.S. Environmental Protection Agency.

Table 97. Potential Energy Savings from Occupancy-based Feedback Sensors

SPACE TYPE	CALIFORNIA ENERGY COMMISSION (CEC) (%) [1]	Esource (%) [1]	ELECTRICAL POWER RESEARCH INSTITUTE (EPRI) (%) [1]	Novitas (%) [1]	Watt Stopper (%) [1]
PRIVATE OFFICE	25-50	13-50	30	40-55	15-70
OPEN OFFICE	20-25	20-28	15	30-35	5-25
CLASSROOM	-	40-46	20-35	30-40	10-75
CONFERENCE	45-65	22-65	35	45-65	20-65
RESTROOM	30-75	30-90	40	45-65	30-75
WAREHOUSE	50-75	-	55	70-90	50-75
STORAGE	45-65	45-80	-	-	45-65

(1) "An Analysis of the Energy and Cost Savings Potential of Occupancy Sensors for Commercial Lighting Systems". VonNeida, Bill; IES Paper #43; U.S. Environmental Protection Agency, ENERGY STAR Building Program; Aug. 16, 2000.

In reference to the above table, it is possible to see a thirty-percent (30%) reduction in HVAC load due to reduced occupancy.

In order to analyze the energy savings from installing demand control ventilation, Quick Energy Simulation Tool (eQUEST) version 3.64 is used. This model is based on a 350,000 ft^2, 10 story office building in Columbus, OH. The model simulates energy consumption with and without demand control. The specifications of the buildings that are provided in the following table:

Table 98. Simulated Building Specifications

Building	**Building Area**	350,000-ft^2 with 10 floors
	Schedule	Monday to Saturday: 9am to 6pm, and closed on Sunday and holidays
	Lighting density (W/ft^2)	1.55 (perimeter office) and 1.45 (core offices)
	Plug load density (W/ft^2)	1.6 (perimeter office) and 0.7 (core offices)
	Wall construction	Glass curtain wall (R-8)
	Roof construction	Built-up roof (R-14)
	Glazing type	Multipane
HVAC	HVAC system type	Single zone air handler with HW heat

	HVAC system sizing	Based on ASHRAE design day conditions, 10% oversizing assumed
	Chiller type	Electric Centrifugal Hermetic, with water cooled condenser, with constant speed compressor
	Boiler type	Hot water, 80% efficiency
	Thermostat setpoints	Occupied hours: 75F (cooling) and 70F (heating) Unoccupied hours: 80F (heating) and 65F (heating)

Based on a 10% over-sizing of the system, this building requires a 1,250 ton unit to maintain comfort and air quality. The modeled cooling system without demand control ventilation consumes approximately 7,617,056-kWh/yr. The modeled heating system without demand control ventilation consumes approximately 145,634 therms or 0.425 therm/yr/ft^2.

The modeled cooling system with demand control ventilation consumes approximately 7,437,978-kWh/yr. The modeled heating system with demand control ventilation consumes approximately 105,310 therms.

In this simulation, energy savings occur all year because of the demand control ventilation modifying the percentage of outside air to reduce the amount of mechanical cooling and heating load needed. The amount of electrical energy saved from installing demand control ventilation in this sample building is 140,179-kWh/yr, which is a reduction to the air conditioning energy consumption of 2%. The amount of heating energy saved is approximately 40,879-therms/yr which is a reduction of space heating energy consumption of 28%.

Measure Life and Incremental Measure Cost

The measure life is 15 years. Typical sensor cost is $950 per sensor based on Federal Energy Management Program35. It is assumed that one sensor is used to control 5,000 square feet. Therefore, the cost is $0.19 per sq ft or $190 per 1,000 ft^2.

[35] Demand Controlled Ventilation Using CO_2 Sensors, http://www1.eere.energy.gov/femp/pdfs/fta_co2.pdf

Demand Control Ventilation – Parking Garage[36]	
Measure Description	Incentives are available for the control of exhaust ventilation fans for an existing enclosed parking garage using carbon monoxide sensor and controls. The control system must vary the number of fans on line, the fan speed, or fan blade pitch in response to the carbon monoxide concentration as sensed at representative locations in the garage. Systems must be capable of turning off fan power during periods of low activity as compared to high-activity periods. If controlling garage ventilation systems are required by code, then they are not eligible for these incentives.
Units	Per HP
Base Case Description	Existing garage ventilation with no controls, continuous operation.

Measure Savings

The savings are 1,632 kWh/hp and 0.1351 kW/hp.

Measure Savings Analysis

The savings analysis uses the following set of assumptions[37]:

- 24/7 operation with no control
- One sensor controls 8,000 ft^2 of space
- Fan power is 1.2W/ft^2

Fan power in watts is converted to horsepower assuming an efficiency of 92% and a load factor of 70% which results in 0.002114 hp/ft^2. Then the conversion is rounded to the nearest horsepower for 8,000 ft^2 of space is 17hp. Therefore, the baseline usage is 1.2 W/ft^2 fan power x 8,760 hours per year x 8,000 ft^2/sensor = 84,096 kWh per year per sensor or 4,497 per hp (savings per sensor divided by 17 hp).

The savings percentage (or the % off time based on sensor control) is based a figure provided by Krarti, Moncef in the book, Energy Audit of Building Systems (p. 7-14). The average percentage savings expected is 33% with CO sensors. Therefore, the savings is the baseline energy usage x 33%.

Measure Life and Incremental Measure Cost

The measure life is 15 years. DNV KEMA estimate from reviewing projects is about $200 per horespower.

[36] This measures is considered as hybrid-prescriptive. The workpaper documents the default value, however KEMA will report a site-specific value for the final approved project.
[37] APS PS_S4B 2011 Plan documentation

Motors and Drives

Motor measures are eligible for prescriptive new construction incentives, too. Variable speed drives are only available for new construction when they are not required by code.

Self direct measures can also use these set of workpapers, by referring to the savings calculation methodology, run time hours, load factor, and coincidence factors are used. The actual existing unit and replacement unit efficiencies are used for the savings calculation instead of code baseline.

NEMA® Premium-Efficiency Motors

Measure Description	Motors eligible for an incentive are three-phase AC induction motors, 1-200 hp, of open drip-proof (open) and totally enclosed fan-cooled (closed) classifications. Rewound motors do not qualify. Incentives are based on the motor's nominal full-load efficiencies, tested in accordance with IEEE (Institute of Electrical and Electronics Engineers) Standard 112, method B, that exceed the NEMA premium-efficiency. The application must include the manufacturer's performance data sheet that at least shows equipment type, equipment size, model number, and efficiency rating. Customers should consider matching water or air flows (GPM, CFM) of the existing pump or fan when installing energy-efficient motors that inherently have higher speeds (less slip), which may increase energy savings.
Units	Per motor
Base Case Description	Federal minimum NEMA Premium Nominal efficiency

Measure Savings

The following tables provide the measure savings for exceeding NEMA premium motor efficiency levels or EISA 2007 standards. The minimum qualifying efficiency levels are provided below.

Table 99. Measure Coincident kW Savings, EISA 2007 Baseline (per motor)

	1200 RPM		1800 RPM		3600 RPM	
HORSEPOWER	**ODP**	**TEFC**	**ODP**	**TEFC**	**ODP**	**TEFC**
1	0.006	0.006	0.006	0.006	0.007	0.007
1.5	0.008	0.008	0.008	0.008	0.009	0.009
2	0.011	0.010	0.011	0.011	0.011	0.011
3	0.016	0.015	0.015	0.015	0.017	0.016
5	0.026	0.026	0.026	0.026	0.027	0.026
7.5	0.038	0.037	0.037	0.037	0.039	0.038
10	0.049	0.049	0.049	0.049	0.051	0.050
15	0.073	0.074	0.071	0.072	0.075	0.074
20	0.096	0.097	0.095	0.095	0.099	0.099
25	0.118	0.118	0.117	0.117	0.122	0.122
30	0.140	0.142	0.139	0.140	0.146	0.146
40	0.185	0.185	0.185	0.185	0.192	0.192
50	0.231	0.231	0.229	0.229	0.237	0.237
60	0.275	0.275	0.272	0.272	0.281	0.281
75	0.344	0.344	0.340	0.338	0.351	0.351
100	0.454	0.454	0.450	0.450	0.468	0.463

	1200 RPM		1800 RPM		3600 RPM	
HORSEPOWER	ODP	TEFC	ODP	TEFC	ODP	TEFC
125	0.567	0.567	0.563	0.563	0.578	0.567
150	0.675	0.670	0.670	0.670	0.694	0.681
200	0.900	0.893	0.893	0.886	0.908	0.900
250	1.126	1.116	1.116	1.107	1.135	1.116

Table 100. Measure kWh Savings, EISA 2007 Baseline (per motor)

	1200 RPM		1800 RPM		3600 RPM	
HORSEPOWER	ODP	TEFC	ODP	TEFC	ODP	TEFC
1	22	22	21	21	26	26
1.5	30	30	30	30	32	32
2	40	39	41	41	42	42
3	58	57	57	57	62	61
5	95	95	95	95	101	97
7.5	173	170	170	167	180	176
10	223	227	223	223	234	231
15	335	340	326	330	346	340
20	440	446	434	434	453	453
25	651	651	642	642	669	669
30	771	781	763	771	803	803
40	1,017	1,017	1,017	1,017	1,055	1,055
50	1,271	1,271	1,261	1,261	1,301	1,301
60	1,982	1,982	1,962	1,962	2,020	2,020
75	2,478	2,478	2,452	2,432	2,525	2,525
100	3,269	3,269	3,242	3,242	3,367	3,332
125	3,988	3,988	3,954	3,954	4,064	3,988
150	4,745	4,706	4,706	4,706	4,877	4,785
200	6,327	6,275	6,275	6,223	6,380	6,327
250	7909	7843	7843	7779	7975	7843

Measure Savings Analysis
The two types of capacity savings estimates discussed here are connected-load reduction achieved by the measure (non-coincident) and demand reduction coincident with the utility's system peak. The non-coincident demand reduction achieved by the measure is estimated from engineering analyses using the following formula:

Non-coincident kW reduction = kW of existing equipment - kW of replacement equipment

$$kW = \frac{(\text{Motor HP}) \times (0.746\ \text{kW/HP}) \times (\text{Load Factor})}{\text{Motor Efficiency}}.$$

Generally motors are oversized and so the load factor is assumed to be 75 percent.[38]

Energy savings are based on the difference between baseline and efficient equipment connected wattage and annual operating hours, according to the following formula:

kWh Reduction = (kW of existing equipment - kW of replacement equipment) * (Annual operating hours)

To determine coincident demand reduction, engineering estimates of savings are multiplied by a coincident diversity factor. Coincident diversity factors have been estimated to be 0.74[39].

Coincident kW Reduction = Coincident Diversity Factor * Non-coincident reduction with Demand Interactive Effects

DEER uses the data from a study for the Department of Energy completed in 1998[40]. The data for Overall Manufacturing, SIC 20 through 39, is used as for the operating hours to represent the industrial market sector. These hours are assumed reasonable for use with all market sectors.

Table 101. Annual Operating Hours[41]

Size Category	Operating Hours
1 to 5 hp	2,745
6 to 20 hp	3,391
21 to 50 hp	4,067
51 to 100 hp	5,329
101 to 200 hp	5,200

[38] 2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report - Residential and Commercial Non-Weather Sensitive Measures and Ohio TRM.
[39] 2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report - Residential and Commercial Non-Weather Sensitive Measures and VEIC comments filed November 15, 2010.
[40] Xenergy, United States Industrial Electric Motor Systems Market Opportunities Assessment. Burlington, MA, 1998. Hours are from Page B-2 for Overall Manufacturing (SIC 20-39).
[41] 2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report - Residential and Commercial Non-Weather Sensitive Measures referencing the Xenergy study.

Baseline and retrofit equipment assumptions are presented in the next tables. Motor replacement is considered a replace on burn-out measure. The baseline represents the nonenergy-efficient equipment that would be purchased, which is set at NEMA Premium efficiency values, which are equivalent to U.S. minimum standards for 1 – 200 HP general purpose motors, per EISA 2007. This table shows the standard efficiencies used for the savings calculations. The average efficiency improvement found on the CEE motor list is 1% higher than EISA 2007. Savings calculation is based on this improvement level for all motor sizes and speed.

Table 102. EISA 2007 or NEMA Premium Efficiencies Motors

HORSEPOWER	1200 RPM		1800 RPM		3600 RPM	
	ODP	TEFC	ODP	TEFC	ODP	TEFC
1	82.5%	82.5%	85.5%	85.5%	77.0%	77.0%
1.5	86.5%	87.5%	86.5%	86.5%	84.0%	84.0%
2	87.5%	88.5%	86.5%	86.5%	85.5%	85.5%
3	88.5%	89.5%	89.5%	89.5%	85.5%	86.5%
5	89.5%	89.5%	89.5%	89.5%	86.5%	88.5%
7.5	90.2%	91.0%	91.0%	91.7%	88.5%	89.5%
10	91.7%	91.0%	91.7%	91.7%	89.5%	90.2%
15	91.7%	91.0%	93.0%	92.4%	90.2%	91.0%
20	92.4%	91.7%	93.0%	93.0%	91.0%	91.0%
25	93.0%	93.0%	93.6%	93.6%	91.7%	91.7%
30	93.6%	93.0%	94.1%	93.6%	91.7%	91.7%
40	94.1%	94.1%	94.1%	94.1%	92.4%	92.4%
50	94.1%	94.1%	94.5%	94.5%	93.0%	93.0%
60	94.5%	94.5%	95.0%	95.0%	93.6%	93.6%
75	94.5%	94.5%	95.0%	95.4%	93.6%	93.6%
100	95.0%	95.0%	95.4%	95.4%	93.6%	94.1%
125	95.0%	95.0%	95.4%	95.4%	94.1%	95.0%
150	95.4%	95.8%	95.8%	95.8%	94.1%	95.0%
200	95.4%	95.8%	95.8%	96.2%	95.0%	95.4%
250	95.4%	95.8%	95.8%	96.2%	95.0%	95.8%

Measure Life and Incremental Measure Cost

The measure life is assumed to be 15 years.[42]

The following table provides the incremental measure cost. Incremental cost is cost difference between the energy-efficient equipment and the less efficient or standard option. However for the cost differences between NEMA premium and the retrofit motor at the efficiency stated above are provided in the table based on analysis of Motor Master data.

Table 103. Motor Incremental Measure Cost for Exceeding NEMA (EISA 2007) Efficiency[43]

HORSEPOWER	1200 RPM		1800 RPM		3600 RPM	
	ODP	TEFC	ODP	TEFC	ODP	TEFC
1	$ 41.00	$ 112.83	$ 55.33	$ 163.05	$ 18.00	$ 78.04
1.5	$ 27.71	$ 245.90	$ 41.10	$ 205.77	$ 24.00	$ 139.89
2	$ 14.71	$ 232.77	$ 60.36	$ 226.31	$ 33.08	$ 155.70
3	$ 126.63	$ 340.33	$ 12.40	$ 259.40	$ 54.38	$ 175.93
5	$ 46.00	$ 254.27	$ 29.45	$ 237.06	$ 71.78	$ 201.27
7.5	$ 150.63	$ 360.01	$ 92.73	$ 349.00	$ 45.44	$ 371.01
10	$ 204.25	$ 308.93	$ 13.00	$ 255.33	$ 127.67	$ 253.19
15	$ 135.43	$ 201.06	$ 21.09	$ 341.20	$ 143.90	$ 270.60
20	$ 111.40	$ 426.10	$ 130.58	$ 199.77	$ 229.13	$ 185.53
25	$ 494.14	$ 281.10	$ 114.07	$ 102.34	$ 122.57	$ 111.42
30	$ 247.20	$ 585.29	$ 28.92	$ 159.73	$ 683.00	$ 106.86
40	$ 668.83	$ 859.70	$ 368.10	$ 169.76	$ 392.50	$ 254.25
50	$ 511.67	$ 583.94	$ 59.38	$ 58.20	$ 599.13	$ 66.22
60	$ 642.83	$ 1,205.69	$ 342.60	$ 764.11	$ 782.50	$ 60.31
75	$ 836.83	$ 597.12	$ 700.62	$ 670.95	$ 676.27	$ 549.15
100	$ 911.43	$ 866.51	$ 115.09	$ 633.04	$ 793.82	$ 1,320.57
125	$ 1,148.88	$ 260.72	$ 852.13	$ 568.68	$ 765.82	$ 182.77
150	$ 1,312.71	$ 103.87	$ 619.00	$ 88.96	$ 1,213.43	$ 657.38
200	$ 794.33	$ 5,088.92	$ 1,325.60	$ 200.70	$ 2,080.33	$ 1,301.07
250	$ 794.33	$ 5,088.92	$ 1,325.60	$ 200.70	$ 2,080.33	$ 1,301.07

42 2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report - Residential and Commercial Non-Weather Sensitive Measures
43 MotorMaster+ v4.1, October 1, 2010. All costs based on list price

Variable Speed Drives for HVAC and Process Applications

Measure Description	This applies to variable-speed drives (VSDs) installed on existing HVAC or process fans or pumps up to 200 horsepower. The installation of a VSD must accompany the permanent removal or disabling of any flow control devices such as inlet vanes, bypass dampers, and throttling valves. This measure does not apply to chillers. VSDs for chillers are considered under a separate measure.
Units	Per rated motor HP controlled
Base Case Description	Mechanical restriction (damper or valve), bypass, on/off cycling, or no flow control.

Variable-speed drives (VSDs) installed on existing HVAC or non-HVAC fans or pumps and air compressors are eligible for this incentive. The installation of a VSD must accompany the permanent removal or disabling of any flow control devices such as inlet vanes, bypass dampers, and throttling valves to be eligible. Other requirements include:

- Rated motor horsepower ≤ 200 hp and minimum annual operating hours are as indicated below.
- Does not apply to redundant or backup/standby motors that are expected to operate less than 1,200 operating hours per year.
- Does not apply to variable pitch fans and forward curve with inlet guide vanes unless applicant supplies proof of kWh savings from logged or measured data.
- Does not apply to replacement of a multi-speed motor.
- Does not apply to VFDs on new chillers (existing chillers qualify under a lower rebate of $30 per hp).
- Does not apply for new air compressors with VSD.
- Applies only to VSDs installed with an automatic control technology.
- For motors greater than 100 hp, applicant must provide information regarding the equipment type and location, the equipment the drive is installed on, the daily and weekly operating schedule, a description of the existing flow control method, the proposed control strategy and, to the extent possible an estimate of hours the system will operate at 10 percent load increments[44].

Measure Savings

The measure default HVAC VSD savings by building type are summarized in the first two tables. Details on analysis methodology are in the following section. The HVAC motor savings application are based on the large office building type (eQuest model prototype), since that is to

[44] Additional information may be required for all projects, upon request.

date been where the highest penetration of the measure. To calculate the savings by building type, the large office building savings value is multiplied by a ratio of operating hours of the other building type and large office for the specific fan and pump application. The third table provides the peak demand savings which is from the large office models only and assumed to representative for all the building types[45].

Savings are provided by fan and pump types for space conditioning for human comfort. If specific supply/return fan and pre-retrofit control types are known, The second table should be used.

Table 104. HVAC Motor Default VSD Savings by Building Type by Application Type (kWh/yr/hp)

Building Type	Supply/Return Fan	Chilled Water Pump	Hot Water Pump	Condenser Water Pump	Cooling Tower Fan	Other HVAC Motor
Large Office	495	177	201	438	267	315
Small Office	515	223	209	438	267	315
School	770	315	312	358	218	290
Small Retail/Service	1520	247	617	550	335	464
Large Retail/Servie	1278	403	518	550	335	509
Hotel/Motel	1805	1193	732	1054	642	1013
Medical - Hosptial	1519	1286	616	550	335	1013
Medical - Nursing Home	1409	1274	572	1054	642	1013
Assembly/Meeting Place	1659	265	673	550	335	507
Restaurant	2004	486	813	550	335	612
Grocery	2211	641	897	1054	642	676
Conditioned Warehouse	1505	217	610	550	335	460
Unconditioned Warehouse	0	0	0	0	0	0
Industrial/Manufacturing	1141	187	463	362	221	348
College/University	1511	751	613	763	465	902

[45] It is understood that this assumption is not appropriate, but nevertheless, DNV KEMA is using it to simplify analysis and will consider revisions if the measure penetration is high in other building types.

Government/Municipal	1077	221	437	494	301	411
Other/Miscellaneous	1353	503	549	601	366	579

Table 105. HVAC Supply Return Fan Motor Default VSD Savings by Building Type by Application Type (kWh/yr/hp)

Building Type	VAV with inlet guide vanes / forward curve	VAV with inlet guide vanes / airfoil (backward inclined)	VAV with discharge dampers / forward curve	VAV with discharge dampers / airfoil (backward inclined)
Large Office	59	449	331	706
Small Office	61	567	344	706
School	92	799	514	578
Small Retail/Service	181	626	1016	887
Large Retail/Service	152	1023	854	887
Hotel/Motel	215	3026	1206	1701
Medical - Hospital	181	3263	1015	887
Medical - Nursing Home	168	3231	942	1701
Assembly/Meeting Place	198	673	1108	887
Restaurant	239	1232	1339	887
Grocery	264	1626	1477	1701
Conditioned Warehouse	180	550	1006	887
Unconditioned Warehouse	0	0	0	0
Industrial/Manufacturing	136	475	762	585
College/University	180	1905	1010	1231
Government/Municipal	128	561	719	796
Other/Miscellaneous	161	1276	904	970

Table 106. HVAC Motor Default VSD Savings by Application Type (kW/ hp)[46]

Motor Type[47]	PJM kW	AEP kW
Supply/Return Fan	0.1841	0.1837
VAV with inlet guide vanes / forward curve	0.023	0.023
VAV with inlet guide vanes / airfoil (backward inclined)	0.190	0.190
VAV with discharge dampers / forward curve	0.117	0.117
VAV with discharge dampers / airfoil (backward inclined)	0.245	0.244
Chilled Water Pump	0.139	0.1316
Hot Water Pump	0.002	0.0016
Condenser Water Pump	0.128	0.129
Cooling Tower Fan	0.171	0.167
Other HVAC Motor	0.125	0.123
Air Compressor Motor	0.162	0.162
Other Non-HVAC Motor	0.073	0.073

The following table provides a summary of the default savings values for non HVAC motors.

Table 107. Non HVAC Motor Default Savings (per hp)

Motor Type	kWh/hp	kW/hp
Air Compressor Motor	1,211	0.162
Domestic Water Pump	744	0.083
Other	721	0.073

Measure Savings Analysis

DNV KEMA used DEER based eQuest models modified for ComEd specific elements including climate, building type and basic system type (central chilled water plant)[48]. Large offices were used as the basis for the models based on the historical predominance of this building in applications for this measure.

[46] Savings are based on large office building as the representative building type.
[47] FC = forward curve, AF/BI = airfoil/backward inclined, IGV = inlet guide vanes.
[48] At this time, DNV KEMA assumes Chicago weather is sufficient for Columbus, Ohio.

DNV KEMA modeled using eQuest 3.64 the following pre-retrofit cases for a prototype large office building and determined the kWh/hp savings from installation of variable speed control for each pre-retrofit case. Specifics of the fan models include:

- A 1.30 sizing ratio applied to the fan supply volume and the coil size
- Fan power – 0.0006 kW/cfm based off a standard 25,000 CFM size fan (source is Greenheck manufacturer)
- To convert the calculated kW sizing of the motors from eQuest to rated (or nameplate) horsepower, the following calculation is used where motor efficiency is the default eQuest efficiency from DEER, kW is an output field from .sim file, and LF is assumed to be 0.75.

$$\textit{Rated hp} = kW_{eQuest} \times \textit{motor eff} / 0.746 / LF$$

- Used various eQUEST default fan performance curves: FC-Fan-w/Dampers, FC-Fan-w/Vanes, AF-Fan-w/Dampers, AF-Fan-w/Vanes
- eQUEST is not capable of modeling VFDs for each FC fan and AF fan, but only as applied to general fan. The fan curve used for the measure is Fan-Pwr-fPLR-w/VFD.

The chilled water and hot water pump models assume a conversion from 3-way to 2-way coil admission valves for the bypass pre-retrofit cases only. The models do not include any conversion from primary to primary/secondary distribution loops. The following table shows the results of this effort.

Table 108. Large Office Parametric Runs and Results (per hp)

<table>
<tr><th rowspan="2">Motor Type</th><th rowspan="2">Pre-Retrofit</th><th colspan="3">Average</th></tr>
<tr><th>kWh</th><th>Peak PJM kW</th><th>Peak AEP Ohio kW</th></tr>
<tr><td>Supply/Return fan</td><td>CV to VAV</td><td colspan="3">NA</td></tr>
<tr><td>Supply/Return fan</td><td>VAV with inlet guide vanes / forward curve</td><td colspan="3">NA</td></tr>
<tr><td>Supply/Return fan</td><td>VAV with inlet guide vanes / airfoil (backward inclined)</td><td rowspan="3">495</td><td rowspan="3">0.1841</td><td rowspan="3">0.1837</td></tr>
<tr><td>Supply/Return fan</td><td>VAV with discharge dampers / forward curve</td></tr>
<tr><td>Supply/Return fan</td><td>VAV with discharge dampers / airfoil (backward inclined)</td></tr>
<tr><td>Chilled water pump</td><td>Throttle, 3-way valves</td><td rowspan="4">177</td><td rowspan="4">0.1387</td><td rowspan="4">0.1316</td></tr>
<tr><td>Chilled water pump</td><td>Throttle, 2-way valves</td></tr>
<tr><td>Chilled water pump</td><td>Bypass, 3-way valves</td></tr>
<tr><td>Chilled water pump</td><td>Bypass, 2-way valves</td></tr>
</table>

Hot water pump	Throttle, 3-way valves	201	0.0016	0.0016
Hot water pump	Throttle, 2-way valves			
Hot water pump	Bypass, 3-way valves			
Hot water pump	Bypass, 2-way valves			
Condenser Water Pump	Constant speed	438	0.128	0.129
Cooling Tower Fan	Single Speed	261	0.171	0.167
Cooling Tower Fan		NA		

The AEP demand savings for each case is captured as the average hourly savings during the Peak Hours (3 PM to 6 PM, June 1 – August 31, excluding weekends and federal holidays) from eQuest 8,760 hour files. The PJM hours are between 2:00 and 6:00 PM, during the same days and months.

To determine savings by building type, fan and pump run hours for each building type were determined by modeling a chilled water system for a typical large office building and then calculating the ratio of modeled hours to typical office building motor operating hours for supply/return fans, chilled water pumps, hot water pumps, and cooling tower fans (calculation is shown below). The table below provides the operating hour data extracted from the models. Cooling tower fan and chilled (and condenser) water pump run hours are assumed to be the same as chiller run hours. The 300 ton centrifugal chiller baseline model (used to calculate the deemed chiller savings) was used to as the source for extracting the run hours data.

Potential savings by building type is provided in the first two tables. The team recognizes that the energy intensity will vary by building type and additional modeling may be considered for building types that exhibit high penetration for this measure.

$$Annual\ \ kWh\ \ Savings_{BuildingType} = Annual\ \ kWh\ \ Savings_{Large\ Office} \times \frac{RunHours_{Building\ \ Type}}{RunHours_{Large\ Office}}$$

Table 109. Baseline Annual Operating Hours from SS-E Report

Building Type	Chilled Water Loop	Hot Water Loop	Condenser Water Loop	DHW System Loop	Hours Fan On
Large Office	1,308	1,206	1,308	3,636	2,727

Small Office	1,360	1,522	1,360	3,636	2,727
School	2,033	2,145	2,033	2,976	2,511
Small Retail/Service	4,015	1,680	4,015	4,568	4,015
Large Retail/Service	3,376	2,746	3,376	4,568	4,399
Hotel/Motel	4,767	8,125	4,767	8,760	8,760
Medical - Hospital	4,012	8,760	4,012	4,568	8,760
Medical - Nursing Home	3,722	8,674	3,722	8,760	8,760
Assembly/Meeting Place	4,380	1,806	4,380	4,568	4,380
Restaurant	5,293	3,309	5,293	4,568	5,293
Grocery	5,840	4,367	5,840	8,760	5,840
Conditioned Warehouse	3,975	1,477	3,975	4,568	3,975
Unconditioned Warehouse					
Industrial/Manufacturing	3,012	1,275	3,012	3,012	3,012
College/University	3,992	5,116	3,992	6,340	7,801
Government/Municipal	2,844	1,506	2,844	4,102	3,554
Other/Miscellaneous	3,573	3,427	3,573	4,997	5,003

Savings for non HVAC motors are based on final project estimates for VSD applications from the program. The following table summarizes the data collected and analyzed. The kW was determined by dividing the kWh by 4800 hours (as an estimate).

Table 110. Custom VSD Projects Sampled

Custom VSD Measure Type	Sample Size	Total Ex-Ante kWh	Total Ex Ante kW	Total HP	kWh/HP	kW/HP
VSD on Air Compressor	15	2,890,207	364	1575	1,211	0.162
VSD on Process	7	462,222	62	353	744	0.083
Other VSD	7	778,599	79	735	721	0.073

Savings for VSD on air compressors were determined using pre and post-power measurements and applicable production data, while kWh savings for other non-HVAC applications were mostly determined using load profiles submitted by customers or trade allies, and actual power measurements when available.

The deemed values are based on the ex-ante kWh and kW savings. Since the prescriptive measure is acceptable for motors with at least 1,200 hours of operation and the projects analyzed above have unknown operating hours, DNV KEMA assumed a “correction” factor of 80% the average value to minimize evaluation risk.

Table 111. Custom VSD Savings Data

Custom VSD Measure Type	Calculated kWh/HP	Calculated kW/HP
Air Compressor	1,211	0.162
Process	744	0.083
Other Motor	721	0.073

Measure Life and Incremental Measure Cost

The measure life for variable speed drives is 15 years[49]. The incremental measure cost documented for this measure is $125 per horsepower[50].

Pool Pump - VSD Control

Measure Description	This measure is for the replacement or conversion of existing single speed pump systems with variable-speed capability for controlling the flow rate of commercial pool/spa pumps.
Units	Per Motor horsepower
Base Case Description	Pool Pumps with No Control

This measure is for the replacement or conversion of existing single speed pump systems with variable-speed capability for controlling the flow rate of commercial pool/spa pumps, based on the following requirements:

- Applies to swimming pool or spa pump systems of all sizes. Non-pool pump systems such as decorative fountains, wells, will not be prescriptive. Incentives for non-pool pump types will be handled under the custom application.
- If the replacement system is larger in horsepower than the original system the replacement system shall be capable of being dialed back to match the flow of the original system; this capability must be activated.

[49] 2008 Database for Energy Efficiency Resources (DEER), www.deeresources.com
[50] Average from Connecticut CL&P and UI Program Savings Documentation for 2008 Program Year.

- The replacement system shall have an operating automatic programmable scheduling and capacity control capability.
- The incentive applied for under the prescriptive measure applies to simple replacement of the pump system only. Additional savings or savings reductions may result from piping, filter or other system modifications. These impacts will be calculated separately. Added energy use will be deducted from or added to the prescriptive incentive through a separate custom application.

Measure Savings
The savings for this measure is 1,817 kWh and 0.12 kW per horsepower.

Measure Savings Analysis
Energy savings are based on a document from the Nevada Sure Bet program, that looked at a 2 HP system, that was running 8760 hours prior to the retrofit, and whose calculations resulted in 6,639.81 kWh savings. These savings were multiplied by 4794/8760, the 4794 being based on a YMCA indoor pool schedule in the Chicago area.

Measure Life and Incremental Measure Cost
The measure life is the same as HVAC VSD at 15 years. The measure cost is $1800 per HP per KEMA.

Refrigeration

DNV KEMA has developed a refrigeration savings calculator in Refrigeration Spreadsheet AEP.xls. The spreadsheet uses a cooling load calculation to calculate the refrigeration load of a typical refrigerated case, walk-in cooler or freezer found in convenience stores, grocery stores, or restaurants. The calculator is designed to be most applicable to convenience stores. It is not applicable for stand-alone display cases without a walk-in main door. Savings calculated in the spreadsheet are attributed to decreased cooling load and compressor usage.

Cooling load calculations are based on ASHRAE methodology[51] for typical refrigeration loads. Details of the analysis are provided in a separate attachment and spreadsheets. The total cooling load of a refrigerated space requires the calculation of the following:

1. Transmission or conduction load
2. Anti-sweat heater (ASH) load
3. Internal load (load due to evaporator fan motors, lighting, and people)
4. Product load (product shelving and product pull-down load)
5. Infiltration load

Additional assumptions must be made regarding the air properties of the refrigerated and adjacent spaces, number of doors, door type, and door size. Current values are based on DNV KEMA field observations in California, SCE Workpaper assumptions[52], and ADM evaluation results of gasket and strip curtain installations[53]. All assumptions and their source are documented in the spreadsheet.

Savings estimates for different measures can be calculated by adjusting these parameters and comparing the pre-retrofit and post-retrofit annual energy consumptions. The spreadsheet calculator contains the details. The calculator is set up for cooler walk-in, freezer walk-in, cooler reach-in, and freezer reach-in. The difference between the two in this document is that the reach-in is a walk-in with glass doors. Stand-alone refrigerated cases are not applicable to the calculator. The analysis adjustments per measure are discussed below.

Calculator Shortcomings

The calculator methodology is based on assumptions that require further research to validate. However based on the available information, they are satisfactory for calculating deemed savings. DNV KEMA believes this approach uses the most up to date data available and building up from the basics. Much of the calculator is based on the methodology and

[51] ASHRAE 2002. Refrigeration Handbook. Atlanta, Georgia. pp. 12.1
[52] Southern California Edison Company. WPSCNRRN002.1 – Infiltration Barriers – Strip Curtains, October 2007.
[53] “Commercial Facilities Contract Group Direct Impact Evaluation Draft Final Report: HIM Appendices”. ADM Associates, Inc., prepared for the California Public Utilities Commission, December 8, 2009.

assumptions found in the SCE refrigeration workpapers[54]. The SCE methodology assumes that the system is comprised of a single reciprocating compressor and an air cooled condenser. Refrigeration system configurations vary widely depending on capacity and use. For example, many systems found at large commercial grocery stores are comprised of multiplex systems with water cooled condensers. There was also disagreement over the calculation methodology regarding the defrost heater internal load, which resulted in this internal load being omitted from the spreadsheet calculations[55].

In addition, the methodology for determining the EER for both medium and low temperature applications uses SCE's internal review of reciprocating compressor manufacturer performance curves to calculate EER. Their data and analysis is not available for review. Questions have arose about whether this data is applicable to different areas of the country, since these performance curves are dependent on saturated condensing temperature, cooling load, and the cooling capacity of the compressor. Further research is recommended to account for different types and how they would affect overall system efficiency and energy usage. Weather normalization analysis can be improved by using TMY3 8760 hourly weather data. However, only a simplified normalization is currently used.

[54] Southern California Edison Company. WPSCNRRN002.1 – Infiltration Barriers – Strip Curtains, October 2007.
[55] Defrost heater load should be considered in future iterations.

Anti-sweat Heater Controls

Measure Description	Installation of relative humidity sensors for the air outside of the display case and controls that reduce or turn off the glass door (if applicable) and frame anti-sweat heaters at low-humidity conditions.
Units	Per Linear Foot (width of door)
Base Case Description	No Anti-Sweat Heater controls installed.

An anti-sweat heater is a device that senses the relative humidity in the air outside of the display case and reduces or turns off the glass door (if applicable) and frame anti-sweat heaters at low-humidity conditions. Technologies that can turn off anti-sweat heaters based on sensing condensation (on the inner glass pane) also qualify.

Measure Savings [56]

The anti-sweat heat (ASH) controller determines the amount of power necessary by sensing the ambient dew point within the installation's location. Methodology is taken from the SCE workpaper, which derives ASH runtime based on ambient space conditions and controller setpoints. It's assumed that these controllers are set to turn off at 42.89°F dew point (35% relative humidity) as the "All OFF SetPoint" and all on at 52.87°F dew point (50% relative humidity) as the "All ON SetPoint." Between these values, the ASH duty cycle changes proportionally:

$$\mathrm{ASHON\%} = \frac{\mathrm{DP_{meas}} - \mathrm{AllOFFSet\,Point}}{\mathrm{AllONSet\,Point} - \mathrm{AllOFFSet\,Point}}$$

where
DP_{meas} = measured dew point temperature inside the sales area

Energy savings are dependent on climate zone. Direct power savings are calculated using TMY3 weather data for the two typical AEP OH cities, using the methodology outlined above for each representative hour. The percent ASH on-time is then multiplied by the instantaneous ASH power, which is assumed to be 0.04255 kW/linear foot per the SCE workpaper. The total ASH direct energy consumption is calculated by taking the sum of all 1-hour kW consumption values for the entire representative TMY3 year. Interactive savings are calculated for the retrofit case by multiplying the baseline ASH heat load by the percent ASH runtime for each representative city.

56 "Anti-Sweat Heat (ASH) Controls," Workpaper WPSCNRRN0009. Southern California Edison Company. 2007. PG&E uses the same method as SCE, ASH Controls PGECOREF108.

Table 112. Savings for Anti-Sweat Heater Controls (per linear ft)

City	Columbus		Canton	
Application Type	**kWh**	**kW**	**kWh**	**kW**
Cooler (MT) walk-in door	0	0	0	0
Freezer (LT) walk-in door	303	0.0346	307	0.0350
Cooler (MT) walk-in door w/reach-in glass	288	0.0329	292	0.0333
Freezer (LT) walk-in door w/reach-in glass	292	0.0334	296	0.0338
Average	294	0.034	298	0.034

Both energy and peak kW savings take into account additional savings due to interactive effects.

Measure Life and Incremental Measure Cost
The measure life is 12 years and $34 per linear foot per the SCE workpapers.

Electronically Commutated Motors (ECM)

Measure Description	This measure is applicable to the replacement of an existing standard-efficiency shaded-pole evaporator fan motor in refrigerated display cases or fan coil in walk-ins. The replacement unit must be an ECM. This measure cannot be used in conjunction with the evaporator fan controller measure.
Units	Per Motor
Base Case Description	Shaded Pole Motors

Measure Savings[57]

Energy savings are based on the methodology found in SCE's work paper and depend on display-case type, either cooler or freezer. The baseline condition assumes a motor with a connected wattage of 135.5W per the FSTC report, with a fan motor efficiency of 70%. The post retrofit condition assumes a power reduction of 67% (44W) and a new efficiency of 85%. These motors are assumed to be in continuous operation, i.e., no evaporator fan controller installed. Total savings for replacing an existing electronically commuted motor with a new, more efficient unit are presented in the following table. The savings values from the spreadsheet Refrigeration Spreadsheet AEP.xls are added to the wattage reduction from the shaded-pole unit to the electronically commutated motor for walk-in cases.

Table 113. EC Motor Savings for Walk-ins (per motor)

City	Columbus		Canton	
Application Type	**kWh**	**kW**	**kWh**	**kW**
Cooler (MT) walk-in door	859	0.0981	859	0.0980
Freezer (LT) walk-in door	877	0.1001	875	0.0999
Average	864	0.0986	863	0.0985

Average savings values in the table above are a weighted average of walk-in cooler (75 percent) and freezer (25 percent) applications. This is the weighing methodology used in the SCE workpapers.[58]

Savings values for ECMs for Reach-In coolers are obtained from the SCE workpaper for efficient evaporator fan motors, which covers all 16 California climate zones, since stand-alone refrigerated cases are not applicable to the calculator. SCE savings values were determined

[57] "Efficient Evaporator Fan Motors (Shaded Pole to ECM)," Workpaper WPSCNRRN0011. Southern California Edison Company. 2007.
[58] "Average Infiltration Barriers". Workpaper WPSCNRRN0007.1. Southern California Edison Company. 2007.

using a set of assumed conditions for restaurants and grocery stores. We have used only PG&E climate zones in calculating our averages and have taken out the drier, warmer climates of southern California.

Table 114. SCE Grocery Savings Reach-In

	Grocery			
SCE Workpaper Values	Cooler		Freezer	
Northern California Climate Zones	kWh Savings Per Motor	Peak kW Savings Per Motor	kWh Savings Per Motor	Peak kW Savings Per Motor
1	306	0.031	362	0.031
2	269	0.033	273	0.035
3	331	0.032	421	0.034
4	332	0.032	422	0.034
5	323	0.032	402	0.033
11	357	0.034	476	0.037
12	350	0.034	462	0.036
13	355	0.034	472	0.037
16	325	0.032	409	0.034
Average	328	0.033	411	0.035

Table 115. ECM Reach-In Savings Values Summary

kWh Savings/ft	Peak kW Savings/ft
345	0.033

Measure Life and Incremental Measure Cost
The measure life is 15 years per the 2008 DEER. The cost of a reach-in ECM is $185 per the SCE workpaper. The cost of a walk-in ECM is $250 per Fisher Nickel[59].

[59] "GE ECM Evaporator Fan Motor Energy Monitoring" Food Service Technology Center, Fisher-Nickel Inc. 2006. Prepared for PG&E.

Evaporator Fan Control

Measure Description	This measure is for the installation of controls in medium and low temperature walk-in coolers. The controller reduces airflow of the evaporator fans when there is no refrigerant flow. The measure must control a minimum of 1/20 HP where fans operate continuously at full speed. The measure also must reduce fan motor power by at least 75 percent during the off cycle. This measure is not applicable if any of the following conditions apply: 1) The compressor runs all the time with high duty cycle 2) The evaporator fan does not run at full speed all the time 3) The evaporator fan motor runs on poly-phase power 4) Evaporator does not use off-cycle or time-off defrost.
Units	Per Motor
Base Case Description	Cooler with continuously running evaporator fan.

Measure Savings

The base case for the existing equipment is walk-in cooler or freezer with either shaded-pole evaporator or electronically commutated motors that are continuously running at full speed. Shaded pole and electronically commutated motor wattages are taken from the FSTC Evaporator Fan Motor Energy Monitoring Study[60]. One shaded pole evaporator fan motor has an average connected wattage of 135.5 watts. One electronically commutated motor has an average connected wattage of 44 watts. Walk-in cases are assumed to contain two evaporator fan motors each. Walk-in cases with reach-in glass doors are assumed to contain six evaporator fan motors.

Evaporator fan controller savings are dependant on compressor duty cycle. Assumed compressor duty cycle is 40% for winter and 50% for non-winter seasons. Weather data for the representative cities is used to find the distribution of annual below freezing (winter) and above freezing (non-winter) hours. These hours are multiplied by their respective duty cycle assumptions to arrive at an estimate for compressor annual operating hours. The operation of the fan controller specifies that fans are to be turned off when the compressor is off. Fan power savings are calculated by multiplying the connected evaporator fan motor wattage by the total hours the compressor is turned off. Interactive effects are calculated by multiplying the evaporator fan heat load by the % On-Time of the compressor. Savings are provided in the table below using the cooler/ freezer distruction of 75%/25%..

[60] GE ECM Evaporator Fan Motor Energy Monitoring, FSTC Report # 5011.04.13. Fisher-Nickel, Inc. July 2006.

Table 116. Shaded Pole Motor Evaporator Fan Controller Savings (per motor)

City	Columbus		Canton	
Application Type	**kWh**	**kW**	**kWh**	**kW**
Cooler (MT) walk-in door	1322	0.151	1329	0.152
Freezer (LT) walk-in door	1348	0.154	1353	0.154
Cooler (MT) walk-in door w/reach-in glass	3999	0.457	4018	0.459
Freezer (LT) walk-in door w/reach-in glass	4064	0.464	4078	0.466
Average	2672	0.305	2684	0.306

Table 117. ECM Evaporator Fan Controller Savings (per motor)

City	Columbus		Canton	
Application Type	**kWh**	**kW**	**kWh**	**kW**
Cooler (MT) walk-in door	445	0.0508	462	0.0527
Freezer (LT) walk-in door	458	0.0523	484	0.0552
Cooler (MT) walk-in door w/reach-in glass	1378	0.1573	1463	0.1670
Freezer (LT) walk-in door w/reach-in glass	1396	0.1594	1479	0.1688
Average	915	0.1045	967	0.1104

Measure Life and Incremental Measure Cost

The measure life is 16 years and $162 per motor per the 2008 DEER.

Efficient Refrigeration Condenser

Measure Description	Oversized condensers for refrigeration systems, which allow for reduced system head pressures and reduced compressor power consumption.
Units	Per ton of refrigeration capacity
Base Case Description	Refrigeration system with efficiency of 1.92 kW/ton @ 82°F ambient temperature and 1.85 kW/ton @ 70°F ambient temperature.

Incentives are available for the design and installation of oversized condensers for multiplex refrigeration systems. A design reducing the approach (difference in existing refrigerant and ambient dry build temperature) lowers the head pressure and conserves compressor horsepower. The new condenser must result in 85 Btu/hr of heat rejection per watt of fan power for air cooled condensers. For evaporative cooled equipment, a minimum of 195 Btu/h/Watt is required.

Measure Savings Analysis
The coincident demand savings is 0.12 kW per ton of refrigeration capacity and annual energy savings is 120 kWh per ton of refrigeration capacity.

Measure Savings Analysis
The energy and demand savings are derived from the methodology outlined in the Michigan CI Technologies Workpapers. Savings are derived from computer modeling software. The model system assumptions are as follows:

- *System capacity = 40 tons*
- *Full Load capacity = 2.3 kW per ton at 105°F saturated condensing temperature*
- *Operating hours = 4,380. Savings are assumed to occur only in warmer months (1/2 year)*

Computer models calculated savings at two temperatures: 82°F and 70°F ambient temperature. Savings are averaged across the two temperatures. Assumptions and calculations are presented in the following table.

Table 118: Baseline and Retrofit Assumptions for Oversized Condensers

	82°F			**70°F**			**Average**
	Existing	**Retrofit**		**Existing**	**Retrofit**		
Average Annual Load	81.6%	83.2%		78.9%	80%		
Average kW/Ton	1.92	1.86		1.85	1.78		
peak kW/ton	2.30	2.18		2.30	2.18		
			Savings			**Savings**	
kW	92.00	87.20	4.80	92.00	87.20	4.80	
Annual kWh	274,489	271,126	3,364	255,731	249,485	6,246	
kW/Ton			0.120			0.120	0.120
Annual kWh/ton			84			156	120

Measure Life and Incremental Measure Cost
The measure life is 15 years and the incremental measure cost is $35 per ton per the MI workpaper.

Floating Head Pressure Controls

Measure Description	This measure is for the addition of an adjustable condenser head pressure control valve (i.e. "floating head pressure controls") to refrigeration systems with single compressors. Head pressure control (flood back) valve must be set to 70 degrees F or lower. Compressor must be 1 HP or larger.
Units	Per HP
Base Case Description	A refrigeration system without floating head pressure control

Head pressure control valve (flood-back control valve) must be installed to lower minimum condensing head pressure from a fixed position (180 psig for R-22) to a saturated pressure equivalent to 70 degrees F or less. Either a balanced-port or electronic expansion valve that is sized to meet the load requirement at a 70 degree condensing temperature must be installed and vary head pressure based on outdoor air temperature. Alternatively, a device may be installed to supplement refrigeration feed to each evaporator attached to condenser that is reducing head pressure.

Measure Savings
The savings for this measure are 496 kWh per hp and 0.0639 kW per hp.

Measure Savings Analysis
Annual energy savings and the peak coincident demand savings were calculated by taking weighted average savings from the Efficiency Vermont TRM, per the tables below, and adjusting the savings using a bin analysis comparing the TMY3 hourly dry bulb temperatures of Montpelier Vermont, and Port Columbus International Airport[61].

[61] Full analysis can be found in the spreadsheet called “Floating Head Pressure Controls Bin Analysis 6-26-12.xlsx”

Table 119. Floating Head Pressure Control kWh Savings per Horsepower from Efficiency Vermont TRM[62]

Compressor Type	Low Temperature (-35°F to -5°F SST)	Med Temperature (0°F to 30°F SST)	High Temperature (35°F to 55°F SST)
Reference Temp	-20°F SST	20°F SST	45°F SST
Standard Reciprocating	695	727	657
Condensing Unit	607	598	694
Remote Condenser	669	599	509

It was assumed that low temperature, medium temperature, and high temperature had weightings of 25%, 25%, and 50%, consistent with the weightings assumed for other refrigeration measures. A straight average weighting was assumed for the different compressor types.

A linear interpolation was used to accommodate for the higher amount of savings that would occur at lower temperatures. The two points used for the linear interpolation are as follows: The weighted average kW/HP for VT was determined by dividing the average kWh/HP value (determined using the weight factors and values described above) by the total number of hours from the TMY3 data in Montpelier that savings were expected to occur, which is all of the hours when the temperature is below 75 deg F. It was assumed that this average kW/HP value would correspond to the average temperature that savings were expected to occur, which turned out to be 43.13 degrees. This was the first point for the interpolation. The second point for the interpolation was 75 deg F, the point at which 0 savings are expected to occur. A simple linear equation was written alongside the 8760 TMY3 temperature data with hourly bin information, and the average VT kWh/HP value was reproduced. The linear equation was run again, only using the Columbus temperature bin data, and the kWh/HP savings were determined.

Measure Life and Incremental Measure Cost

[62] Efficiency Vermont – Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions.

The measure life is 10 years. The incremental capital cost is shown in the table below[63]. Using the costs provided and assuming a 5 hp compressor per evaporator, the average cost is $76 per horsepower.

Table 120. Floating Head Pressure Controls Incremental Measure Cost

Number of Evaporators	Incremental Cost
1	$518
2	$734
3	$984
4	$1,233

Reach-In Refrigerated Display Case Door Retrofit

Measure Description	This measure consists of the replacement of existing open multi-deck case with a new enclosed multi-deck case with standard doors. The new case must be equipped with high efficiency T8 lamps and electronic ballast combinations or LED and electronically commutated (EC) motors. The main benefit of replacing an open multi-deck case with a new enclosed multi-deck case is the reduction in cooling load due to reduced air infiltration. Compressor savings occur due to a decrease in refrigeration load on the case. In addition, the more efficient evaporator fan motors and lights use less energy, resulting in additional electrical energy savings.
Units	Per linear feet of case
Base Case Description	Open multi-deck case (without doors)

This measure is for installing new, vertical, glass doors on existing open, vertical (or multi-deck), medium or low temperature (MT or LT), display cases or for replacing existing, open, vertical (or multi-deck), display cases with new, reach-in, glass door, display cases.

[63] Efficiency Vermont – Technical Reference User Manual (TRM) Measure Savings Algorithms and Cost Assumptions.

Measure Savings

For Medium Temperature units, the coincident peak demand savings is 0.074 kW per linear foot of case and annual energy savings is 648 kWh per linear foot of case. For Low Temperature units, the coincident peak demand savings is 0.180 kW per linear foot of case and annual energy savings is 1,573 kWh per linear foot of case.

Measure Savings Analysis

Medium Temperature Energy Savings Calculations

Electric savings are derived by a decrease in case infiltration load; this load accounts for more than 70% of total cooling load for open multi-deck cases. Calculations evaluate the energy consumption of two leading display case manufacturers for both multi-deck and reach-in cases. Cases for evaluation were chosen based on cases with similar dimensions, number of evaporator fan motors, type of lighting system, and number of defrost cycles. Refer to the two tables below for physical characteristics and electrical data of MT open multi-deck cases and MT reach-in cases, respectively on a per foot basis.

Table 121. Physical and Electrical Data for MT Open Multi-Deck Cases[64]

Manufacturer	Model	Type	Suction Temp	Evap Fan Amps (per ft)	ASH Amps (per ft)	Lighting Amps (per ft)	Defrost Amps (per ft)	Cooling Capacity (Btuh/ft)
Hussmann	M5X-E	5-Deck Meat and Deli Merchandiser	21	0.15	0.00	0.39	0.00	1,465
Hussmann	D5H	5-Deck Dairy and Deli Merchandiser	21	0.10	0.00	0.32	0.00	1,330
Hussmann	D5L	5 Deck Dairy and Deli Merchandiser	21	0.10	0.00	0.32	0.00	1,495
Tyler	N5DH	5-Deck Dairy and Deli Merchandiser	15	0.08	0.00	0.37	0.00	1,299
Average				**0.11**	**0.00**	**0.35**	**0.00**	**1,397**

Note: Off-time Defrost

Table 122. Physical and Electrical Data for MT Reach-In Cases[65]

[64] PG&E Workpaper – PGECOREF104.1 – New Refrigeration Display Cases with Doors
[65] PG&E Workpaper – PGECOREF104.1 – New Refrigeration Display Cases with Doors

Manufacturer	Model	Type	Suction Temp	Evap Fan Amps (per ft)	Door ASH Amps (per ft)	Frame ASH Amps (per ft)	Lighting Amps (per ft)	Defrost Amps (per ft)	Cooling Capacity (Btuh/ft)
Hussmann	RM/RMN	Standard Reach-in case with Innovator Doors	27	0.26	0.00	0.18	0.24	0.00	372
Tyler	P5NGN/P5NG	Glass Door Medium Temperature Merchandiser	27	0.21	0.03	0.05	0.23	0.00	354
Average				**0.24**	**0.01**	**0.11**	**0.24**	**0.00**	**363**

Note: Off-time Defrost

Calculation Assumptions for Medium Temperature Cases

The following assumptions were made when calculating the direct energy reduction.

- Shelf lighting not changed.
- Electrical HVAC energy usage impacts of this measure were assumed negligible.
- Off-cycle defrost assumed for medium temperature cases
- The compressor Duty Factor is a conservative approximation based on the data provided in the Pacific Gas and Electric's (PG&E) workpaper[66]

Calculating Direct Energy Reduction

Based on the data in the above tables, direct demand reduction can be calculated. The direct demand reductions are based on reduction of electric load or power consumption of the display case components; more specifically, looking at evaporator fan motors, lighting, and anti-sweat heater controls. It is notable that for medium temperature cases, the direct power consumption increases with the addition of doors primarily due to the need for ASH (anti-sweat heaters.)

Direct energy reduction is calculated by the following equation.

$$\Delta kWh_{direct} = kWh_{basecase} - kWh_{new}$$

Where,

ΔkWh_{direct} = Annual direct energy reduction (kWh)
$kWh_{basecase}$ = Annual kilowatt-hour usage by components of open cases (kW)
kWh_{new} = Annual kilowatt-hour usage by components of closed cases (kW)

The below tables 3 and 4 show the calculated annual, direct power consumption for open case and closed cases.

66 PG&E Workpaper – PGECOREF104.1 – New Refrigeration Display Cases with Doors

Table 123. Annual Energy Consumption for MT Open Cases

	Evap Fan	ASH	Lighting	Defrost	Component Total (annual kWh/lin.ft)
Amps/ft	0.11	0	0.35	0	
Annual Run hours	8760	8760	8760	730	
Voltage	115	115	115		
Annual kWh	110.8	0	352.6	0	463.4

Table 124. Annual Energy Consumption for MT Reach-In Cases

	Evap Fan	ASH	Lighting	Defrost	Component Total (annual kWh/lin.ft)
Amps/ft	0.24	0.12	0.35	0	
Annual Run hours	8760	8760	8760	730	
Voltage	115	115	115		
Annual kWh	241.8	120.9	352.6	0	715.3

$$\Delta kWh_{direct} = 463.4 - 715.3 = -\frac{251.9kWh}{ft}/yr$$

Calculating Energy Reduction Due to Reduced Infiltration

The two tables above show the cooling capacity (average) of the open case and the reach in case, where the cooling capacity of the reach-in case is much less per linear foot than its open case counterpart. The decreased necessity for cooling capacity is primarily due to the greatly reduced infiltration of reach-in cooler with in turn decreases the compressor energy. Using these values, an annual compressor energy reduction due to reduced infiltration may be obtained. First, an Energy Efficiency Ratio (EER) is obtained for the medium temperature case using the below equation:[67]

[67] PG&E Workpaper – PGECOREF104.1 – New Refrigeration Display Cases with Doors

EER_{MT} = a + (b * SCT) + (c * PLR) + (d * SCT^2) + (e * PLR^2) + (f * SCT * PLR) + (g * SCT^3) + (h * PLR^3) + (i * SCT * PLR^2) +
(j * SCT^2 * PLR)

Where,

a = 3.75346018700468
b = -0.049642253137389
c = 29.4589834935596
d = 0.000342066982768282
e = -11.7705583766926
f = -0.212941092717051
g = -1.46606221890819E-06
h = 6.80170133906075
i = -0.020187240339536
j = 0.000657941213335828
PLR = $PLR_{baseline}$ or $PLR_{post\_retrofit}$ The part load compressor ratio is taken to be 0.87
SCT = Saturated Condensing Temperature = DB (design dry bulb) +15.

For Columbus, Ohio the design dry bulb temperature is 90°F[68]. Thus, the EER calculates to:

EER_{MT} = 6.54
kW/ton = 12/ EER_{MT} = 12/6.54 = 1.83 kW/ton

From Tables 1 & 2, the compressor energy reduction due to reduced cooling capacity is calculated as follows:

$$\Delta Capacity_{compressor} = \dot{\mathrm{Q}}_{\mathrm{Open\ Case}} - \dot{\mathrm{Q}}_{\mathrm{Closed\ Case}}$$

$$\Delta Capacity_{compressor} = 1{,}397\ \mathrm{btuh/ft} - 363\ \mathrm{btuh/ft} = 1{,}034\ \mathrm{btuh/ft}$$

Where,

$\Delta Capacity_{compressor}$ = *Cooling capacity savings from the compressor, (Btu/ft)*

$\dot{Q}_{Open\ Case}$ = *Cooling capacity for an open case*

[68] 2001 ASHRAE Handbook - Fundamentals

$\dot{Q}_{Closed\ Case}$ = Cooling capacity for a closed case

The annual electric energy savings from reducing the cooling capacity is calculated using the compressor energy savings and the compressor duty factor.

$$\Delta kWh_{compressor} = \Delta Capacity_{compressor} \times C_1 \times \frac{kW}{ton} \times 8760 \frac{hrs}{year} \times Duty\ Factor$$

$$\Delta kWh_{compressor} = \frac{1{,}034\ btuh}{ft} x \frac{1\ ton}{12{,}000 btuh} x \frac{1.83\ kW}{ton}\ x \frac{8760 hrs}{year}\ x\ 0.65\ = \frac{899.9 \frac{kWh}{ft}}{yr}$$

Where,

$\Delta kWh_{compressor}$ =	Annual energy savings from the compressor, (kWh/yr)
$\Delta Capacity_{compressor}$ =	Cooling capacity savings from the compressor, (Btu/ft)
C_1 =	Conversion Factor, 1 ton refrigeration = 12,000 Btuh
kW/ton =	kW/ton = 12/EER
Duty Factor =	Based on typical supermarket energy usage, base on the PG&E study, assumed to be 65%.

The total annual energy savings is the sum of the energy savings from the compressor and the energy savings from a reduction of electric load or power consumption of the display case components, such as the evaporator fan motors, lighting, and anti-sweat heater controls.

$$\Delta kWh_{Total} = \Delta kWh_{direct} + \Delta kWh_{compressor}$$

$$\Delta kWh_{Total} = \frac{(-251.9 kWh/ft/yr) + 899.9 \frac{kWh}{ft}}{yr} = 648 \frac{kWh}{ft}/yr$$

Where,

ΔkWh_{Total} =	Total annual energy savings from replacing existing multi-deck case, (kWh/yr)
ΔkWh_{direct} =	Energy reduction in electric load or power consumption, (kWh/yr)
$\Delta kWh_{compressor}$ =	Annual energy savings from the compressor, (kWh/yr)

Low Temperature Energy Savings Calculations

Electric savings are derived by a decrease in case infiltration load; this load accounts for more than 70% of total cooling load for open multi-deck cases. Calculations evaluate the energy consumption of three leading display case manufacturers for both multi-deck and reach-in cases. Cases for evaluation were chosen based on cases with similar dimensions, number of evaporator fan motors, type of lighting system, and number of defrost cycles. See Tables 5 and 6 for physical characteristics and electrical data of LT open multi-deck cases and LT reach-in cases, respectively on a per foot basis.

Table 125. Physical and Electrical Data for LT Open Multi-Deck Cases[69]

Manufacturer	Model	Type	Suction Temp	Evap Fan Amps (per ft)	ASH Amps (per ft)	Lighting Amps (per ft)	Defrost Amps (per ft)	Cooling Capacity (Btuh/ft)
Hussmann	F6L	Multi Deck Frozen Food	-16	0.30	0.40	0.21	2.00	1,755
Hill Phoenix	O5Z	Multishelf Frozen Food	-17	0.30	0.54	0.18	1.67	1,840
Average				**0.30**	**0.47**	**0.19**	**1.83**	**1,798**

Note: Defrost Heaters: 208 Volts, 1 Phase load.

Table 126. Physical and Electrical Data for LT Reach-In Cases[70]

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Manufacturer	Model	Type	Suction Temp	Evap Fan Amps (per ft)	Door ASH Amps (per ft)	Frame ASH Amps (per ft)	Lighting Amps (per ft)	Defrost Amps (per ft)	Cooling Capacity (Btuh/ft)
Hussmann	RL/RLN	Standard Reach-in case with Innovator Doors	-19	0.12	0.31	0.16	0.24	1.35	520
Tyler	P5FGN/P5FG	Glass Door Frozen Food Merchandiser	-17	0.13	0.29	0.28	0.23	1.35	560
Average				**0.12**	**0.30**	**0.22**	**0.24**	**1.35**	**540**

Note: Defrost Heaters: 208 Volts, 1 Phase load.

Engineering Parameters Assumptions for Low Temperature Cases

1. Shelf lighting not changed.
2. HVAC energy usage impacts of this measure were assumed negligible.

[69] PG&E Workpaper – PGECOREF104.1 – New Refrigeration Display Cases with Doors
[70] PG&E Workpaper – PGECOREF104.1 – New Refrigeration Display Cases with Doors
[71] KEMA, New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review, July 10, 2009.

Calculating Direct Energy Reduction

Based on the data in the two tables above, direct demand reduction can be calculated. The direct demand reductions are based on reduction of electric load or power consumption of the display case components; more specifically, looking at evaporator fan motors, lighting, electric defrost mechanism, and anti-sweat heater controls. Direct energy reduction is calculated by the following equation:

$$\Delta kWh_{direct} = kWh_{basecase} - kWh_{new}$$

Where,

ΔkWh_{direct} = Annual direct energy reduction (kWh)

$kWh_{basecase}$ = Annual kilowatt-hour usage by components of open multi-deck cases (kW)

kWh_{new} = Annual kilowatt-hour usage by components of reach-in display cases (kW)

The below tables show the calculated annual, direct power consumption for open case and closed cases.

Table 127. Annual Energy Consumption for LT Open Cases

	Evap Fan	ASH	Lighting	Defrost	Component Total (annual kWh/lin.ft)
Amps/ft	0.3	0.47	0.19	1.83	
Annual Run hours	8760	8760	8760	273.75	
Voltage	115	115	115	208	
Annual kWh	302.22	473.478	191.406	104.2002	1071.3

Table 128. Annual Energy Consumption for LT Reach-In Cases

	Evap Fan	ASH	Lighting	Defrost	Component Total (annual kWh/lin.ft)
Amps/ft	0.12	0.52	0.19	1.35	
Annual Run hours	8760	8760	8760	273.75	
Voltage	115	115	115	208	
Annual kWh	120.888	523.848	191.406	76.869	913.0

$$\Delta kWh_{direct} = 1071.3 - 913 = \frac{158.3kWh}{ft}/yr$$

Calculating Energy Reduction Due to Reduced Infiltration

The two tables above show the cooling capacity (average) of the open case and the reach in case. As can be seen from the table, the cooling capacity of the reach-in case is much less per linear foot than its open case counterpart. The decreased necessity for cooling capacity is primarily due to the greatly reduced infiltration of reach-in cooler with in turn decreases the compressor energy. Using these values, an annual compressor energy reduction due to reduced infiltration may be obtained. First, an EER is obtained for the medium temperature case using the below equation:[72]

$EER_{LT} = a + (b * SCT) + (c * PLR) + (d * SCT^2) + (e * PLR^2) + (f * SCT * PLR) + (g * SCT^3) + (h * PLR^3) + (i * SCT * PLR^2) + (j * SCT^2 * PLR)$

Where,

a = 9.86650982829017
b = -0.230356886617629
c = 22.905553824974
d = 0.00218892905109218
e = -2.48866737934442
f = -0.248051519588758
g = -7.57495453950879E-06
h = 2.03606248623924
i = -0.0214774331896676
j = 0.000938305518020252
PLR = $PLR_{baseline}$ or $PLR_{post\_retrofit}$ The part load compressor ratio is taken to be 0.87
SCT = Saturated Condensing Temperature = DB (design dry bulb) +10.

For Columbus, Ohio the design dry bulb temperature is 90°F[73]. Thus, the EER calculates to:

$EER_{LT} = 5.06$

kW/ton = 12/ EER_{LT} = 12/5.06 = 2.37kW/ton

From tables presenting the physical and electrical data, the compressor energy reduction due to reduced required cooling capacity is:

[72] PG&E Workpaper – PGECOREF104.1 – New Refrigeration Display Cases with Doors
[73] 2001 ASHRAE Handbook - Fundamentals

$$\Delta Capacity_{compressor} = \dot{Q}_{\text{Open Case}} - \dot{Q}_{\text{Closed Case}}$$

$$\Delta Capacity_{compressor} = 1{,}798 \text{ btuh/ft} - 540 \text{ btuh/ft} = 1{,}258 \text{ btuh/ft}$$

Where,

$\Delta Capacity_{compressor}$ =	Cooling capacity savings from the compressor, (Btu/ft)
$\dot{Q}_{\text{Open Case}}$ =	Cooling capacity for an open case
$\dot{Q}_{\text{Closed Case}}$ =	Cooling capacity for a closed case

The annual electric energy savings from reducing the cooling capacity is calculated using the compressor energy savings and the compressor duty factor.

$$\Delta kWh_{compressor} = \Delta Capacity_{compressor} \times C_1 \times \frac{kW}{ton} \times 8760 \frac{hrs}{year} \times Duty\ Factor$$

$$\Delta kWh_{compressor} = \frac{1{,}258\ btuh}{ft} x \frac{1\ ton}{12{,}000 btuh} x \frac{2.37 kW}{ton} x \frac{8760\ hrs}{year} x\ 0.65 = \frac{1{,}415 \frac{kWh}{ft}}{yr}$$

Where,

$\Delta kWh_{compressor}$ =	Annual energy savings from the compressor, (kWh/yr)
$\Delta Capacity_{compressor}$ =	Cooling capacity savings from the compressor, (Btu/ft)
C_1 =	Conversion Factor, 1 ton refrigeration = 12,000 Btuh
kW/ton =	kW/ton = 12/EER
Duty Factor =	Based on typical supermarket energy usage, base on the PG&E study, assumed to be 65%.

The total annual energy savings is the sum of the energy savings from the compressor and the energy savings from a reduction of electric load or power consumption of the display case components, such as the evaporator fan motors, lighting, and anti-sweat heater controls.

$$\Delta kWh_{Total} = \Delta kWh_{direct} + \Delta kWh_{compressor}$$

$$\Delta kWh_{Total} = \frac{(158\ kWh/ft/yr) + 1{,}415 \frac{kWh}{ft}}{yr} = 1{,}573 \frac{kWh}{ft}/yr$$

Where,

ΔkWh_{Total} = Total annual energy savings from replacing existing multi-deck case, (kWh/yr)

ΔkWh_{direct} = Energy reduction in electric load or power consumption, (kWh/yr)

$\Delta kWh_{compressor}$ = Annual energy savings from the compressor, (kWh/yr)

Coincident kW savings are calculated by normalizing the calculated kWh savings to an annual basis, for both medium and low temperature cases

Measure Life and Incremental Measure Cost

THE CA 2011 DEER provides EUL estimates for similar refrigeration door measures, at a measure life of 12 years. For this measure, it is assumed that the average cost is $906.28 per linear foot for medium temperature display cases and $824.54 per linear foot for low temperature cases[74].

LED Refrigerated Case Lighting – with Doors

Measure Description	Replace fluorescent refrigerated case lighting with light emitting diode (LED) source illumination. Fluorescent lamps, ballasts, and associated hardware are typically replaced with pre-fabricated LED light bars and driver units. Replace fluorescent refrigerated case lighting with light emitting diode (LED) source illumination. Fluorescent lamps, ballasts, and associated hardware are typically replaced with pre-fabricated LED light bars and LED driver units. The two LED lamp products, 5' light bars and 6' light bars are eligible and must meet DesignLights Consortium specification.
Units	Per linear foot of case
Base Case Description	Fluorescent refrigerated case lighting

The LED lighting must meet DesignLights Consortium specification summarized in the table below.

[74] PG&E Workpaper – PGECOREF104.1 – New Refrigeration Display Cases with Doors

Table 129. DLC Criteria for LED Refrigerated Case Lighting

Minimum Light Output	Zonal Lumen Density	Minimum Luminaire Efficacy	Allowable CCTs (ANSI C78.377-2008)	Minimum CRI	Minimum LED Lumen Maintenance at 6000hrs1	Minimum Luminaire Warranty
Center-mounted: >=100 lm/ft End-mounted: >= 50 lm/ft	>=95% 0º-80º	35 lm/W	2700K, 3000K, 3500K, 4000K, 4500K and 5000K	70	95.80%	5 years

Measure Savings
The coincident demand savings is 0.032 KW per linear foot of case and annual energy savings is 215.9 kWh per linear foot of case.

Measure Savings Analysis
The energy and demand savings are derived from the Ohio TRM, August 6, 2010. The TRM provides the possibility of 5-foot or 6-foot LED light bar replacement options. The average demand reduction is 0.024 kW. The savings calculation per foot of case is:

kWh Savings = demand reduction x Hours x (1+waste heat factor) x Energy savings factor / Door Width

where,Hours = 6205

Energy savings factor = 1.0 with no motion sensor
Waste heat factor = 0.41 for coolers and 0.52 for freezers
Door Width = 2.5 feet

The savings across cooler and freezers are weighted with 75.6% and 24.4% split per the SCE workpapers referenced above.

The coincidence factor for peak savings per the TRM is 0.92 and the same waste heat factors for the demand savings.

Measure Life and Incremental Measure Cost
It is well documented that LED life is extended in a low-temperature environment; therefore the expected useful life of 50,000 hours assumed for this application is probably conservative. Based on the fixture run-time of 6,205 hours annually for the facility in the study, the expected life calculates to 8 years (based on Ohio TRM).

The incremental measure cost is assumed to be $100 per linear foot, based on $250 per door, and 2.5 ft/door per the Ohio TRM.

LED Refrigerated Case Lighting in Open Display Cases

Measure Description	Replace fluorescent refrigerated case lighting with light emitting diode (LED) source illumination. Fluorescent lamps, ballasts, and associated hardware are typically replaced with pre-fabricated LED light bars and LED driver units. The two LED lamp products, 5' light bars and 6' light bars are eligible. The LED lighting must meet DesignLights Consortium specification.
Units	Per linear foot of case
Base Case Description	Fluorescent refrigerated case lighting

The LED lighting must meet DesignLights Consortium specification summarized in the table below.

Table 130. DLC Criteria for LED Refrigerated Case Lighting

Minimum Light Output	Zonal Lumen Density	Minimum Luminaire Efficacy	Allowable CCTs (ANSI C78.377-2008)	Minimum CRI	Minimum LED Lumen Maintenance at 6000hrs1	Minimum Luminaire Warranty
Center-mounted: >=100 lm/ft End-mounted: >= 50 lm/ft	>=95% 0º-80º	35 lm/W	2700K, 3000K, 3500K, 4000K, 4500K and 5000K	70	95.80%	5 years

Measure Savings

The coincident demand savings is 0.026 KW per linear foot of case and annual energy savings is 172.1 kWh per linear foot.

Measure Savings Analysis

The energy and demand savings are derived from the Ohio TRM, August 6, 2010. The TRM provides the possibility of 5-foot or 6-foot LED light bar replacement options. The average demand reduction is 0.024 kW. The savings calculation is:

kWh Savings = demand reduction x Hours x (1+waste heat factor) x Energy savings factor / Door Width

where,

Hours = 6205
Energy savings factor = 1.0 with no motion sensor
Waste heat factor = 0.061 for grocery stores (per table in lighting section)
Door Width = 2.5 feet

The savings across cooler and freezers are weighted with 75.6% and 24.4% split per the SCE workpapers referenced above. The coincidence factor for peak savings per the TRM is 0.92 and the same waste heat factors for the demand savings.

Measure Life and Incremental Measure Cost

It is well documented that LED life is extended in a low-temperature environment; therefore the expected useful life of 50,000 hours assumed for this application is probably conservative. Based on the fixture run-time of 6,205 hours annually for the facility in the study, the expected life calculates to 8 years (based on Ohio TRM).

The incremental measure cost is assumed to be $100 per linear foot, based on $250 per door, and 2.5 ft/door per the Ohio TRM.

Lighting Controls for Freezers and Coolers with Doors

Measure Description	Passive infrared, ultrasonic, and fixture-integrated sensors or sensors with a combination thereof are eligible.
Units	Per linear foot of case controlled
Base Case Description	Refrigerated case lighting with no controls

Measure Savings

The coincident demand savings is 0.0096 kW per linear foot of case controlled and annual energy savings is 170.4 kWh per linear foot of case controlled.

Measure Savings Analysis

The electricity use (kWh) savings and gross summer peak demand (kW) reduction comprises two factors: reduced lighting load and reduced refrigeration requirements due to reduced heat gain. Reductions in lighting load occur continuously over the expected annual operating period, which includes the summer peak period. Savings due to reduced heat gain are computed assuming those reduced effects occur during the period in which the lighting systems operate, in consideration of the refrigeration compressor COP and the reduced cooling load, under normal operation (i.e., doors closed).

Connected lighting fixture assumptions are presented in the next table. LED wattages are per the Ohio TRM. The average across all fixture types is 44.2 W per linear foot of case.

Table 131. Equipment Wattages LED Refrigeration Lighting

Fixture Type	Fixture Code	Fixture Wattage	Watts per door[75]	Watts per linear foot of Case[76]	Weight
1-5' T12	F51SS	63	126	50.4	35%

[75] Assume 2 fixtures per door
[76] Assume 2.5 ft per door

1-5' T8	F51ILL	36	72	28.8	35%
1-6' T12 HO	F61SHS	120	240	96	30%
			141.3	**56.5**	
5' LED Lightbar	N/A	38	76	30.4	70%
6' LED Lightbar	N/A	46	92	36.8	30%
			80.8	**32.3**	

kWh Savings = Controlled Wattage per Door x Hours x (1+waste heat factor) x Energy savings factor / Door Width / 1000

where,

Hours = 6205
Energy savings factor = 0.3
Waste heat factor = 0.41 for coolers and 0.52 for freezers
Door Width = 2.5 feet

The savings across cooler and freezers are weighted with 75% and 25% split per the SCE workpapers referenced above.

The coincidence factor for peak savings per the TRM is 0.92 and the same waste heat factors for the demand savings.

Measure Life and Incremental Measure Cost
It's assumed that the average cost of the sensor is the same as general lighting occupancy sensors, which is $66 per the Ohio TRM. It's assumed that a sensor controls on average 3 doors, 2.5 feet wide each. This results in an IMC of $8.8 per foot controlled.

According to 2008 DEER, the EUL for an interior occupancy sensor is estimated to be 8 years. Refrigerated case lighting controls are assumed to have the same EUL, due to the similar characteristics shared between the two control types.

Lighting Controls for Open Display Cases

Measure Description	Passive infrared, ultrasonic, and fixture-integrated sensors or sensors with a combination thereof are eligible
Units	Per linear foot of case controlled
Base Case Description	Refrigerated case lighting with no controls

Measure Savings
The coincident demand savings is 0.0076 kW per linear foot of case controlled and annual energy savings is 135.8 kWh per linear foot of case controlled.

Measure Savings Analysis
The electricity use (kWh) savings and gross summer peak demand (kW) reduction comprises two factors: reduced lighting load and reduced refrigeration requirements due to reduced heat gain. Reductions in lighting load occur continuously over the expected annual operating period, which includes the summer peak period. Savings due to reduced heat gain are computed assuming those reduced effects occur during the period in which the lighting systems operate, in consideration of the refrigeration compressor COP and the reduced cooling load, under normal operation (i.e., doors closed).

Connected lighting fixture assumptions are presented in the next table. LED wattages are per the Ohio TRM. The average across all fixture types is 44.2 W per linear foot of case.

Table 132. Equipment Wattages LED Refrigeration Lighting

Fixture Type	Fixture Code	Fixture Wattage	Watts per door[77]	Watts per linear foot of Case[78]	Weight
1-5' T12	F51SS	63	126	50.4	35%
1-5' T8	F51ILL	36	72	28.8	35%
1-6' T12 HO	F61SHS	120	240	96	30%
			141.3	**56.5**	
5' LED Lightbar	N/A	38	76	30.4	70%
6' LED Lightbar	N/A	46	92	36.8	30%
			80.8	**32.3**	

kWh Savings = Controlled Wattage per Door x Hours x (1+waste heat factor) x Energy savings factor / Door Width / 1000

where,

Hours = 6205
Energy savings factor = 0.3
Waste heat factor = 0.061 for grocery stores (per table in lighting section)
Door Width = 2.5 feet

The savings across cooler and freezers are weighted with 75% and 25% split per the SCE workpapers referenced above.

[77] Assume 2 fixtures per door
[78] Assume 2.5 ft per door

The coincidence factor for peak savings per the TRM is 0.92 and the same waste heat factors for the demand savings.

Measure Life and Incremental Measure Cost
It's assumed that the average cost of the sensor is the same as general lighting occupancy sensors, which is $66 per the Ohio TRM. It's assumed that a sensor controls on average 3 doors, 2.5 feet wide each. This results in an IMC of $8.80 per foot controlled.

According to 2008 DEER, the EUL for an interior occupancy sensor is estimated to be 8 years. Refrigerated case lighting controls are assumed to have the same EUL, due to the similar characteristics shared between the two control types.

ENERGY STAR® Solid or Glass Door Reach-In Freezer

Measure Description	This measure consists of the replacement of a conventional solid or glass reach-in freezer unit with an ENERGY STAR Version 2.0 rated unit. Only units with built-in refrigeration systems are qualified. Units with remote refrigeration systems or units do not qualify. Customers must provide proof that the appliance meets the CEE Tier II efficiency specifications using ASHRAE Standard 117-1992 (38°F ± 2°F).
Units	Per freezer
Base Case Description	Conventional, non ENERGY STAR unit

Table 133.ENERGY STAR Qualified Commercial Freezers (kWh per day)[79]

Product Volume, cubic feet	Solid Door Freezer	Glass Door Freezer
$0 < V < 15$	$\le 0.250V + 1.250$	$\le 0.607V + 0.893$
$15 \le V < 30$	$\le 0.400V - 1.000$	$\le 0.733V - 1.000$
$30 \le V < 50$	$\le 0.163V + 6.125$	$\le 0.250V + 13.500$
$50 \le V$	$\le 0.158V + 6.333$	$\le 0.450V + 3.500$

Measure Savings
The savings for this measure is calculated using the IL TRM methodology. Savings are calculated using an average volume for all qualified Solid Door Reach-In Freezer units, which is 35.12 cubic feet and Glass Door Reach-In Freezer is 34.31 cubic feet[80].

[79] www.energystar.gov, Note: V = Internal volume in ft^3

Table 134. Commercial Freezer Savings (per unit)

Type	kWh	kW
Solid Door Freezer	1307	0.1491
Glass Door Freezer	2067	0.2368

Measure Savings Analysis

The estimated annual savings is calculated by taking the difference of maximum daily energy consumption and multiplying by the number of days per year (365.25 days per year). The baseline is based on federal minimum code requirements of maximum daily use based on volume.

Table 135. Baseline Maximum Daily Energy Consumption for Commercial Freezers (kWh per day)[81]

Type	kWhbase
Solid Door Freezer	0.40 * V + 1.38
Glass Door Freezer	0.75 * V + 4.10

Measure Life and Incremental Measure Cost

The measure life is 12 years based on DEER 2008 (and referenced in the IL TRM). The measure cost is from the IL TRM and is based on the volume categories defined by ENERGY STAR. KEMA uses the incremental measure cost for the 30 ≤ V ≤ 50 category since the average falls here and lacking any market penetration data. The cost is $166 per unit.

ENERGY STAR® Solid or Glass Door Refrigerator

Measure Description	This measure consists of the replacement of a conventional Solid Reach-In Refrigerator unit with an ENERGY STAR rated unit. Only units with built-in refrigeration systems are qualified. Units with remote refrigeration systems or units do not qualify.
Units	Per refrigerator
Base Case Description	Conventional, non ENERGY STAR unit

[80] Per the Energy Star listing as of October 19, 2012.
[81] Energy Policy Act of 2005. Accessed on 7/7/10. <http://www.epa.gov/oust/fedlaws/publ_109-058.pdf>

Table 136. ENERGY STAR Qualified Commercial Solid Door Refrigerators (kWh per day)[82]

Product Volume, cubic feet	Solid Door Refrigerator	Glass Door Refrigerator
0 < V < 15	≤ 0.089V + 1.411	≤ 0.118V + 1.382
15 ≤ V < 30	≤ 0.037V + 2.200	≤ 0.140V + 1.050
30 ≤ V < 50	≤ 0.056V + 1.635	≤ 0.088V + 2.265
50 ≤ V	≤ 0.060V + 1.416	≤ 0.110V + 1.50

The baseline federal maximum energy usage for solid door refrigerations is 0.10V + 2.04 kWh per day. V is in cubic feet[83]. For glass door refrigerators, the baseline is 0.12V +3.34 kWh per day.

Measure Savings
The savings for this measure is calculated using ENERGY STAR methodology. Savings are calculated using an average volume for all qualified Solid Door and Glass Door Reach-In Refrigerator units, which is 30.46 cubic feet and 27.76 cubic feet respectively[84]. The estimated annual savings is 637 kWh and 0.0727 kW for solid door, and 634 kWh and 0.0723 kW for glass door. Actual savings will vary based on equipment type and volume.

Measure Life and Incremental Measure Cost
The measure life is 12 years and IMC is $164 per unit per the 3/16/12 Draft IL TRM.

Reach-in (Novelty) Cooler Controls

Measure Description	The reach-in cooler controller is for refrigerated merchandise coolers with glass fronts. These coolers typically have fluorescent display lamps that operate 8,766 hours per year and refrigeration equipment that cycles continuously. The cooler contains only nonperishable bottled and canned beverages. The controller must include a passive infrared occupancy sensor to turn off fluorescent lights and other systems when the surrounding area is unoccupied for 15 minutes or longer. Additional interactive savings are realized by eliminating the heat sources (evaporator fan and display lighting) within the cooler's cold box cabinet, thereby reducing the

[82] www.energystar.gov, Note: V = Internal volume in ft^3
[83] http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr;sid=6897a2d07f4267b3924df5885ccd44ae;rgn=div5;view=text;node=10%3A3.0.1.4.19;idno=10;cc=ecfr, Note: V = Internal volume in ft^3
[84] Per the ENERGY STAR listing as of October 19, 2012.

	refrigeration load. The control logic should power up the machine at 2-hour intervals to maintain product temperature and provide compressor protection.
Units	Per Machine
Base Case Description	No controls

Measure Savings
Reach-in (novelty) cooler controls savings are taken from the Illinois TRM. It is assumed that controls are only effective during off-peak hours and therefore, have no peak-kW savings. The annual energy savings are 1,613 kWh per year.[85]

From TRM:

ΔkWh= WATTSbase / 1000 * HOURS * ESF

Wattsbase = 400

Hours = 8766

ESF = 46%

Measure Life and Incremental Measure Cost
The measure life is 5 years and the IMC documented for this measure is $180 per unit.[86]

[85] Illinois TRM
[86] Illinois TRM

Food Service

The measures in the following section are not based on the Ohio TRM or the responses from VEIC from November 2010. Updates to the measure savings may be considered that address the TRM to adjust the baseline and retrofit efficiencies actual found in the market place.

Ice makers, steam cookers, combination ovens, and hot food holding cabinet may qualify for new construction.

ENERGY STAR® Steam Cooker

Measure Description	This measure consists of the replacement of a conventional Steam Cooker unit with an ENERGY STAR rated unit.
Units	Per cooker
Base Case Description	Conventional, non ENERGY STAR unit

This measure consists of the replacement of a conventional Steam Cooker unit with an ENERGY STAR rated unit. Steamer performance is determined by applying the ASTM *Standard Test Method for the Performance of Steam Cookers* (F1484),[87] considered to be the industry standard for quantifying the efficiency and performance of steamers. The following table is the ENERGY STAR standards for electric steam cookers. The standard is version 1.1, current as of August 2003.

Table 137. ENERGY STAR Steam Cooker Standards

Pan Capacity	Cooking Energy Efficiency	Idle Rate (watts)
3-pan	50%	400
4-pan	50%	530
5-pan	50%	670
6-pan and larger	50%	800

*Cooking Energy Efficiency is based on heavy load (potato) cooking capacity

Measure Savings

The savings for this measure is calculated using the IL TRM methodology. However, a default savings approach is adopted here with the values summarized in the table below. The savings based on these defaults is 25,545 kWh per year and 3.526 peak kW.

Table 138. Default Values for Steam Cooker Savings Analysis

Adjustable Variable	Adjustable Variable Description	Default
$HOURS_{day}$	Average Daily Operation (hours)	8
F	Food cooked per day (lb)	100
$Days_{Year}$	Annual Days of Operation (days)	365.25
# of pans		4

Measure Life and Incremental Measure Cost

[87] American Society for Testing and Materials. 2005. *Standard Test Method for the Performance of Steam Cookers.* ASTM Designation F1484-05, in *Annual Book of ASTM Standards,* West Conshohocken, PA.

The measure life is 12 years and IMC[88] is $2,490 per unit. Both values are documented in the IL TRM.

ENERGY STAR® Combination Oven

Measure Description	This measure consists of the replacement of a conventional Combination Oven unit with an ENERGY STAR rated unit.
Units	Per oven
Base Case Description	Conventional, non ENERGY STAR unit

This measure consists of the replacement of a conventional Combination Oven unit with an ENERGY STAR rated unit. Oven performance is determined by the ASTM Standard Test Method for the Performance of Combination Ovens defined in standard F1639-05 or F2861,[89] considered to be the industry standard for quantifying combination oven efficiency and performance.[90] Savings calculations for combination ovens assume they meet or exceed heavy-load cooking energy efficiencies of > 60%, utilizing the ASTM standard F1639 or F2861.

Measure Savings
The savings for this measure is calculated using ENERGY STAR methodology, with updates based upon research done at the Food Service Technology Center. Measure data for savings calculations are based on average equipment characteristics, as established by ENERGY STAR. Annual energy use was calculated based on preheat, idle, and cooking energy efficiency and production capacity test results from applying ASTM F1639.

The following is the calculation for daily energy consumption per the PG&E workpapers.

$$EDay = LBFood * \frac{EFood}{Efficiency} + IdleRate * (OpHrs - \frac{LBFood}{PC} - \frac{TpreHT}{60}) + EpreHT$$

$$Average\ Demand = \frac{EDay}{OpHrs}$$

[88] 2009 PG&E Workpaper – PGECOFST104.1 – Commercial Steam Cooker – Electric and Gas
[89] American Society for Testing and Materials. "Standard Test Method for the Performance of Convection Ovens." ASTM Designation F1639-05. in *Annual Book of ASTM Standards*, West Conshohocken, PA. F2861 test method tests for cooking energy efficiency and idle energy rates in convection and steam mode.
[90] PG&E Food Service

Table 139: Combination Oven Variable Assumptions[91]

Variable	Variable Description (Units)	Value Assumed (Baseline)	Value Assumed (Energy Efficient)
EDay	Daily Energy Consumption (kWh/day)	106	55
LBFood	Pounds of Food Cooked per Day (lb/day)	200	200
Efood	ASTM Energy to Food (kWh/lb) = kWh/pound of energy absorbed by food product during cooking	0.0732	0.0732
Efficiency	Heavy Load Cooking Energy Efficiency %	44%	60%
IdleRate	Idle Energy Rate (kW)	7.5	3.0
OpHrs	Operating Hours/Day (hr/day)	12	12
PC	Production Capacity (lbs/hr)	80	100
TPreHt	Preheat Time (min/day)	15	15
EPreHt	Preheat Energy (kWh/day)	3.0	1.5

Savings assume a 10-pan steam cooker, operating 12 hours a day, 365 days per, with one preheat daily. The annual savings calculated for the combination oven is 18,432 kWh. Average demand savings is 1.697 kW.

Measure Life and Incremental Measure Cost

The following table provides the measure life and IMC[92] documented for this measure as well as the source of the data. Incremental cost is cost difference between the energy-efficient equipment and the less efficient option.

Table 140: Measure Life and Incremental Measure Cost

	Value	Source
Measure Life	12	DEER2008
Incremental Measure Cost	$3,824	PG&E

[91] PG&E Food Service Equipment Workpapers (October 2005)
[92] 2009 PG&E Workpaper – PGECOFST100.1 – Commercial Combination Oven – Electric and Gas

ENERGY STAR® Hot Food Holding Cabinet

Measure Description	This measure consists of the replacement of a conventional Hot Food Holding Cabinet unit with an ENERGY STAR rated unit.
Units	Per cabinet
Base Case Description	Conventional, non ENERGY STAR unit

This measure consists of the replacement of a conventional Hot Food Holding Cabinet unit with an ENERGY STAR rated unit (last updated April 2009). Hot-food holding cabinets that meet current ENERGY STAR specifications are 60% more energy-efficient than standard models and must meet a maximum idle energy rate of 40 watts/ft^3. All operating energy rates' savings assumptions are used in accordance with American Society for Testing and Materials' (ASTM) Standard F2140. Energy-usage calculations are based on 15 hours-a-day, 365 days-per-year operation (5,475 hours) at a typical temperature setting of 150°F (based on ENERGY STAR assumptions).

Measure Savings
The savings based on ENERGY STAR savings methodology are summarized in the table below. The average is 5293kWh per year and 0.3899 peak kW.

Table 141. Hot Holding Cabinet Savings by Size

	Full-size	Three-quarter size	Half size
Energy (kWh/year)	9,308	3,942	2,628
Demand (kW)	0.686	0.290	0.194

To estimate energy savings, hot food holding cabinets are categorized into three size categories, as in the following table.

Table 142. Cabinet Size Assumptions[93]

Size	Internal volume	Average volume for calculations
Full-size	> 15 ft^3	20 ft^3
Three-quarter size	10 – 15 ft^3	12 ft^3
Half size	< 10 ft^3	8 ft^3

The following is the calculation for daily energy consumption per the ENERGY STAR Hot Food Holding Cabinet calculator. The operating hours are assumed to 15 hours per day 365 days per

[93] ENERGY STAR Commercial Hot Food Holding Cabinet Calculator based on PG&E FSTC research

year. The coincidence factor is the average across food service types at 0.04033. The analysis is based on the IL TRM approach.

$$EDay = \frac{InternalVolume * (IdleRate) * (OpHrs)}{1000}$$

$$PeakDemand = \frac{EDay}{OpHrs} * CF$$

Measure Life and Incremental Measure Cost
The estimate useful life of this measure is 12 years (DEER 2008), as indicated in the IL TRM. The following table provides the IMC documented for this measure by the IL TRM. The average is $1500 per unit.

Table 143. Hot Food Holding Cabinet Incremental Measure Cost

Size Category	Cost per unit
Full-Size	$1200
Three-quarter size	$1800
Half size	$1500

High Efficiency Icemakers

Measure Description	The rebate covers ice machines that generate 60 grams (2 oz.) or lighter ice cubes, flaked, crushed, or fragmented ice. Only air-cooled machines qualify (self contained, ice making heads, or remote condensing). The machine must have a minimum capacity of 101 lb of ice per 24-hour period (per day). The minimum efficiency required is per ENERGY STAR® or CEE Tier 1.[94] A manufacturer's specification sheet must accompany the application that shows rating in accordance to ARI standard 810.
Units	Per icemaker
Base Case Description	Federal Minimum

[94] The websites have a list of qualifying model numbers, www.energystar.gov or www.cee1.org.

The rebate covers ice machines that generate 60 grams (2 oz.) or lighter ice cubes, flaked, crushed, or fragmented ice. Only air-cooled machines qualify (self-contained, ice-making heads, or remote condensing). The machine must have a minimum capacity of 101 lb of ice per 24-hour period (per day). The minimum efficiency required is per ENERGY STAR® or CEE Tier 1. A manufacturer's specification sheet must accompany the application that shows rating in accordance to ARI standard 810.

Measure Savings

Savings values are based on the methodology outlined in the IL TRM, derived from assumptions and values found in the PG&E workpaper[95].

Table 144. Ice Maker Savings, per icemaker

Ice Harvest Rate (IHR) (lbs per 24 hrs.)	KWh	kW
101-200	251.4	0.04714
201-300	416.4	0.07808
301-400	517.4	0.09702
401-500	604.3	0.1133
501-1,000	960.3	0.1801
1,001-1,500	1197	0.2245
> 1,500	1676	0.3143

Measure Savings Analysis

Federal minimum and ENERGY STAR® efficiency requirements can be found in the following table.

Table 145. Ice Maker Efficiency Standards

Equipment Type	Federal Standard, kWh_{base}	ENERGY STAR®, kWh_{ee}
Ice Making Head (H < 450)	10.26-0.0086*H	9.23-0.0077*H
Ice Making Head (H ≥ 450)	6.89-0.0011*H	6.20-0.0010*H
Remote Condensing Unit, without remote compressor (H < 1000)	8.85-0.0038*H	8.05-0.0035*H
Remote Condensing Unit, without remote compressor (H ≥ 1000)	5.1	4.64
Remote Condensing Unit, with remote compressor (H < 934)	8.85-0.0038*H	8.05-0.0035*H
Remote Condensing Unit, with remote compressor (H ≥ 934)	5.3	4.82
Self Contained Unit (H < 175)	18-0.0469*H	16.7-0.0436*H
Self Contained Unit (H ≥ 175)	9.8	9.11

[95] Work Paper PGECOFST108.2 – Commercial Ice Machines, Pacific Gas and Electric 2009

The savings methodology for this measure is based on the method presented in PG&E's 2009 Ice Machine workpaper. The savings are based on the difference of the ice harvest rate (IHR) which is expressed as kWh per 100 lb. Icemaker sizes are expressed by the rate of their production in lb per 24-hour period. The following equations are used to calculate savings.

$$Annual\ kWh\ Savings = \frac{(kWh_{base} - kWh_{retrofit})}{100} \times Duty\ Cycle \times IHR \times 365$$

Where

- 100 = conversion factor to convert kWh_{base} and kWh_{ee} into maximum kWh consumption per pound of ice.
- DC = Duty Cycle of the ice machine = 0.57
- IHR = Ice Harvest Rate (pounds of ice made per day)
- 365.25 = days per year
-

$$Coincident\ peak\ kW\ savings = \frac{Annual\ kWh\ Savings}{Annual\ operating\ hours \times Duty\ Cycle} \times Summer\ Peak\ Coincident\ Factor$$

Where:

- Annual operating hours= 8766 (365.25 days)
- Summer Peak Coincidence Factor for measure= 0.937

The following table provides values for average IHR, baseline kWh and retrofit kWh used to calculate savings.

Table 146. Savings Calculation Inputs[96]

Ice Harvest Rate (IHR) (lbs per 24 hrs.)	Average IHR (lbs/day)	Assumed Ice Machine Type	Baseline (kWh/100 lbs)	Retrofit (kWh/100 lbs)
101-200	150	Self Contained	10.97	10.16
201-300	250	Ice Making Head	8.11	7.31
301-400	350	Ice Making Head	7.25	6.54
401-500	450	Ice Making Head	6.40	5.75
501-1,000	750	Ice Making Head	6.07	5.45
1,001-1,500	1,250	Remote Condensing w/o remote compressor	5.10	4.64
> 1,500	1,750	Remote Condensing w/o remote compressor	5.10	4.64

[96] Work Paper PGECOFST108.2 – Commercial Ice Machines, Pacific Gas and Electric 2009.

Measure Life and Incremental Measure Cost
The measure life for icemakers is 10 years based on 2008 DEER as references in the IL TRM. The IL TRM uses the following incremental measure cost data.

Table 147. Ice Maker Incremental Measure Cost

Harvest Rate (lbs / 24 hrs)	$ per unit
101-200	$296
201-300	$312
301-400	$559
401-500	$981
501-1,000	$1,485
1,001-1,500	$1,821
> 1,500	$2,194

Beverage Machine Controls

Measure Description	The beverage machine is assumed to be a refrigerated vending machine that contains only nonperishable bottled and canned beverages. The controller must include a passive infrared occupancy sensor to turn off fluorescent lights and other vending machine systems when the surrounding area is unoccupied for 15 minutes or longer. For the beverage machine, the control logic should power up the machine at 2-hour intervals to maintain product temperature and provide compressor protection.
Units	Per machine
Base Case Description	No controls

Measure Savings
Beverage machine controls savings are taken from the DEER 2005 database. It is assumed that controls are only effective during off-peak hours and so have no peak-kW savings. The annual energy savings are 1,612 kWh per year. The Ohio TRM results in the same savings when assuming that the baseline wattage is 400 W and energy savings factor is 46% at 8,760 hours of operation.

Measure Life and Incremental Measure Cost
The measure life is 5 years.[97] The IMC documented for this measure is $180 per unit.[98]

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[97] Ohio TRM and DEER 2008
[98] 2005 DEER

Snack Machine Controls

Measure Description	The controller must include a passive infrared occupancy sensor to turn off fluorescent lights and other vending machine systems when the surrounding area is unoccupied for 15 minutes or longer.
Units	Per machine
Base Case Description	No controls

Measure Savings
Snack machine controls savings are taken from the DEER database. It is assumed that controls are only effective during off-peak hours and so have no peak-kW savings. The annual energy savings are 387 kWh per year.[99]

A baseline is used to calculate savings and incremental cost. In this case, the baseline for this measure assumes that there are controls installed for the machine.

Measure Life and Incremental Measure Cost
The measure life is 5 years[100]. The IMC documented for this measure is $80 per unit per DEER 2005.

ENERGY STAR® Refrigerated Beverage Vending Machine Refurbishment Kit

Measure Description	ENERGY STAR beverage vending machines qualify for an incentive. Qualifying machines can be found at http://www.energystar.gov/ia/products/prod_lists/vending_machines_prod_list.pdf.
Units	Per Machine
Base Case Description	Standard Unit

Measure Savings[101]
Beverage machine savings are taken from the ENERGY STAR savings calculator and summarized in the following table. ENERGY STAR provides savings numbers for machines with

[99] DEER 2005. The Ohio TRM assumes 345 kWh per year using a 46% energy savings factor and connected watts of the machine at 85 Watts.
[100] DEER 2008 and Ohio TRM
[101] ENERGY STAR Savings Calculator.
http://www.energystar.gov/index.cfm?c=vending_machines.pr_vending_machines

and without control software. The average savings are calculated here. It is assumed that controls are only effective during off-peak hours and so have no peak-kW savings.

Table 148. ENERGY STAR Vending Machine Savings

Vending Machine Capacity (cans)	kWh Conventional Machine	kWh ENERGY STAR Machine w/o software	kWh ENERGY STAR Machine w/ software	kWh Savings Per Machine w/o software	kWh Savings Per Machine w/ software
<500	3,113	2,014	1,454	1,099	1,659
500	3,916	2,162	1,685	1,754	2,231
699	3,551	2,309	1,800	1,242	1,751
799	4,198	2,457	1,915	1,741	2,283
800+	3,318	2,605	2,030	713	1,288
Average	3,619	2,309	1,777	1,310	1,842
Total Average	1,576				

Measure Life and Incremental Measure Cost

The measure life is 14 years according to ENERGY STAR. The measure cost is $200 according to ENERGY STAR.

Pre-Rinse Sprayers

Measure Description	This measure consists of installing low-flow pre-rinse sprayers, placed at the entrance to a commercial dishwasher or over a sink. A low-flow, high efficiency pre-rinse sprayer less than or equal to 1.6 gallons per minute (gpm) must replace a sprayer of 1.9 gpm or greater. The measure is only applicable for systems with electric storage water heaters and gas heaters with electric booster heaters if used anytime the sprayer is used.
Units	Per sprayer
Base Case Description	Pre-rinse sprayer of 2.2 gpm or greater.

This measure consists of installing low-flow pre-rinse sprayers, placed at the entrance to a commercial dishwasher or over a sink. A low-flow, high efficiency pre-rinse sprayer less than or equal to 1.6 gallons per minute must replace a sprayer of 1.9 gpm or greater. Installing devices such as the low-flow pre-rinse sprayer is an inexpensive and lasting approach to water conservation. These products help to save energy by reducing the amount of energy needed to process, move, and heat the water.

Measure Savings

The savings are 0 kW and 3792 kWh per year per sprayer[102].

Measure Savings Analysis

The annual electrical energy savings (kWh/yr), the peak coincident demand savings (kW), and annual natural gas savings are calculated using the assumptions and equations listed below[103].

1. Cold water supply temperature of 54.1°F
2. Hot water supply temperature (from sprayer) of 124.1°F
3. Average use of 1.7 hours per day, for 312 days per year
4. Existing sprayer is 1.75 gpm, an average of the retrofit baseline of 1.9 gpm, and a time of sale baseline of 1.6 gpm
5. A coincidence factor of 0 is used
6. Hours per day is assumed to be 1.7 on average
7. Days per year is assumed to be 312, per IL TRM

ΔkWH = ΔGallons x 8.33 x 1 x (Tout - Tin) x (1/EFF electric) /3,413 x FLAG

Where:

ΔGallons	= amount of water saved as calculated below
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
Tout	= Water Heater Outlet Water Temperature
	=Tin + 70° F temperature rise from Tin[104]
Tin	= Inlet Water Temperature

ΔGallons = (FLObase - FLOeff)gal/min x 60 min/hr x HOURSday x DAYSyear

Where:

FLObase = base case flow in gallons per minute

FLOeff = Efficient case flow in gallons per minute

Hoursday = hours per day that the pre-rinse spray valve is used at the site

DAYSyear = Days per year pre-rinse spray valve is used at the site

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[102] Illinois TRM

[103] Illinois TRM

[104] If unknown, assume a 70 degree temperature rise from Tin per Food Service Technology Center calculator assumptions to account for variations in mixing and water heater efficiencies

Measure Life and Incremental Measure Cost
The measure life is 5 years per the Illinois TRM. The typical equipment cost is $100.00, also per the IL TRM.

ENERGY STAR Heat Pump Water Heaters and High Efficiency Electric Water Heater

Measure Description	**ENERGY STAR Heat Pump Water Heater:** Must meet ENERGY STAR criteria with an Energy Factor ≥2.0 and first hour rating (FHR) ≥ 50 gallons per hour. **High Efficiency Hot Water Heater:** New hot water heater must be ≥ 40 gallons have an Energy Factor ≥0.93.
Units	Per unit
Base Case Description	Baseline is based on January 2004 standard energy factor, 0.97-(0.00132 x rated storage volume in gallons)

Measure Savings
The coincident electrical demand (kW), annual electrical energy savings (kWh/yr are provided in the following table.

Table 149. Water Heater Savings, per unit

Building Type	HP Water Heater kWh Savings	HP Water Heater kW Savings	Electric Water Heater kWh Savings	Electric Water Heater kW Savings
Large Office	8,893	1.956	929	0.204
Small Office	2,500	0.550	261	0.057
School	1,249	0.275	131	0.029
Small Retail/Service	4,259	0.937	445	0.098
Large Retail/Service	11,090	2.440	1,159	0.255
Hotel/Motel	9,965	2.192	1,042	0.229
Guest Rooms	8,727	1.920	912	0.201
Medical - Hospital	2,541	0.559	266	0.058
Medical - Nursing Home	1,524	0.335	159	0.035
Restaurant	2,589	0.570	271	0.060
Grocery	11,252	2.475	1,176	0.259
Conditioned Warehouse	7,743	1.703	809	0.178
Unconditioned Warehouse	7,743	1.703	809	0.178
Manufacturing – Light Industrial (1 shift)	7,743	1.703	809	0.178
Manufacturing – Light Industrial (2 shift)	7,743	1.703	809	0.178

Manufacturing – Light Industrial (3 shift)	7,743	1.703	809	0.178
College/University	15,728	3.460	1,644	0.362
Government/Municipal	1,316	0.290	138	0.030
Assembly	1,316	0.290	138	0.030
Miscellaneous	8,205	1.805	858	0.189

Measure Savings Analysis

The following tables summarize the savings analysis and calculations for hot water heater savings.

Table 150. Water Heater Savings Analysis

Building Type	Typical Storage (gallons)	EUI - kWh/year/sf	UEC, kWh/year (Fed min)	UEC, kWh/year (assuming 100% efficient)	UEC, kWh/Year (Assuming 93% efficient)	UEC, kWh/year (assuming 200% efficient	Area (Sq Ft)	# of smaller water heaters
Large Office	100	0.21	36,750	32,737	35,201	16,368	175,000	1.667
Small Office	30	0.31	3,100	2,761	2,969	1,381	10,000	0.500
School	310	0.16	16,000	14,253	15,326	7,126	100,000	5.167
Small Retail/Service	10	0.22	1,760	1,568	1,686	784	8,000	0.167
Large Retail/Service	60	0.22	27,500	24,497	26,341	12,249	125,000	1.000
Hotel/Motel	85	1.01	35,006	31,183	33,530	15,591	34,659	1.417
Guest Rooms	450	1.01	162,289	144,567	155,448	72,283	160,682	7.500
Medical - Hospital	500	0.21	52,500	46,767	50,287	23,384	250,000	8.333
Medical - Nursing Home	200	0.21	12,600	11,224	12,069	5,612	60,000	3.333
Restaurant	60	2.14	6,420	5,719	6,149	2,859	3,000	1.000
Grocery	100	0.93	46,500	41,422	44,540	20,711	50,000	1.667
Conditioned Warehouse	150	0.32	48,000	42,758	45,977	21,379	150,000	2.500
Unconditioned Warehouse	150	0.32	48,000	42,758	45,977	21,379	150,000	2.500
Manufacturing – Light Industrial (1 shift)	150	0.32	48,000	42,758	45,977	21,379	150,000	2.500
Manufacturing – Light Industrial (2 shift)	150	0.32	48,000	42,758	45,977	21,379	150,000	2.500
Manufacturing – Light Industrial (3 shift)	150	0.32	48,000	42,758	45,977	21,379	150,000	2.500
College/University	500	0.5	325,000	289,510	311,301	144,755	650,000	8.333
Government/Municipal	200	0.32	10,880	9,692	10,421	4,846	34,000	3.333
Assembly	200	0.32	10,880	9,692	10,421	4,846	34,000	3.333
Miscellaneous	187.1052632	0.493157895	63,445	56,516	60,770	28,258	128,650	3.118

The savings presented here are based on the approach in the PG&E workpapers, PGECODHW107 R1 Elec Storage Water Heater Nonres.doc. ComEd building types are mapped to the PG&E workpaper building types (averages are used when more than one building type maps). Savings are determined using electric water heating Energy-Use Indices (EUI) values provided by the California Commercial End Use Study (CEUS). An EUI value is defined as the annual energy usage for a specific fuel and end-use per square foot of area served. These EUI values are then multiplied by square footage for the non-residential DEER building prototypes to result in total water heater usage for each building type. Energy savings at the building level are calculated by assuming an Energy Factor improvement from federal minimum for a 60 gallon tank, 0.8908 to 2.0. To determine the energy savings per unit, the energy savings per building is divided by the average number of water heaters there are per building. The number of hot water heaters per building is determined by dividing the typical water storage capacity found in the different buildings in gallons as determined by the CEUS, by the average electric water heater size in gallons, which according to the ComEd Cadmus 2009 Commercial study, is 60 gallons. Peak demand impact is based on the load shapes contained in the California Energy Commission's (CEC) peak demand forecasting model. In all cases, the energy/peak factor for water heating measures is 0.22.[105] The energy/peak factor is the ratio of the connected load reduction to peak energy demand.

A climate factor is added to the equation (for electric storage water heater, the climate factor is 1.0). This climate factor takes into consideration the lower winter temperatures affect on heat pump operation. This factor was calculated using data from the ACEEE report on emerging hot water technologies[106]. The factor is the ratio between the savings of residential heat pump water heater savings for moderate and northern climates, which is 72.7%.

[105] 2004-2005 Database for Energy Efficiency Resources (DEER), Version 2.01, Measure ID D03-939, Section 6 and 7
[106] http://www.aceee.org/consumer/water-heating

Hot Water Energy Savings/unit =

$$\frac{\left[(EUI \times Building\_Area) \times EF_{fed\,\min} \times \left(1 - \frac{1}{EF_{new}}\right)\right]}{\#Hot\_Water\_Heaters\_per\_Building} \times ClimateFactor$$

Table 151. Mapping Building Types

DEER 2005 Prototype	AEP Bldg Types
Assembly	Assembly
Primary School	School
Secondary School	School
Community College	College/University
University – Instruction	College/University
Grocery	Grocery
Hospital	Medical - Hospital
Nursing Home	Medical - Nursing Home
Hotel – Public Area	Hotel/Motel
Hotel – Guest Rooms	Guest Rooms
Motel	Hotel/Motel
Manufacturing – BioTech	Manufacturing
Manufacturing – Light	Manufacturing
Large Office	Large Office
Small Office	Small Office
Sit Down Restaurant	Restaurant
Fast Food Restaurant	Restaurant
3-Story Retail	Large Retail
1-Story Retail	Large Retail
Small Retail	Small Retail

Table 152. DEER Water Heater Data

DEER 2005 Prototype	Typical Storage (gallons)	Building square feet	EUI - kWh/year/sf
Assembly	200	34,000	0.32
Primary School	120	50,000	0.16
Secondary School	500	150,000	0.16
Community College	500	300,000	0.5
University – Instruction	500	1,000,000	0.5
Grocery	100	50,000	0.93
Hospital	500	250,000	0.21
Nursing Home	200	60,000	0.21
Hotel – Public Area	120	39,318	1.01
Hotel – Guest Rooms	450	160,682	1.01
Motel	50	30,000	1.01
Manufacturing – BioTech	200	200,000	0.32
Manufacturing – Light	100	100,000	0.32
Large Office	100	175,000	0.21
Small Office	30	10,000	0.31
Sit Down Restaurant	60	4,000	2.14
Fast Food Restaurant	60	2,000	2.14
3-Story Retail	60	120,000	0.22
1-Story Retail	60	130,000	0.22
Small Retail	10	8,000	0.22

Table 153. Mapped Data to AEP Building Types

Building Type	gallons	Typical Bldg SF (from DEER)	EUI
Large Office	100	175000	0.21
Small Office	30	10000	0.31
School	310	100000	0.16
Small Retail/Service	10	8000	0.22
Large Retail/Service	60	125000	0.22
Hotel/Motel	85	34659	1.01
Guest Rooms	450	160682	1.01
Medical - Hospital	500	250000	0.21

Medical - Nursing Home	200	60000	0.21
Restaurant	60	3000	2.14
Grocery	100	50000	0.93
Conditioned Warehouse	150	150000	0.32
Unconditioned Warehouse	150	150000	0.32
Manufacturing – Light Industrial (1 shift)	150	150000	0.32
Manufacturing – Light Industrial (2 shift)	150	150000	0.32
Manufacturing – Light Industrial (3 shift)	150	150000	0.32
College/University	500	650000	0.5
Government/Municipal	200	34000	0.32
Assembly	200	34000	0.32
Miscellaneous	187	128650	0.49

Measure Life and Incremental Measure Cost

Table 154. Hot Water Heat Measures EUL and IMC

	Heat Pump Water Heater	High Eff Hot Water Heater
EUL	10	10
EUL Source	Ohio Draft TRM	Ohio Draft TRM
IMC	Default: $1000	$72
IMC Source	ACEEE Report[107]	PG&E Workpapers

[107] Emerging Hot Water Technologies and Practices for Energy Efficiency as of 2011, Report Number A112, October 2011.

Compressed Air

Variable Speed Drive Air Compressor

Measure Description	Only new air compressors whose rated horsepower (HP) is less than or equal to 100 HP qualify for this incentive. Air compressors larger than 100-hp may qualify for a Custom Incentive. The new VSD air compressor must be replacing an existing constant speed compressor having an equal or higher HP rating and annually operating hours of at least 1,200 hours per year. Back-up and redundant air compressors are not eligible for this incentive. Air compressors on multiple-compressor systems are not eligible. System and demand conditions requiring the air compressor to be loaded constantly above eighty percent (80%) or constantly loaded below thirty percent (30%) are not eligible for this incentive. These operating conditions will not realize savings from a VSD controlled compressor. This incentive cannot be combined with the VFD incentive.
Units	Per horsepower
Base Case Description	Air compressor system without variable speed drive.

This work-paper focuses on the control mechanism applied to control the capacity of air produced by the compressor. Since rotary screw machines are the dominant type, the analysis here is based on this type. They have four major control mechanisms: inlet modulation (IM), variable displacement (VD), load/no-load (LNL), and variable speed drive (VSD) controls. These controls are presented in increasing order of their ability to maintain high system efficiency at part loads, with IM being the least efficient and VSD controls being the most efficient at part load operation.

It is expected that the applicant must provide the following operating conditions in order to qualify for prescriptive incentives:

1. Rated power (hp) of the air compressors
2. Rated volume flow rate (scfm) of the air compressors
3. Existing (if any) storage capacity per rated volume flow rate (gallons per scfm) of the air compressors
4. Annual operating hours

Measure Savings

The annual kWh and peak kW savings per horsepower is 1,729 kWh per year and 0.2397 peak kW.

Measure Savings Analysis

Savings will be estimated by establishing average compressor power draw for both base case and measure case capacities. Applying this difference in compressor power load between base and measure case to the estimated full load compressor energy usage over the year will result in energy savings due to the variable speed drive.

Annual energy (kWh) and maximum non-coincident demand (kW) saved are calculated using the following formulas. The base case assumes a single compressor with LNL controls, while the measure case assumes the same sized air compressor with VSD control. The savings is calculated based on the horsepower (HP) rating of the new air compressor.

$$kWh_{Saved} = \left\{ \left(\frac{HP_x \times SF}{\eta_x} \times PPD_x \right) - \left(\frac{HP_p \times SF}{\eta_p} \times PPD_p \right) \right\} \times C_1 \times NEI \times hours$$

$$kW_{Saved} = \left\{ \left(\frac{HP_x \times SF}{\eta_x} \times PPD_x \right) - \left(\frac{HP_p \times SF}{\eta_p} \times PPD_p \right) \right\} \times C_1 \times NEI \times CF_{comp\ air}$$

where:

HP_x = rated horsepower of the existing air compressor, hp
HP_p = rated horsepower of the proposed air compressor, hp
SF = Service Factor, 118%
η_x = motor efficiency of the existing air compressor, 90%
η_p = motor efficiency of the proposed air compressor, 95%
PPD_x = percentage of the existing air compressor's full load power draw, 72.05%
PPD_p = percentage of the proposed air compressor's full load power draw, 50.00%
C_1 = conversion constant, 0.746-kW/hp
NEI = increase in nameplate efficiency, 1.15
hours = Projected operating hours
CF comp air = compressed air coincidence factor, 86.5 %

Table 155. Variables for VSD Air Compressor Savings

Component	Type	Value	Source
HP_x	Fixed	HP_p	Assumption
SF	Fixed	118%	Review of three manufacturer specification sheet data[(a)]

Component	Type	Value	Source
η	Fixed	Existing, 90 Proposed, 95%	Assumption
PPD	Fixed	Existing, 72.05% Proposed, 50.00%	Review of 12 air compressor projects, average[(b)]
NEI	Fixed	1.15	Review of three manufacturer specification sheet data[(c)]
Hours	Variable	Hours range through 8,760 hours. Default: 6,240 hours[108]	Application, DNV KEMA[(d)]
$CF_{comp\ air}$	Fixed	0.865	New Jersey's Clean Energy Program[109]

Please refer to the following notes:

a. The service factor was fixed at one hundred and eighteen percent (118%) after averaging the values provided on the specification sheets of three major manufactures of VSD compressors in the US (Sullair, Kaeser, and Quincy compressors). Forty (40) different compressors were surveyed, ratings from 50-hp to 300-hp. Tables below are available for reference.
b. Twelve (12) custom compressed air projects were surveyed (sourced from programs in Michigan and Ohio), where older, traditional controlled air compressors were replaced with similar sized VSD air compressors. The total power consumption was metered over a seven day period both before construction and after construction. The average power draw (kW) for each project was analyzed. Using this data, the percent volume flow rate (CFM) loading of all of the VSD compressors was found using the manufactures' specification sheet. It showed that on average, these compressors were loaded to 47% of their full load CFM. The after construction files (with VSD installed) were analyzed because the profile with these compressors give the most accurate prediction of the facility's actual air demand, with the assumption that the facility's air demand did not change from before to after construction conditions. For a VSD compressor loaded at 47% it draws 50.00% of its full load rated kW, hence PPD = 50.00%. An IM and LNL, at this loading will draw 84.10% and 60.00% respectively, and by averaging these two values, the PPD is calculated as 72.05%. The PPD for IM and LNL compressors were

[108] 16 hours per day, 5 days per week, minus 9 holidays and 3 scheduled down time days
[109] DNV Kema, New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review, July 10 2009.

averaged because of the ability to run a LNL compressor in IM mode and vice versa. The PPD was determined from standardized CAGI estimated performance comparison curves.

c. From the before mentioned forty (40) air compressors surveyed, the average name plate efficiency was 4.69 CFM/HP. The old compressor efficiency was assumed to be 4.00 CFM/HP as a result of age and other factors. This represents a 15% increase in efficiency, hence the 1.15 factor included in the equation as the NEI. Refer to the following three tables.
d. Based on the compressed air system being continuously operated (8,760-hrs/yr), or never being shut off, the usage factor (UF) is shown as eighty-one percent (81%). On average, the compressed air systems in these industrial projects operate approximately 7,100-hours per year. We believe that this compressed air measure will be installed in similar industrial facilities operating in similar circumstances. For this analysis, we have determined that a typical industrial facility using compressed air operates three (3) shifts per week or approximately 6,240-hrs/yr.

Table 156. Average air Compressor use factor

	File #	Controls	% Loading	Weekly Operating Hours	Use Factor
Michigan Program	CE 8420	VSD	16%	168	100%
	CE 7198	VSD	50%	168	100%
	CE 9239	VSD	53%	114	68%
	CE 8148	VSD	48%	168	100%
	CE 7345	VSD	45%	136	81%
	CE 7926	VSD	54%	146	87%
Ohio Program	KEMA - 1936	VSD	65%	30	18%
	KEMA - 2865	VSD	41%	113	67%
	KEMA - 3158	VSD	68%	167	99%
	KEMA - 0511	VSD	28%	114	68%
	KEMA - 1506	VSD	44%	144	86%
	KEMA - 2388	VSD	55%	168	100%
TOTALS			**47%**		**81%**

These following three tables summarize the name-plate efficiency and Service Factor calculated directly from data on three compressor manufacturer's CAGI data sheet.

Table 157. Manufacturer CAGI Data Sheet, Sullair[110]

Model #	Hp	Fan Hp	kW @ Full load	Hp @ Full load	Full load CFM	Name-plate Eff. (CFM/ Hp)	Service Factor
1107eV	15.0	1.0	14.6	19.57	62.90	4.19	18.2%
1507eV	20.0	1.0	19.3	25.87	90.60	4.53	18.8%
1807eV	25.0	1.0	24.0	32.17	107.80	4.31	19.2%
1807V	25.0	1.0	23.8	31.90	116.00	4.64	18.5%
2207V	30.0	1.0	28.3	37.94	138.00	4.60	18.3%
3007V	40.0	1.5	38.2	51.21	182.00	4.55	19.0%
4509V	60.0	2.0	54.9	73.59	260.00	4.33	15.8%
4507PV	60.0	3.0	56.9	76.27	305.00	5.08	17.4%
5507V	75.0	3.0	70.5	94.50	377.00	5.03	17.5%
7507V	100.0	3.0	93.7	125.60	493.00	4.93	18.0%
7507PV	100.0	3.0	92.8	124.40	500.00	5.00	17.2%
V200S-125LAC	125.0	3.0	114.4	153.35	633.00	5.06	16.5%
V200S-150LAC	150.0	3.0	139.0	186.33	757.00	5.05	17.9%
V200S-200LAC	200.0	7.5	181.6	243.43	967.00	4.84	14.8%
V320TS-250LAC	250.0	5.0	225.6	302.41	1300.00	5.20	15.7%
V320TS-300HAC	300.0	10.0	320.0	428.95	1400.00	4.67	27.7%
V320TS-300LAC	300.0	10.0	269.4	361.13	1550.00	5.17	16.9%
Hp limit for this Manufacturer							
Average Name-plate Efficiency				Average Service Factor			
4.78				18.1%			

Table 158. Manufacturer CAGI Data Sheet, Quincy[111]

[110] http://www.sullair.com/corp/details/0,10294,CLI1_DIV61_ETI5707,00.html

[111] http://www.quincycompressor.com/cagi.html

Model #	Hp	Fan Hp	kW @ Full load	Hp @ Full load	Full load CFM	Name-plate Eff. (CFM/ Hp)	Service Factor
QGV-20	20	1	18.3	24.53	83.50	4.18	14.4%
QGV-25	25	1	21.4	28.69	116.40	4.66	9.4%
QGV-30	30	1	26.8	35.92	135.70	4.52	13.7%
QGV-40	40	1	36.8	49.33	185.30	4.63	16.9%
QGV-50	50	1.5	41.8	56.03	226.10	4.52	8.1%
QGV-60	60	3	58.5	78.42	291.30	4.86	19.7%
QGV-75	75	3	72.4	97.05	371.50	4.95	19.6%
QGV-100	100	3	89.1	119.44	470.90	4.71	13.8%
QGV-125	125	7.5	119.2	159.79	583.10	4.66	17.1%
QGV-150	150	5	142.2	190.62	738.10	4.92	18.7%
QGV-200	200	10	179	239.95	960.20	4.80	12.5%
Hp limit for this Manufacturer							
Average Name-plate Efficiency				Average Service Factor			
4.67				14.9%			

Table 159. Manufacturer CAGI Data Sheet, Kaeser[112]

Model #	Hp	Fan Hp	kW @ Full load	Hp @ Full load	Full load CFM	Name-plate Eff. (CFM/ Hp)	Service Factor
SFC18	25	0.75	26.7	35.79	124.00	4.96	28.1%
SFC22	30	0.75	31.1	41.69	137.40	4.58	28.0%
SFC30 S	40	0.75	38.4	51.47	190.70	4.77	22.3%
SFC37	50	1.2	45.9	61.53	220.00	4.40	18.7%
SFC45	60	1.5	58.8	78.82	291.30	4.86	23.9%
SFC55	75	1.5	76.2	102.14	367.30	4.90	26.6%
SFC90	100	3	98	131.37	475.70	4.76	23.9%
SFC110	125	3	123.4	165.42	613.10	4.90	24.4%
SFC 132S	175	3	146	195.71	706.30	4.04	10.6%
SFC 132S	200	3	164.2	220.11	867.00	4.34	9.1%
SFC 200	270	3.5	231.7	310.59	1236.00	4.58	13.1%
Hp limit for this Manufacturer							
Average Name-plate Efficiency				Average Service Factor			
4.64				20.8%			
Overall average System Efficiency				**4.70**			
Overall average Service Factor				**18%**			

A recent compressed air study surveyed a dozen compressed air projects within Michigan and Ohio energy efficiency program. The following table summarizes the percent usage and the usage factors of compressors recorded from these projects.

The anticipated annual energy savings (kWh/yr per HP) for this analysis can be realized by the following:

$$\boldsymbol{kWh\ Savings} = \left\{\left(\frac{\boldsymbol{HP} \times \mathbf{1.18}}{\mathbf{0.90}} \times \mathbf{0.72}\right) - \left(\frac{\boldsymbol{HP} \times \mathbf{1.18}}{\mathbf{0.95}} \times \mathbf{0.500}\right)\right\} \times \frac{\mathbf{0.746kW}}{\mathbf{hp}} \times \mathbf{1.15} \times \mathbf{6,240}\ \boldsymbol{hrs/yr}$$

112 http://us.kaeser.com/Advisor/CAGI_data_sheets/default.asp

= *1,729–kWh/yr per HP*

Measure Life and Incremental Measure Cost

The anticipated life of this measure has been estimated at 15 years, the same as energy efficient motors and variable speed drives.

From the twelve (12) VSD compressed air projects analyzed, the average equipment cost for a VSD compressor is: $428/HP.

Added Compressor Storage on Load/No Load Systems

Measure Description	Addition of air receiver tanks for 5 gallons per cfm capacity or more for air compressor systems that have load/no load controls. This prescriptive measure is eligible for air compressor systems whose rated horse-power (hp) is less than or equal to 300 hp. Both new and retrofit receivers are eligible for incentives. The additional air receiver tanks must meet or exceed the minimum receiver size of 5 gallons of storage per rated volume flow rate (scfm) of the compressor, while the existing air receiver capacity must be less than or equal to 2 gallons per scfm compressor capacity to qualify. Compressed air systems with variable-speed or variable displacement controlled compressors are not eligible.
Units	Per gallon[113]
Base Case Description	Air compressor system with 1 gallon per cfm capacity

This measure describes the addition of compressed air receiver tanks for systems whose compressors have load/no load (LNL) controls. Adding receiver tank capacity to compressors that have LNL controls can potentially offset power consumption of the compressor by reducing the frequency of cycling periods between loading and unloading the compressor. It is not intended for the consequential purpose of increasing storage capacity due to lowering the system's operating pressure or other system changes.

Air receivers buffer the air demand that the supply side (compressor) experiences. With LNL controlled compressors, there is a period of time that elapses during an unloading event that

[113] Savings is dependent not only on compressor size, but also on a nonlinear compressor power load factor. Thus, savings is kept on a arbitrary per "unit" basis, where the unit in the default case is a 25 hp compressor with air receiver capacity increasing from 1 gal/cfm to 5 gal/cfm.

uses considerably more energy than the final unloaded (and possibly turned off if compressor has dual-control, depending on air demand and controls in place) state. Reducing the frequency of these transitions increases the overall efficiency of compressor usage. An increased receiver capacity will decrease the frequency of these inefficient unloading transition periods, hence saving energy.

It is expected that the applicant must provide the following operating conditions in order to qualify for prescriptive incentives:

5. Rated power (hp) of the air compressors that the receiver tanks serve
6. Rated volume flow rate (scfm) of the air compressors
7. Existing (if any) storage capacity per rated volume flow rate (gallons per scfm) of the air compressors
8. Proposed storage capacity in gallons per scfm

Measure Savings
The annual kWh and peak kW savings per gallon increased air capacity is 62.4 kWh per year and 0.009 peak kW.

Measure Savings Analysis
Savings will be estimated by establishing average annual air compressor power capacity factors for both base case and measure case air receiver capacities. The increase in air receiver capacity to the system effectively reduces the average compressor power load over the year; applying this difference in compressor power load between base and measure case to the estimated full load compressor energy usage over the year will result in energy savings due to the increase in air receiver capacity.

Annual energy (kWh) and maximum non-coincident demand (kW) saved are calculated using the following formulas. The base and measure cases both assume the same single compressor with LNL controls; the base case conditions assume the compressor has a total of 2 gallon per cfm storage capacity, while the measure case assumes the compressor has a total of 5 gallons per cfm storage capacity.

$$kWh_{saved} = \frac{\eta_{air\ comp} \times Hours \times \eta_{Savings}}{DC_{existing}}$$

$$kW_{saved} = \frac{(kWh_{saved} \times CF_{comp\ air})}{(Hours)}$$

Definition of Variables

kWh_{saved} = *Annual kWh saved*

kW_{saved} = *Demand (kW) reduced*

$Hours$ = *typical compressed air process annual hours of operation, 3,9686,240-hrs/yr*

ηair comp = *compressed air generation efficiency, 0.20-kW/scfm*

ηsavings =*total percent of energy savings by increasing the capacity of the receiver tank, 10%*

DC existing = *air demand unit capacity of the existing compressed air system, 2-scfm/gallon*

CF comp air = *compressed air coincidence factor, 86.5 %*

Table 160. Variables for Increased Air Receiver Capacity

Component	Type	Value	Source
Hours	Variable	Ranges through 8,760 hours. Default: 6,240 hours	Application, DNV KEMA
ηair comp	Fixed	0.18 kW/scfm	US DOE
UF	Fixed	0.81, see the following table	Review of 12 air compressor projects, average
ηsavings	Fixed	10%, See figure below	US DOE
DC existing	Fixed	2 gal/scfm	Existing condition assumption
$CF_{comp\ air}$	Fixed	0.865	New Jersey's Clean Energy Program[114]

[114] DNV Kema, New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review, July 10, 2009.

The following table summarizes 12 projects air compressor load factors recorded and calculated from metered data.

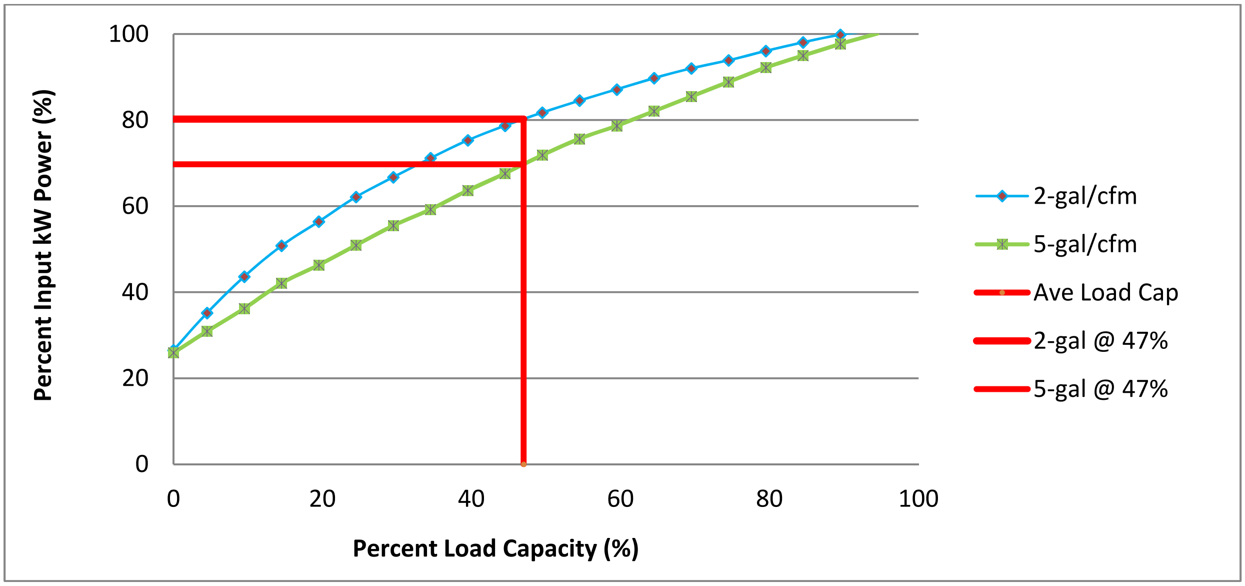
Table 161. Average Compressor Loading Summary

	File #	Controls	% Loading	Weekly Operating Hours	Use Factor
Michigan Program	CE 8420	VSD	16%	168	100%
	CE 7198	VSD	50%	168	100%
	CE 9239	VSD	53%	114	68%
	CE 8148	VSD	48%	168	100%
	CE 7345	VSD	45%	136	81%
	CE 7926	VSD	54%	146	87%
Ohio Program	KEMA - 1936	VSD	65%	30	18%
	KEMA - 2865	VSD	41%	113	67%
	KEMA - 3158	VSD	68%	167	99%
	KEMA - 0511	VSD	28%	114	68%
	KEMA - 1506	VSD	44%	144	86%
	KEMA - 2388	VSD	55%	168	100%
TOTALS			**47%**		**81%**

Assuming that the facilities' ability to generate compressed air equals the facilities' ability to properly dry the generated compressed air, the dryers' load factor would equal the air compressors' load factor of forty-seven percent (47%). Based on the compressed air system being continuously operated (8,760-hrs/yr), the usage factor (UF) is shown as eighty-one percent (81%). On average, the compressed air systems in these industrial projects operate approximately 7,100-hours per year. We believe that this compressed air measure will be installed in similar industrial facilities operating in similar circumstances. For this analysis, we have determined that a typical industrial facility using compressed air operates three (3) shifts per week or approximately 6,240-hrs/yr (24 hours per day, 5 days a week).

Some load/unload capacity control air compressors are claiming to be the most energy efficient, which is only true if the compressed air system has adequate compressed air receiver volume.[115] The following chart depicts the effect of receiver capacity on the compressed air systems energy consumption:

Figure 1. Effect of Receiver Capacity on Air Compressor Control[116]



Please note that the data on the preceding figure was originally developed for 1-gal/cfm, 3-gal/cfm, 5-gal/cfm, and 10-gal/cfm. The 2-gal/cfm curve was calculated through a linear relationship between the 1-gal/cfm and 3-gal/cfm curves on the original data set.

As depicted in the chart, assuming a forty-seven percent (47%) compressor load factor, the power draw of a 5-gal/cfm system draws approximately ten percent (10%) less power than a compressed air system with only 2-gal/cfm storage capacity.

$\eta_{Savings}$ = total percent of energy savings by increase the capacity of the receiver tank, %

$\eta_{2\text{-}gal/cfm}$ = percent input kW electrical power consumption of a 2-gal/cfm receiver system, %

$\eta_{5\text{-}gal/cfm}$ = percent input kW electrical power consumption of a 5-gal/cfm receiver system, %

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[115] US DOE Energy Efficiency and Renewable Energy – Improving Compressed Air System Performance, a sourcebook for industry; Lawrence Berkeley National Lab, p 42-43.

[116] ibid.

$$\boldsymbol{\eta_{Savings}} = \eta_{5.gal/cfm} - \eta_{2.gal/cfm} = \mathbf{80\%} - \mathbf{70\%} = \mathbf{10\%}$$

The actual system efficiency will vary significantly depending on the air compressor type and application. Referencing a recent internal review of CAGI data sheets for rotary screw air compressor systems, compressor efficiencies of 0.19-kW/scfm to 0.23-kW/scfm were typically witnessed, with efficiencies approaching 0.29-kW/scfm for poorly performing, under-loaded systems. The results of this review is in line with other sources which show typical specific power at 100-psig at approximately 18-kW/100 scfm to 22-kW/100 scfm[117] and a common "rule of thumb" of 4 cfm per kW or 0.25-kW/scfm[118]. It is expected that industrial compressed air systems being retrofitted with this measure will not be the most efficient systems. The engineering calculations for this analysis assume a system efficiency of 0.20-kW/scfm.

Measure Life and Incremental Measure Cost

Measure life is assumed to be 10 years.[119] The incremental measure cost (IMC) is estimated to be $4.58 per gallon incremental receiver capacity over existing capacity (i.e. IMC($) = $4.58 x (Efficient tank size – existing tank size)). [120,121]

117 http://www.plantservices.com/articles/2008/013.html?page=2
118 http://www.airbestpractices.com/industries/plastics/bottler-best-practices-california
119 Efficiency Vermont (EVT) Technical Resource Manual (TRM)
120 See supplemental spreadsheet AEPAirReceiver.xlsx for regression cost curve. In line with the EVT TRM IMC of $5 per gallon incremental receiver capacity over existing capacity.
121 Regression analysis of tank prices sold by air receiver vendor: http://www.pneumaticdepot.com/

Cycling Compressed Air Dryer

Measure Description	This measure replaces a non-cycling refrigerated air dryer with a cycling refrigerated air dryer of equivalent capacity. Prescriptive incentives are limited to dryers whose capacities are equal to or less than 600 scfm; dryers with larger capacities are handled on a custom basis. The cycling dryer must run exclusively in cycling mode – the dryer cannot be equipped with a feature that allows it to run in a non-cycling mode and have dewpoint control.
Units	Per sCFM
Base Case Description	Compressed air system with a non-cycling refrigerated air dryer with a capacity of 600 scfm or less

Potential power savings over non-cycling refrigerated dryers arise when the compressor inlet air's heat and moisture content vary below the full load rating of the dryer. This can happen frequently under multiple conditions: 1) Seasonal changes where compressor inlet air has lower humidity (i.e. cold winters), or average air inlet temperatures are lower than the full load rating of the dryer, 2) less than full load flow through the dryer, 3) or air pressure at the inlet of the dryer is higher than the full load rating. These conditions affect the drying (cooling load) required by the discharge air of the compressor to reach an adequate temperature and relative humidity for the compressed air system. A cycling dryer allows the unit's compressor to cycle on and off relative to the 'drying demand' of the compressed air.

It is expected that the applicant must provide the following operating conditions of the compressed air system upon request in order to qualify for prescriptive incentives:

1. Daily, weekly, and annual operating schedule of the compressed air system
2. HP rating of the air compressor system that the existing and proposed dryers would be servicing
3. Rated flow rate (scfm) of existing and proposed dryers (Flow rates should be equivalent)
4. Rated and maximum operating flow rate of the compressor
5. Detailed load demand profile, or estimation of percentage of time the compressor will operate at full and 10% increments of partial load/flow

Measure Savings
The annual kWh and non-coincident kW savings per air dryer depends on the retrofit type.

Table 162. Measures Savings for Cycling Compressed Air Dryer (per scfm)

Dryer Type	kWh	kW
Thermal-Mass	10.48	0.00145
VSD	34.07	0.00472
Digital Scroll	32.32	0.00448
Average	25.62	0.00355

Measure Savings Analysis

Several sources were reviewed in order to gain a consensus of savings methodologies currently being used for cycling dryers. Although the best source would be large samples of cycling dryer projects that leverage power trend metering in order to develop an empirically derived savings unit (i.e. kW per full flow rated cfm of the dryer; kW/cfm), the sources reviewed did offer a consistent method for determining savings relative to the prescriptive criteria for this measure. The table below presents the sources reviewed, and the savings unit values used for the prescriptive cycling dryer measure.

Table 163. Cycling Dryer kW/cfm Savings by Source

Source	Savings Value (kW/cfm)		Notes
Massachusetts TRM	Dryer Capacity (cfm)	kW Reduction per cfm	Includes cycling dryers or dryers equipped with a VSD controller.
	< 100	0.00474	
	≥ 100 and < 200	0.00359	
	≥ 200 and < 300	0.00316	
	≥ 300 and < 400	0.00290	
	≥ 400	0.00272	
Efficiency Vermont TRM	0.00305[122]		Base/measure case dryer capacities are less than or equal to 600 cfm. Compressor load profiles were developed from motors ≤ 40 hp

[122] EVT TRM uses 1) a compressor cfm to baseline (non-cycling) dryer kW conversion factor of 0.0087 (kW/cfm), 2) an average compressor operating capacity of 65% to calculate, and 3) a derating factor of 0.925 to account for the chilled coil response time for cycling dryers, to develop a 'kW/cfm' savings unit. The derating factor was not included because this measure is a thermal mass dryer and is assumed to have a negligible coil response time (0.0087 x (1-65%) = 0.00305)

Source	Savings Value (kW/cfm)	Notes
AEP Ohio Compressed Air Project #1	0.00068	125 hp compressor; 800 rated cfm dryer (base/measure cfm are equivalent)
AEP Ohio Compressed Air Project #2	0.00805	40 hp compressor; 200 rated cfm dryer (base/measure cfm are equivalent)
Ingersoll Rand Nirvana Dryer specifications & TEP TRM	0.00211	Uses compressor operating hours distribution referenced from a Tucson Electric Power (TEP) TRM[123] spreadsheet to calculate an average compressor capacity(%). See AEPCyclicDryer.xlsx for derivation of savings value.
Average	0.00344	Average of above values

Savings assume that a non-cyclic refrigerated dryer is replaced with an equivalently sized cyclic thermal mass refrigerated dryer and the dryers are properly sized for the compressor they are serving. For the purposes of this prescriptive measure, the savings values were referenced but the following was the methodology used.

Referencing the Compressed Air Challenge Best Practices Cycling Refrigerate Air Dryers article dated November, 2011, fully loaded refrigerated air dryer specific power levels range between 0.6-kW and 0.8-kW per 100-scfm[124]. For this analysis, we shall use a specific power of 0.7-kW per 100-scfm or 0.007-kW per scfm.

The full load percentage energy consumption of ing dryers is based on the inlet volume flow rate percentage[125]. A typical Inlet Volume Flow Rate Percentage is fifty percent (50%). At this level, per the following 4 graphs, the full load percentage energy consumption is summarize in the following table.

[123] Tucson Electric Power Technical Resource Manual (TRM) No. 2008-1. VariableScrewComp_MAS_CI_TEP_2011_01_14.xlsx

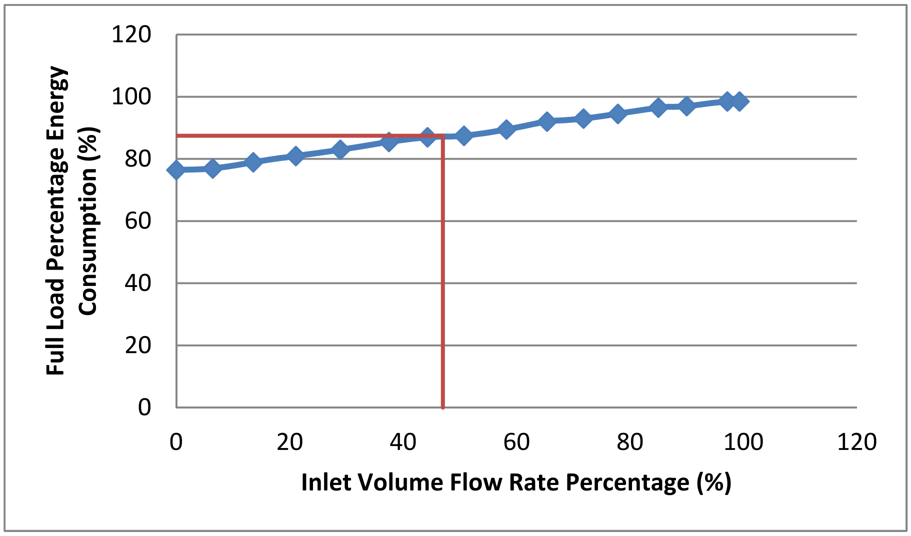
[124] Compressed Air Challenge: Compressed Air Best Practice, written by Timothy J. Fox and Ron Marshall – Cycling Refrigerated Air Dryers – Are Savings Significant?

[125] Compressed Air Challenge: Compressed Air Best Practice, written by Timothy J. Fox and Ron Marshall – Cycling Refrigerated Air Dryers – Are Savings Significant?

Table 164. Full Load Percentage Energy Consumption per Air Dryer Type

Dryer Type	%
Non-cycling	88%
Thermal-Mass	76%
VSD	49%
Digital Scroll	51%

Figure 2. NON-CYCLING COMPRESSED AIR DRYER[126]



[126] Compressed Air Challenge: Compressed Air Best Practice, written by Timothy J. Fox and Ron Marshall – Cycling Refrigerated Air Dryers – Are Savings Significant?

Figure 3. THERMAL-MASS CYCLING COMPRESSED AIR DRYER[127]

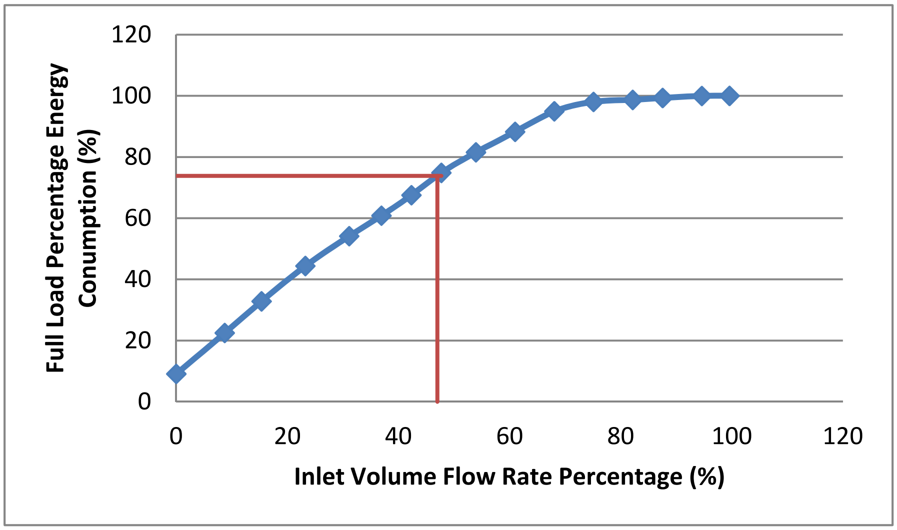
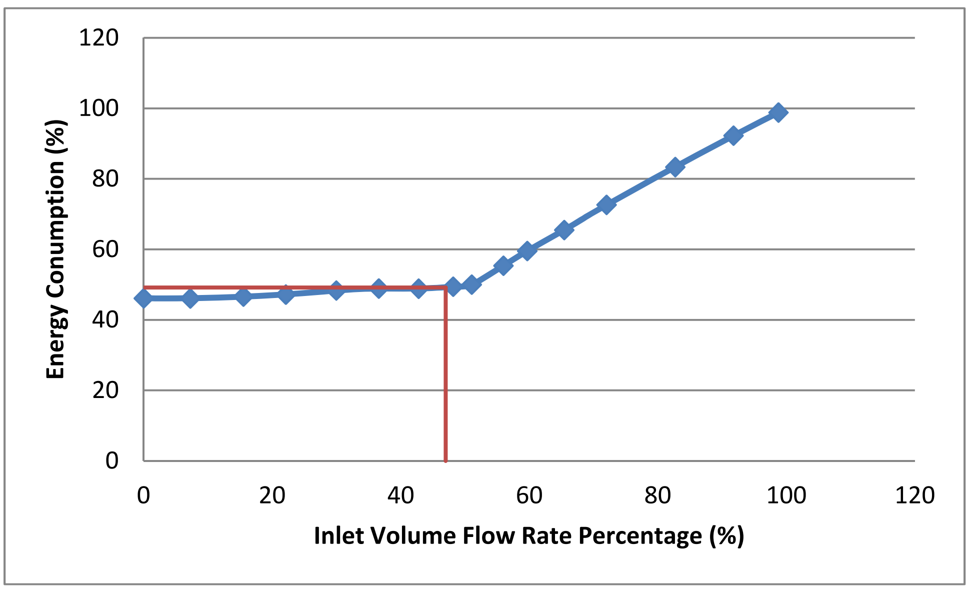


Figure 4. VSD CYCLING COMPRESSED AIR DRYER[128]



[127] Compressed Air Challenge: Compressed Air Best Practice, written by Timothy J. Fox and Ron Marshall – Cycling Refrigerated Air Dryers – Are Savings Significant?
[128] Compressed Air Challenge: Compressed Air Best Practice, written by Timothy J. Fox and Ron Marshall – Cycling Refrigerated Air Dryers – Are Savings Significant?

Annual energy (kWh) and non-coincident average demand (kW) saved are calculated using the simple equations below:

$$kWh_{saved} = \left(\frac{kW}{cfm} dryer\right) \times (cfm_{dryer}) \times \left(PL\%_{non-cycling} - PL\%_{new\ dryer}\right) \times (Hours)$$

$$kW_{saved} = \left(\frac{kW}{cfm} dryer\right) \times (cfm_{dryer}) \times \left(PL\%_{non-cycling} - PL\%_{new\ dryer}\right) \times CF_{comp\ air}$$

Definition of Variables

$Hours$ = *Projected operating hours of the dryer*

$\frac{kW}{cfm} dryer$ = *Power (kW) per rated dryer capacity (cfm) reduced by measure*

cfm_{dryer} = *Full flow rated capacity of the refrigerated air dryer in cubic feet per minute (cfm)*

$PL\%_{non-cycling}$ =*Typical non-cycling compressed air dryer's part-load percent of energy consumption at 50% inlet volume flow rate operation*

$PL\%_{new\ dryer}$ = *New cycling compressed air dryer's part-load percent of energy consumption at 50% inlet volume flow rate operation*

$CF_{comp\ air}$ = *compressed air coincidence factor, 86.5 %*

Table 165. Variables for Cycling Dryer Savings

Component	Type	Value	Source
$\frac{kW}{cfm} Savings$	Fixed	0.007	See above
cfm_{dryer}	Variable	cfm ranges through 600 cfm Default: 300 cfm	Application, DNV KEMA
PL %			See Table 164. Full Load Percentage Energy Consumption per Air Dryer

Component	Type	Value	Source
			Type
Hours	Variable	Hours range through 8,760 hours. Default: 6,240 hours[129]	Application, DNV KEMA
CF $_{comp\ air}$	Fixed	0.865	New Jersey's Clean Energy Program[130]

Measure Life and Incremental Measure Cost
Measure life is assumed to be 15 years.[131] The incremental measure cost (IMC) is estimated to be $2.47 per scfm.[132]

No Loss Condensate Drain for Compressed Air Systems

Measure Description	A no loss condensate drain is controlled by a sensor that monitors the level of condensate in the trap, and opens only for enough time for the condensate to be purged without the unintentional purging and wasting of compressed air. This measure describes the savings associated with the installation of a no loss condensate drain in both new and retrofit compressed air system projects. The condensate drain being replaced (or being proposed in new construction projects) must be a timed drain or manually opened drain. Manual drains, timed drains, and electronic solenoid valve drains are not considered no loss drains, and are not eligible. This prescriptive measure is eligible for compressed air systems whose rated horse-power (HP) is less than or equal to 300 HP. The compressed air system HP shall not include redundant, backup, or out-of-service compressors.
Units	Per drain
Base Case Description	Timed or manually opened condensate drain

[129] 16 hours per day, 5 days per week, minus 9 holidays and 3 scheduled down time days
[130] DNV Kema, New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review, July 10 2009.

[131] After reviewing Efficiency Vermont (EVT) Technical Resource Manual (TRM), February 2010; and Massachusetts TRM, 2011 Program Year, October 2010
[132] EVT TRM 2010

It is expected that the applicant must provide the following operating conditions upon request in order to qualify for prescriptive incentives:

1. Daily, weekly, and annual operating schedule of the compressed air system
2. Existing flow control method (Load/No Load (LNL), variable-speed, variable displacement (VD), etc.)
3. Compressed air system operating pressure
4. Type of drain being replaced (e.g. timed drain, manual drain, solenoid valve drain, etc.)
5. Purging orifice size of drain being replaced and new drain.
6. If a timed drain is being replaced, the time interval between openings and the amount of time that the drain remains open. If a manual drain or other type of drain, an estimate of time that the drain is opened and frequency of opening intervals.

Measure Savings
The annual kWh and peak demand kW savings per drain is 931 kWh per year and 0.2033 peak kW.

Measure Savings Analysis
Energy savings is realized from this measure by estimating the amount of compressed air saved from unintentional purging through a conventional timed drain. Unintentionally purged air must eventually be remade for the system to maintain its operating pressure so the compressor works longer to reclaim that lost air. Below is a frequently referenced table that estimates air loss based on system operating pressure and drain orifice diameter.

Table 166. Air Loss Rates (cfm) by Operating Pressure and Orifice Diameter[133]

Pressure (psig)	Orifice Diameter (inches)					
	1/64	1/32	1/16	1/8	1/4	3/8
70	0.29	1.16	4.66	18.62	74.4	167.8
80	0.32	1.26	5.24	20.76	83.1	187.2
90	0.36	1.46	5.72	23.1	92	206.6
100	0.4	1.55	6.31	25.22	100.9	227
125	0.48	1.94	7.66	30.65	122.2	275.5

The table will provide the assumed air loss rate through the timed drain for the portion of time when the drain is open and purging compressed air instead of condensate. The following

[133] For well rounded orifices, values should be multiplied by 0.97 and by 0.61 for sharp ones. Source: Compressed Air Challenge (CAC), "Compressed Air Tip Sheet #3", August, 2004

equations are used to estimate the energy (kWh) and demand (kW) savings from replacing a timed drain with a no loss drain. The timed drain is assumed to open according to a preset schedule regardless of condensate level, while the no loss drain operates only when there is a need to drain condensate and closes before compressed air can be purged. For this analysis, we have determined that a typical industrial facility using compressed air operates three (3) shifts per week or approximately 6,240-hrs/yr.

The annual hours the timed drain operates (t) is based on one (1) cycle every ten (10) minutes, each cycle lasts 10 seconds, throughout the year[134].

$$t = \frac{6\ cycles}{hr} \times \frac{10\ sec}{cycle} \times \frac{1\ min}{60\ sec} \times \frac{1\ hr}{60\ min} \times \frac{6{,}240\ hrs}{yr} = \mathbf{104\ hrs/yr}$$

The actual system efficiency will vary significantly depending on the air compressor type and application. Referencing a recent internal review of CAGI data sheets for rotary screw air compressor systems, compressor efficiencies of 0.19-kW/scfm to 0.23-kW/scfm were typically witnessed, with efficiencies approaching 0.29-kW/scfm for poorly performing, under-loaded systems. The results of this review is in line with other sources which show typical specific power at 100-psig at approximately 18-kW/100 scfm to 22-kW/100 scfm[135] and a common "rule of thumb" of 4 cfm per kW or 0.25-kW/scfm[136].

It is expected that industrial compressed air systems being retrofitted with this measure will not be the most efficient systems. The engineering calculations for this analysis assume a system efficiency of 0.20-kW/scfm.
The Efficiency Vermont Technical Resource Manual[137] (EVT TRM 2010) has been heavily referenced due to the comprehensive approach that its no loss condensate drain methodology follows.

[134] Efficiency Vermont Technical Reference User Manual – Measure Savings Algorithms and Cost Assumptions. February 19, 2010

[135] http://www.plantservices.com/articles/2008/013.html?page=2
[136] http://www.airbestpractices.com/industries/plastics/bottler-best-practices-california
[137] Efficiency Vermont Technical Resource Manual – Measure Savings Algorithms and Cost Assumptions. February 19, 2010

$$kWh_{saved} = ALR \times ODT \times \frac{kW}{cfm}_{compressor}$$

$$kW_{saved} = \frac{kWh_{saved}}{Hours} \times CF_{air\ compress}$$

Definition of Variables

kWh_{saved} = *Annual energy (kWh) saved per no loss drain*

kW_{saved} = *Power demand (kW) saved per no loss drain*

ALR = *Air loss rate (cfm) of base case drain when valve/orifice is open*

ODT = *Open drain time (hours) – the cumulative amount of time that the base case (timed) drain is open during the annual operating schedule*

$\frac{kW}{cfm}_{compressor}$ = *Compressor average power demand per cfm compressed air produced.*

$CF_{comp\ air}$ = *Compressed air coincidence factor, 86.5 %*

Table 167. Variables for No Loss Condensate Drain Savings

Component	Type	Value	Source
ALR	Multiple	Orifice size and operating pressure required on application. ALR default = 92 cfm. (See Table 166)	Compressed Air Challenge (CAC), "Compressed Air Tip Sheet #3", August, 2004
ODT	Variable	Open time interval required on application, if timed drain retrofit. Default = 104 hours	DNV KEMA
$\frac{kW}{cfm}_{compressor}$	Multiple	Default = 0.2 kW/cfm	Compressed Air Challenge (CAC), "Compressed Air Tip Sheet #3", August, 2004
$CF_{comp\ air}$	Fixed	0.865	New Jersey's Clean Energy Program[138]

Measure Life and Incremental Measure Cost

[138] DNV Kema, New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review, July 10 2009.

Measure life is assumed to be 5 years.[139] The incremental measure cost (IMC) is estimated to be $200 per drain[140].

Low Pressure Drop Filter for Compressed Air Systems

Measure Description	Filters must be installed on compressor systems whose rated horse-power (HP) is greater than 25-HP, but less than or equal to 300-HP and have a rated capacity ≤ 500 SCFM. Filter must be of the deep-bed "mist eliminator" style, have a pressure loss at rated flow ≤ 1 psi when new and ≤ 3 psi at element change, have particulate filtration that is 100% at ≥ 3.0 microns and at least 99.98% at 0.1 to 3.0 microns, be rated for ≤ 5 PPM liquid carryover, and have a filter element life greater than or equal to five (5) years.
Units	Per scfm
Base Case Description	Standard performance air filter

The replacement of standard filters with high performance, low pressure drop filters can prevent the over filtering of compressed air systems and save energy by reducing the cumulative pressure drops throughout the compressed air system. The energy savings result from allowing a lower pressure set point at the compressors, thereby reducing system pressure and maximizing air flow. Suitable air filters should have high dust separation capacity, low-pressure drops, and robust design to avoid frequent cleaning and replacement.

Measure Savings
The annual kWh and peak kW savings per scfm is 14.98 kWh and 0.00315 kW.

Measure Savings Analysis
Pressure drops in the compressed air distribution system should always be minimized. For every 2-psig reduction at the compressor, 1% reduction in power draw can be achieved, as a result of the compressor not having to work as hard to overcome the pressure drops throughout

[139] EVT TRM 2010
[140] EVT TRM 2010

the system[141]. The table below shows the relationship between the pressure drop across an air filter and the power consumption at the compressor.

Table 168. Effect of pressure drop across the filter on increase in power consumption

Pressure Drop Across Air Filter (mmWC)	Increase in Power Consumption (%)
0	0
200	1.6
400	3.2
600	4.7
800	7

As a general rule, “For every 250 mm WC pressure drop increase across at the suction path due to choked filters etc, the compressor power consumption increases by about 2 percent for the same output”[142]. A rule of thumb is that a pressure drop of 2 psi will reduce the capacity by 1% (USDOE, 2010). The table below presents findings from various sources on average pressure drops across filters before and after filter replacement.

Table 169. Estimated Pressure Drops Across Filter by Source

Pressure Drop Across	Baseline Pressure Drop (psig)	Retrofit Pressure Drop (psig)	Energy Savings	Source	
Filter	6	2	2%	*Best Practices & Preventive Maintenance Strategies for Compressed Air Systems* (US DOE, 2010)	
Dryer + Filter			4 - 6%	*Industrial Motor Systems Market Opportunities Assessment* (US DOE, 1998)	
Filter	4	0.5		National Resources Canada[143]	
Dryer + Filter	10	3	5%	National Resources Canada	
Filter	6-10	1.5		*Compressed Air Energy* Efficiency (A. Bhatia. Continuing Education and Development, Inc.)	

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[141] US DOE Energy Efficiency and Renewable Energy – Improving Compressed Air System Performance, a sourcebook for industry; Lawrence Berkeley National Lab, p 35.
[142] Ministry of Power, Government of India, Bureau of Energy Efficiency. (2005). *National certificate examination for energy managers and energy auditors - chapter 3.3 compressed air system*. New Delhi
[143] Cunha, I. National Resources Canada . *Compressed Air Energy Efficiency Reference Guide*. CEA Technology (2007)

Using these values, the following averages have been derived for use in calculation.

Table 170. Average Pressure Drops Across Single Filter

Baseline Pressure Drop (psi)	Retrofit Pressure Drop (psi)	Approximate Capacity Reduction
5	1	2.00%

The actual system efficiency will vary significantly depending on the air compressor type and application. Referencing a recent internal review of CAGI data sheets for rotary screw air compressor systems, compressor efficiencies of 0.19-kW/scfm to 0.23-kW/scfm were typically witnessed, with efficiencies approaching 0.29-kW/scfm for poorly performing, under-loaded systems. The results of this review is in line with other sources which show typical specific power at 100-psig at approximately 18-kW/100 scfm to 22-kW/100 scfm[144] and a common "rule of thumb" of 4 cfm per kW or 0.25-kW/scfm[145].

144 http://www.plantservices.com/articles/2008/013.html?page=2
145 http://www.airbestpractices.com/industries/plastics/bottler-best-practices-california

The following table summarizes 12 projects air compressor load factors recorded and calculated from metered data.

Table 171. Average Compressor Loading Summary

	File #	Controls	% Loading	Weekly Operating Hours	Use Factor
Michigan Program	CE 8420	VSD	16%	168	100%
	CE 7198	VSD	50%	168	100%
	CE 9239	VSD	53%	114	68%
	CE 8148	VSD	48%	168	100%
	CE 7345	VSD	45%	136	81%
	CE 7926	VSD	54%	146	87%
Ohio Program	KEMA - 1936	VSD	65%	30	18%
	KEMA - 2865	VSD	41%	113	67%
	KEMA - 3158	VSD	68%	167	99%
	KEMA - 0511	VSD	28%	114	68%
	KEMA - 1506	VSD	44%	144	86%
	KEMA - 2388	VSD	55%	168	100%
TOTALS			**47%**		**81%**

Assuming that the facilities' ability to generate compressed air equals the facilities' ability to properly dry the generated compressed air, the dryers' load factor would equal the air compressors' load factor of forty-seven percent (47%). Based on the compressed air system being continuously operated (8,760-hrs/yr), the usage factor (UF) is shown as eighty-one percent (81%). On average, the compressed air systems in these industrial projects operate approximately 7,100-hours per year. We believe that this compressed air measure will be installed in similar industrial facilities operating in similar circumstances. For this analysis, we have determined that a typical industrial facility using compressed air operates three (3) shifts per week or approximately 6,240-hrs/yr (24 hours per day, 5 days a week).

The annual kWh and non-coincident kW savings are calculated per the sum total HP of the existing compressor system at the facility using the following equation:

$$kWh_{saved} = V_{system} \times PRC \times \eta_{air\ comp} \times t$$

$$kW_{saved} = (kWh_{saved}) \times CF_{comp\ air} \div t$$

Where:

V_{system}	=	Total volume flow rate of the system, provided by the Customer, scfm
PRC	=	Percent Reduction in Capacity, 2.0%
$\eta_{air\ comp}$	=	Compressed air generation efficiency, 0.20-kW/scfm[146]
t	=	Typical production annual hours of operation, 6,240-hrs/yr[147]
$CF_{comp\ air}$	=	compressed air coincidence factor, 86.5 %[148]

Measure Life and Incremental Measure Cost
Measure life is assumed to be 5 years. The incremental measure cost (IMC) is estimated to be $75 per filter.

Compressed Air Leak Repair

Measure Description	The repair of leaks in compressed air systems is eligible for an incentive. The air compressors supplying air to the leaks must run more than 7,000 (24-hr operation) or more than 3,000 (non-24 hour operation) hours per year to qualify. The local pressure of the compressed air leak must be above 65 psig. The application must include the decibel readings recorded with an ultrasonic leak detector for all leaks before the repair work. Use an ultrasonic leak detector manufacturer's companion tool to obtain the CFM values of the leaks; convert from decibel readings using appropriate pressure level at which the compressed air is leaking. Single leaks larger than 15 CFM are eligible for a 15 CFM maximum. This measure must be combined with another compressed air measure to meet eligibility requirements.
Units	Per CFM of air leaked

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146 US DOE Energy Efficiency and Renewable Energy – Energy Tips: Compressed Air Tip Sheet #3, August 2004.

147 Focus on Energy Evaluation "Business Programs: Deemed Savings Manual V1.0" March 22, 2010, using a 50/50 weighting of industrial and commercial values.

148 DNV Kema, New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review, July 10, 2009.

Base Case Description	Air compressor system without variable speed drive.

A compressed air audit is an essential component that helps highlight inefficiencies in the compressed air system of facilities. This audit often time includes, metering kW (or Ampere draw), pressure, and flow rate. This information is then analyzed to observe trends and make recommendations to increase system efficiency. In addition to most audits, a leak detection survey is done to identify and tag leaks in the system. It is highly recommended that an audit is conducted as part of the leak survey. The energy wasted resulting from leaks can account for wastage of about 20% - 30%[149] of the compressor(s) output. This workpaper details the requirements of leak repair, and provides energy savings calculations associated with the fixing of air leaks. The savings is calculated per CFM of air being leaked.

In order to receive the incentive, the contractor must complete the following items:

- Determine the average hours of operation
- Major compressed air leak detection survey, including: identification, tagging and quantification of air leaks.
- Capital improvement project for the compressed air system.
- The customer/contractor must submit evidence of the completion of repairs detailing leak location, leak volume, and date of repair on a spreadsheet. Verification of repairs may include: repair tickets, work orders, and invoices for material and labor.

Measure Savings

For non-24 hour operation, the annual kWh and peak kW savings per scfm is 600 kWh per year and 0.173 peak kW. For 24-hr operation, the annual kWh and peak kW savings per scfm is 1,400 kWh per year and 0.173 peak kW.

Measure Savings Analysis

The energy savings associated with leak repair fifty is calculated by the following.

$$kWh_{Savings} = \left(\mathbb{V}_{identified}\right) \times \eta_{air\ comp} \times t$$

149 http://www.plantservices.com/articles/2008/013.html?page=2

Where:

$V_{identified}$ = Amount of air leaks repaired, scfm

$\eta_{air\ comp}$ = compressed air generation efficiency, 0.20-kW/scfm

t = typical production annual hours of operation, 3,000-hrs/yr (non-24 hour operation) and 7,000-hrs/yr (24-hr operation)

$$kWh_{Savings,non-24\ hr\ operation} = \frac{\mathbf{600\ kWh}}{\mathbf{yr}}\mathbf{per\ scfm}$$

$$kWh_{Savings,24\ hr\ operation} = \frac{\mathbf{1,400\ kWh}}{\mathbf{yr}}\mathbf{per\ scfm}$$

The peak coincidental demand reduction can be determined by the following:

$$kW_{Savings} = kWh_{Savings} \times CF_{comp\ air} \div t$$

Where:

$CF_{comp\ air}$ = compressed air coincidence factor, 86.5 %[150]

The actual system efficiency will vary significantly depending on the air compressor type and application. Referencing a recent internal review of CAGI data sheets for rotary screw air compressor systems, compressor efficiencies of 0.19-kW/scfm to 0.23-kW/scfm were typically witnessed, with efficiencies approaching 0.29-kW/scfm for poorly performing, under-loaded systems. The results of this review is in line with other sources which show typical specific power at 100-psig at approximately 18-kW/100 scfm to 22-kW/100 scfm[151] and a common "rule of thumb" of 4 cfm per kW or 0.25-kW/scfm[152].

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150 KEMA, New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review, July 10, 2009.
151 http://www.plantservices.com/articles/2008/013.html?page=2
152 http://www.airbestpractices.com/industries/plastics/bottler-best-practices-california

It is expected that industrial compressed air systems being retrofitted with this measure will not be the most efficient systems. The engineering calculations for this analysis assumes a system efficiency of 0.20-kW/scfm.

Measure Life and Incremental Measure Cost

The cost of fixing air compressor leaks is assumed to be $40 per scfm. The measure life is assumed to be 3 years.

Compressed Air Engineered Nozzle

Measure Description	Engineered nozzles entrain atmospheric air into a stream, increasing pressure and mass flow, by decreasing airflow velocity. Since the mass flow is increased, the cooling and drying effects of the compressed air are improved, allowing for a lower demand on the compressor.
Units	Per nozzle
Base Case Description	Open copper tube or air gun with open end.

Measure Savings

The annual kWh and peak kW savings per nozzle is 2,418 kWh and 0.335 peak kW.

Measure Savings Analysis

The calculations are based on the OH TRM.

$$kWh_{saved} = (FLOW_{base} - FLOW_{eff}) \times kW_{scfm} \times \%USE \times AOH$$

$$kW_{saved} = \frac{kWh_{saved}}{AOH} \times CF$$

Where,

FLOW$_{base}$ =The flow rate of compressed air without nozzle

FLOW$_{eff}$ =The flow rate of compressed air with an engineered nozzle

k kW_{scfm}	= The electrical demand needed to produce one cfm of air at 100 PSI (default 0.25 kW/scfm – See below)
AOH	= this is the assumed hours of operation to be used to calculate incentive hrs/yr (Default = 6,240 hours[153]).
%USE	= *percent of the compressor total operating hours that the nozzle is in use (5% for 3 seconds of use per minte, i.e. 0.05)*
CF	= *Coincident Factor = 0.865*[154]

The actual system efficiency will vary significantly depending on the air compressor type and application. Referencing a recent internal review of CAGI data sheets for rotary screw air compressor systems, compressor efficiencies of 0.19-kW/scfm to 0.23-kW/scfm were typically witnessed, with efficiencies approaching 0.29-kW/scfm for poorly performing, under-loaded systems. The results of this review is in line with other sources which show typical specific power at 100-psig at approximately 18-kW/100 scfm to 22-kW/100 scfm[155] and a common "rule of thumb" of 4 cfm per kW or 0.25-kW/scfm[156].

Table 172. Baseline and Efficient Case Average Flowrates

Nozzle Size	Open Flow (SCFM) $FLOW_{base}$	Engineered Nozzle (SCFM) $FLOW_{eff}$	ΔSCFM
1/8" Nozzle	21	6	15
1/4" Nozzle	58	11	47
Average	39.5	8.5	31

$$kWh_{saved} = (39.5\ scfm - 8.5\ scfm) \times 0.25 \frac{kW}{scfm} \times 0.05 \times\ 6{,}240 = 2{,}418\ \mathrm{kWh}$$

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153 16 hours per day, 5 days per week, minus 9 holidays and 3 scheduled down time days
154 KEMA, New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review, July 10, 2009.
155 http://www.plantservices.com/articles/2008/013.html?page=2
156 http://www.airbestpractices.com/industries/plastics/bottler-best-practices-california

Measure Life and Incremental Measure Cost
Measure life is assumed to be 15 years per Ohio TRM. The incremental cost is assumed to be $80, per KEMA research.

Agriculture

VSD on Dairy Milking Pumps (Agricultural)

Measure Description	Vacuum Pump: • Existing milking pump must operate at constant speed. • Applicants are required to submit the following information: o Nominal HP of pump o Number of milking units controlled by pump/VSD o Estimated hours per day milking pump operates o Estimated days per year that milking pump runs Transfer Pump: • Transfer pump must be used in conjunction with a once-through well water-to-milk pre-cooler • Existing transfer pump must operate at a constant speed. • Applicants are required to submit the following information: o Nominal HP of pump o Estimated days per year that pump runs	
Units	Vacuum Pump VSD: Per Horsepower (HP)	
	Transfer Pump VSD: Per 100 gallons of milk production per day	
Base Case Description	Milk Vacuum Pumping Station without a VSD control, or Milk Transfer Pumping Station with a pre-cooler plate, but without a VSD control	

Two VSD measures with similar applications are covered in this work paper – VSD for milking transfer pumps and VSD for milk vacuum pumps. VSD controls on milk transfer pumps allows the motor to match its speed with the amount (load) of milk in the receiver tank and allows a more uniform flow over the pre-cooler plate, which increases the plate's effectiveness and reduces the amount of energy needed to mechanically cool the milk. Note that a pre-cooler plate is a prerequisite for this measure to be incentivized. VSD controls on milk vacuum pumps modulate the speed of the pump when the milking units are taken on and off the cows' udders. Less vacuum is needed when the units are attached to udders, thus appreciable savings are realized (due to lower motor speeds) during the actual milking process, and also help by reducing possible udder irritation/inflammation due to high pressure suction.

Measure Savings

The coincident kW and the annual kWh savings per pump HP controlled by VSD are documented below. The savings are heavily informed by the measures and assumptions covered in the California PG&E work papers developed by EnSave, Inc[157158].

[157] PG&E Measure Codes WPenNRPR0006 Rev7 (Milk Vacuum Pump VSD. EnSave, Inc. March 10, 2010) and WPenNRPR0004 Rev11 (Milk Transfer Pump VSD. EnSave, Inc. March 5, 2010)

Table 173. Measure Savings for Milking Pump VSDs (per unit)

Measure	Unit Definition	kWh	Peak kW
Milking Vacuum Pump VSD	HP	2,409	0.440
Milking Transfer Pump VSD	100 gallons of milk production per day	142.4	0.013

Measure Savings Analysis

Milk Vacuum Pump:

The following equation is used to estimate the milking vacuum pump VSD savings:

$$Annual\ kWh\ Savings\ per\ HP = \frac{[(HP - (0.25 \times MilkUnits)) \times 0.88 \times MilkHours \times MilkDays]}{HP}$$

$$Peak\ kW\ Savings\ per\ HP = \frac{Annual\ kWh\ Savings\ per\ HP}{MilkHours \times MilkDays} \times CF$$

Where,

$HP = Pump\ power\ in\ horsepower$

$0.25 = HP\ required\ per\ milking\ unit\ that\ VSD\ uses$

$MilkUnits = Numbers\ of\ milking\ units\ with\ VSD$

$0.88 = {}^{kW}/_{HP}\ conversion\ and\ efficiency\ (Assumed\ 85\%)\ constant. \frac{0.746\ {}^{kW}/_{HP}}{0.85} = 0.88$

$MilkHours = Hours\ per\ day\ milking\ pump\ runs$

$MilkDays = Days\ per\ year\ that\ milking\ pump\ runs$

$CF = On\ peak\ coincidence\ factor$

[158] The PG&E VSD Vacuum pump work paper value was derived using an equation for the California 2006-2008 Dairy Energy Efficiency Program and averaged results across all installations

Table 174. Variables for Milking Vacuum Pump VSD Savings[159]

Component	Type	Value	Source
MilkUnits	Variable	Default: 10 units	DNV KEMA
MilkHours	Variable	Default: 15 hours (3x per day, 5 hours each milking, assumed conservative)	DNV KEMA
MilkDays	Variable	Default: 365 days	DNV KEMA
HP	Variable	Default: 5 HP	DNV KEMA
CF	Constant	1.0	DNV KEMA
0.25 HP	Constant	0.25 HP per milking unit that VSD consumes	PG&E Milk Transfer Pump VSD work paper (WPenNRPR0004.11)
0.88 kW/HP	Constant	Conversion from HP to kW (0.746 kW/HP) and assumed 85% motor efficiency	PG&E Milk Transfer Pump VSD work paper (WPenNRPR0004.11)

To form variable estimates based on the Ohio state milking production, an Ohio source[160] was used to approximate average farm size (i.e. milking units) and milking rates per day.

Milk Transfer Pump:

The following equation is used to estimate the milking transfer pump VSD savings:

$$\frac{Annual\ kWh\ Savings}{100\ gallons\ per\ day\ of\ milk\ production\ per\ dairy\ site} = 0.39 \times MilkDays = AnnualkWh$$

$$\frac{Peak\ kW\ Savings}{100\ gallons\ per\ day\ of\ milk\ production\ per\ dairy\ site} = \frac{AnnualkWh}{AnnualOperatingHours} \times CF$$

Where,

$0.39 = Daily\ savings\ in\ kWh\ per\ 100\ gallons\ milk\ production$

[159] Reference to: "Variable Frequency Drives in Dairy Vacuum Milking Systems". Prepared by Southern California Edison (SCE), Design and Engineering Services. March 25, 1998. This source was used to find a proxy for pump size and number of milking units for a farm size typical to Ohio (See footnote below)
[160] www.ohiodairyfarms.com estimates that, in Ohio, there are 272,000 dairy cows that live on more than 3,200 dairy farms. In 2010, Ohio's dairy cows produced more than 600 million gallons of milk. This equates to approximately 85 cows per dairy farm, and about 6 gallons of milk per cow per day.

$365 = Number\ of\ days\ per\ year\ dairy\ farm\ produces\ milk$

$CF = On\ peak\ coincidence\ factor$

$AnnualOperatingHours = Number\ of\ hours\ milking\ transfer\ pump\ is\ in\ operation\ per\ year$

Table 175. Variables for Milking Transfer Pump VSD Savings

Component	Type	Value	Source
0.39	Constant	0.39 kWh/day/100gal	kW Engineering. March 15, 2007. EM&V for the 2004-2005 California Multi-Measure Farm Program
MilkDays	Variable	Default: 365	PG&E Milk Transfer Pump VSD work paper (WPenNRPR0004.11)
CF	Constant	0.5	PG&E Milk Transfer Pump VSD work paper (WPenNRPR0004.11)
AnnualOperatingHours	Variable	Default: 5,475 hours (15 hours per day, 365 days per year)	2006-2008 California Dairy Energy Efficiency Program, as discussed in the PG&E Milk Transfer Pump VSD work paper (WPenNRPR0004.11)

Measure Life and Incremental Measure Cost

The measure life for both measures, the VSD on milk transfer pumps and VSD on milk vacuum pumps, is 15 years, according to DEER 2008.

The next table provides incremental measure cost (IMC) documented for this measure. Incremental cost is cost difference between the VSD-controlled pump and the non-VSD-controlled (constant speed or on/off) pump. Note that the measure units are different for each measure – the vacuum pump VSD unit is per motor HP and the transfer pump VSD unit is per 100 gallons of milk production per day.

Table 176. VSD for Milk Pump Applications Incremental Measure Cost ($/HP)[161]

Measure	IMC ($/unit)
VSD for Milking Vacuum Pump	$468/HP
VSD for Milk Transfer Pump	$32.86/100 gal milk/day

[161] The VSD for milk vacuum pumps was derived in the PG&E work paper as the average per-drive cost from all milk vacuum pump VSD installations during the 2006-2008 California Dairy Energy Efficiency Program ($6,631) divided by the corresponding average of 14.2 HP per drive. The VSD for milk transfer pumps was derived as the average of all VSD transfer pump installations during the 2006-2008 California Dairy Energy Efficiency Program ($2,257) divided by the corresponding average of 68.68 hundreds of gallons of daily milk production.

Low Pressure Nozzles (Agricultural)

Measure Description	Low pressure sprinkler nozzles that replace (by retrofit) high pressure sprinkler nozzles with an operating pressure of greater than 50 psi at the sprinkler head are eligible for an incentive. Permanent or solid set (nozzle placement fixed in the area being irrigated) and portable, hand-move nozzles are allowed for incentive. The pumping plant for the farmland must rely on electric pumping, and must have an overall pumping efficiency of 45% or above.
Units	Per nozzle
Base Case Description	High pressure sprinkler nozzle of respective application (50 psi or higher)

This low pressure sprinkler nozzle is for irrigation field applications only. High pressure nozzles generally break water droplets in to various sizes over its coverage; low pressure nozzles have different orifice shapes to accomplish the same water coverage while operating under a lower pressure, thus requiring less pumping energy and less water.

Measure Savings

The coincident kW and the annual kWh savings per low pressure nozzle are documented below. The savings are based on the measures and assumptions covered in the 2005 DEER which heavily references the California Express Efficiency nozzle measure[162,163].

Table 177. Measure Savings for Low Pressure Sprinkler Nozzles (per nozzle)

Measure	kWh	kW
Portable	31.25	0.029
Solid Set	9.25	0.00375

Measure Savings Analysis

The low pressure nozzle measure documented in the 2005 DEER has savings estimates for central valley and coastal/coastal valley California regions. It is assumed that these regions' energy savings differences are based primarily on net water applied per acre of irrigated land, which is assumed to be highly correlated to average annual temperatures and relative humidity. The measure savings applied for Ohio will be a weighted mix of central valley and coastal/coastal valley California regional DEER savings – 75% central valley and 25%

[162] DEER Measure IDs D03-970 and D03-971
[163] Canessa, Peter. 2002. Review of Low Pressure Sprinkler Nozzles – An Express Efficiency Measure, Fresno, CA.

coastal/coastal valley, based on judgment after review of differences between annual average relative humidity and temperatures of Ohio and California.

Measure Life and Incremental Measure Cost
The measure life for low pressure sprinkler nozzles is 3 years for portable-set nozzles and 5 years for solid-set nozzles, according to DEER 2008.

The next table provides incremental measure cost (IMC) documented for this measure. Incremental cost is cost difference between the energy-efficient equipment and the less efficient option.

Table 178. Low Pressure Sprinkler Nozzle Incremental Measure Cost[164]

Measure	Solid-Set	Portable-Set
Low Pressure Sprinkler Nozzle	$1.74	$1.24

Sprinkler to Drip Irrigation (Agricultural)

Measure Description	To qualify for incentives, the existing irrigation system must consist of high pressure sprinkler nozzles operating at 50 psi or more, and retrofitted with a micro-irrigation system. Incentives are not applicable to new planting of vineyards or orchards unless the previous crop was one of the aforementioned (For means of comparing energy needs). Drip tape systems do not qualify as micro-irrigation systems due to their shorter life time.
Units	Per acre
Base Case Description	High pressure sprinkler nozzle irrigation of respective application (50 psi or higher)

Micro-irrigation systems consist of systems of above and below ground pipelines and hoses that deliver water under pressure, to specialized drip devices located at, or very near, individual plants. The basic intent is to accurately supply small amounts of water on a frequent basis so as to maintain constant, comparatively high, root-zone soil moisture. There are possible energy and water savings by converting from a high pressure sprinkler irrigation system to a micro-irrigation system because the irrigation system's water pressure is reduced, and because these

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systems have a potentially higher irrigation efficiency (lower wind sensitivity and lower evaporation losses) thus reducing the amount of water pumping energy required.

Measure Savings

The coincident kW and the annual kWh savings per acre of crop land irrigated are documented below. The savings are based on the measures[165] and assumptions covered in the 2005 DEER and a PG&E workpaper[166], which heavily reference the California Express Efficiency agriculture measure[167,168,169].

Table 179. Measure kWh Savings for Micro-Irrigation (per acre)

Measure	Field/Vegs kWh		Deciduous Trees kWh		Citrus Trees kWh		Grapes kWh	
Micro-Irrigation	Non well	Well	Non well	Well	Non well	Well	Non well	Well
	385.75	444	590.75	688.25	566.25	660.25	466.5	543.5
Average	543.2							

Table 180. Measure kW Savings for Micro-Irrigation (per acre)

Measure	Field/Vegs kW	Deciduous Trees kW	Citrus Trees kW	Grapes kW
Micro-Irrigation	0.354	0.309	0.169	0.213
Average	0.261			

Measure Savings Analysis

The micro-irrigation measure documented in the 2005 DEER has savings estimates for central valley and coastal/coastal valley California regions. It is assumed that these regions' energy savings differences are based primarily on net water applied and absorbed per acre of irrigated land, which is assumed to be highly correlated to average annual temperatures and relative

[165] DEER Measure IDs D03-972, D03-974, D03-975, D03-978, D03-979
[166] "Sprinkler to Drip Irrigation". Work paper PGECOAGR111 Revision #2.
[167] Canessa, Peter. 2002. Review of Low Pressure Sprinkler Nozzles – An Express Efficiency Measure, Fresno, CA.
[168] Canessa, 1995. Micro-Irrigation for Energy-Use Reduction, San Luis Obispo, CA.
[169] Canessa, Peter. 2002. Review of Sprinkler to Micro Irrigation Conversion – An Express Efficiency Measure, Fresno, CA

humidity. The measure savings applied for Ohio will be a weighted mix of central valley and coastal/coastal valley California regional DEER savings – 75% central valley and 25% coastal/coastal valley, based on judgment after review of differences between annual average relative humidity and temperatures of Ohio and California.

Measure Life and Incremental Measure Cost
The measure life for micro-irrigation is 20 years, according to DEER 2008. The incremental measure cost (IMC) is $1,000 per acre, according to DEER 2005.

Engine Block Heater Timer (Agricultural)

Measure Description	Engine block heater timers save energy by reducing the amount of time that the heaters operate. Typical heater operation involves the heater being plugged in during the night, and staying on until the engine is used in the morning. With a timer-controlled heater, the heater can turn on at a pre-set time during the night, therefore only supplying power to the engine block heater when it's needed. In addition to the timer function, the timers included under this measure require a thermostat function that restricts power from being delivered to the engine block heater if ambient temperature is above a certain threshold, typically 39°F.
Units	Per timer, controlling a single engine block heater
Base Case Description	An engine block heater that is turned on/off manually

Measure Savings
The annual kWh savings per engine block timer is 576 kWh per year per timer. There is no peak demand or non-coincident demand savings because it is assumed that the timer (and heater) is operating only during off-peak hours and there is no reduction in heater load because of the timer.

Measure Savings Analysis
The annual kWh savings are calculated using the following equation:

$$Annual\ kWh\ Savings\ per\ timer = Power\ \times Hours\ x\ Days\ \times (1 - ManualUse)$$

Where,

$$Power = Load\ of\ engine\ block\ heater\ in\ kW$$

$$Hours = Number\ of\ Hours\ per\ night\ that\ engine\ block\ heater\ timer\ offsets\ compared\ to\ manual\ operation$$

$$* \, Includes \; time \; that \; thermostat \; overrides \; timer.$$

$$Days = \; Number \; of \; days \; per \; year \; that \; engine \; block \; heater \; is \; used$$

$$ManualUse = Fraction \;\; of \; time \; that \; engine \; block \; heater \; is \; used \; manually$$

It is assumed that a typical engine block heater without a timer would be turned on during the night before the operator retires for the day, and is turned off when the operator resumes work in the morning. This amount of time can vary significantly depending on the operator; however, it is assumed that a typical time range would be around 10-12 hours. The timer would turn the heater on only long enough to sufficiently heat the engine, which typically can range from 2-4 hours.

Table 181. Variables for Engine Block Timer Savings[170]

Component	Type	Value
Power	Variable	Default: 1 kW. Depending on engine size, heaters typically range from 0.4 kW to 2 kW[171]
Hours	Variable	Default: 8 hours.
Days	Variable	Default: 90 days (Heater used during coldest months only)
ManualUse	Variable	Default: 0.20 (Assumes timer is not used/used incorrectly 20% of the time)

Measure Life and Incremental Measure Cost

The measure life for engine block heater timers is assumed to be 11 years, with reference to DEER 2008 that reports the EUL of "Time Clocks (heating/cooling)". While the actual application for these time clocks may not apply to engine block heater timers, other DEER time clock applications ranged between 8 and 11 years. The relatively low usage of the engine block heater timer gives reasonable conclusion to use the upper bound of 11 years.

The incremental measure cost (IMC) documented for this measure is $40 per timer[172].

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[170] DNV KEMA assumptions

[171] http://www.focusonenergy.com/files/Document_Management_System/Business_Programs/engineblockheaters_factsheet.pdf

[172] Ibid. The fact sheet referenced above states that 120-volt block heaters drawing 1.8 kW or less can accept plug-in timers that cost $20, and for 240-volt, 1.8 kW or more block heaters, timers can range from $40-60. The mid-range was taken to be the average IMC ($40)

Miscellaneous

Network PC Management Software

Measure Description	Network PC management software allows network administrators to control the power settings on all network computers. Most computers come with power settings that include "on", "standby", "sleep" and "off" modes, each of which can be set to activate during periods of inactivity. These modes however may not be set properly. This measure can achieve savings by allowing network administrators to put all network computers on low power settings during appropriate hours. The software installed must automatically control the power settings of networked personal computers at the server level. Software must be capable of managing power consumption for each individual PC and must be capable of reporting energy saving results. A report directly from the network energy management software that verifies the number of PC's that are being controlled by the system must be supplied.
Units	Per Workstation
Base Case Description	Computers without network power management software.

Measure Savings

The savings result due to an increase in the rate of idle to standby mode and the time spent in the "Off". Savings for network PC power management is 115 kWh per year per workstation. Coincident peak demand reduction is 0 kW.

Measure Savings Analysis

Various studies have been conducted on the savings achieved by central computer power management systems. Savings depend on both the baseline conditions as well as the usage type of the computers. The analysis in this paper is based on the savings documentation for the Regional Technical Forum (RTF). The documentation can be found at http://www.nwcouncil.org/energy/rtf/measures/com/NetworkComputerPwrMgmnt_Provisional_FY10v2_0.xls. The RTF documentation includes recent studies conducted by ECOS, Quantec, Lawrence Berkeley National Laboratories using data from U.S. Consumer Electronics Sales and Forecasts 2002 – 2007 and Energy Star[173]. The savings analysis includes weighing laptop and

173 Ecos Analysis of ENERGY STAR v5.0 Desktop Computer Dataset, 2008. Ecos/NRDC ENERGY STAR v4.0 Desktop Energy Use and Savings Estimates, 2004, LBNL-48581, "Surveyor Network Energy Manager, Market Progress Evaluation Report, No 2," Prepared by Quantec for Northwest Energy Efficiency Alliance. Section V. Verification of Surveyor Functionality and Energy Savings. January 19, 2005., "Energy Use and Power Levels in New Monitors and Personal Computers" by Roberson et al, July 2002, and CEA, U.S. Consumer Electronics Sales and Forecasts 2002 - 2007, January 2007, and forecasts from website articles.

desktop distributions by type, assumes some built-in power management of computers and monitors before applying the effects of a centralized power management control.

There is no peak demand saving for this measure, since at peak times it is assumed that the computers are on.

Measure Life and Incremental Measure Cost
Measure life indicates the license life and so goes beyond the useful life of the computer itself (usually 3-5 years). The measure life is assumed to be ten years and cost of $23 per computer[174].

Plug Load Occupancy Sensors

Measure Description	Plug-load sensors in combination with smart strip or other technology must control electricity using equipment in offices or cubicles, including lighting, shared copiers, and/or printers.
Units	Per sensor
Base Case Description	50W of task lighting and a computer monitor with no controls

Measure Savings
The coincident demand savings is 0 kW and annual energy savings is 169 kWh per application.

Measure Savings Analysis
The savings analysis method can be found in the Ohio TRM, draft August 6, 2010. The savings is for devices that are at least 100 connected watts during the 'on' mode.

Measure Life and Incremental Measure Cost
The measure life is assumed to be 8 years and cost of $70 per sensor per the Ohio TRM.

[174] "Surveyor Network Energy Manager, Market Progress Evaluation Report, No 2," Prepared by Quantec for Northwest Energy Efficiency Alliance. Section V. Verification of Surveyor Functionality and Energy Savings. January 19, 2005.

Intelligent Surge Protector

Measure Description	This incentive applies to surge protectors with built-in plug-load detection and control capabilities. The surge protector (power strip) must include at least one uncontrolled socket, which would be a primary device. Turning the primary device (usually a computer) on or off subsequently will turn the associated controlled devices in the power strip on or off (for example, printers, monitors, etc.). The intelligent power strip also may contain sockets for devices that require a constant supply of power. These will not be affected by the "control" device.
Units	Per unit
Base Case Description	No detection or control capabilities.

Measure Savings

The savings are based on the Ohio Draft TRM. They are calculated to be 23.6 kWh per year and 0 kW.

Measure Savings Analysis

The savings analysis can be found in the Ohio Draft TRM, p. 280.

Measure Life and Incremental Measure Cost

The measure life is assumed to be 8 years and the incremental measure cost is $15 per unit, as documented in the Ohio Draft TRM.

ENERGY STAR® Commercial Electric Clothes Washer

Measure Description	Incentives are available for high efficiency commercial clothes washers, which wash more clothes per load than standard clothes washers and use less water and energy. Qualified clothes washers must meet a minimum efficiency of CEE© Tier 2, with a Modified Energy Factor (MEF) ≥ 2.00 and a Water Factor (WF) ≤ 6.00.
Units	Per unit
Base Case Description	Baseline clothes washer that meets federal minimum requirements of MEF ≥ 1.26.

Measure Savings

The savings are based on PG&E's workpaper, PGECOAPP115 R1 Clothes Washers Nonres.doc dated October 23, 2009. The savings are 0.245 kW and 587 kWh/year.

Measure Savings Analysis

The savings analysis is based on the PG&E workpapers.

Measure Life and Incremental Measure Cost

The measure life is assumed to be 11 years and the incremental measure cost is $258 per unit, as documented in the ENERGY STAR Calculator Tool.

Industrial 3-Phase High Frequency Battery Charger

Measure Description	Installation of 3-phase High Frequency Battery Charger
Units	Per unit
Base Case Description	Ferroresonant or Silicon Controlled Rectifier (SCR) Chargers

The measure consists of replacing SCR or ferroresonant chargers with high frequency chargers, or installing a new high frequency charger where no charger existed previously.

Measure Savings

The table below shows the default savings for high-frequency battery chargers. This measure savings will be a calculated for each project. The deemed savings are not used.

Table 182. Measure Savings for High Frequency Battery Chargers

Shift	kWh Savings	Coin-kW Savings
8-hour shift	1405	0.2775
16-hour shift	2588	0.2775
24-hour shift	3502	0.9251

Measure Savings Analysis

The savings for this measure are based on the application assessment report #0808 prepared for PG&E. The savings are reported based on the length of the shift, and the type of baseline technology. The savings from the different baseline technologies were averaged together, weighted according to the estimate of existing charger stock found in CA provided in the assessment report. In order to accommodate both replacement, and new construction, different savings were calculated for the two situations, the difference being that part of the market baseline for new construction included high frequency (market baseline since not mandated by code), and an assumption was made that about 75% of the units installed through the program will be replacement, and the remainder will be new units, where not existed previously.

Table 183. Measure Savings for High Frequency Battery Chargers Based on Baseline Technology – Retrofit Only Case

Baseline Technology	Weight Factor[175]	8-hour shift		16-hour shift		24-hour shift	
		kWh Savings	Coin-kW Savings	kWh Savings	Coin-kW Savings	kWh Savings	Coin-kW Savings
Ferroresonant	63%	1035	0.39	2125	0.39	2911	1.3
SCR	38%	2169	0.12	3627	0.12	4849	0.4
Weighted Average	100%	1460	0.289	2688	0.289	3638	0.963

Table 184. Measure Savings for High Frequency Battery Chargers Based on Baseline Technology – New Construction Case

Baseline Technology	Weight Factor[176]	8-hour shift		16-hour shift		24-hour shift	
		kWh Savings	Coin-kW Savings	kWh Savings	Coin-kW Savings	kWh Savings	Coin-kW Savings
Ferroresonant	53%	1035	0.39	2125	0.39	2911	1.3
SCR	32%	2169	0.12	3627	0.12	4849	0.4
Hybrid	5%	149	0.008	439	0.015	575	0.047
High Frequency	11%	0	0	0	0	0	0
Weighted Average	100%	1238	0.2436	2287	0.2439	3094	0.8130

Table 185. Measure Savings for High Frequency Battery Chargers Based on 25% Assumed New Construction Cases, 75% Replacement Cases

Baseline Technology	8-hour shift		16-hour shift		24-hour shift	
	kWh	Coin-	kWh	Coin-	kWh	Coin-

[175] PG&E Application Assessment Report #0808 page 2, Table 2.
[176] PG&E Application Assessment Report #0808 page 2, Table 2.

	Savings	kW Savings	Savings	kW Savings	Savings	kW Savings
Ferroresonant	1035	0.39	2125	0.39	2911	1.3
SCR	2169	0.12	3627	0.12	4849	0.4
Hybrid	149	0.008243	439	0.014524	575	0.047432
High Frequency	0	0	0	0	0	0
Weighted Average	1405	0.2775	2588	0.2775	3502	0.9251

Measure Life and Incremental Measure Cost
The incremental measure cost for this measure is $872.50, based on information provided in the PG&E technology assessment report #0808. The measure life is 20 years, based on the same report.

Table 186. Incremental Measure Cost for High Frequency Chargers

Technology	Average Total Cost	Incremental Cost to High Frequency	Weight Factor
SCR	$2,100	$710	38%
Ferroresonant	$1,840	$970	63%
High Frequency	$2,810	NA	
Average Incremental Cost		$872.50	

NEMA Premium Low Voltage Dry-Type Distribution Transformers

Measure Description	Single or three phase low voltage dry-type distribution transformers meeting or exceeding the NEMA Premium efficiency requirements at 35% load, provided in the table below, are eligible for incentives. ‘Low voltage dry-type distribution transformer’ means a distribution transformer that – (A) has an input voltage of 600 volts or less; (B) is air-cooled; and (C) does not use oil as a coolant. Non-distribution transformers, such as transformers with multiple voltage taps where the highest is at least 20% more than the lowest; and transformers designed to be used in special purpose applications, such as drive transformers, rectifier transformers, auto-transformers, impedance transformers, regulating transformers, sealed and non-ventilating transformers, machine tool transformers, welding transformers, grounding transformers, and testing transformers, are not eligible for a prescriptive incentive, but as with liquid and medium voltage transformers, may apply for custom incentives. Utility-owned transformers are not eligible.
Units	Per transformer

Base Case Description	Federal Minimum Required Efficiency

Transformers are eligible for an incentive if they have a rated efficiency greater than or equal to the NEMA Premium efficiency at 35% load provided in the below table. Additional incremental incentives are also available for transformers exceeding the NEMA Premium efficiency values.

Table 187. NEMA Premium Efficiencies[177]

Single Phase		Three Phase	
kVA	Efficiency @ 35%	kVA	Efficiency @35%
15	98.39%	15	97.90%
25	98.60%	30	98.25%
37.5	98.74%	45	98.39%
50	98.81%	75	98.60%
75	98.95%	112.5	98.74%
100	99.02%	150	98.81%
167	99.09%	225	98.95%
250	99.16%	300	99.02%
333	99.23%	500	99.09%
		750	99.16%
		1000	99.23%

Measure Savings

The following tables show the energy and demand savings for each transformer size category.

Table 188. Base Energy Savings, Meeting NEMA Premium Efficiency Levels (kWh / Unit)

Single Phase	Three Phase

177 http://www.nema.org/gov/energy/efficiency/premium/upload/NEMA_Premium_Efficiency_Transformer_Product_Specifications.pdf Accessed 2-20-12. NB: There was some confusion about the efficiency requirements for NEMA premium based on some contradictory information on the NEMA transformer program requirements sheet, but a conversation with Scott Choinski of NEMA on 2/16/12 confirmed that the efficiency levels provided on this website, and reproduced here, are accurate, and that NEMA Premium efficiency levels are indeed higher than the efficiencies required by Federal Code.

kVA	kWh Savings	kVA	kWh Savings
15	302.64	15	640.35
25	386.02	30	849.03
37.5	470.89	45	1,024.93
50	551.83	75	1,254.98
75	659.95	112.5	1,482.04
100	764.28	150	2,826.39
167	1,042.58	225	3,272.32
250	1,302.46	300	3,703.41
333	1,480.31	500	4,842.34
		750	5,865.09
		1000	6,519.21

Table 189. Base Demand Savings, Meeting NEMA Premium Efficiency Levels (kW / Unit)

Single Phase		Three Phase	
kVA	kW Savings	kVA	kW Savings
15	0.1142	15	0.1572
25	0.1456	30	0.2085
37.5	0.1974	45	0.2516
50	0.2449	75	0.3081
75	0.3320	112.5	0.3639
100	0.4119	150	0.3929
167	0.6051	225	0.4549
250	0.8189	300	0.5149
333	1.0154	500	0.6732
		750	0.8154
		1000	0.9063

Table 190. Incremental Energy Savings, For Units Exceeding NEMA Premium Efficiency Levels by 0.01% (kWh / Unit)

Single Phase		Three Phase	
kVA	kWh Savings	kVA	kWh Savings
15	4.39	15	7.11
25	6.43	30	11.32
37.5	8.72	45	14.85
50	10.82	75	20.92

75	14.67	112.5	27.45
100	18.20	150	55.42
167	26.73	225	72.72
250	36.18	300	88.18
333	44.86	500	124.16
		750	162.92
		1000	197.55

Table 191. Incremental Demand Savings, For Units Exceeding NEMA Premium Efficiency Levels by 0.01% (kW / Unit)

Single Phase		Three Phase	
kVA	Peak kW Savings	kVA	Peak kW Savings
15	0.00165	15	0.00175
25	0.00243	30	0.00278
37.5	0.00366	45	0.00365
50	0.00480	75	0.00514
75	0.00738	112.5	0.00674
100	0.00981	150	0.00770
167	0.01552	225	0.01011
250	0.02275	300	0.01226
333	0.03077	500	0.01726
		750	0.02265
		1000	0.02747

Measure Savings Analysis

The base annual energy savings and peak demand savings are obtained from the differences in the total losses (core plus coil) between transformers meeting the Federal Minimum efficiency levels, and NEMA Premium efficiency levels, adjusted to 15.9 percent load. The NEMA Premium levels are listed above, and the Federal Minimum efficiency levels are listed below.

Table 192. Federal Minimum Efficiencies[178]

[178] http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=54db424b6e123bf285e86842fd705e4a&rgn=div8&view=text&node=10:3.0.1.4.19.11.64.4&idno=10

Single Phase		Three Phase	
kVA	Efficiency @ 35%	kVA	Efficiency @ 35%
15	97.70%	15	97.00%
25	98.00%	30	97.50%
37.5	98.20%	45	97.70%
50	98.30%	75	98.00%
75	98.50%	112.5	98.20%
100	98.60%	150	98.30%
167	98.70%	225	98.50%
250	98.80%	300	98.60%
333	98.90%	500	98.70%
		750	98.80%
		1000	98.90%

On February 10, 2012, the DOE made public their 'Notice of Proposed Rulemaking' (NOPR) giving industry and vested stakeholders one last opportunity to make comments on the proposed new efficiency levels, which after final comments are taken into consideration, will be made official on October 1, 2012, and which will take effect on January 1, 2016[179]. With the NOPR, the DOE provided extensive documentation on savings and cost values for various types and sizes of transformers so stakeholders could understand how the DOE determines the proposed values. The engineering analysis spreadsheets for low voltage dry-type transformers provide over 9,000 transformer design configurations. For each design point, which is based on coil sizing, material selection, and other variables, a unique transformer efficiency value is given. In these extensive tables compiled by the DOE, core losses, also known as constant, or no-load losses, are presented for each design and efficiency value. Also presented are coil losses, which are dependent on the square of the load factor, and are presented by the DOE at both 35% and 100% load. According to sources in the 2010 Efficiency Vermont TRM, the average load on low voltage dry-type transformers is 15.9%, so an adjustment was made to the coil losses presented by the DOE at 100% load according to the following equation which relates the coil losses at a desired load to the coil losses at full load by the desired load squared:

$$\text{Coil Losses}_{15.9\%} = \text{Coil Losses}_{100\%} \times (15.9\%)^2$$

[179] http://www1.eere.energy.gov/buildings/appliance_standards/commercial/distribution_transformers.html Accessed 2/20/12

In order to keep the engineering analysis for the NOPR simple, the DOE looked at three reference sizes within each design line (DL), and provided a scaling algorithm derived from the physical laws affecting transformers (further information can be found in the DOE documents). The representative units for each design line are shown below:

Single Phase		
kVA	**Design Line**	
15		DL 6
25	Rep Unit	
37.5		
50		
75		
100		
167		
250		
333		

Three Phase		
kVA	**Design Line**	
15		DL 7
30		
45		
75	Rep Unit	
112.5		
150		
225		DL 8
300	Rep Unit	
500		
750		
1000		

The scaling factors can be applied to the total losses according to the following equation:

$$TL_1 = TL_0 \times (kVA_1/kVA_0)^E$$

Where TL_0 are the total losses of the reference size transformer, and TL_1 are the total losses for a unit of a different size where all other design aspects besides size are kept constant. The variable kVA_0 is the size of the reference transformer, and kVA_1 is the size of the transformer being scaled. The exponent E is the scaling factor, and for single phase transformers, has a derived value of 0.75, while for three phase transformers, has a value of 0.67[180].

Based on the many data points from the DOE technical analysis, linear regression equations were derived for the three representative units to show the relationship between transformer efficiency, and total losses. With this relationship set for the reference sizes, total losses for the remaining units are calculated using the scaling rule. Total losses are calculated at 15.9% load to determine annual energy savings impact, and at 85% load to determine the peak demand savings. The 85% load factor is based on documentation in the DOE NOPR[181]. The total losses for NEMA Premium and Federal Minimum transformers at these different loads are shown below.

[180] http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/dt_nopr_tsd_complete.pdf page 507 Accessed 2/20/2012
[181] http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/dt_nopr_tsd_complete.pdf page 202 Accessess 2/20/2012

Table 193. Total Losses for Single Phase Dry-Type Transformers at 15.9% and 85% Load, and at NEMA Premium, and Federal Minimum Transformers

kVA	Total Losses in Watts for Federal Minimum Transformers (@ 15.9% Load)	Total Losses in Watts for NEMA Premium Transformers (@ 15.9% Load)	Total Losses in Watts for Federal Minimum Transformers (@ 85% Load)	Total Losses in Watts for NEMA Premium Transformers (@ 85% Load)
15	99.24	64.70	448.77	334.60
25	126.59	82.52	572.42	426.79
37.5	154.42	100.67	698.27	520.63
50	180.96	117.97	818.29	610.11
75	216.42	141.08	978.63	729.66
100	250.63	163.38	1,133.33	845.01
167	341.89	222.88	1,546.00	1,152.69
250	427.11	278.43	1,931.37	1,440.02
333	485.44	316.45	2,195.11	1,636.66

Table 194. Total Losses for Three Phase Dry-Type Transformers at 15.9% and 85% Load, and at NEMA Premium, and Federal Minimum Transformers

kVA	Total Losses in Watts for Federal Minimum Transformers (@ 15.9% Load)	Total Losses in Watts for NEMA Premium Transformers (@ 15.9% Load)	Total Losses in Watts for Federal Minimum Transformers (@ 85% Load)	Total Losses in Watts for NEMA Premium Transformers (@ 85% Load)
15	221.21	148.11	717.46	560.24
30	293.30	196.38	951.28	742.82
45	354.07	237.07	1,148.35	896.71
75	433.54	290.28	1,406.10	1,097.97
112.5	511.98	342.80	1,660.50	1,296.62
150	845.77	523.13	2,677.45	2,284.50
225	979.21	605.66	3,099.88	2,644.93
300	1,108.21	685.45	3,508.25	2,993.37
500	1,449.03	896.25	4,587.16	3,913.94
750	1,755.08	1,085.54	5,556.01	4,740.60

1000	1,950.82	1,206.61	6,175.66	5,269.31

The equations below describe how the annual energy and peak demand savings are determined. The kWh savings are based on the difference in the total losses in Watts for NEMA Premium (NP) and Federal Minimum (FM) transformers at 15.9% load, operating 8,760 hours per year, and the peak demand savings are based on the difference in total losses in kilowatts at 85% load.

$$\text{kWh Savings} = (TL_{FM\text{-}15.9\%} - TL_{NP\text{-}15.9\%}) \times 8760 / 1000$$

$$\text{Peak Demand Savings} = (TL_{FM\text{-}85\%} - TL_{NP\text{-}85\%}) / 1000$$

Incremental savings (both energy and demand) presented for efficiency improvements above NEMA Premium levels are simply linearly extrapolated from the incremental savings resulting from the Federal Minimum to NEMA premium efficiency gain.

Incremental Savings per 0.01% Efficiency Gain = (Savings from FM to NP) x (NP Efficiency – FM efficiency) / 10,000

Measure Life and Incremental Measure Cost
The measure life is 30 years per the Efficiency Vermont TRM.

Incremental measure costs are provided below, and are derived from the DOE NOPR engineering analysis spreadsheets in the same methodology used to determine savings impacts.

Table 195. Transformer Incremental Measure Costs, per unit

Single Phase			Three Phase		
kVA	**Cost**	**Cost (Per 0.01% Efficiency Improvement over NEMA Premium)**	**kVA**	**Cost**	**Cost (Per 0.01% Efficiency Improvement over NEMA Premium)**
30	$356.49	$5.17	15	$373.74	$4.15
45	$454.72	$7.58	30	$495.54	$6.61
75	$554.69	$10.27	45	$598.21	$8.67
112.5	$650.03	$12.75	75	$732.47	$12.21
150	$777.40	$17.28	112.5	$865.00	$16.02
225	$900.29	$21.44	150	$1,739.30	$34.10
300	$1,228.11	$31.49	225	$2,013.71	$44.75
500	$1,534.23	$42.62	300	$2,278.99	$54.26

750	$1,743.74	$52.84	500	$2,979.87	$76.41
			750	$3,609.24	$100.26
			1000	$4,011.77	$121.57

ENERGY STAR Qualified AC-Output Uninterruptable Power Supplies (UPS)

Measure Description	This measure is for the installation of an ENERGY STAR qualified UPS systems. The installed UPS system must meet or exceed the average loading-adjusted efficiency values required by the ENERGY STAR UPS program, reproduced in the table below. Eligible products include consumer UPS systems intended to protect desktop computers and related peripherals; commercial UPSs intended to protect small business and branch office communication technology equipment such as servers, network switches/routers, and small storage arrays; data center UPSs intended to protect large installations of information and communication technology equipment such as enterprise servers, networking equipment, and large storage arrays. This measure does not include telecommunications DC-output UPSs/rectifiers, products internal to a computer or another end-use, or industrial UPSs specifically designed to protect industrial manufacturing processes. Questions about whether your project may be eligible for this prescriptive measure, or a custom measure, may be directed towards the program staff.
Units	Per UPS
Base Case Description	Less efficient UPS, as defined by 2010 PG&E report on data center baselines.

This measure is for the installation of an ENERGY STAR qualified UPS systems. For single-normal mode UPSs, the installed system must meet or exceed the average loading-adjusted efficiency values required by the ENERGY STAR UPS program, reproduced in the table below. Units greater than 10kW, which are sold with an energy meter which measures kWh may be eligible for a 2% efficiency credit, effectively reducing the efficiency values provided in the table below by 2%.

Table 196. ENERGY STAR UPS Average Loading-Adjusted Minimum Efficiency Requirements for Single-Normal-Mode UPS Systems

	VFD	VI	VFI
$P \leq 1.5$ kW	0.967	0.967	0.0099*ln(P) + 0.815
1.5 kW < $P \leq 10$ kW	0.970	0.967	0.0099*ln(P) + 0.815
P > 10 kW	0.970	0.950	0.0099*ln(P) + 0.805

The average loading adjusted efficiency value for a prospective single-normal-mode UPS is determined by applying the following equation:

$$Eff_{AVG} = t_{25\%} \times Eff_{25\%} + t_{50\%} \times Eff_{50\%} + t_{75\%} \times Eff_{75\%} + t_{100\%} \times Eff_{100\%}$$

Where:

- Eff_{AVG} is the average loading-adjusted efficiency
- $t_{n\%}$ is the proportion of time spent at the particular n% of the reference test load, as specified in the loading assumptions provided in the table below
- $Eff_{n\%}$ is the efficiency at the particular n% of the reference test load, as measured according to the ENERGY STAR test method.

Table 197. Proportion of Time Spent at Specified Proportion of Reference Test Load, $t_{n\%}$

Output Power	Input Dependency	Proportion of Time Spent at Specified Proportion of Reference Test Load, t_n%			
		25%	50%	75%	100%
P ≤ 1.5 kW	VFD	0.2	0.2	0.3	0.3
	VI or VFI	0	0.3	0.4	0.3
1.5 kW < 10 kW	VFD, VI or VFI	0	0.3	0.4	0.3
P > 10 kW	VFD, VI or VFI	0.25	0.5	0.25	0

For multiple-normal-mode UPSs, the average loading-adjusted efficiency, Eff_{AVG}, for each input dependency mode, must be greater than the required average loading-adjusted efficiency provided in the table above. The Eff_{AVG} for multiple-normal-mode UPSs is determined by the following equation:

The $Eff_{AVG} = 0.75 \times Eff_1 + 0.25 \times Eff_2$

Where:

- Eff_{AVG} is the average loading-adjusted efficiency
- Eff_1 is the average loading-adjusted efficiency in the lowest-input dependency mode (i.e. VFI or VI), as calculated in the previous equation
- Eff_2 is the average loading-adjusted efficiency in the highest-input dependency mode (i.e. VFD), as calculated in the previous equation

ENERGY STAR Definitions:

Uninterruptible Power Supply (UPS): Combination of convertors, switches, and energy storage devices (such as batteries) constituting a power system for maintaining continuity of load power in case of input power failure. Input power failure occurs when voltage and frequency are outside rated steady-state and transient tolerance bands or when distortion or interruptions are outside the limits specified for the UPS.

Operational Modes:

Normal Mode: Stable mode of operation that the UPS attains under the following conditions:

i.) AC input supply is within required tolerance and supplies the UPS.

ii.) The energy storage system remains charged or is under recharge.
iii.) The load is within the specified rating of the UPS.
iv.) The bypass is available and within specified tolerances (if applicable).

UPS Input Dependency Characteristics:

i.) Voltage and Frequency Dependent (VFD):Capable of protecting the load from power outage. Also referred to as passive/standby topology.

ii.) Voltage Independent: Also referred to as line interactive, capable of protecting the load as required for VFD, above, and in addition from:
a. Under-voltage applied continuously to the input
b. Over-voltage applied continuously to the input

iii.) Voltage and Frequency Independent (VFI): Independent of voltage and frequency variations and capable of protecting the load against adverse effects from such variations without depleting the stored energy source. Also referred to as double conversion.

Single-normal-mode UPS: A UPS that functions within the parameters of only one set of input dependency characteristics. For example, a UPS that functions only as VFI.
Multiple-normal-mode UPS: A UPS that functions within the parameters of more than one set of input dependency characteristics. For example, a UPS that can function as either VFI or VFD.

Measure Savings

The following tables provide the measure savings for single-normal mode and multiple-normal mode UPS systems.

Table 198. Energy Savings for Single-normal Mode UPS Systems

Output Power Range	Output Power (kW)	Output Power Measure Description (kW)	Energy Savings (kWh)		
			VFD	VI	VFI
P ≤ 1.5 kW	0.5	P ≤ 0.5	41.7	77.7	123.4
	1	0.5 < P ≤ 1	83.4	155.3	316.7
	1.5	1 < P ≤ 1.5	125.1	233.0	535.8
1.5 kW < P ≤ 10 kW	2	1.5 < P ≤ 2	235.8	103.6	49.9
	3	2 < P ≤ 3	353.7	155.3	194.3
	4	3 < P ≤ 4	471.6	207.1	371.3
	5	4 < P ≤ 5	589.5	258.9	572.2
	6	5 < P ≤ 6	707.4	310.7	792.2
	7	6 < P ≤ 7	825.3	362.5	1,027.9
	8	7 < P ≤ 8	943.2	414.2	1,277.1
	9	8 < P ≤ 9	1,061.2	466.0	1,538.0

	10	9 < P ≤ 10	1,179.1	517.8	1,809.4
10 kW < P < 16 kW	11	10 < P ≤ 11	864.6	92.2	1,981.8
	12	11 < P ≤ 12	943.2	100.6	2,229.5
	13	12 < P ≤ 13	1,021.9	109.0	2,482.5
	14	13 < P ≤ 14	1,100.5	117.4	2,740.4
	15	14 < P ≤ 15	1,179.1	125.8	3,002.7
16 kW ≤ P ≤ 80 kW	16	15 < P ≤ 16	1,257.7	1,342.3	89.7
	24	16 < P ≤ 24	1,886.5	2,013.4	756.9
	32	24 < P ≤ 32	2,515.3	2,684.6	1,593.3
	40	32 < P ≤ 40	3,144.2	3,355.7	2,554.9
	48	40 < P ≤ 48	3,773.0	4,026.9	3,615.8
	56	48 < P ≤ 56	4,401.8	4,698.0	4,758.8
	64	56 < P ≤ 64	5,030.7	5,369.2	5,971.9
	72	64 < P ≤ 72	5,659.5	6,040.3	7,246.2
	80	72 < P ≤ 80	6,288.3	6,711.5	8,574.6
P > 80 kW	100	80 < P ≤ 100	7,860.4	8,389.3	12,098.8
	250	100 < P ≤ 250	19,651.0	20,973.3	39,830.7
	500	250 < P ≤ 500	39,302.0	41,946.6	85,879.6
	750	500 < P ≤ 750	58,953.0	62,919.9	125,192.1
	1000	750 < P	78,604.0	83,893.2	155,255.0

Table 199. Peak Demand Savings for Single-normal Mode UPS Systems

Output Power Range	Output Power (kW)	Output Power Measure Description (kW)	Peak Demand Savings (kW)		
			VFD	VI	VFI
P ≤ 1.5 kW	0.5	P ≤ 0.5	0.008	0.013	0.021
	1	0.5 < P ≤ 1	0.016	0.027	0.055
	1.5	1 < P ≤ 1.5	0.024	0.040	0.093
1.5 kW < P ≤ 10 kW	2	1.5 < P ≤ 2	0.041	0.018	0.009
	3	2 < P ≤ 3	0.061	0.027	0.034
	4	3 < P ≤ 4	0.082	0.036	0.064
	5	4 < P ≤ 5	0.102	0.045	0.099
	6	5 < P ≤ 6	0.123	0.054	0.137

	7	6 < P ≤ 7	0.143	0.063	0.178
	8	7 < P ≤ 8	0.164	0.072	0.221
	9	8 < P ≤ 9	0.184	0.081	0.267
	10	9 < P ≤ 10	0.204	0.090	0.314
10 kW < P < 16 kW	11	10 < P ≤ 11	0.225	0.024	0.515
	12	11 < P ≤ 12	0.245	0.026	0.580
	13	12 < P ≤ 13	0.266	0.028	0.646
	14	13 < P ≤ 14	0.286	0.031	0.713
	15	14 < P ≤ 15	0.307	0.033	0.781
16 kW ≤ P ≤ 80 kW	16	15 < P ≤ 16	0.327	0.349	0.023
	24	16 < P ≤ 24	0.491	0.524	0.197
	32	24 < P ≤ 32	0.654	0.698	0.414
	40	32 < P ≤ 40	0.818	0.873	0.664
	48	40 < P ≤ 48	0.981	1.047	0.940
	56	48 < P ≤ 56	1.145	1.222	1.237
	64	56 < P ≤ 64	1.308	1.396	1.553
	72	64 < P ≤ 72	1.472	1.571	1.884
	80	72 < P ≤ 80	1.635	1.745	2.230
P > 80 kW	100	80 < P ≤ 100	2.044	2.181	3.146
	250	100 < P ≤ 250	5.110	5.454	10.357
	500	250 < P ≤ 500	10.220	10.907	22.331
	750	500 < P ≤ 750	15.330	16.361	32.554
	1000	750 < P	20.439	21.815	40.371

Table 200. Energy Savings for Multiple-normal Mode UPS Systems

Output Power Range	Output Power (kW)	Output Power Measure Description (kW)	Energy Savings (kWh)		Peak Demand Savings (kW)	
			$VFD_{25\%}$ / $VI_{75\%}$	$VFD_{25\%}$ / $VFI_{75\%}$	$VFD_{25\%}$ / $VI_{75\%}$	$VFD_{25\%}$ / $VFI_{75\%}$
1.5 kW < P ≤ 10 kW	2	1.5 < P ≤ 2	137	102	0.024	0.018
	3	2 < P ≤ 3	205	239	0.036	0.041
	4	3 < P ≤ 4	273	400	0.047	0.069
	5	4 < P ≤ 5	341	578	0.059	0.100
	6	5 < P ≤ 6	410	769	0.071	0.133
	7	6 < P ≤ 7	478	973	0.083	0.169

	8	7 < P ≤ 8	546	1,185	0.095	0.206
	9	8 < P ≤ 9	615	1,407	0.107	0.244
	10	9 < P ≤ 10	683	1,636	0.118	0.284
10 kW < P < 16 kW	11	10 < P ≤ 11	290	1,667	0.075	0.434
	12	11 < P ≤ 12	316	1,868	0.082	0.486
	13	12 < P ≤ 13	342	2,072	0.089	0.539
	14	13 < P ≤ 14	369	2,279	0.096	0.593
	15	14 < P ≤ 15	395	2,490	0.103	0.648
16 kW ≤ P ≤ 80 kW	16	15 < P ≤ 16	1,321	413	0.343	0.107
	24	16 < P ≤ 24	1,981	1,069	0.515	0.278
	32	24 < P ≤ 32	2,641	1,848	0.687	0.481
	40	32 < P ≤ 40	3,301	2,718	0.858	0.707
	48	40 < P ≤ 48	3,962	3,661	1.030	0.952
	56	48 < P ≤ 56	4,622	4,665	1.202	1.213
	64	56 < P ≤ 64	5,282	5,719	1.374	1.487
	72	64 < P ≤ 72	5,943	6,818	1.545	1.773
	80	72 < P ≤ 80	6,603	7,957	1.717	2.069
P > 80 kW	100	80 < P ≤ 100	8,254	10,952	2.146	2.848
	250	100 < P ≤ 250	20,634	34,408	5.365	8.947
	500	250 < P ≤ 500	41,268	73,465	10.731	19.103
	750	500 < P ≤ 750	61,902	107,650	16.096	27.992
	1000	750 < P	82,536	135,070	21.462	35.122

Measure Savings Analysis
Annual energy savings and the peak coincident demand savings are calculated using the average loading-adjusted efficiency equations outlined in the first section. Baseline and retrofit equipment assumptions are listed in the tables below.

Table 201. Average Loading-Adjusted Baseline Efficiency Assumptions for Single-normal Mode UPSs – With Data from ENERGY STAR UPS Program

Output Power Range	Output Power (kW)	Output Power Measure Description (kW)	Average Loading Adjusted Baseline Efficiency		
			VFD	VI	VFI
P ≤ 1.5 kW	0.5	P ≤ 0.5	95.62%	94.90%	85.32%
	1	0.5 < P ≤ 1	95.62%	94.90%	85.32%

	1.5	1 < P ≤ 1.5	95.62%	94.90%	85.32%
1.5 kW < P ≤ 10 kW	2	1.5 < P ≤ 2	95.62%	96.09%	88.78%
	3	2 < P ≤ 3	95.62%	96.09%	88.78%
	4	3 < P ≤ 4	95.62%	96.09%	88.78%
	5	4 < P ≤ 5	95.62%	96.09%	88.78%
	6	5 < P ≤ 6	95.62%	96.09%	88.78%
	7	6 < P ≤ 7	95.62%	96.09%	88.78%
	8	7 < P ≤ 8	95.62%	96.09%	88.78%
	9	8 < P ≤ 9	95.62%	96.09%	88.78%
	10	9 < P ≤ 10	95.62%	96.09%	88.78%
10 kW < P < 16 kW	11	10 < P ≤ 11	95.62%	94.86%	87.04%
	12	11 < P ≤ 12	95.62%	94.86%	87.04%
	13	12 < P ≤ 13	95.62%	94.86%	87.04%
	14	13 < P ≤ 14	95.62%	94.86%	87.04%
	15	14 < P ≤ 15	95.62%	94.86%	87.04%
16 kW ≤ P ≤ 80 kW	16	15 < P ≤ 16	95.62%	93.58%	90.00%
	24	16 < P ≤ 24	95.62%	93.58%	90.00%
	32	24 < P ≤ 32	95.62%	93.58%	90.00%
	40	32 < P ≤ 40	95.62%	93.58%	90.00%
	48	40 < P ≤ 48	95.62%	93.58%	90.00%
	56	48 < P ≤ 56	95.62%	93.58%	90.00%
	64	56 < P ≤ 64	95.62%	93.58%	90.00%
	72	64 < P ≤ 72	95.62%	93.58%	90.00%
	80	72 < P ≤ 80	95.62%	93.58%	90.00%
P > 80 kW	100	80 < P ≤ 100	95.62%	93.58%	90.00%
	250	100 < P ≤ 250	95.62%	93.58%	90.27%
	500	250 < P ≤ 500	95.62%	93.58%	90.72%
	750	500 < P ≤ 750	95.62%	93.58%	91.18%
	1000	750 < P	95.62%	93.58%	91.63%

Table 202. Average Loading-Adjusted Baseline Efficiency Assumptions for Multiple-normal Mode UPSs– With Data from ENERGY STAR UPS Program

Output Power Range	Output Power (kW)	Output Power Measure Description	Average Loading Adjusted Baseline Efficiency for Multiple-Normal-Mode UPS

		(kW)	$VFD_{25\%}$ / $VI_{75\%}$	$VFD_{25\%}$ / $VFI_{75\%}$
1.5 kW < P ≤ 10 kW	2	1.5 < P ≤ 2	95.97%	90.49%
	3	2 < P ≤ 3	95.97%	90.49%
	4	3 < P ≤ 4	95.97%	90.49%
	5	4 < P ≤ 5	95.97%	90.49%
	6	5 < P ≤ 6	95.97%	90.49%
	7	6 < P ≤ 7	95.97%	90.49%
	8	7 < P ≤ 8	95.97%	90.49%
	9	8 < P ≤ 9	95.97%	90.49%
	10	9 < P ≤ 10	95.97%	90.49%
10 kW < P < 16 kW	11	10 < P ≤ 11	95.05%	89.18%
	12	11 < P ≤ 12	95.05%	89.18%
	13	12 < P ≤ 13	95.05%	89.18%
	14	13 < P ≤ 14	95.05%	89.18%
	15	14 < P ≤ 15	95.05%	89.18%
16 kW ≤ P ≤ 80 kW	16	15 < P ≤ 16	94.09%	91.40%
	24	16 < P ≤ 24	94.09%	91.40%
	32	24 < P ≤ 32	94.09%	91.40%
	40	32 < P ≤ 40	94.09%	91.40%
	48	40 < P ≤ 48	94.09%	91.40%
	56	48 < P ≤ 56	94.09%	91.40%
	64	56 < P ≤ 64	94.09%	91.40%
	72	64 < P ≤ 72	94.09%	91.40%
	80	72 < P ≤ 80	94.09%	91.40%
P > 80 kW	100	80 < P ≤ 100	94.09%	91.40%
	250	100 < P ≤ 250	94.09%	91.61%
	500	250 < P ≤ 500	94.09%	91.95%
	750	500 < P ≤ 750	94.09%	92.29%
	1000	750 < P	94.09%	92.63%

Table 203. Efficient-Case Efficiencies for Multiple-normal Mode UPS Systems

Output Power Range	Output Power (kW)	Output Power Measure Description	Average Loading Adjusted Proposed Case Efficiency for Multiple-Normal-Mode UPS

		(kW)	$VFD_{25\%}$ / $VI_{75\%}$	$VFD_{25\%}$ / $VFI_{75\%}$
1.5 kW < P ≤ 10 kW	2	1.5 < P ≤ 2	96.78%	91.02%
	3	2 < P ≤ 3	96.78%	91.32%
	4	3 < P ≤ 4	96.78%	91.53%
	5	4 < P ≤ 5	96.78%	91.70%
	6	5 < P ≤ 6	96.78%	91.83%
	7	6 < P ≤ 7	96.78%	91.95%
	8	7 < P ≤ 8	96.78%	92.05%
	9	8 < P ≤ 9	96.78%	92.14%
	10	9 < P ≤ 10	96.78%	92.21%
10 kW < P < 16 kW	11	10 < P ≤ 11	95.50%	91.53%
	12	11 < P ≤ 12	95.50%	91.60%
	13	12 < P ≤ 13	95.50%	91.66%
	14	13 < P ≤ 14	95.50%	91.71%
	15	14 < P ≤ 15	95.50%	91.76%
16 kW ≤ P ≤ 80 kW	16	15 < P ≤ 16	95.50%	91.81%
	24	16 < P ≤ 24	95.50%	92.11%
	32	24 < P ≤ 32	95.50%	92.33%
	40	32 < P ≤ 40	95.50%	92.49%
	48	40 < P ≤ 48	95.50%	92.63%
	56	48 < P ≤ 56	95.50%	92.74%
	64	56 < P ≤ 64	95.50%	92.84%
	72	64 < P ≤ 72	95.50%	92.93%
	80	72 < P ≤ 80	95.50%	93.01%
P > 80 kW	100	80 < P ≤ 100	95.50%	93.17%
	250	100 < P ≤ 250	95.50%	93.85%
	500	250 < P ≤ 500	95.50%	94.37%
	750	500 < P ≤ 750	95.50%	94.67%
	1000	750 < P	95.50%	94.88%

The baseline efficiencies for the single-normal-mode UPSs were determined by averaging the market data collected by ENERGY STAR on May 19, 2010. This approach estimates the average efficiency for the different topologies (VFD, VI, VFI) based on their sizes.

The efficient-case efficiencies for single normal-mode UPSs in VFD, VI, and VFI modes were taken directly from the ENERGY STAR criteria. For multiple-mode UPSs, they were taken directly from the ENERGY STAR criteria, but the second equation was applied to determine the adjusted average loading-adjusted efficiency for multiple-normal-mode UPSs.

With the baseline and efficient-case efficiency levels determined, and with the size categories set up, the energy and demand savings are calculated using the following equations:

$$\text{Energy Savings} = \text{Size} \times (1/\text{Eff}_{AVGbase} - 1/\text{Eff}_{AVGeffcase}) \times \text{EFLH} \times \text{EIF}$$

$$\text{Demand Savings} = \text{Size} \times (1/\text{Eff}_{AVGbase} - 1/\text{Eff}_{AVGeffcase}) \times \text{DIF}$$

$$\text{EFLH} = [\, t_{25\%} \times 0.25 + t_{50\%} \times 0.50 + t_{75\%} \times 0.75 + t_{100\%} \times 1.0 \,] \times 8760$$

Where:

- Size is the size of the UPS in output kW
- $\text{Eff}_{AVGbase}$ is the baseline efficiency
- $\text{Eff}_{AVGeffcase}$ is the efficient-case efficiency
- EFLH is the Equivalent Full Load Hours, per equation above
- EIF is the energy interactive factor, assumed to be 1.202 based on the lighting workpapers, miscellaneous building type.
- DIF is the demand interactive factor, conservatively assumed to be 1.369, based on the lighting workpapers, miscellaneous building type.

Measure Life and Incremental Measure Cost

The measure life is 10 years per the APC whitepaper, ‘Battery Technology for Data Centers and Network Rooms: Lifecycle Costs’. According to the ENERGY STAR UPS program, there is not yet enough reliable and consistent data for UPS systems, but as more reliable data is collected from organizations like ENERGY STAR, and industry, this workpaper will be updated.

This foregoing document was electronically filed with the Public Utilities

Commission of Ohio Docketing Information System on

1/24/2013 11:05:34 AM

in

Case No(s). 10-1599-EL-EEC

Summary: Correspondence Updated Prescriptive Protocol Workpapers for the 2013 program year electronically filed by Mr. Yazen Alami on behalf of Ohio Power Company