Lighting

The statewide Express Efficiency lighting program offers incentives to commercial, industrial, and agricultural customers who install lighting equipment that is more efficient than the existing lighting in their facility. Incentives are offered for installing:

- Energy Star rated screw in compact fluorescent lamps with integral ballasts and modular compact fluorescent lamps with electronic ballasts,
- Compact fluorescent fixtures,
- Induction lamps and fixtures,
- Linear fluorescent electronic ballasts,
- T8, T5, or T5/HO linear fluorescent lamps,
- High intensity discharge lamps and ballasts
- Interior high-bay linear fluorescent luminaires,
- Conversion from standard (probe start) high intensity discharge to pulse start lamps and ballasts,
- Ceramic metal halide lamps and ballasts,
- Light emitting diodes in certain sign and signal applications, and
- Lighting controls.

New elements of the 2003 Express Efficiency lighting program are discussed below, followed by a brief market description. Next, a general lighting technology description is given that compares different lighting technology options and explains some of the terms used in the analysis. Common assumptions for the different retrofit measures are discussed next. Specific technology descriptions and engineering calculations are then presented for each measure, with energy and demand savings estimates by market sector.

Changes in the Lighting Express Program for 2003

The 2003 Lighting Express Program is similar to the 2002 program. The following are the major changes from last year's program:

- Program categories have been re-titled and requirements strengthened for greater clarity,
- Screw-in induction lamps have been moved to the compact fluorescent lamp category for simplicity
- Ballast factor has and method of start has been taken into consideration in electronic ballasts
- Pulse start metal halide has replaced standard metal halide
- Ceramic metal halide lamps and fixtures have been added
- Traffic signal LED lamp modules have been deleted due the utilities work in influencing their inclusion in California's Appliance Standard, Title 20, effective March 1, 2003, and
- New strip LED replacement for neon retrofit measures have been added.

Market Description

Lighting accounts for approximately 34% of commercial electricity use (EPRI 1988). In addition, lighting generates internal heat gains which, in commercial buildings, must be removed by air conditioning systems. Since commercial lighting and air conditioning are large energy uses that contribute to peak demand for summer-peaking utilities, lighting programs are an important component of both load management and efficiency programs.

Technology Description

The most common lamp types are incandescent, fluorescent, and high intensity discharge (HID). HID lamps include mercury vapor, metal halide, and high-pressure sodium.

Incandescent sources emit light when a filament is heated by electrical resistance and then radiates. The other common lamp types use gas-discharge to produce light. The incoming voltage and current are modified by a ballast, and then the electricity strikes an arc and causes the gas inside the lamp to glow.

Ballasts for fluorescent lamps are manufactured in three designs: energy saving core/coil, hybrid electronic, and electronic. (In 1987, the National Appliance Energy Conservation Act set ballast efficacy factor standards that precluded manufacture of standard core/coil ballasts as of April 1, 1990.) Electronic ballasts are now available in rapid-start mode, instant-start mode, adjustable output (0-50%-100%), and full-range dimming ballasts.

Lighting efficiency ratings are called efficacies and are given in units of lumens (of visible light) per watt of power input. Table 1 shows the fixture (combined lamp and ballast) efficacies of common light sources (EPRI 1988).

TABLE 1
LIGHTING EFFICACIES

Lamp Type	Efficacies (lumens/watt)
Incandescent	13-24
Tungsten halogen	15-30
Mercury vapor	35-60
Compact fluorescent	20-85
Fluorescent	63-105
Metal halide	63-115
High-pressure sodium	50-127
Low-pressure sodium	80-143

Incandescent lamps have the lowest efficacy of all the common lamp types. Fluorescent lamps are almost four times as efficient as incandescent sources. Some high wattage HID lamps are significantly more efficient than fluorescent light sources.

Different lamps emit different color light. Quality of light is an important factor in lighting design, and one measure is the color rendering index (CRI), which tells how an illuminated object looks under the light. CRI values should only be compared between lamps of similar color temperature. Light sources are ranked below by color rendering index from highest (best) to lowest:

- Incandescent,

- Tungsten halogen,
- Compact fluorescent,
- Metal halide,
- Fluorescent,
- High pressure sodium,
- Mercury vapor, and
- Low pressure sodium.

Fluorescent lamps come in a wide range of color rendering indices. Low-pressure sodium and mercury vapor have poor color rendering indices and should be used only where color rendition is of minor concern.

Net to Gross Ratio

In order to contribute to efforts of statewide uniformity, a Net-to-Gross ratio of 0.96 will be used for lighting measures, in accordance with the CPUC Energy Efficiency Policy Manual Version 1, Prepared by the Energy Division October 2001.

Hours of Operation

Table 2 presents operating hours by business type. Commercial and industrial sector operating hours are based upon M&E studies performed by outside consultants (Quantum 1997b, p. 5; and Xenergy 334b). The Quantum study recommends using an average of 1994 and 1995 hours, while the Xenergy study is based on PY1997 results. Operating hours vary by building type, except in cases where operating hours are the same for all sectors, e.g., exit lighting.

TABLE 2
ANNUAL OPERATING HOURS

Market Sector	Annual Operating Hours
Office	4,000
Retail	4,450
College	3,900
School	2,150
Grocery	5,800
Restaurant	4,600
Health Care/Hospital	4,400
Hotel/Motel	5,500
Warehouse	3,550
Process Industrial	6,650
Assembly Industrial	4,400
All Other	4,500

Outdoor lights are assumed to have the same annual hours of operation for all market sectors. Unless otherwise specified in the individual technical assessments, exterior lights are assumed to be controlled by a time clock and a photocell and to operate for

4,100 hours per year. This value is arrived at by assuming that the lights burn twelve hours per day each day, except during the summer when the photocell turns the lights off for another three hours per day.

For each technology type, the individual assessments list the predominant sector(s) since some technologies are used more in certain sectors than others.

Demand Reduction Calculations

Two types of capacity savings estimates were done for this analysis: connected load reduction achieved by the measure (noncoincident) and demand reduction coincident with system peak.

The noncoincident lighting demand savings achieved by the measure are estimated from engineering analyses using the following formula:

Noncoincident kW savings = kW of existing equipment - kW of replacement equipment

The commercial and industrial sector M&E studies (Quantum 1997b, p. 7; and Xenergy 334b) quantified additional demand savings in avoided air conditioning load because of reduced internal gains from energy efficient lighting by building type. Table 3 presents the resulting interactive effect terms that are used to calculate the demand impacts attributable to indoor lighting retrofits. Demand savings calculations include both the wattage drop between the old lamp and the new lamp, as well as the reduction in cooling loads as result of reduced waste heat generation.

Note: Interactive effects are not included in savings calculations for exterior lighting or lighting controls.

TABLE 3

DEMAND INTERACTIVE EFFECTS BY BUILDING TYPE

Market Sector	Demand Interactive Effects
Office	1.25
Retail	1.19
College	1.22
School	1.23
Grocery	1.25
Restaurant	1.26
Health Care/Hospital	1.26
Hotel/Motel	1.14
Warehouse	1.09
Process Industrial	1.02
Assembly Industrial	1.08
All Other	1.13

Noncoincident kW savings with Interactive Effects = (kW of existing equipment - kW of replacement equipment) * (Demand Interactive Effects)

The kW use of various lighting technologies are taken from catalogs of major lighting manufacturers (General Electric, Sylvania, and Philips).

To determine coincident demand savings, which are used in the economic analysis, engineering estimates of savings are multiplied by a coincident diversity factor, which was determined from the M&E studies (Quantum 1997b, p. 6; and Xenergy 334b). Table 4 presents the resulting coincident diversity factors that are used to calculate the demand impacts attributable to indoor lighting retrofits. In the case of lighting the formula for coincident kW savings is:

Coincident kW Savings = Coincident Diversity Factor * Noncoincident savings with Demand Interactive Effects

TABLE 4
COINCIDENT DIVERSITY FACTORS

Market Sector	Coincident Diversity Factors
Office	0.81
Retail	0.88
College	0.68
School	0.42
Grocery	0.81
Restaurant	0.68
Health Care/Hospital	0.74
Hotel/Motel	0.67
Warehouse	0.84
Process Industrial	0.99
Assembly Industrial	0.92
All Other	0.76

Energy Savings Calculations

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

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

The M&E studies (Quantum 1997b, p. 7; and Xenergy 334b) quantified additional energy savings in avoided air conditioning load because of reduced internal gains from energy efficient lighting by building type. Table 5 presents the resulting interactive effect terms that are used to calculate the energy impacts attributable to indoor lighting retrofits. The penalty for additional heating required in gas buildings was not included as it was small in comparison to the interactive cooling effects. The interactive effects do not apply to exterior lighting.

*kWh Savings with Interactive Effects = (kW of existing equipment - kW of replacement equipment) * (Annual operating hours)*(Energy Interactive Effects)*

TABLE 5

ENERGY INTERACTIVE EFFECTS BY BUILDING TYPE

Market Sector	Energy Interactive Effects
Office	1.17
Retail	1.11
College	1.15
School	1.15
Grocery	1.13
Restaurant	1.15
Health Care/Hospital	1.18
Hotel/Motel	1.14
Warehouse	1.06
Process Industrial	1.01
Assembly Industrial	1.04
All Other	1.08

Baseline Measures and Persistence

Baseline retrofit equipment assumptions used throughout this section are presented in Table 6. Because the Express Lighting program is targeted to an early replacement of existing technologies, the baseline represents the equipment removed. Additional baseline documentation is presented below under each individual technical assessment for qualifying program measures.

For high wattage compact fluorescent lamp and high intensity discharge fixtures, the baseline is split into two categories (incandescent and mercury vapor) to more accurately calculate savings.

TABLE 6
BASELINE WATTAGES FOR HARDWIRED FLUORESCENT AND HID FIXTURES WITH INCANDESCENT AND MERCURY VAPOR BASELINES

Retrofit Description	Wattage Category (lamp only)	Actual Wattage (lamp & ballast)	Baseline Incandescent Wattage (lamp only)	Baseline Mercury Vapor Wattage (lamp only)	Baseline Mercury Vapor Wattage (lamp & ballast)
Hardwired Compact Fluorescent Fixture	5 to 13*	15	60	NA	NA
	14 to 26	26	100	NA	NA
	27 to 65	70	200	100	125
	66 to 156	140	500	250	285
	≥ 157	210	750	400	454
Interior HID Fixture Metal Halide	0 to 35	45	100	50	74
	36 to 70	90	200	100	125
	71 to 100	129	300	175	200
	101 to 175	210	500	250	285
Exterior HID Fixture Metal Halide	0 to 100	129	300	175	200
	101 to 175	210	500	250	285
	≥ 176	295	750	400	454
High Pressure Sodium	0 to 100	95	300	175	200
	101 to 175	130	500	250	285
	≥ 176	240	750	400	454

*Electronic ballasts are not widely available, and therefore not required, for hardwired compact fluorescent 5-13 watt lamps.

The baseline ballast for all full-size fluorescent fixtures is an energy-saving magnetic ballast. For 2-foot fixtures, the baseline lamp is rated at 20 watts. Lamp base cases for 3-foot, 4-foot, and 8-foot lamps have been updated to reflect the impact of the National Energy Policy Act standards. For 3-foot lamps, we assume a 3:1 ratio between energy saving (25 Watt, 3-foot) and standard (30 Watt, 3-foot) lamps. For 4-foot and 8-foot lamps (standard and high output), we assume that all lamps replaced are energy-saving lamps.

Wattages for fluorescent fixtures of different lengths and with varying numbers of lamps are provided in Table 7 below. The weighted average is the baseline number used in all relevant calculations throughout the document. Note: 32-watt T-8 lamps are generally retrofit measures themselves and are thus not included in the baseline.

TABLE 7
BASELINE WATTAGE OF FLUORESCENT FIXTURES

Lamp Description	Standard Lamp Fixture Wattage	Efficient Lamp Fixture Wattage	Weighted Average Wattage
	with 20 watt lamp		
2-foot, ES ballast, 1-lamp	32	N.A.	32
2-foot, ES ballast, 2-lamp	50	N.A.	50
2-foot, ES ballast, 3-lamp	82	N.A.	82
2-foot, ES ballast, 4-lamp	100	N.A.	100
	with 30 watt lamp	with 25 watt lamp	
3-foot, ES ballast, 1-lamp	48	42	44
3-foot, ES ballast, 2-lamp	74	66	68
3-foot, ES ballast, 3-lamp	122	108	112
3-foot, ES ballast, 4-lamp	148	132	136
	with 34 watt lamp		
4-foot, ES ballast, 1-lamp	43	N.A.	43
4-foot, ES ballast, 2-lamp	72	N.A.	72
4-foot, ES ballast, 3-lamp	115	N.A.	115
4-foot, ES ballast, 4-lamp	144	N.A.	144
	with 60 watt lamp		
8-foot, ES ballast, 1-lamp	79	N.A.	79
8-foot, ES ballast, 2-lamp	126	N.A.	126
8-foot, ES ballast, 3-lamp	205	N.A.	205
8-foot, ES ballast, 4-lamp	252	N.A.	252
	with 95 watt lamp		
8-foot, ES ballast, HO 1-lamp	111	N.A.	111
8-foot, ES ballast, HO 2-lamp	207	N.A.	207
8-foot, ES ballast, HO 3-lamp	318	N.A.	318
8-foot, ES ballast, HO 4-lamp	414	N.A.	414

Measure Lifetimes

Measure lifetimes (in hours) vary by technology. The numbers are based on specifications in the catalogs of major lighting equipment and are given in the individual technical assessments. Fixture lifetimes are assumed to be sixteen years, and lighting controls are assumed to have an eight-year lifetime, based on the California Measurement Advisory Committee (CALMAC).

Cost Data

Incremental labor and material costs are used to evaluate the economics of each retrofit. Cost data are primarily from the recently completed 2001 Database for Energy Efficiency Resources (DEER) Update Study, supplemented with information available from CALMAC, and catalogs of lighting equipment manufacturers such as Grainger's General Catalog.

For the replacement or modification of fixtures, the incremental cost is the total cost of the technology, since customers are generally carrying out a retrofit when they otherwise would have taken no action. (No credit is given for the salvage value of the existing fixture.) For lamp replacements, the incremental cost is the cost of the new lamp minus the cost of the baseline lamp. For control devices, the incremental cost is the full cost of the measure.

A life-cycle cost analysis is used in place of a first cost analysis in determining the incremental costs for all incandescent to fluorescent conversions and exit signs. This is a more accurate method for calculating the incremental costs because of the highly different stream of lamp costs over the measure life. The life-cycle cost analysis is based on material costs only and uses an 8.15% discount rate (current cost of capital) and 0% inflation. For example, when a 60 W incandescent lamp is replaced with a 13 W compact fluorescent lamp driven by a magnetic ballast, the life-cycle cost analysis (shown in Table 8) takes all replacement material costs into account over the life of the magnetic ballast. The net present value is calculated for these material costs and summed over the specified life to determine the total cost of each measure. The incremental cost is then equal to the difference between the total life-cycle costs of the two measures. In this example, the life cycle is based on the life of the ballast (32,000 hours).

TABLE 8
LIFE CYCLE COST ANALYSIS EXAMPLE

Item	Life (hrs)	Cost of Each	Number required over 32,000 hrs.	Total Cost	NPV Sums
Magnetic ballast	32,000	$ 5.00	1	$ 5.00	$ 5.00
Fluorescent lamp	8,000	$ 6.90	4	$ 27.60	$ 22.35
Total				$ 32.60	$ 27.35
Incandescent	1,000	$ 0.38	32	$ 12.16	$ 9.21
				Incremental Cost (rounded)	**= $18**

For all other measures, incremental costs are based on first cost differentials since these are a good approximation of life-cycle costs and are much easier to carry out. The unit costs used in the life-cycle cost analyses are provided in Table 9. Results of the life-cycle cost analyses are given in the individual technical assessments that follow. Lamp and ballast disposal costs are not included in the incremental cost calculations.

TABLE 9

COMPACT FLUORESCENT, INCANDESCENT LAMP, AND MERCURY VAPOR LAMP LIFETIMES AND COSTS

Wattage	Lamp Type	Lifetime (hrs)	Cost ($)	Cost Source
20	Incandescent	1,000	0.38	DEER 2001, CCIG: CLE-03, page 4-56
60	Incandescent	1,000	0.38	DEER 2001, CCIG: CLE-03, page 4-56
75	Incandescent	750	0.38	DEER 2001, CCIG: CLE-03, page 4-56
100	Incandescent	750	0.38	DEER 2001, CCIG: CLE-03, page 4-56
200	Incandescent	750	2.50	PY2001 Workpapers
300	Incandescent	750	4.00	PY2001 Workpapers
500	Incandescent	1,000	9.00	PY2001 Workpapers
100	Mercury Vapor	24,000	35.00	PY2001 Workpapers
175	Mercury Vapor	24,000	25.00	PY2001 Workpapers
250	Mercury Vapor	24,000	45.00	PY2001 Workpapers
13 Modular	Fluorescent - Magnetic Ballast	8,000/lamp 32,000/ballast	6.9 5	DEER 2001, CCIG: CLE-03, page 4-55
18 Modular	Fluorescent-Electronic Ballast	8,000/lamp 32,000/ballast	10 6.6	DEER 2001, CCIG: CLE-03, page 4-55
32 Modular	Fluorescent-Electronic Ballast	8,000/lamp 32,000/ballast	13 14	PY2001 Workpapers
13 Hardwired	Fluorescent-Magnetic Ballast	16 years/fixture 8,000/lamp 32,000/ballast	37 6.9 5	DEER 2001, CCIG: CLE-03, pages 4-55 and 4-56
26 Hardwired	Fluorescent-Electronic Ballast	16 years/fixture 8,000/lamp 32,000/ballast	44 10 6.6	DEER 2001, CCIG: CLE-03, pages 4-55 and 4-56

Modular compact fluorescent fixtures have a lifetime of 7.7 years as per CALMAC Public Workshops on PY 2001 Energy Efficiency Programs.

Hardwired compact fluorescent fixture life is 16 years, in accordance with the California Measurement Advisory Council (CALMAC).

The unit costs in Table 10 were used to calculate (full size) fluorescent fixture life-cycle costs for the hardwire incandescent and mercury vapor replacement measures. The lifetime for a full-size fluorescent fixture is 16 years and lamps are estimated to persist for 16,000 hours.

TABLE 10
FLUORESCENT FIXTURE EQUIPMENT COSTS

FIXTURE	COST	COST SOURCE
2-lamp 4-foot T-8 fixture	$ 91	DEER 2001, CCIG: BLE-04, pages 4-70
3-lamp 4-foot T-8 fixture	$ 141	DEER 2001, CCIG: BLE-04, pages 4-71
4-foot T-8 lamp	$ 2.1	DEER 2001, CCIG: BLE-04, pages 4-67

A. Screw-In Compact Fluorescent Lamps

Technology Description

Compact fluorescent lamps are designed to replace standard incandescent lamps. They are approximately four times more efficient than incandescent light sources. Screw-in modular lamps have reusable ballasts that typically last for four lamp lives. Commercial applications for compact fluorescent lamps include general lighting, accent and specialty lighting, decorative and portable lighting, utility lighting, and exterior illumination.

The statewide Express program offers incentives for three categories of compact fluorescent lamp retrofits:

- 5-13 watts,
- 14-26 watts and
- >= 27 watts.

Each compact fluorescent measure is analyzed separately. Screw in induction lamps have been moved from the induction lamp category (where lamps are sold exclusively with matching fixtures) to the CFL category, according to their Wattage.

L64 Screw-In Compact Fluorescent Lamp: 5 - 13 Lamp Watts

Assumptions

Compact fluorescent lamps with reusable ballasts can have up to four lamp replacements before the ballast fails. The calculations assume that four lamps are used before the lamp\ballast assembly is discarded and that a 60-watt incandescent lamp is replaced with a 13-watt compact fluorescent lamp driven by a magnetic ballast. The combined wattage for the ballast and lamp is 15 watts. Total installed wattage drops from 0.060 kW to 0.015 kW.

Predominant Market Sectors

Office, retail, college, school, restaurant

Product Life

32,000 hours for the ballast, which assumes four lamps are used before discarding the ballast. As noted above, a lifetime of 7.7 years is assumed for each ballast, in accordance with CALMAC Public Workshops on the PY 2001 Energy Efficiency Programs.

Cost

Compact fluorescent equipment replacement cost: $5 for the ballast and $6.9 per lamp.

Incandescent equipment baseline replacement cost: $0.38.

Refer to Table 9 above for the sources.

Incremental Cost

$18.13 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Noncoincident Demand Savings

0.045 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.046	211
Retail	4,450	0.88	0.047	222
College	3,900	0.68	0.037	202
School	2,150	0.42	0.023	111
Grocery	5,800	0.81	0.046	295
Restaurant	4,600	0.68	0.039	238
Health Care/Hospital	4,400	0.74	0.042	234
Hotel/Motel	5,500	0.67	0.034	282
Warehouse	3,550	0.84	0.041	169
Process Industrial	6,650	0.99	0.045	302
Assembly Industrial	4,400	0.92	0.045	206
All Other	4,500	0.76	0.039	219

Requirements

See application for current requirements.

L174 Screw-In Compact Fluorescent Lamp: 14 - 26 Lamp Watts

Assumptions

Compact fluorescent lamps with reusable ballasts can have up to four lamp replacements before the ballast fails. The calculations assume that four lamps are used before the lamp/ballast assembly is discarded and that a 75-watt incandescent lamp is replaced with an 18-watt compact fluorescent lamp driven by an electronic ballast. The combined wattage for the ballast and lamp is 18 watts. Total installed wattage drops from 0.075 kW to 0.018 kW.

Predominant Market Sectors

Office, retail, college, school, restaurant

Product Life

32,000 hours for the ballast, which assumes four lamps are used before discarding the ballast. As noted above, a lifetime of 7.7 years is assumed for each ballast, in accordance with CALMAC Public Workshops on the PY 2001 Energy Efficiency Programs.

Cost

Compact fluorescent equipment replacement cost: $6.6 for the ballast and $10 per lamp.

Incandescent equipment baseline replacement cost: $0.38.

Refer to Table 9 above for the sources.

Incremental Cost

$26.72 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Noncoincident Demand Savings

0.057 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.058	267
Retail	4,450	0.88	0.060	282
College	3,900	0.68	0.047	256
School	2,150	0.42	0.029	141
Grocery	5,800	0.81	0.058	374
Restaurant	4,600	0.68	0.049	302
Health Care/Hospital	4,400	0.74	0.053	296
Hotel/Motel	5,500	0.67	0.044	357
Warehouse	3,550	0.84	0.052	214
Process Industrial	6,650	0.99	0.058	383
Assembly Industrial	4,400	0.92	0.057	261
All Other	4,500	0.76	0.049	277

Requirements

See application for current requirements.

L175 Screw-In Compact Fluorescent Lamp: ≥27 Lamp Watts

Assumptions

Compact fluorescent lamps with reusable ballasts can have up to four lamp replacements before the ballast fails. The calculations assume that four lamps are used before the lamp\ballast assembly is discarded and that a 100-watt incandescent lamp is replaced with a 32-watt compact fluorescent lamp driven by an electronic ballast. The combined wattage for the ballast and lamp is 31 watts. Total installed wattage drops from 0.100 kW to 0.031 kW.

Predominant Market Sectors

Small commercial

Product life

32,000 hours for the ballast, which assumes four lamps are used before discarding the ballast. As noted above, a lifetime of 7.7 years is assumed for each ballast, in accordance with CALMAC Public Workshops on the PY 2001 Energy Efficiency Programs.

Cost

Compact fluorescent equipment replacement cost: $14 for the ballast and $13 per lamp.

Incandescent equipment baseline replacement cost: $0.38.

Refer to Table 9 above for the sources.

Incremental Cost

$43.84 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Noncoincident Demand Savings

0.069 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.070	323
Retail	4,450	0.88	0.072	341
College	3,900	0.68	0.057	309
School	2,150	0.42	0.036	171
Grocery	5,800	0.81	0.070	452
Restaurant	4,600	0.68	0.059	365
Health Care/Hospital	4,400	0.74	0.064	358
Hotel/Motel	5,500	0.67	0.053	433
Warehouse	3,550	0.84	0.063	260
Process Industrial	6,650	0.99	0.070	463
Assembly Industrial	4,400	0.92	0.069	316
All Other	4,500	0.76	0.059	335

Requirements

See application for current requirements.

B. Compact and Linear Fluorescent Fixtures With Incandescent and Mercury Vapor Baselines

Technology Description

Incandescent and mercury vapor lamps can be replaced with compact and full-sized fluorescent fixtures. Hardwired fluorescent fixtures ensure persistent savings. Since the ballast is part of the fixture in a hardwired retrofit, incandescent or mercury vapor lamps will not be used when the initial fluorescent replacement lamp burns out. An electronic ballast is required for all lamp. The savings are given based on two different base cases for the wattage categories above 27 watts.

The program offers incentives for five categories of hardwired fluorescent lamp retrofits:

- 5-13 watts
- 14-26 watts
- 27-65 watts
- 66-90 watts
- greater than 90 watts

Note: Each wattage category is analyzed separately.

L66 Compact and Linear Fluorescent Fixtures: 5 - 13 Lamp Watts

Assumptions

The calculations assume replacement of an incandescent fixture that contains a 60 watt incandescent lamp with a surface-mounted or recessed fluorescent fixture that contains a 13 watt fluorescent lamp driven by a magnetic ballast. The combined wattage for the ballast and lamp is 15 watts. Total installed wattage drops from 0.060 kW to 0.015 kW.

Predominant market sectors

All sectors except for warehouse, process, and assembly.

Product life

16 years is the assumed fixture life, and results in the use of two ballasts and seven additional lamps before replacing the fixture, as ballasts persist for 32,000 hours (lasting 7.7 years each) and lamps for 8,000 hours.

Cost

Compact fluorescent replacement cost: $37/fixture ($15 for the original equipment and $22 in labor to complete each installation)

Compact fluorescent equipment replacement costs: $5 per replacement ballast and $6.9 per replacement lamp.

Incandescent equipment baseline replacement cost: $0.38.

Refer to Table 9 above for the sources.

Incremental cost

$65.56 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Noncoincident demand savings

0.045 kW

Coincident demand savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.046	211
Retail	4,450	0.88	0.047	222
College	3,900	0.68	0.037	202
School	2,150	0.42	0.023	111
Grocery	5,800	0.81	0.046	295
Restaurant	4,600	0.68	0.039	238
Health Care/Hospital	4,400	0.74	0.042	234
Hotel/Motel	5,500	0.67	0.034	282
Warehouse	3,550	0.84	0.041	169
Process Industrial	6,650	0.99	0.045	302
Assembly Industrial	4,400	0.92	0.045	206
All Other	4,500	0.76	0.039	219

Requirements

See application for current requirements.

L176 Compact and Linear Fluorescent Fixtures: 14 - 26 Lamp Watts

Assumptions

The calculations assume replacement of an incandescent fixture that contains a 100 watt incandescent lamp with a surface-mounted or recessed fluorescent fixture that contains an 26 watt fluorescent lamp driven by an electronic ballast. The combined wattage for the ballast and lamp is 26 watts. Total installed wattage drops from 0.100 kW to 0.026 kW.

Predominant market sectors

All market sectors with the exception of warehouse, process and assembly.

Product life

16 years is the assumed fixture life, and results in the use of two ballasts and seven additional lamps before replacing the fixture, as ballasts persist for 32,000 hours (lasting 7.7 years each) and lamps for 8,000 hours.

Cost

Compact fluorescent replacement cost: $44/fixture ($22 for the original equipment and $22 in labor to complete each installation)

Compact fluorescent equipment replacement costs: $6.6 per replacement ballast and $10 per replacement lamp.

Incandescent equipment baseline replacement cost: $0.38.

Refer to Table 9 above for the sources.

Incremental cost

$86.12 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Noncoincident demand savings

0.074 kW

Coincident demand savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.075	346
Retail	4,450	0.88	0.077	366
College	3,900	0.68	0.061	332
School	2,150	0.42	0.038	183
Grocery	5,800	0.81	0.075	485
Restaurant	4,600	0.68	0.063	391
Health Care/Hospital	4,400	0.74	0.069	384
Hotel/Motel	5,500	0.67	0.057	464
Warehouse	3,550	0.84	0.068	278
Process Industrial	6,650	0.99	0.075	497
Assembly Industrial	4,400	0.92	0.074	339
All Other	4,500	0.76	0.064	360

Requirements

See application for current requirements.

L178 Compact and Linear Fluorescent Fixtures: 27 - 65 Lamp Watts

Conversion from Incandescent to Fluorescent
Fixture with Electronic Ballast

Assumptions

The calculations assume replacement of an incandescent fixture that contains a 200 watt incandescent lamp with a surface-mounted or recessed fluorescent fixture that contains two 4-foot 32 watt T-8 fluorescent lamps driven by an electronic ballast. The combined wattage for the ballast and lamp is 58 watts. Total installed wattage drops from 0.200 kW to 0.058 kW.

Predominant market sectors

All market sectors with the exception of warehouse, process and assembly.

Product life

16 years is the assumed fixture life, and equal to the ballast life. Assuming 4,000 hours of operation per year, implies a ballast life of 64,000 hours. As noted above, lamps persist for 16,000 hours, which results in the use of three additional lamp replacements before replacing the fixture.

Cost

2-lamp 4-foot T-8 fluorescent fixture: $91/fixture ($75 for the original equipment and $16 in labor to complete each installation)

T-8 fluorescent replacement lamp costs: $2.1 per replacement lamp.

Incandescent equipment baseline replacement cost: $2.5.

Refer to Table 9 and 10 above for the sources.

Incremental cost

-$20.55 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Noncoincident demand savings

0.142 kW

Coincident demand savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.144	665
Retail	4,450	0.88	0.149	701
College	3,900	0.68	0.118	637
School	2,150	0.42	0.073	351
Grocery	5,800	0.81	0.144	931
Restaurant	4,600	0.68	0.122	751
Health Care/Hospital	4,400	0.74	0.132	737
Hotel/Motel	5,500	0.67	0.108	890
Warehouse	3,550	0.84	0.130	534
Process Industrial	6,650	0.99	0.143	954
Assembly Industrial	4,400	0.92	0.141	650
All Other	4,500	0.76	0.122	690

Requirements

See application for current requirements.

L179 Compact and Linear Fluorescent Fixtures: 27 - 65 Lamp Watts

Conversion from Mercury Vapor to Fluorescent
Fixture with Electronic Ballast

Assumptions

The calculations assume replacement of a mercury vapor fixture that contains a 100 watt mercury vapor lamp with a combined lamp and ballast wattage of 125 watts with a fluorescent fixture that contains two 4-foot 32 watt T-8 fluorescent lamps driven by an electronic ballast. The combined wattage for the ballast and lamp is 58 watts. Total installed wattage drops from 0.125 kW to 0.058 kW.

Predominant market sectors

All market sectors with the exception of warehouse, process and assembly.

Product life

16 years is the assumed fixture life, and equal to the ballast life. Assuming 4,000 hours of operation per year, implies a ballast life of 64,000 hours. As noted above, lamps persist for 16,000 hours, which results in the use of three additional lamp replacements before replacing the fixture.

Cost

2-lamp 4-foot T-8 fluorescent fixture: $91/fixture ($75 for the original equipment and $16 in labor to complete each installation)

T-8 fluorescent replacement lamp costs: $2.1 per replacement lamp.

Mercury vapor equipment baseline replacement cost: $35.

Refer to Table 9 and 10 above for the sources.

Incremental cost

$36.17 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Noncoincident demand savings

0.067 kW

Coincident demand saving

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.068	314
Retail	4,450	0.88	0.070	331
College	3,900	0.68	0.056	300
School	2,150	0.42	0.035	166
Grocery	5,800	0.81	0.068	439
Restaurant	4,600	0.68	0.057	354
Health Care/Hospital	4,400	0.74	0.062	348
Hotel/Motel	5,500	0.67	0.051	420
Warehouse	3,550	0.84	0.061	252
Process Industrial	6,650	0.99	0.068	450
Assembly Industrial	4,400	0.92	0.067	307
All Other	4,500	0.76	0.058	326

Requirements

See application for current requirements.

L180 Compact and Linear Fluorescent Fixtures: 66 - 90 Lamp Watts

Conversion from Incandescent to Fluorescent Fixture with Electronic Ballast

Assumptions

The calculations assume replacement of an incandescent fixture that contains a 300 watt incandescent lamp with a 3-lamp, 4-foot fluorescent fixture using 32 watt T-8 fluorescent lamps driven by an electronic ballast. The combined wattage for the ballast and lamps is 84 watts. Total installed wattage drops from 0.300 kW to 0.084 kW.

Predominant market sectors

All market sectors with the exception of warehouse, process and assembly.

Product life

16 years is the assumed fixture life, and equal to the ballast life. Assuming 4,000 hours of operation per year, implies a ballast life of 64,000 hours. As noted above, lamps persist for 16,000 hours, which results in the use of three additional lamp replacements before replacing the fixture.

Cost

3-lamp 4-foot T-8 fluorescent fixture: $141/fixture ($78 for the original equipment and $63 in labor to complete each installation)

T-8 fluorescent replacement lamp costs: $2.1 per replacement lamp.

Incandescent equipment baseline replacement cost: $4.

Refer to Table 9 and 10 above for the sources.

Incremental cost

-$38.59 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Noncoincident demand savings

0.216 kW

Coincident demand savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.219	1011
Retail	4,450	0.88	0.226	1067
College	3,900	0.68	0.179	969
School	2,150	0.42	0.112	534
Grocery	5,800	0.81	0.219	1416
Restaurant	4,600	0.68	0.185	1143
Health Care/Hospital	4,400	0.74	0.201	1121
Hotel/Motel	5,500	0.67	0.165	1354
Warehouse	3,550	0.84	0.198	813
Process Industrial	6,650	0.99	0.218	1451
Assembly Industrial	4,400	0.92	0.215	988
All Other	4,500	0.76	0.186	1050

Requirements

See application for current requirements.

L181 Compact and Linear Fluorescent Fixtures: 66 - 90 Lamp Watts

Conversion from Mercury Vapor to Fluorescent Fixture with Electronic Ballast

Assumptions

The calculations assume replacement of a mercury vapor fixture that contains a 175 watt mercury vapor lamp with a lamp and ballast combined wattage of 200 watts with a 3-lamp, 4-foot fluorescent fixture using 32 watt T-8 fluorescent lamps driven by an electronic ballast. The combined wattage for the ballast and lamps is 84 watts. Total installed wattage drops from 0.200 kW to 0.084 kW.

Predominant market sectors

All market sectors with the exception of warehouse, process and assembly.

Product life

16 years is the assumed fixture life, and equal to the ballast life. Assuming 4,000 hours of operation per year, implies a ballast life of 64,000 hours. As noted above, lamps persist for 16,000 hours, which results in the use of three additional lamp replacements before replacing the fixture.

Cost

3-lamp 4-foot T-8 fluorescent fixture: $141/fixture ($78 for the original equipment and $63 in labor to complete each installation)

T-8 fluorescent replacement lamp costs: $2.1 per replacement lamp.

Mercury vapor equipment baseline replacement cost: $25.

Refer to Table 9 and 10 above for the sources.

Incremental cost

$110.60 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Noncoincident demand savings

0.116 kW

Coincident demand savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.117	543
Retail	4,450	0.88	0.121	573
College	3,900	0.68	0.096	520
School	2,150	0.42	0.060	287
Grocery	5,800	0.81	0.117	760
Restaurant	4,600	0.68	0.099	614
Health Care/Hospital	4,400	0.74	0.108	602
Hotel/Motel	5,500	0.67	0.089	727
Warehouse	3,550	0.84	0.106	437
Process Industrial	6,650	0.99	0.117	779
Assembly Industrial	4,400	0.92	0.115	531
All Other	4,500	0.76	0.100	564

Requirements

See application for current requirements.

L205 Compact and Linear Fluorescent Fixture: > 90 Lamp Watts
Conversion from Incandescent to Fluorescent
Fixture with Electronic Ballast

Assumptions:

The calculations assume replacement of an incandescent fixture that contains a 500 watt incandescent lamp with two fluorescent fixtures each containing two 4-foot 32 watt T-8 fluorescent lamps driven by an electronic ballast. The combined wattage for the ballast and lamps is 116 watts. Total installed wattage drops from 0.500 kW to 0.116 kW.

Predominant market sectors:

All market sectors with the exception of warehouse, process and assembly.

Product life:

16 years is the assumed fixture life, and equal to the ballast life. Assuming 4,000 hours of operation per year, implies a ballast life of 64,000 hours. As noted above, lamps persist for 16,000 hours, which results in the use of three additional lamp replacements before replacing the fixture.

Cost

Two 2-lamp 4-foot T-8 fluorescent fixtures: $182/fixture ($150 for the original equipment and $32 in labor to complete each installation).

T-8 fluorescent replacement lamp costs: $2.1 per replacement lamp.

Incandescent equipment baseline replacement cost: $9.

Refer to Table 9 and 10 above for the sources.

Incremental cost

-$127.23 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Non-coincident demand savings:

0.384 kW

Non-coincident demand savings with interactive effects:

Non-coincident demand savings with interactive effects vary according to building type. All values are shown in the table below.

Coincident demand savings:

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy savings:

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.389	1797
Retail	4,450	0.88	0.402	1897
College	3,900	0.68	0.319	1722
School	2,150	0.42	0.198	949
Grocery	5,800	0.81	0.389	2517
Restaurant	4,600	0.68	0.329	2031
Health Care/Hospital	4,400	0.74	0.358	1994
Hotel/Motel	5,500	0.67	0.293	2408
Warehouse	3,550	0.84	0.352	1445
Process Industrial	6,650	0.99	0.388	2579
Assembly Industrial	4,400	0.92	0.382	1757
All Other	4,500	0.76	0.330	1866

Requirements:

See application for current requirements.

L206 Compact and Linear Fluorescent Fixtures: > 90 Lamp Watts

Conversion from Mercury Vapor to Fluorescent Fixture with Electronic Ballast

Assumptions:

The calculations assume replacement of a mercury vapor fixture that contains a 250 watt mercury vapor lamp with a lamp and ballast combined wattage of 285 watts with two, 2-lamp fluorescent fixtures each containing two 32 watt T-8 fluorescent lamps driven by an electronic ballast. The combined wattage for the ballast and lamps is 116 watts. Total installed wattage drops from 0.285 kW to 0.116 kW.

Predominant market sectors:

All market sectors with the exception of warehouse, process and assembly.

Product life:

16 years is the assumed fixture life, and equal to the ballast life. Assuming 4,000 hours of operation per year, implies a ballast life of 64,000 hours. As noted above, lamps persist for 16,000 hours, which results in the use of three additional lamp replacements before replacing the fixture.

Cost

Two 2-lamp 4-foot T-8 fluorescent fixture: $182/fixture ($150 for the original equipment and $32 in labor to complete each installation)

T-8 fluorescent replacement lamp costs: $2.1 per replacement lamp.

Mercury vapor equipment baseline replacement cost: $45.

Refer to Table 9 and 10 above for the sources.

Incremental cost

$119.47 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Non-coincident demand savings:

0.169 kW

Non-coincident demand savings with interactive effects:

Non-coincident demand savings with interactive effects vary according to building type. All values are shown in the table below.

Coincident demand savings:

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy savings:

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.171	791
Retail	4,450	0.88	0.177	835
College	3,900	0.68	0.140	758
School	2,150	0.42	0.087	418
Grocery	5,800	0.81	0.171	1108
Restaurant	4,600	0.68	0.145	894
Health Care/Hospital	4,400	0.74	0.158	877
Hotel/Motel	5,500	0.67	0.129	1060
Warehouse	3,550	0.84	0.155	636
Process Industrial	6,650	0.99	0.171	1135
Assembly Industrial	4,400	0.92	0.168	773
All Other	4,500	0.76	0.145	821

Requirements:

See application for current requirements.

FOR REFERENCE ONLY L167 Interior Induction Fixtures: <55 Lamp Watts Conversion from an Incandescent Fixture

Assumptions

To simplify the program for 2003, interior induction lamps < 55 Watts are treated as electronically ballasted Compact Fluorescent Lamps (CFLs). The only induction lamp in this category on the market is the 23 Watt, General Electric *Genura*. While utilizing induction in lieu of cathodes, it is similar in its nature to measure L175. Induction lamps < 55 Watts are dropped as a separate category and are treated as CFLs. The assumptions here are retained for reference purposes only.

The calculations are for replacement of 75 watts of incandescent lighting with 23 watts of induction lighting. In this instance, the typical replacement will be of a medium-socketed R-type reflector lamp in a recessed downlight or track light. The induction lamp with integral generator is 23 watts. Total installed wattage drops from 0.075 kW to 0.023 kW.

Predominant market sectors

Office, school, college, and retail

Product life

15,000 hours (lamp/generator unit)

Incremental cost

$24

Source: PY 2001 Work papers.

Noncoincident demand savings

0.052 kW

Coincident demand savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.053	243
Retail	4,450	0.88	0.054	257
College	3,900	0.68	0.043	233
School	2,150	0.42	0.027	129
Grocery	5,800	0.81	0.053	341
Restaurant	4,600	0.68	0.045	275
Health Care/Hospital	4,400	0.74	0.048	270
Hotel/Motel	5,500	0.67	0.040	326
Warehouse	3,550	0.84	0.048	196
Process Industrial	6,650	0.99	0.053	349
Assembly Industrial	4,400	0.92	0.052	238
All Other	4,500	0.76	0.045	253

Requirements

See application for current requirements.

C. L168 Induction Lamp Fixtures: 55-100 Lamp Watts

Conversion from an Incandescent Fixture

Assumptions

We assume that half of the fixtures in this size range are for replacement of 200 watts of incandescent lighting with 55 watts of induction lamp lighting. The other half of the fixtures in this size range are for replacement of 300 watts of incandescent lighting with 85 watts of induction lighting. The average total installed wattage drops from 0.250 kW to 0.070 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process Industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$295 Source: PY 2001 Workpapers

Noncoincident demand savings

0.180 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.182	842
Retail	4,450	0.88	0.188	889
College	3,900	0.68	0.149	807
School	2,150	0.42	0.093	445
Grocery	5,800	0.81	0.182	1,180
Restaurant	4,600	0.68	0.154	952
Health Care/Hospital	4,400	0.74	0.168	935
Hotel/Motel	5,500	0.67	0.137	1,129
Warehouse	3,550	0.84	0.165	677
Process Industrial	6,650	0.99	0.182	1,209
Assembly Industrial	4,400	0.92	0.179	824
All Other	4,500	0.76	0.155	875

Requirements

See application for current requirements.

C. L211 Induction Lamp Fixtures: >100 Lamp Watts

Conversion from a Mercury Vapor Fixture

Assumptions

The calculations are for replacement of 250 watts of mercury vapor lighting with 150 watts of induction lighting. The mercury vapor wattage with ballast is 290 watts. The induction lamp system wattage is 157 watts. Total installed wattage drops from 0.290 kW to 0.157 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process Industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$290

Source: PY 2001 Work papers.

Noncoincident Demand Savings

0.133 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.135	622
Retail	4,450	0.88	0.139	657
College	3,900	0.68	0.110	597
School	2,150	0.42	0.069	329
Grocery	5,800	0.81	0.135	872
Restaurant	4,600	0.68	0.114	704
Health Care/Hospital	4,400	0.74	0.124	691
Hotel/Motel	5,500	0.67	0.102	834
Warehouse	3,550	0.84	0.122	500
Process Industrial	6,650	0.99	0.134	893
Assembly Industrial	4,400	0.92	0.132	609
All Other	4,500	0.76	0.114	646

Requirements

See application for current requirements.

D. L114 Linear Fluorescent Electronic Ballasts

Technology Description

Ballasts regulate the electric current of fluorescent lamps. The ballast supplies a high voltage to initiate the discharge and then rapidly limits the lamp current to operating levels. Electronic ballasts control lamp voltage and current using electronic circuits. They take incoming 60 Hz current and use transistors, resistors, capacitors, and inductors to convert it to 20,000–60,000 Hz. Operating fluorescent lamps at higher frequencies improves lamp efficacy by nearly 10% (Knisley 1990). Thus, using more efficient lamps with electronic ballasts will reduce wattage by more than the lamp wattage reduction alone, which is rated based on magnetic core/coil ballasts. Other advantages of the electronic ballast are the capability to drive up to four 4-foot lamps on one ballast, reduced weight, less audible noise and lamp flicker, cooler operation, and longer life.

When a lamp is operated within manufacturer's specifications, the ballast allows full lamp life and optimal light output. Generally, ballasts are designed to drive only one lamp type. However, some manufacturers produce ballasts that can drive different lamps. (T-8, T-10, and T-12). Customers need to verify that they select a ballast that will drive the lamps that they plan to use.

The statewide Express program offers incentives for retrofit installation of electronic ballasts in 1-lamp, 2-lamp, 3-lamp, and 4-lamp fixtures. Rebates and savings are on a per lamp basis.

AssumptionsTo improve savings estimates for the 2003 program, Ballast Factor has been incorporated. Ballast factor similarly and proportionally affects both lamp light output and electrical power input. Normally it is assumed to be unity, but for electronic ballasts may range from .74 to 1.2, with corresponding affect on the energy savings. For 2003, the number of lamps replaced will be multiplied by the ballast factor, creating the “number of lamps used to calculate the rebate”, or effective number of lamps so far as energy savings are concerned.

Additionally, requirements have been added specifying the type of start appropriate for different applications. Electronic ballasts feature instant start, programmed start, and programmed rapid start. While instant start is the most efficient, since it does not use energy to independently heat the fluorescent lamp cathodes, it tends to shorten the life of lamps when used with occupancy sensors or subject to frequent starts. Programmed start or programmed rapid start is specified for applications with occupancy sensors or subject to frequent starts.

The calculations are for the replacement of an energy-saving magnetic ballast with an electronic ballast in a 4-foot fixture that uses T-12 lamps with a 34-watt lamp. Most 4-foot fixtures are either 2-lamp or 3-lamp fixtures. Savings and cost data are the average of the 2-lamp and 3-lamp data.

Predominant Market Sectors

All market sectors

Product Life

16 years (DSM Measure Life Project)

Incremental Cost

$17.50 per ballast

2001 DEER Update Study, CCIG-BLE-04, p. 4-66, Xenergy, Oakland, CA.

Lamps/ Fixture	Pre-Retrofit Wattage (kW)	Post-Retrofit Wattage (kW)	Savings Per Fixture (kW)	Savings Per Lamp (kW)
2	0.072	0.061	0.011	0.006
3	0.115	0.090	0.025	0.008
			Average:	0.007

Noncoincident Demand Savings

0.007 kW per lamp

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.007	33
Retail	4,450	0.88	0.007	35
College	3,900	0.68	0.006	31
School	2,150	0.42	0.004	17
Grocery	5,800	0.81	0.007	46
Restaurant	4,600	0.68	0.006	37
Health Care/Hospital	4,400	0.74	0.007	36
Hotel/Motel	5,500	0.67	0.005	44
Warehouse	3,550	0.84	0.006	26
Process Industrial	6,650	0.99	0.007	47
Assembly Industrial	4,400	0.92	0.007	32
All Other	4,500	0.76	0.006	34

Requirements

See application for current requirements.

D. L67 Dimming Electronic Ballasts for Daylighting

Technology Description

Dimming electronic ballasts are a relatively new technology that can be incorporated into a daylighting strategy around the perimeter of office buildings or in areas under skylights. These systems use photocells to reduce power consumption and light output when daylight is available. The primary application is for open office areas. Private office spaces would probably use an occupancy sensor and photocell combination.

Assumptions

For this calculation, the base case is assumed to be a 4-foot, 2-lamp fixture using a magnetic ballast and 34-watt lamps (72 watts). The dimming electronic ballast is assumed to drive a 4-foot, 2-lamp fluorescent fixture with 32 watt, T-8 lamps (58 watts per fixture including ballast). 3-lamp dimming ballasts are available, but less common. The location that is modeled is an office building perimeter space. Without the dimming electronic ballast and photocell, lights are assumed to be on for a total of 4,000 hours/year. Although the wattage reduction varies throughout the course of the day, as well as throughout the year, it is assumed that on average, the dimming ballast reduces the power requirements of the lighting system by 20% in addition to the savings derived from the conversion from T-12/magnetic ballasts to T-8/electronic ballasts.

Predominant Market Sectors

Offices

Product Life

16 years

Incremental Cost

$53 per ballast

2001 DEER Update Study, CCIG-BLE-04, p. 4-66, Xenergy, Oakland, CA.

Noncoincident Demand Savings

[(0.072 kW-0.058 kW) + 0.058 kW x 0.2]/2 lamps per fixture = 0.0128 kW per lamp

Coincident Demand Savings with Office Interactive Effects

0.013 kW per lamp (0.0128 kW x 0.81 office sector CDF x 1.25 office sector IE)

Energy Savings

Annual savings are 59.9 kWh per lamp, including office sector interactive effects (0.0128 kW x 4,000 hours/year x 1.17 office sector Energy Interactive Effects).

Requirements

Dimming electronic ballast must be used with photocells for effective use of daylight in perimeter zones and areas under skylights. Only T-8 or T-5 systems are eligible for dimming electronic ballast rebates.

E. Permanent Lamp Removal (Delamping)

Technology Description

The statewide Express program offers incentives for permanent removal of lamps, ballasts, and lamp holders. Fluorescent fixtures typically deliver about 60% of the light that they produce to the work plane while the other 40% of the light is absorbed inside of the fixture. Reflectors direct more light out of the fixture, and customers may opt to design them into a retrofit project.

Specular reflectors usually concentrate the light directly under the fixture while directing less light between fixtures. Customers should be aware that lighting distribution will change. Energy use for a four-lamp fixture can be decreased by 50% by removing two lamps and a ballast. However, even with reflectors, this action will also result in a 20–30% reduction in light level. When considering specular reflectors, make sure both the initial post retrofit and maintained light levels compare. RPI (1992) reviews specular reflector issues in more detail.

Permanent lamp removal rebates for 2-foot, 3-foot, 4-foot, and 8-foot fixtures are offered in the Express program.. Each lamp size is discussed in a separate technical assessment.

L17 Removing a 2-foot Lamp

Assumptions

The calculations are for conversion from a 3-lamp to a 2-lamp fixture. The original fixture uses T-12, 20-watt lamps and energy saving magnetic ballasts. One lamp and its associated ballast are removed. Total installed wattage drops from 0.082 kW to 0.050 kW.

Predominant market sectors

Office, health care/hospital, school, and college

Product life

16 years

Incremental cost

$19 per reflector

2001 DEER Update Study, CCIG-BLE-04, p. 4-67, Xenergy, Oakland, CA.

Noncoincident demand savings

0.032 kW per lamp

Coincident demand savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.032	150
Retail	4,450	0.88	0.034	158
College	3,900	0.68	0.027	144
School	2,150	0.42	0.017	79
Grocery	5,800	0.81	0.032	210
Restaurant	4,600	0.68	0.027	169
Health Care/Hospital	4,400	0.74	0.030	166
Hotel/Motel	5,500	0.67	0.024	201
Warehouse	3,550	0.84	0.029	120
Process Industrial	6,650	0.99	0.032	215
Assembly Industrial	4,400	0.92	0.032	146
All Other	4,500	0.76	0.027	156

Requirements

See application for current requirements.

L18 Removing a 3-foot Lamp

Assumptions

The calculations are for conversion from a 3-lamp to a 2-lamp fixture. The original fixture wattage is based on T-12, 25-watt lamps with energy-saving ballast 75% of the time and T-12, 30-watt lamps and energy saving ballasts the other 25% of the time. One lamp and its associated ballast are removed. Total installed wattage drops from 0.112 kW to 0.068 kW.

Predominant market sectors

All market sectors

Product life

16 years

Incremental cost

$19 per reflector

2001 DEER Update Study, CCIG-BLE-04, p. 4-67, Xenergy, Oakland, CA.

Noncoincident demand savings

0.044 kW per lamp

Coincident demand savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.045	206
Retail	4,450	0.88	0.046	217
College	3,900	0.68	0.037	197
School	2,150	0.42	0.023	109
Grocery	5,800	0.81	0.045	288
Restaurant	4,600	0.68	0.038	233
Health Care/Hospital	4,400	0.74	0.041	228
Hotel/Motel	5,500	0.67	0.034	276
Warehouse	3,550	0.84	0.040	166
Process Industrial	6,650	0.99	0.044	296
Assembly Industrial	4,400	0.92	0.044	201
All Other	4,500	0.76	0.038	214

Requirements

See application for current requirements.

L19 Removing a 4-foot Lamp

Assumptions

The calculations are for conversion from a 3-lamp to a 2-lamp fixture. The original fixture wattage is based on T-12, 34-watt lamps with energy-saving ballast. One lamp and its associated ballast are removed. Total installed wattage drops from 0.115 kW to 0.072 kW.

Predominant market sectors

All market sectors

Product life

16 years

Incremental cost

$19 per reflector

2001 DEER Update Study, CCIG-BLE-04, p. 4-67, Xenergy, Oakland, CA.

Noncoincident demand savings

0.043 per lamp

Coincident demand savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.044	201
Retail	4,450	0.88	0.045	212
College	3,900	0.68	0.036	193
School	2,150	0.42	0.022	106
Grocery	5,800	0.81	0.044	282
Restaurant	4,600	0.68	0.037	227
Health Care/Hospital	4,400	0.74	0.040	223
Hotel/Motel	5,500	0.67	0.033	270
Warehouse	3,550	0.84	0.039	162
Process Industrial	6,650	0.99	0.043	289
Assembly Industrial	4,400	0.92	0.043	197
All Other	4,500	0.76	0.037	209

Requirements

See application for current requirements.

L20 Removing an 8-foot Lamp

Assumptions

The calculations are for conversion from a 3-lamp to a 2-lamp fixture. The original fixture wattage is based on T-12, 60-watt lamps with energy-saving ballasts. One lamp and its associated ballast are removed. Total installed wattage drops from 0.205 kW to 0.126 kW.

Predominant market sectors

Retail, warehouse, and assembly and process Industries

Product life

16 years

Incremental cost

$33 per reflector

2001 DEER Update Study, CCIG-BLE-04, p. 4-63, Xenergy, Oakland, CA.

Noncoincident demand savings

0.079 kW per lamp

Coincident demand savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.080	370
Retail	4,450	0.88	0.083	390
College	3,900	0.68	0.066	354
School	2,150	0.42	0.041	195
Grocery	5,800	0.81	0.080	518
Restaurant	4,600	0.68	0.068	418
Health Care/Hospital	4,400	0.74	0.074	410
Hotel/Motel	5,500	0.67	0.060	495
Warehouse	3,550	0.84	0.072	297
Process Industrial	6,650	0.99	0.080	531
Assembly Industrial	4,400	0.92	0.078	362
All Other	4,500	0.76	0.068	384

Requirements

See application for current requirements.

E. T-8 or T-5 Linear Fluorescent Lamp with Electronic Ballast/New Fixture

Technology Description

The 1-lamp, T-8 system with an electronic ballast has an efficacy of 73 lumens per watt, compared to 57 lumens per watt for the 1-lamp, F40 T-12 lamp system. T-5s have comparable efficacies to T-8s. The fixture retrofit is for customers who elect to replace the inner workings of the fixture when upgrading their lighting system to an electronic ballast with T-8 lamps. The same incentive will be offered to customers who elect to replace an existing fluorescent fixture that has T-12 lamps and an energy-saving magnetic ballast with a new T-8 lamp and electronic ballast fixture.

Energy savings are calculated using a baseline of an energy-saving magnetic ballast. The baseline lamp wattages are 20 watts for a 2-foot fixture, 34 watts for a 4-foot fixture, 60 watts for a standard output 8-foot fixture, and 95 watts for a high output 8-foot fixture. For 3-foot lamps, the baseline is an energy savings magnetic ballast and a 75%/25% split between 25 and 30 watt lamps.

The statewide Express program offers incentives for modifying T-12 and magnetic ballast fixture configurations with the following:

- T-8 or T-5 lamp and electronic ballast installation for 2-foot fixtures,
- T-8 or T-5 lamp and electronic ballast installation for 3-foot fixtures,
- T-8 or T-5 lamp and electronic ballast installation for 4-foot fixtures and
- T-8 or T-5 lamp and electronic ballast installation for 8-foot fixtures.

While T-5 lamps qualify under these categories, the savings calculations assume that all new lamps are T-8s as these are by far the most common retrofit.

L21 T-8 Lamp with Electronic Ballast: 2-foot Fixture

Assumptions

The calculations are for the replacement of the lamp and ballast in a 2-foot fixture. Two-lamp fixtures are the most common. The base case is a fixture with one energy-saving magnetic ballast and two 20 watt, T-12 lamps. An electronic ballast and two 2-foot T-8 lamps (17 watts each) are installed. Total installed wattage drops from 0.050 kW to 0.029 kW for the fixture.

Predominant market sectors

All market sectors

Product life

16 years (fixture life)

Incremental cost

$21 per lamp

2001 DEER Update Study, CCIG-BLE-04, p. 4-74, Xenergy, Oakland, CA.

Noncoincident demand savings

0.011 kW per lamp

Coincident demand savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below and are per lamp.

Energy savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below and are per lamp.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.011	51
Retail	4,450	0.88	0.012	54
College	3,900	0.68	0.009	49
School	2,150	0.42	0.006	27
Grocery	5,800	0.81	0.011	72
Restaurant	4,600	0.68	0.009	58
Health Care/Hospital	4,400	0.74	0.010	57
Hotel/Motel	5,500	0.67	0.008	69
Warehouse	3,550	0.84	0.010	41
Process Industrial	6,650	0.99	0.011	74
Assembly Industrial	4,400	0.92	0.011	50
All Other	4,500	0.76	0.009	53

Requirements

See application for current requirements. Note: While T-5 lamps qualify under this category, the savings calculations assume that all new lamps are T-8s as these are by far the most common retrofit.

L22 T-8 Lamp with Electronic Ballast: 3-foot Fixture

Assumptions

The calculations are for replacement of lamp and ballast(s) in a 3-foot fluorescent fixture. The T-12 lamps and energy saving magnetic ballast(s) are replaced with an electronic ballast and T-8 lamps. Two-lamp fixtures are the most common. For a 2-lamp fixture total installed wattage drops from 0.068 to 0.042 kW per fixture.

Predominant market sectors

All market sectors

Product life

16 years (fixture life)

Incremental cost

$21 per lamp

2001 DEER Update Study, CCIG-BLE-04, p. 4-74, Xenergy, Oakland, CA.

Noncoincident demand savings

0.013 kW per lamp.

Coincident demand savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below and are per lamp.

Energy savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below and are per lamp.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.013	61
Retail	4,450	0.88	0.014	64
College	3,900	0.68	0.011	58
School	2,150	0.42	0.007	32
Grocery	5,800	0.81	0.013	85
Restaurant	4,600	0.68	0.011	69
Health Care/Hospital	4,400	0.74	0.012	67
Hotel/Motel	5,500	0.67	0.010	82
Warehouse	3,550	0.84	0.012	49
Process Industrial	6,650	0.99	0.013	87
Assembly Industrial	4,400	0.92	0.013	59
All Other	4,500	0.76	0.011	63

Requirements

See application for current requirements. Note: While T-5 lamps qualify under this category, the savings calculations assume that all new lamps are T-8s as these are by far the most common retrofit.

L23 T-8 Lamp with Electronic Ballast: 4-foot Fixture

Assumptions

The calculations are for replacement of lamps and ballast(s) in a 4-foot fluorescent fixture. The T-12 lamps and energy saving magnetic ballast(s) are replaced with an electronic ballast and 32 watt, T-8 lamps. Most 4-foot fixtures are either 2-lamp or 3-lamp fixtures. Savings and cost data are the average of the 2-lamp and 3-lamp data.

Predominant Market Sectors

All sectors except warehouse

Product Life

16 years (fixture life)

Incremental Cost

$15 per lamp

2001 DEER Update Study, CCIG-BLE-04, p. 4-71, Xenergy, Oakland, CA.

Lamps/ Fixture	Pre-Retrofit Wattage (kW)	Post-Retrofit Wattage (kW)	Savings Per Fixture (kW)	Savings Per Lamp (kW)
2	0.072	0.058	0.014	0.007
3	0.115	0.084	0.031	0.010
			Average:	0.009

Noncoincident Dmand Savings

0.009 kW per lamp

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table on the following page and are per lamp.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below and are per lamp.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.009	42
Retail	4,450	0.88	0.009	44
College	3,900	0.68	0.007	40
School	2,150	0.42	0.005	22
Grocery	5,800	0.81	0.009	59
Restaurant	4,600	0.68	0.008	48
Health Care/Hospital	4,400	0.74	0.008	47
Hotel/Motel	5,500	0.67	0.007	56
Warehouse	3,550	0.84	0.008	34
Process Industrial	6,650	0.99	0.009	60
Assembly Industrial	4,400	0.92	0.009	41
All Other	4,500	0.76	0.008	44

Requirements

See application for current requirements. Note: While T-5 lamps qualify under this category, the savings calculations assume that all new lamps are T-8s as these are by far the most common retrofit.

L24 T-8 Lamp with Electronic Ballast: 8-foot Fixture

Assumptions

The calculations are for replacement of lamp(s) and ballast in an 8-foot, fluorescent fixture. The T-12 lamps and energy saving ballast(s) are replaced with an electronic ballast and either 8-foot T-8 lamps or end-to-end 4-foot T-8 lamps. Two lamp fixtures are the most common. For a 2-lamp fixture, total installed wattage drops from 0.126 kW to 0.106 kW.

Predominant Market Sectors

Retail, warehouse, and assembly and process industries.

Product Life

16 years (fixture life)

Incremental Cost

$32.50 per lamp

2001 DEER Update Study, CCIG-BLE-04, p. 4-65, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.010 kW per lamp

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below and are per lamp.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below and are per lamp.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.010	47
Retail	4,450	0.88	0.010	49
College	3,900	0.68	0.008	45
School	2,150	0.42	0.005	25
Grocery	5,800	0.81	0.010	66
Restaurant	4,600	0.68	0.009	53
Health Care/Hospital	4,400	0.74	0.009	52
Hotel/Motel	5,500	0.67	0.008	63
Warehouse	3,550	0.84	0.009	38
Process Industrial	6,650	0.99	0.010	67
Assembly Industrial	4,400	0.92	0.010	46
All Other	4,500	0.76	0.009	49

Requirements

See application for current requirements.

L290 High Performance 4 foot T-8 System (from T-12) [Also called PREMIUM T-8 Lamp & Electronic Ballast/New Fixture-Replacement of T-12 Lamps & EnergySaver Ballast-4 foot (based on 2 lamps)]

Assumptions

Measure assumes that a high performance 4-foot T-8 lamp and ballast combination is replacing a standard T-12 system. To be considered a high performance system, the new ballast must have a ballast factor of less than or equal to 0.77 and use premium lamps that initially produce at least 3100 lumens. The existing system is assumed to be a two-lamp T-12 system using 72 watts (34 watt lamps and energy-saver magnetic ballast).

Predominant Market Sectors

Office

Product Life

37,500 hours (assumes fixture lifetime is life of ballast and 1.6 lamp changes)

Cost

$25.40 ($20 for ballast + $5.40 for lamps)

Incremental Cost

$8.98. Life cycle cost based on a 8% discount rate (see lighting introduction for details on life cycle costing).

Noncoincident Demand Savings

(Existing Connected Load KW)-(Retrofit Connected Load KW) = (Connected Load Reduction KW)

[(Connected Load Reduction KW)*(Demand Interactive Effect Factor * (Coincident Diversity Factor)] / (2 Lamps per Fixture) = Demand Savings

Existing 2 lamp T12 system = 72 watts/fixture

High Performance 2 lamp T8 system = 48 watts/fixture

Connected Load Reduction = 24 watts/fixture

Noncoincident demand savings per lamp =12.15 watts

0.012 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Market Sector	Demand Interactive Effects	Coincident Diversity Factor	Coincident Demand Savings per lamp
Office	1.25	0.81	0.012
Retail	1.19	0.88	0.013
College	1.22	0.68	0.010
School	1.23	0.42	0.006
Grocery	1.25	0.81	0.012

Restaurant	1.26	0.68	0.010
Hospital	1.26	0.74	0.011
Hotel/Motel	1.14	0.67	0.009
Warehouse	1.09	0.84	0.011
Process	1.20	0.78	0.012
Assembly	1.20	0.80	0.012
Other	1.13	0.76	0.010

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

[(Connected Load Reduction KW) *(Hours of Operations)*(Energy Interactive Effect Factor)] / (2 Lamps per Fixture) = Energy Savings

Connected Load Reduction = 0.024 kW/fixture

Market Sector	Annual Operating Hours	Energy Interactive Effects	Annual kWh Savings per lamp
Office	4,000	1.17	56
Retail	4,450	1.11	59
College	3,900	1.15	54
School	2,150	1.15	30
Grocery	5,800	1.13	79
Restaurant	4,600	1.15	63
Hospital	4,400	1.18	62
Hotel/Motel	5,500	1.14	75
Warehouse	3,550	1.06	45
Process	5,300	1.09	81
Assembly	4,900	1.09	55
Other	4,500	1.08	58

L291 High Performance 4 foot T-8 System (from T-8)

Assumptions

Measure assumes that a high performance 4-foot T-8 lamp and ballast combination is replacing a standard T-8 system. Although this retrofit is most commonly applicable to an office environment, calculations are provided for all market sectors. To be considered a high performance T-8 system, the new ballast must have a ballast factor of less than or equal to 0.77 and use premium lamps that initially produce at least 3100 lumens. The existing T-8 system is assumed to be a two-lamp system using 58 watts.

Predominant Market Sectors

Office

Product Life

37,500 hours (assumes fixture life is the life of the ballast plus 1.6 lamp change-outs)

Cost

$25.40 ($20 for ballast + $5.40 for lamps)

Incremental Cost

$2.33 Life cycle cost based on a 8% discount rate (see lighting introduction for details on life cycle costing).

Noncoincident Demand Savings

(Existing Connected Load KW)-(Retrofit Connected Load KW) =
(Connected Load Reduction KW)

[(Connected Load Reduction KW)*(Demand Interactive Effect Factor) * (Coincident Diversity Factor)] / (2 Lamps per Fixture)= Demand Savings

Calculation:

Existing 2 lamp T-8 System = 58 watts/fixture

High Performance 2 lamp T8 system = 48 watts/fixture

Connected Load Reduction = 10 watts/fixture

Noncoincident Demand Savings per Lamp = 5 watts
0.005 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Market Sector	Demand Interactive Effects	Coincident Diversity Factor	Coincident Demand Savings per lamp

Office	1.25	0.81	0.005
Retail	1.19	0.88	0.005
College	1.22	0.68	0.004
School	1.23	0.42	0.003
Grocery	1.25	0.81	0.005
Restaurant	1.26	0.68	0.004
Hospital	1.26	0.74	0.005
Hotel/Motel	1.14	0.67	0.004
Warehouse	1.09	0.84	0.005
Process	1.20	0.78	0.005
Assembly	1.20	0.80	0.005
Other	1.13	0.76	0.004

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

[(Connected Load Reduction KW) *(Hours of Operations)*(Energy Interactive Effect Factor)] / (2 Lamps per Fixture) = Energy Savings

Connected Load Reduction = 0.010 kW/fixture

Market Sector	Annual Operating Hours	Energy Interactive Effects	Annual kWh Savings per lamp
Office	4,000	1.17	23
Retail	4,450	1.11	25
College	3,900	1.15	22
School	2,150	1.15	12
Grocery	5,800	1.13	33
Restaurant	4,600	1.15	26
Hospital	4,400	1.18	26
Hotel/Motel	5,500	1.14	31
Warehouse	3,550	1.06	19
Process	5,300	1.09	34
Assembly	4,900	1.09	23
Other	4,500	1.08	24

F. High Intensity Discharge (HID) Fixtures, Pulse Start

Technology Description

There are three basic types of high intensity discharge (HID) lamps: metal halide, high-pressure sodium, and mercury vapor. All HID lamps require ballasts to operate. In addition, some lamps require an external starting igniter to generate high-voltage pulses needed to begin the lamp arc. HID lamps are approximately four times more efficient than incandescent lamps. Low wattage HID lamps are less efficacious than similar type high wattage lamps.

Based on tradeoffs between efficiency and color rendering indices, different types of HID lamps have appropriate market niches. Metal halide lamps have efficacies of 63–115 lumens per watt for the lamp and ballast and generally have better color rendering indices than other HID lamps. Metal halide lamps are available in 32 watt and larger sizes. High-pressure sodium lamps are available from 35 to 1,000 watts. The lamp efficacy ranges from 50–127 lumens per watt and the color rendering index from 18–22. Incandescent and mercury vapor lamps are used as the base case for all HID lamps. The savings for each HID category are calculated against both base case wattages.

The best interior applications for metal halide and white high-pressure sodium are areas with high ceilings, e.g., gymnasiums, corridor and lobby down-lighting, commercial wall-washing, and some office lighting. There are also many commercial and industrial applications for other HID lamps. HID fixtures have a wide range of exterior applications, such as tree up-lights, wall lights, step lights and architectural floodlights. Exterior HID replacements assume that the fixture being installed is a metal halide lamp half the time and a high-pressure sodium lamp the other half (50:50 split). Some fixtures can be retrofitted with HID hardware if the customer does not wish to remove the existing fixture.

The statewide program offers incentives for several different configurations of HID fixtures:

- New interior fixtures (Compact): 0–35 watts,
- New interior fixtures (Compact): 36–70 watts,
- New interior fixtures (Compact): 71–100 watts,
- New interior fixtures (Standard): 101–175 watts,
- New interior fixtures (Standard): 176–250 watts,
- New interior fixtures (Standard): 251–400 watts,
- New exterior fixtures: 0–100 watts,
- New exterior fixtures: 101–175 watts, and
- New exterior fixtures: ≥176 watts.

Each HID measure listed above is analyzed in two technical assessments: one for an incandescent base case and one for a mercury vapor base case.

L185 Interior HID Fixtures (Compact): 0–35 Lamp Watts

Conversion from an Incandescent Fixture

Assumptions

The calculations are for replacement of 100 watts of incandescent lighting with 35 watts of metal halide lighting. The metal halide wattage with ballast is 45 watts. Total installed wattage drops from 0.100 kW to 0.045 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$133

Noncoincident Demand Savings

0.055 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.056	257
Retail	4,450	0.88	0.058	272
College	3,900	0.68	0.046	247
School	2,150	0.42	0.028	136
Grocery	5,800	0.81	0.056	360
Restaurant	4,600	0.68	0.047	291
Health Care/Hospital	4,400	0.74	0.051	286
Hotel/Motel	5,500	0.67	0.042	345
Warehouse	3,550	0.84	0.050	207
Process Industrial	6,650	0.99	0.056	369
Assembly Industrial	4,400	0.92	0.055	252
All Other	4,500	0.76	0.047	267

Requirements

See application for current requirements.

L186 Interior HID Fixtures (Compact): 0–35 Lamp Watts

Conversion from a Mercury Vapor Lamp

Assumptions

The calculations are for replacement of 50 watts of mercury vapor lighting with 35 watts of metal halide lighting. The mercury vapor wattage with ballast is 74 watts. The metal halide wattage with ballast is 45 watts. Total installed wattage drops from 0.074 kW to 0.045 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$60

Noncoincident Demand Savings

0.029 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.029	136
Retail	4,450	0.88	0.030	143
College	3,900	0.68	0.024	130
School	2,150	0.42	0.015	72
Grocery	5,800	0.81	0.029	190
Restaurant	4,600	0.68	0.025	153
Health Care/Hospital	4,400	0.74	0.027	151
Hotel/Motel	5,500	0.67	0.022	182
Warehouse	3,550	0.84	0.027	109
Process Industrial	6,650	0.99	0.029	195
Assembly Industrial	4,400	0.92	0.029	133
All Other	4,500	0.76	0.025	141

Requirements

See application for current requirements.

L187 Interior HID Fixtures (Compact): 36–70 Lamp Watts

Conversion from an Incandescent Fixture

Assumptions

The calculations are for replacement of 200 watts of incandescent lighting with 70 watts of metal halide lighting. The metal halide wattage with ballast is 90 watts. Total installed wattage drops from 0.200 kW to 0.090 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$287

2001 DEER Update Study, CCIG-BLE-07, p. 4-78, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.110 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.111	515
Retail	4,450	0.88	0.115	543
College	3,900	0.68	0.091	493
School	2,150	0.42	0.057	272
Grocery	5,800	0.81	0.111	721
Restaurant	4,600	0.68	0.094	582
Health Care/Hospital	4,400	0.74	0.103	571
Hotel/Motel	5,500	0.67	0.084	690
Warehouse	3,550	0.84	0.101	414
Process Industrial	6,650	0.99	0.111	739
Assembly Industrial	4,400	0.92	0.109	503
All Other	4,500	0.76	0.094	535

Requirements

See application for current requirements.

L188 Interior HID Fixtures (Compact): 36–70 Lamp Watts

Conversion from a Mercury Vapor Lamp

Assumptions

The calculations are for replacement of 100 watts of mercury vapor lighting with 70 watts of metal halide lighting. The mercury vapor wattage with ballast is 125 watts. The metal halide wattage with ballast is 90 watts. Total installed wattage drops from 0.125 kW to 0.090 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$287

2001 DEER Update Study, CCIG-BLE-07, p. 4-78, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.035 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.035	164
Retail	4,450	0.88	0.037	173
College	3,900	0.68	0.029	157
School	2,150	0.42	0.018	87
Grocery	5,800	0.81	0.035	229
Restaurant	4,600	0.68	0.030	185
Health Care/Hospital	4,400	0.74	0.033	182
Hotel/Motel	5,500	0.67	0.027	219
Warehouse	3,550	0.84	0.032	132
Process Industrial	6,650	0.99	0.035	235
Assembly Industrial	4,400	0.92	0.035	160
All Other	4,500	0.76	0.030	170

Requirements

See application for current requirements.

L189 Interior HID Fixtures (Compact): 71–100 Lamp Watts

Conversion from an Incandescent Fixture

Assumptions

The calculations are for replacement of 300 watts of incandescent lighting with 100 watts of metal halide lighting. The metal halide wattage with ballast is 129 watts. Total installed wattage drops from 0.300 kW to 0.129 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$287

2001 DEER Update Study, CCIG-BLE-07, p. 4-78, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.171 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.173	800
Retail	4,450	0.88	0.179	845
College	3,900	0.68	0.142	767
School	2,150	0.42	0.088	423
Grocery	5,800	0.81	0.173	1,121
Restaurant	4,600	0.68	0.147	905
Health Care/Hospital	4,400	0.74	0.159	888
Hotel/Motel	5,500	0.67	0.131	1,072
Warehouse	3,550	0.84	0.157	643
Process Industrial	6,650	0.99	0.173	1,149
Assembly Industrial	4,400	0.92	0.170	782
All Other	4,500	0.76	0.147	831

Requirements

See application for current requirements.

L190 Interior HID Fixtures (Compact): 71–100 Lamp Watts

Conversion from a Mercury Vapor Fixture

Assumptions

The calculations are for replacement of 175 watts of mercury vapor lighting with 100 watts of metal halide lighting. The mercury vapor wattage with ballast is 200 watts. The metal halide wattage with ballast is 129 watts. Total installed wattage drops from 0.200 kW to 0.129 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$287

2001 DEER Update Study, CCIG-BLE-07, p. 4-78, Xenergy, Oakland, CA.

Noncoincident DemandSsavings

0.071 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.072	332
Retail	4,450	0.88	0.074	351
College	3,900	0.68	0.059	318
School	2,150	0.42	0.037	176
Grocery	5,800	0.81	0.072	465
Restaurant	4,600	0.68	0.061	376
Health Care/Hospital	4,400	0.74	0.066	369
Hotel/Motel	5,500	0.67	0.054	445
Warehouse	3,550	0.84	0.065	267
Process Industrial	6,650	0.99	0.072	477
Assembly Industrial	4,400	0.92	0.071	325
All Other	4,500	0.76	0.061	345

Requirements

See application for current requirements.

L191 Interior HID Fixtures (Pulse Start): 101-175 Lamp Watts

Conversion from an Incandescent Fixture

Assumptions

The calculations are for replacement of 500 watts of incandescent lighting with 175watts of pulse start metal halide lighting. The metal halide wattage with ballast is 208 watts. Total installed wattage drops from 0.500 kW to 0.0.208 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$287

2001 DEER Update Study, CCIG-BLE-07, p. 4-78, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.292 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.296	1,367
Retail	4,450	0.88	0.306	1,442
College	3,900	0.68	0.242	1,310
School	2,150	0.42	0.151	722
Grocery	5,800	0.81	0.296	1,914
Restaurant	4,600	0.68	0.250	1,545
Health Care/Hospital	4,400	0.74	0.272	1,516
Hotel/Motel	5,500	0.67	0.223	1,831
Warehouse	3,550	0.84	0.267	1,099
Process Industrial	6,650	0.99	0.295	1,961
Assembly Industrial	4,400	0.92	0.290	1,336
All Other	4,500	0.76	0.251	1,419

Requirements

See application for current requirements.

L192 Interior HID Fixtures (Pulse Start): 101-175 Lamp Watts

Conversion from a Mercury Vapor Fixture

Assumptions

The calculations are for replacement of 250 watts of mercury vapor lighting with 175 watts of pulse start metal halide lighting. The mercury vapor wattage with ballast is 285 watts. The metal halide wattage with ballast is 208 watts. Total installed wattage drops from 0.285 kW to 0.208 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$287

2001 DEER Update Study, CCIG-BLE-07, p. 4-78, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.077 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.078	360
Retail	4,450	0.88	0.081	380
College	3,900	0.68	0.064	345
School	2,150	0.42	0.040	190
Grocery	5,800	0.81	0.078	505
Restaurant	4,600	0.68	0.066	407
Health Care/Hospital	4,400	0.74	0.072	400
Hotel/Motel	5,500	0.67	0.059	483
Warehouse	3,550	0.84	0.071	290
Process Industrial	6,650	0.99	0.078	517
Assembly Industrial	4,400	0.92	0.077	352
All Other	4,500	0.76	0.066	374

Requirements

See application for current requirements.

L193 Interior HID Fixtures (Pulse Start): 176-250 Lamp Watts
Conversion from an Incandescent Fixture

Assumptions

The calculations are for replacement of 750 watts of incandescent lighting with 250 watts of pulse start metal halide lighting. The metal halide wattage with ballast is 288 watts[TMT1]. Total installed wattage drops from 0.750 kW to 0.288 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$287

2001 DEER Update Study, CCIG-BLE-07, p. 4-78, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.462 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.468	2,162
Retail	4,450	0.88	0.484	2,282
College	3,900	0.68	0.383	2,072
School	2,150	0.42	0.239	1,142
Grocery	5,800	0.81	0.468	3,028
Restaurant	4,600	0.68	0.396	2,444
Health Care/Hospital	4,400	0.74	0.431	2,399
Hotel/Motel	5,500	0.67	0.353	2,897
Warehouse	3,550	0.84	0.423	1,739
Process Industrial	6,650	0.99	0.467	3,103
Assembly Industrial	4,400	0.92	0.459	2,114
All Other	4,500	0.76	0.397	2,245

Requirements

See application for current requirements.

L194 Interior HID Fixtures (Pulse Start): 176-250 Lamp Watts

Conversion from a Mercury Vapor Fixture

Assumptions

The calculations are for replacement of 400 watts of mercury vapor lighting with 250 watts of pulse start metal halide lighting. The mercury vapor wattage with ballast is 454 watts. The metal halide wattage with ballast is 272 watts[TMT2]. Total installed wattage drops from 0.454 kW to 0.272 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$287

2001 DEER Update Study, CCIG-BLE-07, p. 4-78, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.182 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.184	852
Retail	4,450	0.88	0.246	1,161
College	3,900	0.68	0.195	1,054
School	2,150	0.42	0.121	581
Grocery	5,800	0.81	0.238	1,540
Restaurant	4,600	0.68	0.201	1,243
Health Care/Hospital	4,400	0.74	0.219	1,220
Hotel/Motel	5,500	0.67	0.179	1,473
Warehouse	3,550	0.84	0.215	884
Process Industrial	6,650	0.99	0.237	1,578
Assembly Industrial	4,400	0.92	0.233	1,075
All Other	4,500	0.76	0.202	1,142

Requirements

See application for current requirements.

L195 Interior HID Fixtures (Pulse Start): 251-400 Lamp Watts

Conversion from an Incandescent Fixture

Assumptions

The calculations are for replacement of 1000 watts of incandescent lighting with 320 watts of metal halide lighting. The metal halide wattage with ballast is 366 watts[TMT3]. Total installed wattage drops from 1.000 kW to 0.366 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$287

2001 DEER Update Study, CCIG-BLE-07, p. 4-78, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.634 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.642	2,967
Retail	4,450	0.88	0.664	3,132
College	3,900	0.68	0.526	2,843
School	2,150	0.42	0.328	1,568
Grocery	5,800	0.81	0.642	4,155
Restaurant	4,600	0.68	0.543	3,354
Health Care/Hospital	4,400	0.74	0.591	3,292
Hotel/Motel	5,500	0.67	0.484	3,975
Warehouse	3,550	0.84	0.580	2,386
Process Industrial	6,650	0.99	0.640	4,258
Assembly Industrial	4,400	0.92	0.630	2,901
All Other	4,500	0.76	0.544	3,081

Requirements

See application for current requirements.

L196 Interior HID Fixtures (Pulse Start): 251-400 Lamp Watts

Conversion from a Mercury Vapor Fixture

Assumptions

The calculations are for replacement of two 400 watts of mercury vapor lighting with 400 watts [TMT4]of pulse start metal halide lighting. The mercury vapor wattage with ballast is 908 watts. The metal halide wattage with ballast is 425 watts[TMT5]. Total installed wattage drops from 0.908 kW to 0.460 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$287

2001 DEER Update Study, CCIG-BLE-07, p. 4-78, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.483 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.489	2,260
Retail	4,450	0.88	0.506	2,386
College	3,900	0.68	0.401	2,166
School	2,150	0.42	0.250	1,194
Grocery	5,800	0.81	0.489	3,166
Restaurant	4,600	0.68	0.414	2,555
Health Care/Hospital	4,400	0.74	0.450	2,508
Hotel/Motel	5,500	0.67	0.369	3,028
Warehouse	3,550	0.84	0.442	1,818
Process Industrial	6,650	0.99	0.488	3,244
Assembly Industrial	4,400	0.92	0.480	2,210
All Other	4,500	0.76	0.415	2,347

Requirements

See application for current requirements.

L197 Exterior HID Fixtures: 0–100 Lamp Watts

Conversion from an Incandescent Fixture

Assumptions

Exterior lighting operation is assumed to be controlled by combination of a time clock and photocell. Hours of operation for all market sectors are 4,100 hr/yr. The calculations are for replacement of 300 watts of incandescent lighting with a 50:50 split of metal halide and high-pressure sodium lighting. The metal halide lighting has lamp wattage of 100 watts and combined lamp and ballast wattage of 129 watts. The high-pressure sodium lighting has lamp wattage of 70 watts and combined lamp and ballast wattage of 95 watts. The average installed wattage is 112 watts; therefore, total installed wattage drops from 0.300 kW to 0.112 kW. Incremental cost data is based on high pressure sodium technology.

Predominant Market Sectors

All sectors

Product Life

16 years (fixture lifetime)

Incremental Cost

$144

2001 DEER Update Study, CCIG-BLE-06, p. 4-75, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.188 kW

Energy Savings

Savings for all market sectors are 771 kWh per year.

Requirements

See application for current requirements.

L198 Exterior HID Fixtures: 0–100 Lamp Watts

Conversion from a Mercury Vapor Fixture

Assumptions

Exterior lighting operation is assumed to be controlled by combination of a time clock and photocell. Hours of operation for all market sectors are 4,100 hr/yr. The calculations are for replacement of 175 watts of mercury vapor lighting with a 50:50 split of metal halide and high-pressure sodium lighting. The mercury vapor baseline has a lamp and ballast wattage of 200 watts. The metal halide lighting has a lamp wattage of 100 watts and a lamp and ballast wattage of 129 watts. The high-pressure sodium lighting has a lamp wattage of 70 watts and a lamp and ballast wattage of 95 watts. The average installed wattage is 112 watts; therefore, total installed wattage drops from 0.200 kW to 0.112 kW. Incremental cost data is based on high pressure sodium technology.

Predominant Market Sectors

All sectors

Product Life

16 years (fixture lifetime)

Incremental Cost

$144

2001 DEER Update Study, CCIG-BLE-06, p. 4-75, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.088 kW

Energy Savings

Savings for all market sectors are 361 kWh per year.

Requirements

See application for current requirements.

L199 Exterior HID Fixtures: 101–175 Lamp Watts

Conversion from an Incandescent Fixture

Assumptions

Exterior lighting operation is assumed to be controlled by combination of a time clock and photocell. Hours of operation for all market sectors are 4,100 hr/yr. The calculations are for replacement of 500 watts of incandescent lighting with a 50:50 split of metal halide and high-pressure sodium lighting. The metal halide lighting has a lamp wattage of 175 watts and a lamp and ballast wattage of 210 watts. The high-pressure sodium lighting has a lamp wattage of 100 watts and a lamp and ballast wattage of 130 watts. The average installed wattage is 170 watts. Total installed wattage drops from 0.500 kW to 0.170 kW. Incremental cost data is based on high pressure sodium technology.

Predominant Market Sectors

All sectors

Product Life

16 years (fixture life)

Incremental Cost

$144

2001 DEER Update Study, CCIG-BLE-06, p. 4-75, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.330 kW

Energy Savings

Savings for all market sectors are 1353 kWh per year.

Requirements

See application for current requirements.

L200 Exterior HID Fixtures: 101–175 Lamp Watts

Conversion from a Mercury Vapor Fixture

Assumptions

Exterior lighting operation is assumed to be controlled by combination of a time clock and photocell. Hours of operation for all market sectors are 4,100 hr/yr. The calculations are for replacement of 250 watts of mercury vapor lighting with a 50:50 split of metal halide and high-pressure sodium lighting. The base case mercury vapor has a lamp and ballast wattage of 285 watts. The metal halide lighting has a lamp wattage of 175 watts and a lamp and ballast wattage of 210 watts. The high-pressure sodium lighting has a lamp wattage of 100 watts and a lamp and ballast wattage of 130 watts. The average installed wattage is 170 watts. Total installed wattage drops from 0.285 kW to 0.170 kW. Incremental cost data is based on high pressure sodium technology.

Predominant Market Sectors

All sectors

Product Life

16 years (fixture life)

Incremental Cost

$144

2001 DEER Update Study, CCIG-BLE-06, p. 4-75, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.115 kW

Energy Savings

Savings for all market sectors are 472 kWh per year.

Requirements

See application for current requirements.

L201 Exterior HID Fixtures: ≥176 Lamp Watts

Conversion from an Incandescent Fixture

Assumptions

Exterior lighting operation is assumed to be controlled by combination of a time clock and photocell. Hours of operation for all market sectors are 4,100 hr/yr. The calculations are for replacement of 750 watts of incandescent lighting with a 50:50 split of metal halide and high-pressure sodium lighting. The metal halide lighting has a lamp wattage of 250 watts and a lamp and ballast wattage of 295 watts. The high-pressure sodium lighting has a lamp wattage of 200 watts and a lamp and ballast wattage of 240 watts. The average installed wattage is 268 watts. Total installed wattage drops from 0.750 kW to 0.268 kW. Incremental cost data is based on high pressure sodium technology.

Predominant Market Sectors

All sectors

Product Life

16 years

Incremental Cost

$144

2001 DEER Update Study, CCIG-BLE-06, p. 4-75, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.482 kW

Energy Savings

Savings for all market sectors are 1,976 kWh per year.

Requirements

See application for current requirements.

L202 Exterior HID Fixtures: ≥176 Lamp Watts

Conversion from a Mercury Vapor Fixture

Assumptions

Exterior lighting operation is assumed to be controlled by combination of a time clock and photocell. Hours of operation for all market sectors are 4,100 hr/yr. The calculations are for replacement of 400 watts of mercury vapor lighting with a 50:50 split of metal halide and high-pressure sodium lighting. The base case mercury vapor has a lamp and ballast wattage of 454 watts. The metal halide lighting has a lamp wattage of 250 watts and a lamp and ballast wattage of 295 watts. The high-pressure sodium lighting has a lamp wattage of 200 watts and a lamp and ballast wattage of 240 watts. The average installed wattage is 268 watts. Total installed wattage drops from 0.454 kW to 0.268 kW. Incremental cost data is based on high pressure sodium technology.

Predominant Market Sectors

All sectors

Product Life

16 years

Incremental Cost

$144

2001 DEER Update Study, CCIG-BLE-06, p. 4-75, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.186 kW

Energy Savings

Savings for all market sectors are 763 kWh per year.

Requirements

See application for current requirements.

G. Ceramic Metal Halide Fixtures

FOR REFERENCE ONLY L208 Interior T8, or HO T5 Lamp Fixtures 36-70 Lamp Watts

Conversion from an Incandescent Fixture

Assumptions

The calculations are for replacement of 300 watts of incandescent lighting with 54 watts of high output (HO) T5 fluorescent lighting. The one-lamp HOT5 lamp-ballast system is 59 watts. Total installed wattage drops from 0.300 kW to 0.059 kW.

The efficacy of T5 and T8 lamps and ballasts is essentially the same. Since this measure addresses fixtures, T8s can be incorporated by presuming that replacement T8 fixtures will have proportionately more lamps to match the light output of the similar T5 fixture.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$239

2001 DEER Update Study, CCIG-BLE-04, p. 4-68, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.241 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.244	1,128
Retail	4,450	0.88	0.252	1,190
College	3,900	0.68	0.200	1,081
School	2,150	0.42	0.125	596
Grocery	5,800	0.81	0.244	1,580
Restaurant	4,600	0.68	0.206	1,275
Health Care/Hospital	4,400	0.74	0.225	1,251
Hotel/Motel	5,500	0.67	0.184	1,511
Warehouse	3,550	0.84	0.221	907
Process Industrial	6,650	0.99	0.243	1,619
Assembly Industrial	4,400	0.92	0.239	1,103
All Other	4,500	0.76	0.207	1,171

Requirements

See application for current requirements.

L212 Interior T8, or HO T-5 Lamp Fixture: 36-70 Lamp Watts

Conversion from a Mercury Vapor Fixture

Assumptions

The calculations are for replacement of 175 watts of mercury vapor lighting with 54 watts of high output (HO) T-5 fluorescent lighting. The mercury vapor wattage with ballast is 215 watts. The one-lamp HO T-5 system wattage is 59 watts. Total installed wattage drops from 0.215 kW to 0.059 kW.

The efficacy of T5 and T8 lamps and ballasts is essentially the same. Since this measure addresses fixtures, T8s can be incorporated by presuming that replacement T8 fixtures will have proportionately more lamps to match the light output of the similar T5 fixture.**Predominant Market Sectors**

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$239

2001 DEER Update Study, CCIG-BLE-04, p. 4-68, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.156 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.158	730
Retail	4,450	0.88	0.163	771
College	3,900	0.68	0.129	700
School	2,150	0.42	0.081	386
Grocery	5,800	0.81	0.158	1,022
Restaurant	4,600	0.68	0.134	825
Health Care/Hospital	4,400	0.74	0.145	810
Hotel/Motel	5,500	0.67	0.119	978
Warehouse	3,550	0.84	0.143	587
Process Industrial	6,650	0.99	0.158	1,048
Assembly Industrial	4,400	0.92	0.155	714
All Other	4,500	0.76	0.134	758

Requirements

See application for current requirements.

L210 Interior T8, or HO T-5 Lamp Fixtures: 101-175 Lamp Watts

Conversion from an Incandescent Fixture

Assumptions

The calculations are for replacement of 500 watts of incandescent lighting with 108 watts of high output (HO) T-5 fluorescent lighting. The two-lamp HO T-5 system wattage is 117 watts. Total installed wattage drops from 0.500 kW to 0.117 kW.

The efficacy of T5 and T8 lamps and ballasts is essentially the same. Since this measure addresses fixtures, T8s can be incorporated by presuming that replacement T8 fixtures will have proportionately more lamps to match the light output of the similar T5 fixture.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$250

2001 DEER Update Study, CCIG-BLE-04, p. 4-70, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.383 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.388	1,792
Retail	4,450	0.88	0.401	1,892
College	3,900	0.68	0.318	1,718
School	2,150	0.42	0.198	947
Grocery	5,800	0.81	0.388	2,510
Restaurant	4,600	0.68	0.328	2,026
Health Care/Hospital	4,400	0.74	0.357	1,989
Hotel/Motel	5,500	0.67	0.293	2,401
Warehouse	3,550	0.84	0.351	1,441
Process Industrial	6,650	0.99	0.387	2,572
Assembly Industrial	4,400	0.92	0.381	1,753
All Other	4,500	0.76	0.329	1,861

Requirements

See application for current requirements.

L214 Interior T8, or HO T-5 Lamp Fixtures (Standard): 101-175 Lamp Watts Conversion from a Mercury Vapor Fixture

Assumptions

The calculations are for replacement of 250 watts of mercury vapor lighting with 108 watts of high output (HO) T5 lighting. The mercury vapor wattage with ballast is 290 watts. The two-lamp HOT5 system wattage is 117 watts. Total installed wattage drops from 0.290 kW to 0.117 kW.

The efficacy of T5 and T8 lamps and ballasts is essentially the same. Since this measure addresses fixtures, T8s can be incorporated by presuming that replacement T8 fixtures will have proportionately more lamps to match the light output of the similar T5 fixture.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$250

2001 DEER Update Study, CCIG-BLE-04, p. 4-70, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.173 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy avings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.175	810
Retail	4,450	0.88	0.181	855
College	3,900	0.68	0.144	776
School	2,150	0.42	0.089	428
Grocery	5,800	0.81	0.175	1,134
Restaurant	4,600	0.68	0.148	915
Health Care/Hospital	4,400	0.74	0.161	898
Hotel/Motel	5,500	0.67	0.132	1,085
Warehouse	3,550	0.84	0.158	651
Process Industrial	6,650	0.99	0.175	1,162
Assembly Industrial	4,400	0.92	0.172	792
All Other	4,500	0.76	0.149	841

Requirements

See application for current requirements.

H. L292 Interior T8, or Standard 400 Metal Halide to High Bay HO T-5

Technical Documentation:

High Output Four Lamp T-5 Fixtures are used in high bay applications with a minimum 20’ mounting height (e.g. warehouses, manufacturing). These fixtures replace existing 400W standard metal halides fixtures. Existing incandescent and mercury vapor fixtures with a minimum of 400W also qualify. To qualify, new four-lamp high output (HO) T-5 fixtures will have a maximum wattage equal to 244 watts, must be hardwired, and must have a reflector with a minimum of 90% reflectivity.

The efficacy of T5 and T8 lamps and ballasts is essentially the same. Since this measure addresses fixtures, T8s can be incorporated by presuming that replacement T8 fixtures will have proportionately more lamps to match the light output of the similar T5 fixture.

Assumptions

Metal halide wattage with ballast is 458 watts;

Four-lamp HO T-5 system wattage is 234 watts; and

Total installed wattage drops from 0.458 kW to 0.234 kW.

Predominant Market Sectors

Warehouse, Process Industrial, Assembly Industrial

Product Life

16 years (fixture life)

Cost

$250 (materials cost is $220, including lamp, installation $30)

Incremental Cost

Incremental cost equals the full cost

Noncoincident Demand Savings

0.224 kW per fixture

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below and are per fixture.

Energy Savings

Energy savings vary by sector and because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below and are per fixture.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.227	1,048
Retail	4,450	0.88	0.235	1,106
College	3,900	0.68	0.186	1,005
School	2,150	0.42	0.116	554
Grocery	5,800	0.81	0.227	1,468
Restaurant	4,600	0.68	0.192	1,185
Health Care/Hospital	4,400	0.74	0.209	1,163
Hotel/Motel	5,500	0.67	0.171	1,404
Warehouse	3,550	0.84	0.205	843
Process Industrial	5300	0.78	0.210	1,504
Assembly Industrial	4900	0.80	0.215	1,025
All Other	4,500	0.76	0.192	1,089

I. L293 Interior Metal Halide Pulse Start Retrofit Fixtures: Conversion from a Standard 400W Metal Halide Fixture[TMT6]

Assumptions

The calculations are for replacement of 400 watts of standard (non pulse start) lighting with 320 watts of pulse start metal halide lighting. The standard metal halide wattage with ballast is 460 watts. The pulse start metal halide wattage with ballast is 349 watts[TMT7]. Total installed wattage drops from 0.460 kW to 0.349 kW.

Predominant Market Sectors

School, college, warehouse, assembly and process industries, and retail

Product Life

16 years (fixture life)

Incremental Cost

$287

2001 DEER Update Study, CCIG-BLE-07, p. 4-78, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.111 kW

Coincident Demand Savings

Coincident demand savings vary by sector because of differences in usage patterns. All values are shown in the table below.

Energy Savings

Energy savings vary by sector because of differences in operating hours. Annual energy savings adjusted for sector-specific interactive effects are given in the table below.

Market Sector	Annual Operating Hours	Coincident Diversity Factor	Coincident kW	Annual kWh Savings
Office	4,000	0.81	0.112	519
Retail	4,450	0.88	0.116	548
College	3,900	0.68	0.092	498
School	2,150	0.42	0.057	274
Grocery	5,800	0.81	0.112	727
Restaurant	4,600	0.68	0.095	587
Health Care/Hospital	4,400	0.74	0.103	576
Hotel/Motel	5,500	0.67	0.085	696
Warehouse	3,550	0.84	0.102	418
Process Industrial	6,650	0.99	0.112	746
Assembly Industrial	4,400	0.92	0.110	508
All Other	4,500	0.76	0.095	539

Requirements

See application for current requirements.

J. Occupancy Sensors

Technology Description

Infrared or ultrasonic motion detection devices turn lights on upon entry of a person into a room, and then turn the lights off from ½ minute to 20 minutes after they have left. Occupancy sensors are reliable market-tested products, but require proper installation and calibration. They are analyzed below based on the mounting type.

L82 Occupancy Sensors: Wallbox-Mounted Sensor

Assumptions

For this calculation, the occupancy sensor is assumed to control three 4-foot 2-lamp fluorescent fixtures with 34 watt, T-12 lamps and energy saving magnetic ballasts (72 watts per fixture including ballast). The location that is modeled is a private office space. Without the occupancy sensor, lights are assumed to burn during building hours of operation (60 hours/week for 50 weeks/year) and be manually switched off 15% of the time, for a total of 2,550 hours/year. It is assumed that the office occupant spends six hours per day in the office for 50 weeks/yr, (1,500 hours/year) so that the occupancy sensor turns off lights for 1,050 hours/year (41% reduction over manual switching). Note that the coincident diversity factor (CDF) is not used in savings calculations, as the assumptions listed in this paragraph already account for the fact that not all of the savings will occur during the peak period.

Predominant Market Sectors

Office buildings

Product Life

8 years

Incremental Cost

$56

2001 DEER Update Study, CCIG-BLC-01, p. 4-52, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.089 kW when controls shut off equipment (0.216 kW x 0.41 reduction in hours).

Coincident Demand Savings

0.111 kW (0.089 kW x 1.25 average office sector Demand Interactive Effects)

Energy Savings

Savings for all market sectors are 266 kWh per year, including 17% average office sector Energy Interactive Effects.

Requirements

Only hardwired, passive infrared and/or ultrasonic detectors are eligible. Sensor must control interior lighting fixtures. Wallbox-mounted sensors must not control more than 350 watts.

L83 Occupancy Sensors: Wall- or Ceiling-Mounted Sensor

Assumptions

For this calculation, the occupancy sensor is assumed to control eight 4-foot 2-lamp fluorescent fixtures with 34 watt, T-12 lamps and energy saving magnetic ballasts (72 watts per fixture including ballast). The location that is modeled is a small conference room. Without the occupancy sensor, lights are assumed to burn 2,600 hours/year (50 hour/week for 52 weeks/year) and be manually switched off 15% of the time, for a total of 2,210 hours/year. It is assumed that the room is used only four hours/day (1,040 hours/year) and therefore the occupancy sensor turns off lights for 1,170 hours/year over the base case (45% reduction over manual switching). Note that the coincident diversity factor (CDF) is not used in savings calculations, as the assumptions listed in this paragraph already account for the fact that not all of the savings will occur during the peak period.

Predominant Market Sectors

All sectors

Product Life

8 years

Incremental Cost

$141

2001 DEER Update Study, CCIG-BLC-01, p. 4-52, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.305 kW when controls shut off equipment (0.576 kW x 0.53 reduction in hours)

Coincident Demand Savings

0.381 kW (0.305 kW x 1.25 average office sector Demand Interactive Effects)

Energy Savings

Savings for all market sectors are 789 kWh per year, including 17% average office sector Energy Interactive Effects.

Requirements

Only hardwired, passive infrared and/or ultrasonic detectors are eligible. Wall – or ceiling-mounted sensors must control not more than 1,000 watts.

L65 Occupancy Sensors: Plug Load Sensor

Assumptions

For this calculation, the occupancy sensor is assumed to control 50 Watts of task lighting and a 100-watt computer monitor. The location that is modeled is a private office or cubicle space. Without the occupancy sensor, this equipment is assumed to be on during the 2,500 hours of building operation (50 hours/week for 50 weeks/year) and left on 20% of the time when the occupant leaves for evenings or weekends (1,200 hours, or 24 hours per week for 50 weeks/year). The total time that equipment is on during the year is 3,700 hours (2,500 +1,200). It is assumed that the office occupant spends five hours per day in the office for 50 weeks/yr, (1,250 hours/year) so that the occupancy sensor turns off equipment for 2,450 hours/year (66% reduction over manual switching). Note that the coincident diversity factor (CDF) is not used in savings calculations, as the assumptions listed in this paragraph already account for the fact that not all of the savings will occur during the peak period.

Predominant Market Sectors

Office buildings

Product Life

8 years

Incremental Cost

$20

Noncoincident Demand Savings

0.099 kW when controls shut off equipment (0.150 kW x 66% reduction in hours)

Coincident Demand Savings

0.124 kW (0.099 kW x 1.25 average office sector Demand Interactive Effects)

Energy Savings

Savings for all market sectors are 290 kWh per year, including 17% average office sector Energy Interactive Effects. The predominant application will be in office buildings.

Requirements

See application for current requirements.

K. L36 Photocell

Technology Description

Photocells can be used to automatically control both outdoor lamps and indoor lamps adjacent to skylights and windows. When lights do not need to be on all night, a photocell in series with a time clock provides maximum savings and eliminates the need for manual operation and seasonal time clock adjustments.

Assumptions

Outside lights controlled by a photocell in conjunction with a time clock operate approximately 4,100 hours per year. Without the photocell, the time clock would operate the light for an additional 280 hours/year (approximately 3 months at 3 hours per day). For this calculation, the photocell is assumed to control four 70-watt (95 watts each including ballast), high-pressure sodium lamps that provide exterior lighting.

Predominant Market Sectors:

All sectors

Product Life

8 years

Cost

$10. The incremental cost was calculated based on a data search of PG&E's MDSS database. The 1,038 photocells purchased in 1994 under the Retrofit Express program had an average installed cost of $9.67.

Incremental Cost

$10

Noncoincident Demand Savings

0.380 kW when controls shut off equipment

Coincident Demand Savings

0.000 kW

Energy Savings

Savings for all market sectors are 106 kWh per year.

Requirements

See application for current requirements.

L. L31 Time Clocks

Technology Description

Time clocks enable users to turn on and off electrical equipment at specific times during the day or week.

Assumptions

For this calculation, the time clock is assumed to control four 70 watt (95 watts each including ballast), high-pressure sodium lamps that provide exterior lighting. The time clock is used to turn the lights off during the day on weekends. Without the time clock, lights are assumed to burn 12 hours/day on weekdays and 24 hours a day on weekends, for a total of 5,628 hrs/year. With the time clock, the lights will burn 12 hours/day each day, for a total of 4,380 hours/year, which is 1,248 hours/year less than the base case. In actual practice, lights may not be turned off for 12 hours during the week and therefore the savings estimates presented below are conservative.

Predominant Market Sectors

All sectors

Product Life

8 years

Incremental Cost

$100

2001 DEER Update Study, CCIG-CLC-03, p. 4-55, Xenergy, Oakland, CA.

Noncoincident Demand Savings

0.380 kW when controls shut off equipment

Coincident Demand Savings

0.000 kW

Energy Savings

Savings for all market sectors are 474 kWh per year.

Requirements

Time clock must control lighting equipment.

L166 (Application Code A) Exit Sign Retrofit Kit

Technology Description

Incandescent exit signs are extremely inefficient and operate continuously. Light emitting diode (LED), and super efficient fluorescent (such as T-1s) exit signs are more efficient alternatives. Retrofit kits are available to upgrade existing incandescent fixtures, with any number of approved technologies, given they meet the 10 year life, 8.6 candela luminance, and 5 Watt maximum power per face requirements, and are ENERGY STAR certified.

Assumptions

The calculations assume that an exit sign fixture containing two 20-watt incandescent lamps is converted to an LED fixture. Total installed wattage drops from 0.040 kW to 0.004 kW.

Predominant market sectors

All market sectors. Even though California's Appliance Standard, Title 20, effective March 1, 2003, requires that only ENERGY STAR equivalent exit signs be sold for new or replacement applications, building owners can still replace the lamps in existing Exit signs. This rebate measure is intended to influence the conversion of existing exit signs to high efficiency light sources with lamp retrofit kits, or the replacement of old exit signs with new ENERGY STAR compliant ones, in lieu of simple lamp replacement.

Product life

16 years is the assumed fixture life. These systems operate continuously over the 16 year period, requiring many baseline system lamp replacements during each lifetime.

Cost

Exit sign LED retrofit kit: $38/fixture ($25 for the original equipment and $13 in labor to complete each installation)

Incandescent equipment baseline replacement cost: $0.38 per lamp.

(Source: 2001 DEER Update Study, CCIG: CLE-03, pages 4-60 and 4-56).

Incremental cost

-$23.04 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Noncoincident demand savings

0.036 kW

Noncoincident demand savings with interactive effects

0.042 kW (based on average Demand Interactive Effects of 1.18)

Coincident demand and energy savings

Fire code requires exit lights to operate 8,760 hrs/yr. Therefore, energy savings for all market sectors will be 0.036 kW x 8760 hrs x 1.114 = 351 kWh per year (includes 11.4% average Energy Interactive Effects). Coincident demand savings will be 0.042 kW × 1.0 = 0.042 kW.

Requirements

See application for current requirements.

M. L137 High Efficiency Exit Sign

Technology Description

Light emitting diode (LED), and super efficient fluorescent (such as T-1s) exit signs (and possibly others) are all approved technologies, given they meet the 10 year life, 8.6 candela luminance, and 5 Watt maximum power per face requirements, and are ENERGY STAR certified.

Light emitting diodes (LEDs) use solid state circuits rather than conventional incandescent or fluorescent lamps. The advantages are reduced energy consumption and extremely long lamp lifetimes.

Assumptions

The calculations assume that an exit sign fixture containing two 20-watt incandescent lamps is replaced with a new LED fixture. Total installed wattage drops from 0.040 kW to 0.004 kW.

Predominant market sectors

All market sectors

Product life

16 years is the assumed fixture life. These systems operate continuously over the 16 year period, requiring many baseline system lamp replacements during each lifetime.

Cost

New LED exit sign: $111/fixture ($48 for the original equipment and $63 in labor to complete each installation)

Incandescent equipment baseline replacement cost: $0.38 per lamp.

(Source: 2001 DEER Update Study, CCIG: CLE-03, pages 4-60 and 4-56).

Incremental cost

$49.96 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Noncoincident demand savings

0.036 kW

Noncoincident demand savings with interactive effects

0.042 kW (based on average Demand Interactive Effects of 1.18)

Coincident demand and energy savings

Fire code requires exit lights to operate 8,760 hrs/yr. Therefore, energy savings for all market sectors will be 0.036 kW x 8760 hrs x 1.114 = 351 kWh per year (includes 11.4% average Energy Interactive Effects). Coincident demand savings will be 0.042 kW × 1.0 = 0.042 kW.

Requirements

See application for current requirements.

N. L282 thru L289 Channel Sign Light Emitting Diode (LED)

Technology Description

Channel signage is similar to the illuminated signs found inside and outside shopping malls to identify store names. Typically these signs are constructed from sheet metal sides forming the shape of the letters and a translucent plastic lens. Luminance is most commonly provided by single or double strip neon lamps, powered by neon sign transformers. Retrofit kits are available to upgrade existing signage from neon to LED light sources, substantially reducing the electrical power and energy required for equivalent sign luminance. Red, green, blue, yellow, and white LED’s are available, but at higher cost than red. Red is the most common color and the most cost-effective to retrofit, currently comprising about 80% of the market. To provide an incentive for market transformation, and be consistent with the approach taken in LED traffic signals, this program proposes initially to pay double rebate levels for colors other than red.

Assumptions

The calculations assume that channel signage 2 feet high or less is lighted by a single neon lamp of length equivalent to the length of the letter. To provide for even luminance and acceptable aspect ratio, signs greater than 2 feet high are lighted by a double strip of neon lamps.

Neon lamps are powered by 456 watt high voltage neon transformers providing low current at 12,000 to 15,000 volts. The input power is reasonably constant for 20 to 40 foot lamp lengths at 3.8 amps at 120 volts, or 456 watts. Using a typical lamp system length of 40 feet, the power dissipation for neon lamp systems is nominally 11.4 watts per foot for signs 2 feet high and under, and 22.8 watts per foot for signs greater than 2 feet high.

Red LEDs installed to provide equivalent luminance operate on low voltage and power demand in the range of 0.9 to 1.2 watts per foot, conservatively offering a demand reduction of 10 watts per linear foot of sign for signs 2 feet high and under, and 20 watts per linear foot for signs greater than2 feet high. Other LED colors demand slightly more or less power, ranging from 0.5 watts per foot to 2 watts per foot for equivalent luminance. In any case, LEDs demand significantly less power than neon lamps.

Predominant Market Sectors

Commercial market sector

Product Life

16 years: LEDs are rated at 100,000 hours of operation, which, at 12 hours of operation per day, is 22.8 years. For consistency with other programs and consideration of other sign components, effective useful life is assumed to be 16 years. This is also consistent with the *CALMAC Workshops on 2001 Energy Efficiency Programs* report.

Cost

- <=2 feet high: $18/foot installed: $12/foot for the LEDs and $6/foot for labor
- >2 feet high: $33/foot installed: $24/foot for the LEDs and $9/foot for labor

Incremental Cost

- Retrofit applications: Incremental cost is the full $18/foot and $33/foot cost for the <=2 feet and >2 feet high sign respectively.
- Sign replacement applications: Incremental cost is just the $12/foot and $24/foot LED cost for the <=2 feet and >2 feet high sign respectively, as it is assumed that the sign will be replaced anyway, negating the labor cost. It is assumed there is no difference in maintenance cost over the product life. This is a conservative assumption, as low voltage LEDs are inherently more durable than high voltage neon applications.

Noncoincident demand savings

- <=2 feet high: 0.010 kW/foot
- >2 feet high: 0.020 kW/foot

Noncoincident demand savings with interactive effects

- <=2 feet high: 0.010 kW/foot
- >2 feet high: 0.020 kW/foot

Hours of Operation and Coincidence with System Peak

Two categories of applications are proposed for inclusion in the program:

- Indoor signs, such as those inside malls, are estimated to operate, on annual average, from 10 a.m. to 10 p.m., or 12 hours per day. The coincidence factor is estimated to be 1.0.
- Outdoor signs are estimated to operate, on annual average, from 4 p.m. to midnight, or 6 hours per day. The coincidence factor is estimated to be 0.0.

Coincident Demand Savings

Indoor signs:

- <=2 feet high: 0.010 kW/foot
- >2 feet high: 0.020 kW/foot

Outdoor signs:

- <=2 feet high: 0.000 kW/foot
- >2 feet high: 0.000 kW/foot

Annual Energy Savings

Indoor signs:

- <=2 feet high: 43.8 kWh/foot (10 watts X 12 hours X 365 days/1000)
- >2 feet high: 87.6 kWh/foot

Outdoor signs:

- <=2 feet high: 21.9 kWh/foot (10 watts X 6 hours X365 days/1000)
- >2 feet high: 43.8 kWh/foot

Rebate Structure

Rebate levels are to be determined and will depend on the combination of the following parameters:

- Retrofit or replacement
- <=2 feet height or >2 feet height
- Red color or other than red color
- Indoor or outdoor

Requirements

See application for current requirements.

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Application ID: Y. Efficient Lighting System for Display Case Case Lighting Electronic Ballast
Measure ID: R10

Technology Description

Electronic ballasts have become very popular in office and retail lighting systems due to utility incentive programs. Lighting systems in refrigeration display cases are almost immune to this trend with a typical case containing standard core and coil ballasts. One reason is that the starting temperature of these applications can be as low as -20° F. Typically medium temperature cases have 800 ma 48", 60", or 72" lamps. Low temperature cases typically have 1500 ma 48", 60", or 72" lamps. Replacing standard ballasts with electronic ballasts or installing electronic ballasts in new cases will have direct energy savings within the lighting system. It is not known how this affects the heat load to the case, since not all of the energy is transferred into conductive and convective heat. It is also thought that the design of the electronic ballast would try to maintain the bulb wall temperature to optimize light output.

This is a new technology that offers significant promise when compared to the success of electronic ballasts in the office and retail markets after years of non-acceptance. There are a few companies that offer electronic ballasts for the application of refrigeration cases, but the ballasts have not been marketed diligently.

The primary objective of this rebate measure is to stimulate an overlooked energy efficiency market segment by commercializing an existing technology for a different application. A second goal is to encourage the use of multi-lamp ballasts in refrigeration cases (currently the majority of cases have single-lamp ballasts).

Measure Savings

Although it is believed that most refrigeration display cases contain standard core and coil ballasts, the energy savings are conservatively determined by comparing the electronic ballast to the new energy saving ballast required by California's Title 20. Because this is a new emerging application of electronic ballasts, exact numbers for ballast wattage with many of the combinations seen in display cases could not be found. Therefore the savings methodology determines average savings ratio for 72" and 96" lamps and applies this ratio to 48", 60", and 72" lamps. This is not the preferred method, but until the market is further developed, there appears to be no better alternative than using averages and making conservative assumptions.

Assumptions

[There is a problem here – I have been informed that 1500ma ballasts are NOT used in cases, they power VHO lamps for big signs. Where did the savings assumptions come from]

- Majority of cases have single lamp ballasts (Anthony & Ardco price books)
- Same model ballast will run (1) F96HO, (1) F72HO, (1) F60HO, and (2) F48HO (based on review of various manufacturers' catalogs)
- Lamps and ballasts are rated at 95% of maximum wattage at 78° F (IES, 1984, pp.8-29)
- Average low temperature case is -10° F, medium temperature case is +20° F
- Protective sleeve covers will increase bulb wall temperature 10° F above case temperature Lamp temperature would then be assumed to be 0^{o}F and $+30^{o}$F
- Lamps and ballasts draw 65% of maximum wattage at 0° F, 70% of maximum wattage at +30° F (IES, 1984, pp. 8-29, fig. 8-34 (top))
- 80% of light systems in display cases run 24 hrs/day, 365 days/year
- 20% of light systems in display cases are EMS controlled and run 16 hrs/day, 365 days/yr.
- The majority of the participants will be for new cases

Calculations

m-amps	# of Lamps	Type	Lamp Watts	Standard Ballast Total Watts	EE Ballast Total Watts	% Change	Electronic Ballast Total Watts	EE vs. Elec. %	EE vs Elec. Watts Saved/ Lamp
800	1	F48	60	75	72	4.0%			
	2	F48	60	140	136	2.9%			
	1	F72	85	106	102	3.8%	75	26.5%	27
	1	F96	110	130	123	5.4%	95	22.8%	28
	2	F96	110	250	241	3.6%	190	21.2%	26
	1	F96	95	112	106	5.4%	80	24.5%	26
	2	F96	95	216	210	2.8%	160	23.8%	25
					Averages =	4.2%		23.7%	26
1500	1	F96	215	230	227	1.3%	200	11.9%	27
	2	F96	215	470	446	5.1%	400	10.3%	23
	1	F96	195	209	206	1.4%	180	12.6%	26
	2	F96	195	408	404	1.0%	350	13.4%	27
					Averages =	2.2%		12.0%	26

- Assume a 4.5% off gain from standard to EE ballast and 20% gain from EE to electronic for 800 ma if data is not available.
- Assume a 2.5% off gain from standard to EE ballast and 10% gain from EE to electronic for 1500 ma if data is not available.

m-amps	# of Lamps	Type	Lamp Watts	Min. Temp	Stnd Ballast Total Watts	EE Ballast Total Watts	Watts Saved	Electronic Ballast Total Watts	EE vs Elec Watts Saved	Savings per Lamp
800	2	F48	60	-20	140	134	6	107	27	13
	1	F60	74	-20	100	96	5	76	19	19
	1	F72	85	-20	106	102	4	75	27	27
					Averages =	115	5	92	23	16
1500	2	F48	116	-20	241	235	6	211	23	12
	1	F60	138	-20	157	153	4	138	15	15
	1	F72	168	-20	181	176	5	159	18	18
					Averages =	194	5	175	19	14

By applying a temperature correction factor for lamps operating at low temperatures to the results from spreadsheet attached at the end of the documentation for this measure, the average savings per lamp were determined to be:

Medium temperature cases, 800ma = 16 watts/lamp * 70%/95% = 11.8 watts/lamp
Low temperature cases, 1500 ma = 14 watts/lamp * 65%/95% = 9.6 watts/lamp
Average savings = 10.7 watts
Demand savings = 0.0107 kW/lamp
Average operating hours = (80% * 8760) + (20% * 16 * 365) = 8176 hours/yr
Energy savings = 0.0107 kW * 8176 hrs/yr = 87.5 kWh/lamp

Measure Life

16 years (California Public Utilities Commission *Energy Efficiency Policy Manual* Version 1 Prepared by the Energy Division October 2001)

Measure Cost

$14/lamp for single-lamp ballast. This is the incremental material cost between an energy-efficient magnetic ballast and an electronic ballast. Only incremental material cost was considered since it is believed that most participation will be for new cases. The cost information was provided by Russ Penrose, Pacific Gas and Electric Company's lighting program sponsor who developed the Retrofit Express Lighting program. The cost was derived by taking the average incremental cost of an electronic ballast ($10) and increasing it by 40% since this is an undeveloped market.

Conditions

Must install fully electronic ballasts to control lights in a refrigeration display case. Ballast must have a maximum total harmonic distortion of 32%. Rebate is available only for 800 mA and 1500 mA (or equivalent) ballast. Rebate is based on the number of lamps controlled.

Summary

kWh/yr-lamp controlled.	88
kW/lamp controlled, non-coincident	0.011
kW/lamp controlled, coincident	0.009, using 0.81 coincident diversity factor for lighting, grocery market sector
Life	16 years
Cost	$14/lamp controlled

L166 (Application Code A) Exit Sign Retrofit Kit

Technology Description

Incandescent exit signs are extremely inefficient and operate continuously. Light emitting diode (LED), and super efficient fluorescent (such as T-1s) exit signs are more efficient alternatives. Retrofit kits are available to upgrade existing incandescent fixtures, with any number of approved technologies, given they meet the 10 year life, 8.6 candela luminance, and 5 Watt maximum power per face requirements, and are ENERGY STAR certified.

Assumptions

The calculations assume that an exit sign fixture containing two 20-watt incandescent lamps is converted to an LED fixture. Total installed wattage drops from 0.040 kW to 0.004 kW.

Predominant market sectors

All market sectors. Even though California's Appliance Standard, Title 20, effective March 1, 2003, requires that only ENERGY STAR equivalent exit signs be sold for new or replacement applications, building owners can still replace the lamps in existing Exit signs. This rebate measure is intended to influence the conversion of existing exit signs to high efficiency light sources with lamp retrofit kits, or the replacement of old exit signs with new ENERGY STAR compliant ones, in lieu of simple lamp replacement.

Product life

16 years is the assumed fixture life. These systems operate continuously over the 16 year period, requiring many baseline system lamp replacements during each lifetime.

Cost

Exit sign LED retrofit kit: $38/fixture ($25 for the original equipment and $13 in labor to complete each installation)

Incandescent equipment baseline replacement cost: $0.38 per lamp.

(Source: 2001 DEER Update Study, CCIG: CLE-03, pages 4-60 and 4-56).

Incremental cost

-$23.04 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Noncoincident demand savings

0.036 kW

Noncoincident demand savings with interactive effects

0.042 kW (based on average Demand Interactive Effects of 1.18)

Coincident demand and energy savings

Fire code requires exit lights to operate 8,760 hrs/yr. Therefore, energy savings for all market sectors will be 0.036 kW x 8760 hrs x 1.114 = 351 kWh per year (includes 11.4% average Energy Interactive Effects). Coincident demand savings will be 0.042 kW × 1.0 = 0.042 kW.

Requirements
See application for current requirements.

L137 (Application Code A) High Efficiency Exit Sign

Technology Description

Light emitting diode (LED), and super efficient fluorescent (such as T-1s) exit signs (and possibly others) are all approved technologies, given they meet the 10 year life, 8.6 candela luminance, and 5 Watt maximum power per face requirements, and are ENERGY STAR certified.

Light emitting diodes (LEDs) use solid state circuits rather than conventional incandescent or fluorescent lamps. The advantages are reduced energy consumption and extremely long lamp lifetimes.

Assumptions

The calculations assume that an exit sign fixture containing two 20-watt incandescent lamps is replaced with a new LED fixture. Total installed wattage drops from 0.040 kW to 0.004 kW.

Predominant market sectors

All market sectors

Product life

16 years is the assumed fixture life. These systems operate continuously over the 16 year period, requiring many baseline system lamp replacements during each lifetime.

Cost

New LED exit sign: $111/fixture ($48 for the original equipment and $63 in labor to complete each installation)

Incandescent equipment baseline replacement cost: $0.38 per lamp.

(Source: 2001 DEER Update Study, CCIG: CLE-03, pages 4-60 and 4-56).

Incremental cost

$49.96 life-cycle cost-based on a 8.15% annual discount rate. Refer to the Table 8 example and discussion above for details on these life-cycle cost calculations.

Noncoincident demand savings

0.036 kW

Noncoincident demand savings with interactive effects

0.042 kW (based on average Demand Interactive Effects of 1.18)

Coincident demand and energy savings

Fire code requires exit lights to operate 8,760 hrs/yr. Therefore, energy savings for all market sectors will be 0.036 kW x 8760 hrs x 1.114 = 351 kWh per year (includes 11.4% average Energy Interactive Effects). Coincident demand savings will be 0.042 kW × 1.0 = 0.042 kW.

Requirements

See application for current requirements.

L164, L325 (Application Code B) LED Traffic Signals - Replacement of Incandescent Pedestrian Signals

Program Modification for 2003

Effective March 1, 2003, the California Appliance Standard, Title 20, requires that Traffic Signal Modules meet the ENERGY STAR LED Traffic Signal Specification. Further, incandescent traffic signal lamps are limited to 20 Watts or less. The effect of this new regulation, which was developed and sponsored by the utilities, is that all traffic signal lamps must be LED or yet-to-be developed technologies of equivalent energy-efficiency. This appliance standard does not apply to pedestrian heads; therefore, the LED Traffic Signal program category is narrowed to pedestrian heads only. For reference, the workpaper materials concerning traffic signals has been retained here.

Technology Description

A light-emitting diode (LED) is a semiconductor device that uses solid-state electronics to create light. Power is applied to excite the electrons, which in turn emit photons of light. The color composition of the light is determined by the chemical composition of the material between the diodes. These diodes are then packaged in a form suitable for use in traffic signals. Traffic signals that use LEDs consume about 80-90 percent less energy than comparable incandescent light signals.

Anywhere from 18 to 300 or more of these "lamps" can be packaged in an array for use in a signal head. Signals include 8 and 12 inch red, yellow, and green balls, 12 inch red and green arrows, hand only and hand/walking person combination.

Measure Savings

Table 1 below provides a summary of the assumptions for demand reduction and energy savings for each LED signal retrofit. The table includes base case demand, post-retrofit demand, duty cycles, peak kW reduction and annual kWh savings. Energy and demand savings formulas are given below:

Peak Load kW Reduction = (Incandescent Watts - LED Watts) X (kW Duty Cycle) / 1000

Annual kWh Energy Savings = (Incandescent Watts - LED Watts) X (kWh Duty Cycle) X 8760 hours/year / 1000

Demand reduction and energy savings assumptions, including pre- and post-retrofit watts and kW and KWh duty cycles, are from Quantum Consulting's December 2001 *Statewide LED Traffic Signal Saturation Study*. Data reported for PG&E's 2001 program use actual pre- and post-retrofit watts as reported by the participating cities.

Net-to-Gross Ratio

The net-to-gross ratio is 0.96, the value established for the Express program by the CPUC *Energy Efficiency Policy Manual Version 1 Prepared by the Energy Division October 2001*.

Effective Useful Measure Life (EUL)

EUL for traffic signal lighting is assumed to be 10 years, although actual service life is expected to exceed this. This is taken from PG&E's October 1996 Advice Filing. EUL for LED traffic signals was not developed in the public planning process for PY2001, nor published in the *Energy Efficiency Policy Manual* prepared by the Energy Division of the CPUC in October 2001.

Incremental Measure Cost (IMC)

Incremental measure costs are from the 2001 DEER Update Study (DEER), except equipment costs for the hand and hand/walking person combo signals, which are the average equipment costs reported by participating cities in PG&E's 2001 LED Traffic Signal Program. Installation costs are assumed to be $66 per unit for all LED Traffic Signal measures, as reported in DEER. Refer to Table 1 below.

Table 1

Meas. Code	Traffic Signal Type	Pre Watts(1)	Post Watts(1)	Change Watts	kW Duty Cycle(1)	kWh Duty Cycle(1)	Annual Hours	Peak kW Reduction (kW)	Energy Savings (kWh)	Equip. Cost ($)(2)	Labor Cost ($)(2)	Total Installed Cost ($)
L162	Red Arrow - 12 inch	150	9	141	0.80	0.80	8,760	0.1128	988.1	$ 76	$ 66	$ 142
L161	Red Ball - 12 inch	150	11	139	0.55	0.55	8,760	0.0765	669.7	$ 97	$ 66	$ 163
L163	Red Ball - 8 inch	69	8	61	0.55	0.55	8,760	0.0336	293.9	$ 76	$ 66	$ 142
L321	Green Arrow - 12 inch	150	11	139	0.20	0.20	8,760	0.0278	243.5	$ 119	$ 66	$ 185
L320	Green Ball - 12 inch	150	15	135	0.42	0.42	8,760	0.0567	496.7	$ 212	$ 66	$ 278
L322	Green Ball - 8 inch	69	12	57	0.42	0.42	8,760	0.0239	209.7	$ 130	$ 66	$ 196
L323	Yellow Flashing - 12 inch	150	22	128	0.50	0.50	8,760	0.0640	560.6	$ 96	$ 66	$ 162
L324	Yellow Flashing - 8 inch	69	13	56	0.50	0.50	8,760	0.0280	245.3	$ 93	$ 66	$ 159
L164	Hand Only	69	10	59	0.80	0.80	8,760	0.0472	413.5	$ 117	$ 66	$ 183
L325	Hand/Walking Person Combo	69	9	60	0.90	0.90	8,760	0.0540	473.0	$ 196	$ 66	$ 262

(1) Energy data is from *Statewide LED Traffic Signal Saturation Study* , Quantum Consulting Inc., December 2001.
(2) Incremental equipment and labor costs are from the *2001 DEER Update Study* , except equipment costs for Hand Only and Hand/Walking Person Combo measures are the average reported by participating cities in PG&E's 2001 Program.

L282 thru L289 (Application Code C) Light Emitting Diode (LED) Channel Signage Retrofit

Technology Description

Channel signage is similar to the illuminated signs found inside and outside shopping malls to identify store names. Typically these signs are constructed from sheet metal sides forming the shape of the letters and a translucent plastic lens. Luminance is most commonly provided by single or double strip neon lamps, powered by neon sign transformers. Retrofit kits are available to upgrade existing signage from neon to LED light sources, substantially reducing the electrical power and energy required for equivalent sign luminance. Red, green, blue, yellow, and white LED’s are available, but at higher cost than red. Red is the most common color and the most cost-effective to retrofit, currently comprising about 80% of the market. To provide an incentive for market transformation, and be consistent with the approach taken in LED traffic signals, this program proposes initially to pay double rebate levels for colors other than red.

Assumptions

The calculations assume that channel signage 2 feet high or less is lighted by a single neon lamp of length equivalent to the length of the letter. To provide for even luminance and acceptable aspect ratio, signs greater than 2 feet high are lighted by a double strip of neon lamps.

Neon lamps are powered by 456 watt high voltage neon transformers providing low current at 12,000 to 15,000 volts. The input power is reasonably constant for 20 to 40 foot lamp lengths at 3.8 amps at 120 volts, or 456 watts. Using a typical lamp system length of 40 feet, the power dissipation for neon lamp systems is nominally 11.4 watts per foot for signs 2 feet high and under, and 22.8 watts per foot for signs greater than 2 feet high.

Red LEDs installed to provide equivalent luminance operate on low voltage and power demand in the range of 0.9 to 1.2 watts per foot, conservatively offering a demand reduction of 10 watts per linear foot of sign for signs 2 feet high and under, and 20 watts per linear foot for signs greater than2 feet high. Other LED colors demand slightly more or less power, ranging from 0.5 watts per foot to 2 watts per foot for equivalent luminance. In any case, LEDs demand significantly less power than neon lamps.

Predominant Market Sectors

Commercial market sector

Product Life

16 years: LEDs are rated at 100,000 hours of operation, which, at 12 hours of operation per day, is 22.8 years. For consistency with other programs and consideration of other sign components, effective useful life is assumed to be 16 years. This is also consistent with the *CALMAC Workshops on 2001 Energy Efficiency Programs* report.

Cost

- <=2 feet high: $18/foot installed: $12/foot for the LEDs and $6/foot for labor

- >2 feet high: $33/foot installed: $24/foot for the LEDs and $9/foot for labor

Incremental Cost

- Retrofit applications: Incremental cost is the full $18/foot and $33/foot cost for the <=2 feet and >2 feet high sign respectively.
- Sign replacement applications: Incremental cost is just the $12/foot and $24/foot LED cost for the <=2 feet and >2 feet high sign respectively, as it is assumed that the sign will be replaced anyway, negating the labor cost. It is assumed there is no difference in maintenance cost over the product life. This is a conservative assumption, as low voltage LEDs are inherently more durable than high voltage neon applications.

Noncoincident demand savings

- <=2 feet high: 0.010 kW/foot
- >2 feet high: 0.020 kW/foot

Noncoincident demand savings with interactive effects

- <=2 feet high: 0.010 kW/foot
- >2 feet high: 0.020 kW/foot

Hours of Operation and Coincidence with System Peak

Two categories of applications are proposed for inclusion in the program:

- Indoor signs, such as those inside malls, are estimated to operate, on annual average, from 10 a.m. to 10 p.m., or 12 hours per day. The coincidence factor is estimated to be 1.0.
- Outdoor signs are estimated to operate, on annual average, from 4 p.m. to midnight, or 6 hours per day. The coincidence factor is estimated to be 0.0.

Coincident Demand Savings
Indoor signs:

- <=2 feet high: 0.010 kW/foot
- >2 feet high: 0.020 kW/foot

Outdoor signs:

- <=2 feet high: 0.000 kW/foot
- >2 feet high: 0.000 kW/foot

Annual Energy Savings

Indoor signs:

- <=2 feet high: 43.8 kWh/foot (10 watts X 12 hours X 365 days/1000)
- >2 feet high: 87.6 kWh/foot

Outdoor signs:

- <=2 feet high: 21.9 kWh/foot (10 watts X 6 hours X365 days/1000)
- >2 feet high: 43.8 kWh/foot

Rebate Structure

Rebate levels are to be determined and will depend on the combination of the following parameters:

- Retrofit or replacement
- <=2 feet height or >2 feet height
- Red color or other than red color
- Indoor or outdoor

Requirements

See application for current requirements.

L? (Application Code D) Strip Neon, Light Emitting Diodes

Technology Description

Strip Neon is often used indoors and outdoors as an a source of luminance to create visual interest, outline building architectural features, or illuminate parapets or coves. While linear in shape, this LED technology is essentially the same as that used in single stroke channel sign LED replacement for neon.

Other Assumptions, Costs, & Savings

The other assumptions for this measure are exactly the same as Application Code C, Light Emitting Diode (LED) Channel Signage Retrofit, 2 foot height or below.

Refrigeration

The energy consumption by commercial refrigeration systems is a prime target for the statewide Express Efficiency program. These systems have peak loads that are coincident with peak generating demands, operate long hours, and have economically feasible energy efficiency opportunities. A 1992 study by Southern California Edison (SCE) and PG&E (referenced in Shephard et al. 1990) indicates that refrigeration makes up 8.4% of the commercial sector electricity use. Another study indicates that grocery stores consume approximately 85% of commercial refrigeration energy (referenced in Shephard et al. 1990). According to trade allies, the average size of commercial refrigeration systems is increasing at a fast pace. This is attributed to an increase in the variety of prepackaged refrigerated food due to changing lifestyles and the desire to save more time.

The measures featured in the Express Efficiency Refrigeration program focus on reducing the refrigerated load and improving the design and performance of equipment that provides refrigeration. The Express Efficiency Refrigeration program was designed to streamline the process of providing incentives for energy efficiency in the field of commercial refrigeration. The program applies to equipment in existing facilities only.

The remainder of the documentation for the refrigeration retrofit program consists of a discussion of changes to the Express Efficiency refrigeration program in 2001, market applicability and common assumptions used in the engineering analysis, followed by individual analyses of each measure. The documentation for each measure includes a technology description, measure savings, measure life, cost, terms and conditions, and a summary. The results include energy and demand savings. Results are expressed in terms that are normalized by equipment parameters so factors such as equipment size can be used on the incentive application and so incentives are proportional to energy savings.

Changes in the Refrigeration Program for 2003

- The 2003 claimed energy savings are based on the *2001 Express Efficiency New Refrigeration DOE2 Modeling Report* prepared by Design and Engineering Services.
- The measures in the Refrigeration Program remain the same; changes from the 2002 program are minor, involving corrections and improvements to savings and cost calculations..

Measurement and Evaluation Results and Changes

In order to contribute to efforts of statewide uniformity, a Net –to-Gross ratio of 0.80 for refrigeration measures. This is based on study id 567.

Market Applicability

The Refrigeration program is targeted to commercial and industrial refrigeration systems such as grocery stores and cold storage facilities. Commercial refrigeration systems typically use R-12, R-22, and R-502 as their refrigerant.

Industrial refrigeration systems typically use R-717 (ammonia) although other refrigerants, such as R-22, are also found.

Factors that affect the energy usage and savings of refrigeration equipment are: humidity, the condition and efficiency of the existing and proposed equipment, the size and configuration of the refrigerant piping, refrigeration load, infiltration, rotating case stock, and the refrigeration system operating hours. Surprisingly, on a per ton basis, the peak ambient conditions have little to do with the energy usage. A system may be designed for additional tonnage but the energy use per ton is generally the same except for systems that incorporate floating head pressure. If head pressure is allowed to float, the peaks and lows of outside ambient conditions have more of an impact on system EER. Fixed head setting systems simulate the (high ambient) design condition, which is locked in as the optimum operating point. Floating head strategies incorporate balance port expansion valves and surge receiver setups and allow compressor compression ratios to fluctuate along with the varying condensing pressure / outside ambient variances. This fluctuation is generally quantified as 1-degree ambient difference equals 2-degree saturated condensing temperature difference equaling a 0.5% system EER difference.

Assumptions

Participation rates: Throughout the documentation are assumptions on the breakdown of the type of customer or equipment likely to participate in this incentive program. It is important to note that these rates may be different than the existing breakdown of equipment in the field. One such example is display cases with doors. It is recognized that the breakdown of display cases in the field with doors may be close to 70% low temperature and 30% medium temperature, it is felt that the breakdown of display cases that are retrofitting doors to an existing case or replacing an open case with a case with doors is 50/50. The reason is that most low temperature cases already have doors and the trend of putting doors on medium temperature cases is growing.

Unfortunately, many assumptions, especially participation rates of equipment type or size, are not documented in known research reports that can be referenced. These assumptions are based on personal experience, talking with refrigeration engineers within the PG&E system, and some thoughts that are not always obvious. In many cases where an assumption does not have a known reference it is noted that “no known reference exists.” This is to assist the review of the documentation by the Office of Ratepayer Advocates (ORA) and the Lawrence Berkeley Laboratory (LBL) that had previously questioned if any known source of some assumptions existed. However, many of these assumptions have been updated with references from the 1995 paid year M&E studies prepared by Quantum Consulting.

Best Judgment: The format of determining many of the values used in the documentation is to list all known sources, the values listed within that source, and the conditions at which the values exist. Various studies and other types of information sources were investigated and all known sources, with respect to the specific value, are listed. Some of the sources and values listed were more credible or applicable for the given situation - with the intent to stay conservative at all times. With this format, sometimes not all values listed are used or the average may be swayed to the conservative side; in these cases a final representative value was used and said to be the best judgment.

Duty Cycle Demand Savings: In some cases there are obvious demand savings due to implementing energy efficiency measures, such as when an incandescent light is replaced with a fluorescent light. In some cases demand savings are not so obvious, especially when a group of participants is considered. One such case is when the duty cycle time of a piece of equipment is reduced. An energy efficiency measure may directly reduce the cycle time, such as with humidistat controls on anti-condensate heaters, or the cycle time may be reduced due to a reduced load or by adding capacity, as with a compressor. This is called “duty cycle demand savings” and is determined by multiplying the demand rating of the equipment by the percent change in the duty cycle. The duty cycle demand savings is then multiplied by the coincident diversity factor to determine the coincident demand savings.

Refrigerants Used

The table below shows the common types of refrigerants and their share of the world commercial sector refrigerant use. However, due to concerns over CFCs, this mix is changing.

WORLD COMMERCIAL SECTOR REFRIGERATION: REFRIGERANT SHARES

REFRIGERANT	SHARE OF WORLD COMMERCIAL REFRIGERANT USE
R-12	50%
R-22	10%
R-115	-
R-502	40%
R-134a	-
Source: Competitek 1990, p. 180	

End Use

The table below shows commercial sector refrigeration shares by type of establishment.

COMMERCIAL REFRIGERATION SHARES BY TYPE OF ESTABLISHMENT

END USE	SHARE OF TOTAL ELECTRIC USE FOR COMMERCIAL REFRIGERATION

Retail food stores	85%
Food service establishments	9%
Refrigerated warehouses	5%
Miscellaneous applications	1%
Source: Competitek 1990, p. 154	

Temperature Ranges by Application

VLT = Very low temperature, ice cream cases, -33°F
LT = Low temperature, other frozen foods, -23°F
MT1 = Medium temperature, meat, meat walk-in, 9°F to 16°F
MT2 = Medium temperature, dairy, deli, produce, walk-in boxes, 26°F
HT = High temperature, produce, dairy, deli walk-in boxes, meat preparation, 26°F

Source: Competitek 1990, p. 155

Full Load Operating Hours

Mean = 4,960 hours/year
Range = 4,570 to 5,708 hours/year
Source: ADM assessment of Commercial New Construction, page 15 ADM/SCE, April 1989.

Energy Usage (kWh/day)

The table below shows baseline energy consumption for a refrigeration system.

BASELINE ENERGY CONSUMPTION

CONVENTIONAL BASELINE	LOW TEMP.	MED. TEMP.	HIGH TEMP.	TOTAL COMPRESSORS	ELECTRIC DEFROST	COOLING TOWER	TOTAL
kWh/day	714	654	385	1,753	82	306	2,141
kWh/year	260,610	238,710	140,525	639,845	29,930	111,690	781,465
Compressor capacity, tons	15.3	32.9	21.8	70.0			70.0
Energy Use kWh/yr.-ton	16,997	7,257	6,446	9,137			11,160
Source: Electric Power Research Institute (EPRI) CU 6268, pp. 3-7, 2-5, 2-6							

Conditions for energy data shown above include:

- Standard reed-type valve compressors

- Tuned up system
- Hot gas heat reclaim
- Cooling Tower-it is estimated that most will be air-cooled
- Fairly mild climate compared to PG&E system

Accounting for Possible Changes in Refrigerants due to CFC Issues

EFFICIENCY LOSS FOR R-12 TO R-22 AT M.T.

LOSS	CONDITIONS	SOURCE
3.2%	110°F CT, 0°F ST	Competitek, p. 183
4.5%	110°F CT, 20°F ST	Competitek, p. 183
3.3%	Average	Foster Miller
3.0%	Cycle performance R-22 (COP = 4.59) versus R-12 (4.73)	W.F. Stoecker, Ind. Refrig., BNP, 1988, p. 320
3.5%	Average	

INCREASED EFFICIENCY FOR R-502 TO R-22 AT M.T.

GAIN	CONDITIONS	SOURCE
3.5%	110°F CT, 20°F ET, 45°F	EPRI present. matl, refrig. return gas temp. design review, April 1991
4%	110°F CT, 20°F ET, 25°F return gas temperature	EPRI present matl, refrig. design review, April 1991
4.8%	Cycle performance R-22 (COP = 4.59) versus R-502 (4.38)	W. F. Stoecker, ind. refrig., BNP, 1988, p. 320
4.1%	Average	
Note: Although it is not practical to perform a direct changeout from R-502 to R-22 in most cases, R-22 can be used for low temperature applications using two stage or compounding compression.		

Performing a weighted average for refrigerant changeout:

REFRIGERANT MARKET SHARE WORLDWIDE [a]

R-12	50%
R-22	10%
R-502	40%
[a]Competitek 1990, pg. 180	

For an average change out to R-22, assuming an average loss of 3.5% for R-12, an average gain of 4.1% for R-502 and the market share above, the expected loss due to refrigeration changes is:

REFRIGERANT	MARKET SHARE	% SAVINGS	WEIGHTED AVERAGE
R-12	50%	-3.5%	-1.75%
R-22	10%	0%	0%
R-502	10%	+4.1%	+1.64%
Total			-0.11%
Note: less than 1% considered negligible			

Refrigeration Load and Energy Use for Multideck

APPLICATION	CASE LOAD (BTU/HR-FT)	CONVENTIONAL SYSTEM (KWH/FT-DAY)	MULTIPLEX SYSTEM (KWH/FT-DAY)
Low temperature, open	1,425	9.05	6.4
Med. temperature, open	1,380	4.54	3.2
Source: Competitek, pg. 160, Hussman Corp., personal comm., April 1990			

Assume 50% of applications will be conventional systems, 50% multiplex systems, and convert to annual usage.

	LOAD (BTU/HR-FT)	(KWH/FT-YR.)
Low temp.	1,425	2,820
Med. temp	1,380	1,396

Application ID: A. Night Covers For Display Cases
Measure IDs: Medium Temp.: R74, Low Temp.: R1

Technology Description

Installing film or blanket type night covers on display cases can significantly reduce the infiltration of warm ambient air into the refrigerated space. Energy savings occur because the compressor will operate less frequently due to the reduction in load in a display case with properly applied night covers.

The target market for this measure is small, independently owned grocery stores and other stores that are typically closed at night and restock their shelves during the day. The target cases are vertical stand-up (medium temperature), of the single- or double-air curtain front design, and tub (coffin, low temperature) type cases.

There are many companies that manufacture film and blanket covers. Smaller, independent refrigeration companies typically sell these products.

Measure Savings

Night Cover for Open Vertical Cases

Cooling Savings

$Q\text{-cooling}_{svg}$ = Q-cooling x [(C-inf x K-inf) + (C-rad x K-rad)]

Where:

$Q\text{-cooling}_{svg}$:	Cooling savings, (Btu/hr/ft)
Q-cooling:	Case rating given by manufacturer, (Btu/hr/ft)
C-inf:	% of cooling from infiltration, *80% of Q-cooling*
K-inf:	% of infiltration saving factor, ***assumed to be 70%***
C-rad:	% of cooling coming from radiation, *10% of Q-cooling*
K-rad:	% of radiation saving factor, ***assumed to be 50%***

input	Q-cooling =	1,450	Btu/hr/ft (Tyler DDCM8 & DDCM12 Multishelf dairy/del; 1,450 Btu/hr/fti @ +20F ST)
	C-inf =	80%	
	K-inf =	70%	
	C-rad =	10%	
	K-rad =	50%	
Result:	**$Q\text{-cooling}_{svg}$ =**	**885**	**Btur/hr/ft**

Compressor Power Savings [per foot of night cover]

ΔkW = [$Q\text{-cooling}_{svg}$ / EER] / 1000

Where:

ΔkW:	Compressor power savings (excluding condenser power), (kW/ft)
$Q\text{-cooling}_{svg}$:	Cooling savings, (Btu/hr/ft)
EER:	Compressor rating from manufacturer, (Btu/hr/watts)

	$Q\text{-cooling}_{svg}$ =	885	Btu/hr/ft
input	EER =	8.51	Btu/hr/watts (Copeland R-502 MT, @ +95F SCT & +20F ST)
Result:	**ΔkW =**	**0.104**	**kW/ft**
		0	Coincident Diversity Factor

0 **KW/ft Coincident with Peak**

Annual Compressor Energy Savings (excluding condenser energy)

ΔkWh = ΔkW x EFLH x (t / 24)

Where:

ΔkWh:	Annual compressor energy savings, (kWh/ft)
ΔkW:	Compressor power savings, (kW/ft)
EFLH:	Equivalent full load hours, (hours/year)
t:	Time case shields are applied per day, (hours)

	ΔkW =	0.104	kW/ft
input	EFLH =	5,700	hours/year
input	t =	6	hours
Result:	**ΔkWh =**	**148**	Annual kWh/ft
		0	Coincident Diversity Factor
		0	**Annual KW/ft Coincident with Peak**

Night Cover for Open Horizontal Cases

Cooling Savings

$Q\text{-cooling}_{svg}$ = Q-cooling x [(C-inf x K-inf) + (C-rad x K-rad)]

Where:

$Q\text{-cooling}_{svg}$:	Cooling savings, (Btu/hr/ft)
Q-cooling:	Case rating given by manufacturer, (Btu/hr/ft)
C-inf:	% of cooling from infiltration, *24% of Q-cooling*
K-inf:	% of infiltration saving factor, ***assumed to be 80%***
C-rad:	%of cooling from radiation, *42% of Q-cooling*
K-rad:	Percentage of radiation saving factor, ***assumed to be 90%***

input	Q-cooling =	369	Btu/hr/ft (Hill Phoenix ONIZ-8 narrow island freezer; 369 Btu/hr/ft @ -23F Evap. Temp.)
	C-inf =	24%	
	K-inf =	80%	
	C-rad =	42%	
	K-rad =	90%	
Result:	**$Q\text{-cooling}_{svg}$ =**	**210**	**Btur/hr/ft**

Compressor Power Savings [per foot of night cover] (excluding condenser power)

ΔkW = [$Q\text{-cooling}_{svg}$ / EER] / 1000

Where:

ΔkW:	Compressor power savings, (kW/ft)
$Q\text{-cooling}_{svg}$:	Cooling savings by, (Btu/hr/ft)
EER:	Compressor rating given by manufacturer, (Btu/hr/watts)

$Q\text{-cooling}_{svg}$ =	210	Btu/hr/ft

input	EER =	5.12	Btu/hr/watts (Copeland R-502 LT, @ 95F SCT & -23F ST)
Result:	**ΔkW =**	**0.04**	kW/ft
		0	Coincident Diversity Factor
		0	**Annual kW/ft Coincident with Peak**

<u>Annual Compressor Energy Savings</u>(excluding condenser energy

ΔkWh = ΔkW x EFLH x (t / 24)

Where:

ΔkWh:	Annual compressor energy savings), (kWh/ft)
ΔkW:	Compressor power savings, (kW/ft)
EFLH:	Equivalent full load hours, (hours/year)
t:	Hours case shields applied per day, (hours)

	ΔkW =	0.04	kW/ft
input	EFLH =	5,700	hours/year
input	t =	6	hours
Result:	**ΔkWh =**	**59**	kWh/ft
		0	Coincident Diversity Factor
		0	**Annual KW/ft Coincident with Peak**

Measure Life

5 years --(from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Cost

The average cost of this measure was calculated using the incremental costs found through a data search in PG&E's MDSS database. The data reflects all night covers purchased in 1994 that were rebated through the Retrofit Express Program. Based on a sample size of 3,991 linear feet, the average cost is calculated to be $9.27/ln. ft. (rounded to $9.25/ln. ft.).

Terms and Conditions

Customer must install a cover on an otherwise open refrigeration case to decrease infiltration into the case at night. The case manufacturer must have no objections to the use of such front covers. The film type covers must be made of five mil (or more) polyethylene and be self-rolling. It is recommended that film type covers have small, perforated holes to decrease moisture buildup. Blanket-type covers must have a synthetic fiber based insulating layer with nylon outer layers. It is suggested that single compressor units be equipped with cylinder unloader(s) when covers are installed. Incentive is based on the linear footage (length in feet) of the case.

Summary

	VERTICAL CASES	HORIZONTAL CASES
kWh/yr.-ln. ft	148	59
kW/ln. ft	0	0

Life	5 years	5 years
Cost	$9.25 /ln. ft	$9.25 /linear foot of case

Application ID: B. Strip Curtains For Walk-in
Measure ID: R2

Technology Description

Installing strip curtains on doorways to walk-in boxes and refrigerated warehouses can produce energy savings due to decreased infiltration of outside air into the refrigerated space. Although refrigerated spaces have doors, which if kept closed would make strip curtains obsolete, they are often left open.

Strip curtains are a simple application and have been supported in the technical field for years. Though the consumer market has been receptive to their use, there is still potential for additional market penetration.

Measure Savings

ASHRAE methodology and assumptions are used to calculate savings (ASHRAE, 1994, p.26.3). The calculations listed below are modified from the 1996 M&E study on Refrigeration (Quantum 1997b, p. B.5-2).

<u>Assumptions for Calculations</u>

- 3 foot x 7 foot door
- Strip curtains are 80% effective in reducing infiltration (ASHRAE, 1994)
- Sensible heat ratio of the infiltration air heat gain (R) = 0.59 for coolers, 0.63 for freezers (ASHRAE, 1994, Table 7, p. 26.4)
- Sensible heat load of infiltration per square foot of doorway (Q/A) = 0.16 tons/sq. ft. for coolers, 0.61 tons/sq. ft. for freezers (ASHRAE, 1994, Fig. 3, p. 26.4)
- 50% of participants are grocery stores, and another 30% are split between warehouse and misc. commercial
- Business hours are assumed to be 20 hours / day seven days a week
- Walk-in doors are open 3 hours a day, according to Advice Filing estimates for Auto-Closer on Cooler or Freezer p. RF-40
- Annual hours doors purposefully open = 1,095
- 80% of installations are coolers, 20% freezers, assumption used by Advice Filing estimates for Auto-Closer on Cooler or Freezer p. RF-40

Non-coincident Demand Savings are calculated:

Infiltration by air exchange, according to ASHRAE, 1994 p. 26.3.

qt = 3,790 x W x H^1.5 x (Q/A) x (1/R) x Dt x Df x (1-E)

where:

qt = average heat gain in a period (Btu/h)

W = door width

H = door height

Q/A = sensible heat load of infiltration per square foot of doorway

R = sensible heat ratio of the infiltration air heat gain

D_t = door open time factor

D_f = door flow factor

E = effectiveness of doorway protective device (0 = unobstructed doorway)

The cooler impact is initially calculated with the assumption that the door is left open for an entire hour.

Dt = 1.0

Df = 0.8 flow factor

E = 80%

Q/A = 0.16 tons/sqft

R = 0.59

The baseline loads and demand are first calculated for coolers:

Baseline Loads (cooler) = 3,790 x 3ft x (7^1.5ft) x (0.16 tons/sqft) x (1/0.59) x 80% x 1.0 x (1-0)

= **45,684 Btuh**

Baseline Demand (cooler) = (45,648 Btuh)*(1ton/12,000 Btuh)*(1.6 kW/ton)

= **6.086 kW**

This is a theoretical calculation, and assumes that a door would be left open for an entire hour.

Next, retrofit loads and demand are calculated for coolers:

Retrofit Loads (cooler) = 3,790 x 3ft x (7^1.5ft) x (0.16 tons/sqft) x (1/0.59) x (80% flow factor) x (1 - 80%)

= **9,137 Btuh**

Retrofit Demand (cooler) = (9,137 Btuh) x (1ton/12,000 Btuh) x (1.6 kW/ton)

= **1.218 kW**

Again, this impact assumes that the cooler door is left open for an entire hour.

Retrofit demand is subtracted from baseline demand to calculate non-coincident demand savings for coolers:

NC Demand Savings (cooler) = 6.086 kW - 1.218 kW

= **4.634 kW**

Again, this impact assumes that the cooler door is left open for an entire hour.

The freezer impact is initially calculated with the assumption that the door is left open for an entire hour. The first step is to calculate the baseline loads:

Q/A = 0.61 tons/sqft

R = 0.63

Baseline Loads (freezer) = 3,790 x 3ft x (7^1.5ft) x (0.61 tons/sqft) x (1/0.63) x 80% x 1.0 x (1-0)

= **163,112 Btuh**

Baseline Demand (freezer) = (163,112 Btuh)*(1ton/12,000 Btuh)*(2.4 kW/ton)

= **32.622 kW**

Again, this impact assumes that the freezer door is left open for an entire hour.

The process is repeated for freezer retrofit loads:

Retrofit Loads (freezer) = 3,790 x 3ft x (7^1.5ft) x (0.61 tons/sqft) x (1/0.63) x 80% x 1.0 x (1-80%)

= **32,622 Btuh**

Retrofit Demand (freezer) = (32,622 Btuh)*(1ton/12,000 Btuh)*(2.4 kW/ton)

= **6.524 kW**

Again, non-coincident demand savings are calculated by subtracting retrofit demand from baseline demand:

NC Demand Savings (freezer) = 32.622 kW - 6.524kW

= **26.098 kW**

Again, this impact assumes that the freezer door is left open for an entire hour.

Non-coincident demand savings for strip curtains are calculated by assuming that 80% of the installations will be for coolers, and 20% will be for freezers:

Average NC Demand Savings:

= (4.634kW x 80%) + (26.098kW x 20%)

= **8.926 kW**

= 8.926 kW/21 sqft

= 0.425 kW/sqft

Energy Savings are calculated assuming that coolers and freezers are left open intentionally for 3 hours a day, or 1,095 hours a year. Calculations assume a 3 ft by 7 ft door:

Average Energy Savings = [(4.634 kW x 80%) + (26.098 kW x 20%)] x 1,095 hrs/yr.

= 9,774 kWh/yr.

= (9,774 kWh/yr.)/(21 sqft)

= **465 kWh/yr.-sqft**

Coincident Demand Savings:

Assume savings are spread across an entire year.

= (465 kWh/yr.-sqft)/8,760 hrs/yr.

= **0.0531 kWh/yr.-sqft**

Measure Life

4 years -- (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Cost

The average cost of this measure was calculated using the incremental costs found through a data search in PG&E's MDSS database. The data reflects all strip curtains for walk-ins purchased in 1994 that were rebated through the Retrofit Express Program. Based on a sample size of 4,583 square feet, the average cost is calculated to be $3.05/sq. ft. (This is comparable to CCIG CRI-01 on page 4-86 of the 2001 Database for Energy Efficiency Resources (DEER) Update Study that reflects an incremental cost of $67 per unit.)

Terms and Conditions

Must install strip curtains on doors of walk-in cases and doorways of refrigerated warehouses. This incentive is not available for display cases or for the replacement of existing strip curtains. Rebate is based on the square footage of the doorway.

Summary

	STRIP CURTAINS FOR WALKIN BOXES
kWh/yr.-ft^2	465
kW/ft^2	0.425 duty cycle
	0.0531 coincident duty cycle
Life	4 years
Cost	$3.05 / ft^2 of doorway

Application ID: C. Glass Doors: Low Temperature Case
Measure ID: R3

Technology Description

The addition of glass doors to existing open multideck low temperature refrigeration cases can significantly reduce heat gain to the case and thus produce energy savings. Savings occur at the compressor due to a decrease in refrigeration load for the case, as well as reduced evaporative fan energy use. A 50% decrease in load is the most common cited. Additional energy is required for anti-sweat heaters.

This measure has been supported in the technical field for years and is one of the simpler retrofit applications in refrigeration. In the market, it is more commonly seen on low temperature than on medium temperature cases.

Measure Savings

<u>Install Glass Doors on Open Vertical Display Cases (Low Temp.)</u>

<u>ASSUME:</u> TXV is resized and suction pressure reset to a higher value

<u>Cooling Savings</u>

$Q\text{-cooling}_{svg} = Q\text{-cooling} \times (C\text{-inf} \times K\text{-inf}) \times (1-h)$

Where:

$Q\text{-cooling}_{svg}$:	Cooling saving, (Btu/hr/door)
Q-cooling:	Case rating given by manufacturer, (Btu/hr/door)
C-inf:	Percentage of cooling coming from infiltration, *80% of Q-cooling*
K-inf:	Door effectiveness in preventing infiltration, ***assumed to be 100%***
%t :	Percentage of hours in one day door is open

input	**Q-cooling =**	4,645	Btu/hr/door (Tyler D6F8, 1,742 Btu/hr/ft @ -20F ST)
	C-inf =	80%	
	K-inf =	100%	
input	**%t =**	15%	
Result:	**$Q\text{-cooling}_{svg}$ =**	**3,159**	**Btur/hr/door**

<u>Compressor Power Savings (excluding condenser power)</u>

$\Delta kW = [Q\text{-cooling}_{svg} / EER] / 1000$

Where:

ΔkW:	Comp. power savings, (kW/door)
$Q\text{-cooling}_{svg}$:	Cooling savings, (Btu/hr/door)
EER:	Compressor rating given by manufacturer, (Btu/hr/watts)

	$Q\text{-cooling}_{svg}$ =	3,159	Btu/hr/door
input	EER =	5.19	Btu/hr/watts (Copeland R-502 LT, @ 95F SCT & -20F ST)
Result:	**ΔkW =**	**0.61**	**kW/door**

<u>Anti-Sweat Heater (ASH) Power Penalty</u>

ASH kW Penalty = [(ASH watts/door) / (1000)]

Where:

ASH kW Penalty:	Penalty due to ASH, (kW/door)
ASH watts/door:	Power consumed by ASH per door, (watts/door)

input	ASH watts/door =	75	watts/door (From Actual Test: 230 kW per 3 doors)
Result:	ASH kW Penalty =	**0.08**	**kW/door**

<u>Annual Compressor Energy Savings (excluding condenser energy)</u>

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

Where:

ΔkWh:	Annual compressor energy savings (excluding condenser energy), (kWh/door)
ΔkW:	Compressor power savings, (kW/door)

		EFLH:	Equivalent full load hours, (hours/year)
	ΔkW =	0.61	kW/door
input	EFLH =	5,700	hours/year
Result:	**ΔkWh =**	**3,469**	**Annual kWh/door**

<u>Annual Anti-Sweat Heater (ASH) Energy Penalty</u>

ASH kWh Penalty = (ASH kW Penalty) x h

Where:

ASH kWh Penalty:	Annual Penalty due to ASH, (kWh/door)
ASH kW Penalty:	Penalty due to ASH, (kW/door)
h:	Annual runtime of ASH, (hours/year)

	ASH kW Penalty =	0.08	kW/door
input	h =	8,760	hours/year
Result:	**ASH kWh Penalty =**	**657**	**Annual kWh/door**

Measure Life

12 years -- (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Cost

COST	CONDITIONS	SOURCE
$160/ft	Retrofit cost	ADM/BPA, pg. B-9/LBL
$160	Materials only	DEER 2001, CCIG: CRE-02, page 4-84
$197.19/ft	Retrofit cost	PG&E T.A. tables
$197	Labor and materials	Best judgment

This measure is an addition to existing equipment, rather than a replacement. Therefore, both material and labor should be considered.

Terms and Conditions

Must install glass doors on existing open upright (multi-deck) display cases. The incentive is limited to low-temperature cases – those with a case temperature below 0°F. Rebate is based on the linear footage (length) of the case.

Summary

	LOW TEMPERATURE CASE DOOR
kWh/year/door	2,812
kW/ln.ft, non-coincident	0.530
kW/ln.ft, coincident Life	0.286 12 years
Cost	$197/ linear foot of case length

Application ID: D. Glass Doors: Medium Temperature Case
Measure ID: R25

Technology Description

The addition of glass to existing open multi-deck medium temperature refrigeration cases can significantly reduce heat gain to the case and thus produce energy savings. Savings occur at the compressor due to a decrease in refrigeration load for the case, as well as reduced evaporative fan energy use additional energy is required for anti-sweat heaters.

This measure has been supported in the technical field for years and is one of the simpler retrofit applications in refrigeration.

Measure Savings

Install Glass Doors on Open Vertical Display Cases (Medium Temp.)

Cooling Savings

$Q\text{-cooling}_{svg}$ = Q-cooling x (C-inf x K-inf) x (1-h)

Where:

	$Q\text{-cooling}_{svg}$:		Cooling saving, (Btu/hr/door)
	Q-cooling:		Case rating given by manufacturer, (Btu/hr/door)
	C-inf:		Percentage of cooling coming from infiltration, *80% of Q-cooling*
	K-inf:		Door effectiveness in preventing infiltration, ***assumed to be 100%***
	%t:		Percentage of hours in one day door is open
input	Q-cooling =	3,979	Btu/hr/door (Tyler L6DLRA-8, 1,492 Btu/hr/ft @ +21F ST)
	C-inf =	80%	
	K-inf =	100%	
input	%t =	15%	
Result:	**$Q\text{-cooling}_{svg}$ =**	**2,706**	**BtuR/hr/door**

Compressor Power Savings (excluding condenser power)

ΔkW = [$Q\text{-cooling}_{svg}$ / EER] / 1000

Where:

	ΔkW:		Comp.- power savings(kW/door)
	$Q\text{-cooling}_{svg}$:		Cooling savings, (Btu/hr/door)
	EER:		Compressor rating given by manufacturer, (Btu/hr/watts)
	$Q\text{-cooling}_{svg}$ =	2,706	Btu/hr/door
input	EER =	8.51	Btu/hr/watts (Copeland R-502 MT, @ +95F SCT & +20F ST)
Result:	**ΔkW =**	**0.32**	**kW/door**

Anti-Sweat Heater (ASH) Power Penalty

ASH kW Penalty = [(ASH watts/door) / (1000)]

	Where:		
		ASH kW Penalty:	Penalty due to ASH, (kW/door)
		ASH watts/door:	Power consumed by ASH per door, (watts/door)
input	ASH watts/door =	75	watts/door (From Actual Test: 230 kW per 3 doors)
Result:	**ASH kW Penalty =**	**0.08**	**kW/door**

Annual Compressor Energy Savings (excluding condenser energy)

ΔkWh = ΔkW x EFLH

	Where:		
		ΔkWh:	Annual compressor energy savings, (kWh/door)
		ΔkW:	Compressor power savings, (kW/door)
		EFLH:	Equivalent full load hours, (hours/year)
	ΔkW =	0.32	kW/door
input	EFLH =	5,700	hours/year
Result:	**ΔkWh =**	**1,812**	**Annual kWh/door**

Annual Anti-Sweat Heater (ASH) Energy Penalty

ASH kWh Penalty = (ASH kW Penalty) x h

	Where:		
		ASH kWh Penalty:	Annual Penalty due to ASH, (kWh/door)
		ASH kW Penalty:	Penalty due to ASH, (kW/door)
		t:	Annual runtime of ASH, (hours/year)
	ASH kW Penalty =	0.08	kW/door
input	t =	8,760	hours/year
Result:	**ASH kWh Penalty =**	**657**	**Annual kWh/door**

Measure Life

12 years -- (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Cost

COST	CONDITIONS	SOURCE
$105	Materials only	DEER 2001, CCIG: CRE-02, page 4-85
$160/ft	Retrofit cost	ADM/BPA,pg. B-9/LBL
$197.19/ft	Retrofit cost	PG&E T.A. tables
$197	Labor and materials	Best judgment

This measure is an addition to existing equipment, rather than a replacement. Therefore, both material and labor should be considered.

Terms and Conditions

Must install glass or acrylic doors on existing open upright (multi-deck) display cases. The incentive is limited to low-temperature cases – those with a case temperature below 0°F. Rebate is based on the linear footage (length) of the case.

Summary

	MEDIUM TEMPERATURE CASE DOOR
kWh/year/door	1,155
kW/ln.ft, non-coincident	0.24
kW/ln.ft, coincident Life	0.130 12 years
Cost	$197/ linear foot of case length

Application ID: E. New Refrigeration Case With Doors: Low-Temperature Case

Measure ID: R4

Technology Description

Replacing an existing open multi-deck case with a new multi-deck case with doors produces energy savings by reducing heat gain to the case. Savings occur at the compressor due to a decreased refrigeration load on the case, in addition to the decreased load on the evaporative fan. An increase in anti-sweat heater load is expected. The technical support for installing a new refrigeration case with doors is widely available in the field, more so than for adding doors to an existing open case. This application is seen more commonly for low temperature than for medium temperature cases, due to the larger energy savings obtained.

Measure Savings

Replacing Existing Open Vertical Display Case with a New Energy Efficient Fixture Equipped with ECM Fan Motors, T8EB and Doors (Low Temp.)

Cooling Savings

$Q\text{-cooling}_{svg}$ = Q-cooling x [((C-inf x K-inf) x (1-h)) +(C-motor x K-motor) + (C-lighting x K-lighting)]

Where:

$Q\text{-cooling}_{svg}$:	Cooling saving, (Btu/hr/ft)
Q-cooling:	Case rating given by manufacturer, (Btu/hr/ft)
C-inf:	Percentage of heat gain coming from infiltration, *80% of Q-cooling*
K-inf:	Percentage of infiltration saving factor due to door installation, ***assumed to be 100%***
C-motor:	Percentage of heat gain coming from fan motors, *3% of Q-cooling*

	K-motor:		Percentage of motor saving factor due to retrofitting with efficient fan motors (ECM), ***11% reduction***
	C-lighting:		Percentage of heat gain coming from lighting, *7% of Q-cooling*
	K-lighting:		Percentage of lighting saving factor due to retroffiting with T8EB, ***3% reduction***
	%t:		Percentage of hours in one day door is open
input	Q-cooling =	1,742	Btu/hr/ft (Tyler D6F8, 1,742 Btu/hr/ft @ -20F ST)
	C-inf =	80%	
	K-inf =	100%	
	C-motor =	3%	
	K-motor =	11%	
	C-lighting =	7%	
	K-lighting =	3%	
input	%t =	15%	
Result:	**$Q\text{-cooling}_{svg}$ =**	**1,194**	**BtuR/hr/ft**

<u>Compressor Power Savings (excluding condenser power)</u>

ΔkW-Comp = [$Q\text{-cooling}_{svg}$ / EER] / 1000

Where:

	ΔkW-Comp:		Compressor power savings (excluding condenser power), (kW/ft)
	$Q\text{-cooling}_{svg}$:		Cooling savings, (Btu/hr/ft)
	EER:		Compressor rating given by manufacturer, (Btu/hr/watts)
	$Q\text{-cooling}_{svg}$ =	1,194	Btu/hr/ft
input	EER =	5.19	Btu/hr/watts (Copeland R-502 LT, @ 95F SCT & -20F ST)
Result:	**ΔkW-Comp =**	**0.23**	**kW/ft**

<u>Additional Savings From Efficient Lighting & Motors less Penalty From ASH</u>

<u>Additional Power Savings From Lighting and Motor Efficiency:</u>

ΔkW-Light = [(ΔkW/lamp) x (# of Lamps /case)]/L

Where:

	ΔkW-light:		Lighting power savings, (kW/ft)
	ΔkW/lamp:		Saving per each retrofitted lamp and ballast, (kW/lamp)
	#of Lamps/case:		Number of lamps per disply of case, (lamps/case)
	L:		Display case length (ft)
input	# of lamps per case =	2	lamp(s)/case
input	L =	8	ft
input	ΔkW/Lamp =	0.0052	kW/lamp
Results:	**ΔkW-Light =**	**0.0013**	**kW/ft**

ΔkW-Motor = [(ΔkW/motor) x (# of Motors / case)]/L

Where:

	ΔkW-Motor:		Motors power savings, (kW/ft)

		ΔkW/motor:		Saving per each retrofitted motor, (kW/motor)
		# of Motors:		Number of motors per case
		L:		Display case length (ft)
input	Number of motors =		2	motor(s)/case
input	ΔkW/motor =		0.06	kW/motor
Results:	**ΔkW-Motor =**		**0.015**	**kW/ft**

<u>Anti-Sweat Heater (ASH) Power Penalty:</u>

ASH kW Penalty = [(ASH watts/door) / (1000) x N] / L

Where:

		ASH kW Penalty:		Penalty due to ASH, (kW/ft)
		ASH watts/door:		Power consumed by ASH per door, (watts/door)
		N:		Number of Doors
input	ASH watts/door =		75	watts/door (From Actual Test: 230 kW per 3 doors)
input	N =		3	doors
Result:	**ASH kW Penalty =**		**0.03**	**kW/ft**

<u>Annual Compressor Energy Savings (excluding condenser energy)</u>

ΔkWh-Comp = ΔkW-Comp x EFLH

Where:

		ΔkWh-Comp :		Annual compressor energy savings (excluding condenser energy), (kWh/ft)
		ΔkW-Comp :		Compressor power savings, (kW/ft)
		EFLH :		Equivalent full load hours, (hours/year)
	ΔkW-Comp =		0.23	kW/ft
input	EFLH =		5,700	hours/year assumed from 8760 hrs of operation
Result:	**ΔkWh-Comp =**		**1,311**	**Annual kWh/ft**

<u>Additional Energy Savings From Lighting & Motor Efficiency, and Penalty From ASH</u>

<u>Additional Energy Savings From Lighting and Motor Efficiency:</u>

ΔkWh-Light = (ΔkW-Light) x t — The units are assumed to be operating 24/7, 8760 hrs/yr

Where:

		ΔkWh-Light:		Annual lighting energy savings, (kWh/door)
		ΔkW-Light:		Lighting power savings, (kW/door)
		t:		Annual runtime of lighting, (hours/year)
	ΔkW-Light =		0.0013	kW/ft
input	t =		8,760	hours/year
Result:	**ΔkWh-Light =**		**11**	**Annual kWh/ft**

ΔkWh-Motor = (ΔkW-Motor) x t — The units are assumed to be operating 24/7, 8760 hrs/yr

Where:

		ΔkWh-Motor:		Annual motor energy savings, (kWh/ft)
		ΔkW-Motor:		Motor power savings, (kW/ft)
		t:		Annual runtime of motors, (hours/year)
	ΔkW-Motor =		0.015	kW/ft

input	t =	8,760	hours/year
Result:	**ΔkWh-Motor =**	**131**	**Annual kWh/ft**
	Anti-Sweat Heater (ASH) Energy Penalty:		
	ASH kWh Penalty = (ASH kW Penalty) x t		
	Where:		The units are assumed to be operating 24/7, 8760 hrs/yr
		ASH kWh Penalty:	Annual Penalty due to ASH, (kWh/door)
		ASH kW Penalty:	Penalty due to ASH, (kW/door)
		t:	Annual runtime of ASH, (hours/year)
	ASH kW Penalty =	0.03	kW/door
input	t =	8,760	hours/year
Result:	**ASH kWh Penalty =**	**246**	**Annual kWh/ft**

Measure Life

16 years -- (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Cost

COST	CONDITIONS	SOURCE
$620.60/ft	common doors	PG&E T.A. tables
$1,050/ft	low temperature, 1986 dollars	Competitek, pg. 163/EPRI/Safeway
$80/ft	incremental cost, new low temperature case	ADM/BPA, pg. B-9/pers. comm., Hill Refrigeration
$100/ft	Incremental, installed cost	Best judgment

Terms and Conditions

Must replace an existing open refrigeration case with a new refrigeration case with glass or acrylic doors. New case length must be equal or shorter than the original case. Low temperature = a case temperature below 0°F; medium temperature = a case temperature between 1 F and 35 F. New case cannot be a self-contained unit (with its own compressor). Rebate is based on the linear footage (length) of the case.

Summary

	LOW TEMPERATURE CASE
kWh/year-ln.ft.	1,208
kW/ln.ft, non-coincident	0.218
kW/ln.ft, coincident Life	0.118 16 years
Cost	$100/ linear foot of case length

Application ID: F. New Refrigeration Case With Doors: Medium-Temperature Case

Measure ID: R5

Technology Description

Replacing an existing open multi-deck case with a new multi-deck case with doors produces energy savings by reducing heat gain to the case. Savings occur at the compressor due to a decreased refrigeration load on the case. The technical support for installing a new refrigeration case with doors is widely available in the field, more so than for adding doors to an existing open case. This application is seen more commonly for low temperature than for medium temperature cases, due to the larger energy savings obtained.

Measure Savings

Replacing Existing Open Vertical Display Case with a New Energy Efficient Fixture Equipped with ECM Fan Motors, T8EB and Doors (Medium Temp.)

Cooling Savings

$Q\text{-cooling}_{svg}$ = Q-cooling x [((C-inf x K-inf) x (1-%t)) +(C-motor x K-motor) + (C-lighting x K-lighting)]

Where:

$Q\text{-cooling}_{svg}$:	Cooling saving, (Btu/hr/ft)
Q-cooling:	Case rating given by manufacturer, (Btu/hr/ft)
C-inf:	Percentage of heat gain coming from infiltration, *80% of Q-cooling*
K-inf:	Percentage of infiltration saving factor due to door installation, ***assumed to be 100%***
C-motor:	Percentage of heat gain coming from fan motors, *3% of Q-cooling*
K-motor:	Percentage of motor saving factor due to retrofitting with efficient fan motors (ECM), ***11% reduction***
C-lighting:	Percentage of heat gain coming from lighting, *7% of Q-cooling*

		K-lighting:	Percentage of lighting saving factor due to retroffiting with T8EB, ***3% reduction***
		%t:	Percentage of hours in one day door is open
input	Q-cooling =	1,492	Btu/hr/ft (Tyler L6DLRA-8, 1,492 Btu/hr/ft @ +21F ST)
	C-inf =	80%	
	K-inf =	100%	
	C-motor =	3%	
	K-motor =	11%	
	C-lighting =	7%	
	K-lighting =	3%	
input	%t =	15%	
Result:	**Q-cooling$_{svg}$ =**	**1,023**	**Btur/hr/ft**

<u>Compressor Power Savings (excluding condenser power)</u>

ΔkW-Comp = [Q-cooling$_{svg}$ / EER] / 1000

Where:

		ΔkW-Comp:	Compressor power savings, (kW/ft)
		Q-cooling$_{svg}$:	Cooling savings, (Btu/hr/ft)
		EER:	Compressor rating given by manufacturer, (Btu/hr/watts)
	Q-cooling$_{svg}$ =	1,023	Btu/hr/ft
input	EER =	8.51	Btu/hr/watts (Copeland R-502 MT, @ +95F SCT & +20F ST)
Result:	**ΔkW-Comp =**	**0.12**	**kW/ft**

<u>Additioanl Savings From Efficient Lighting & Motors less Penalty From ASH</u>

<u>Additional Power Savings From Lighting and Motor Efficiency:</u>

ΔkW-Light = [(ΔkW/lamp) x (# of Lamps /case)]/L

Where:

		ΔkW-Light:	Lighting power savings, (kW/ft)
		ΔkW/lamp:	Saving per each retrofitted lamp and ballast, (kW/lamp)
		# of Lamps/case:	Number of lamps per display case, (lamps/case)
		L:	Display case length (ft)
input	# of lamps per case =	2	lamp(s)/case
input	L =	8	ft
input	ΔkW/Lamp =	0.0052	kW/lamp
Results:	**ΔkW-Light =**	**0.0013**	**kW/ft**

ΔkW-Motor = [(ΔkW/motor) x (# of Motors / case)]/L

Where:

		ΔkW-Mtr:	Motors power savings, (kW/ft)
		ΔkW/motor:	Saving per retrofitted motor, (kW/motor)
		# of Motors:	Number of motors per case
		L:	Display case length (ft)
input	Number of motors =	2	motor(s)/case
input	ΔkW/motor =	0.06	kW/motor
Results:	**ΔkW-Motor =**	**0.015**	**kW/ft**

<u>Anti-Sweat Heater (ASH) Power Penatly:</u>

ASH kW Penalty = [(ASH watts/door) / (1000) x N] / L

Where:

	ASH kW Penalty:		Penalty due to ASH, (kW/ft)
	ASH watts/door:		Power consumed by ASH per door, (watts/door)
	N:		Number of Doors
input	ASH watts/door =	75	watts/door (Actual Test: 230 kW per 3 doors)
input	N =	3	doors
Result:	**ASH kW Penalty =**	**0.03**	**kW/ft**

<u>Annual Compressor Energy Savings (excluding condenser energy)</u>

ΔkWh-Comp = ΔkW-Comp x EFLH

Where:

	ΔkWh-Comp:		Annual compressor energy savings, (kWh/ft)
	ΔkW-Comp:		Compressor power savings, (kW/ft)
	EFLH:		Equivalent full load hours, (hours/year)
	ΔkW-Comp =	0.12	kW/ft
input	EFLH =	5,700	hours/year
Result:	**ΔkWh-Comp =**	**685**	**Annual kWh/ft**

Additional Energy Savings From Lighting & Motor Efficiency,& Penalty From ASH

<u>Additional Energy Savings From Lighting and Motor Efficiency:</u>

ΔkWh-Light = (ΔkW-Light) x t

Where:

	ΔkWh-Light:		Annual lighting energy savings, (kWh/door)
	ΔkW-Light:		Lighting power savings, (kW/door)
	h:		Annual runtime of lighting, (hours/year)
	ΔkW-Light =	0.0013	kW/ft
input	t =	8,760	hours/year
Result:	**ΔkWh-Light =**	**11**	**Annual kWh/ft**

ΔkWh-Motor = (ΔkW-Motor) x t

Where:

	ΔkWh-Motor:		Annual motor energy savings, (kWh/ft)
	ΔkW-Motor:		Motor power savings, (kW/ft)
	h:		Annual runtime of motors, (hours/year)
	ΔkW-Motor =	0.015	kW/ft
input	t =	8,760	hours/year
Result:	**ΔkWh-Motor =**	**131**	**Annual kWh/ft**

<u>Anti-Sweat Heater (ASH) Energy Penalty:</u>

ASH kWh Penalty = (ASH kW Penalty) x t

Where:

	ASH kWh Penalty:		Annual Penalty due to ASH, (kWh/door)
	ASH kW Penalty:		Penalty due to ASH, (kW/door)
	t:		Annual runtime of ASH, (hours/year)
	ASH kW Penalty =	0.03	kW/door
input	t =	8,760	hours/year
	ASH kWh Penalty =	**263**	**kWh/door**

Measure Life

16 years -- (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Incremental Cost

COST	CONDITIONS	SOURCE
$620.60/door	common doors	PG&E T.A. tables
$920/door	medium temperature, 1986 dollars	Competitek, pg.163/EPRI/Safeway
$100/ft	incremental, installed cost	Best judgment

Terms and Conditions

Must replace an existing open refrigeration case with a new refrigeration case with glass or acrylic doors. New case length must be equal or shorter than the original case. Low temperature means a case temperature below 0°F; medium temperature means a case temperature between 1 F and 35 F. New case cannot be a self-contained unit (with its own compressor). Rebate is based on the linear footage (length) of the case.

Summary

	MEDIUM TEMPERATURE CASE
kWh/year-ln.ft.	581
kW/ln.ft, non-coincident	0.108
kW/ln.ft, coincident Life	0.058 16 years
Incremental Cost	$100/linear foot of case length

Application ID: G. High Efficiency Low Temperature Reach-in Display Case with Special Doors

Measure ID: R87

This measure applies only to low temperature reach-in display cases. The new reach-in fixture equipped with high efficiency lighting, fan motors and low/no ASH glass doors will replace an exiting reach-in display case with standard glass doors. Compressor savings occur due to a decrease in heat dissipation from fan motors, lights and anti-sweat heaters. Additionally, efficient lighting and fan motors will contribute further to the savings.

Measure Savings

Energy saving calculations are enclosed in Appendix H.

Application

Small/Medium/Large Groceries

Measure Life

16 years -- (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Cost

$700 per linear foot (sample invoices from PY2001 rebate program)

Application ID: H. Special Doors with Low/No Anti- Sweat Heat (ASH) Controls- Low Heat/No Heat Refrigeration Case Door

Measure ID: R6

Technology Description

Traditional clear glass display case doors consist of two-pane glass (three-pane in low and medium temperature cases), and aluminum doorframes and door rails. Glass heaters may be included to eliminate condensation on the door or glass. The door heaters are traditionally designed to overcome the highest humidity conditions as cases are built for nation-wide applications. New low heat/no heat door designs incorporate heat reflective coatings on the glass, gas inserted between the panes, non-metallic spacers to separate the glass panes, and/or non-metallic frames (such as fiberglass).

The primary focus of this rebate measure is on new cases - to incent customers to specify advanced doors when they are purchasing refrigeration cases.

The two major manufacturers of refrigeration case doors, Anthony and Ardco, offer the above-mentioned advanced doors. Zerowatt, a smaller company in Oakland, also offers advanced doors.

Measure Savings

Replace Existing Glass Doors with the Special Polymer Type that Eliminates Glass Heating (Low Temp.)

Assumptions: Indoor Dry-Bulb Temperature of 75°F and Relative Humidity of 55%, [4-minute opening intervals for 16-second], Neglect Heat conduction through doorframe / assembly

Cooling Savings

Q-cooling $_{svg}$ = (Q-cooling x K-ASH)

Where:

	Q-cooling$_{svg}$:		Cooling saving, (Btu/hr/door)
	Q-cooling:		Case rating given by manufacturer, (Btu/hr/door)
	K-ASH:		% of cooling load reduction due to low anti-sweat heater, ***1.5% Btu/hr/door reduction***
input	Q-cooling =	1,400	Btu/hr/door (Hill Phoenix ORZ-8, 1,400 Btu/hr/door @ -13F Evap. Temp.)
	K-ASH =	1.5%	
Result:	**Q-cooling$_{svg}$ =**	**21**	**Btur/hr/door**

Compressor Power Savings (excluding condenser power)

ΔkW = [Q-cooling$_{svg}$ / EER] / 1000

Where:

ΔkW:	Compressor power savings, (kW/door)

		Q-cooling$_{svg}$:		Cooling savings, (Btu/hr/door)
		EER:		Compressor rating given by manufacturer, (Btu/hr/watts)
	Q-cooling$_{svg}$ =		21	Btu/hr/door
input	EER =		5.43	Btu/hr/watts (Copeland R-502 LT, @ 95F SCT & -15F ST)
Result:	**ΔkW =**		0.090	kW/door
			0.054	Coincident Diversity Factor
			0.049	kW/door coincident with peak

<u>Anti-Sweat Heater (ASH) Power Reduction</u>

ASH kW Reduction = [(ΔASH watts/door) / (1000)]

Where:

		ASH kW Reduction :		Reduction due to ASH, (kW/door)
		ΔASH watts/door :		Reduction in ASH power per door, (watts/door)
	ΔASH watts/door =		83	watts/door (From Actual Test: 0.250 kW per 3 doors)
Result:	**ASH kW Reduction =**		**0.083**	**kW/door**

<u>Annual Compressor Energy Savings (excluding condenser energy)</u>

ΔkWh = ΔkW x EFLH — The units are assumed to be operating 24/7, 8760 hrs/yr

Where:

		ΔkWh:		Annual compressor energy savings (excluding condenser energy), (kWh/door)
		ΔkW:		Compressor power savings, (kW/door)
		EFLH:		Equivalent full load hours, (hours/year)
	ΔkW =		0.0039	kW/door
input	EFLH =		5,700	hours/year
Result:	**ΔkWh =**		**22**	**Annual kWh/door**

<u>Annual Anti-Sweat Heater (ASH) Energy Reduction</u>

ASH kWh Reduction = (ASH kW Reduction) x t

Where:

		ASH kWh Reduction:		Annual Reduction, (kWh/door)
		ASH kW Reduction:		Reduction, (kW/door)
		t:		Annual runtime of ASH, (hrs/yr)
	ASH kW Reduction =		0.08	kW/door
input	t =		8,760	hours/year
Result:	**ASH kWh Reduction =**		**727**	**Annual kWh/door**

Measure Life

16 years -- (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Incremental Cost

Assuming the same market share and breakdown of temperature applications, the average incremental cost is $77/ft. (See tables below for calculations.) We are considering material cost only since the majority of the applications will be on new cases.

Terms and Conditions

Must install a no-heat/low-heat clear glass door on an upright display case. Limited to door heights of 57 inches or more. Doors must have either heat reflective treated glass, be gas filled, or both. Applies to low temperature cases only—those with a case temperature below 0°F. Doors must have 3 or more panes. Total door rail, glass, and frame heater amperage (@ 120 volt) cannot exceed 0.97 amps per foot for low temperature cases. Rebate is based on the door width (not including case frame).

Summary

	SPECIAL DOORS FOR LOW TEMP
kWh/door	749
kW/door, non-coincident	0.049
kW/door, coincident	0.015
Life	16 years
Cost	$77/linear foot of door

Application ID: I. Anti-Sweat Heat (ASH) Controls
Humidistat Control

Measure ID: R7

Technology Description

A humidistat control is a control device to turn refrigeration display case anti-sweat heaters off when ambient relative humidity is low enough that sweating will not occur. Anti-sweat heaters evaporate moisture by heating the door rails, case frame and glass of display cases. Savings result from reducing the operating hours of the anti-sweat heaters, which without a humidistat control generally run continuously. There are various types of control strategies. The most common turns the heater on/off at a set humidity, while more sophisticated controls cycle the heaters on/off over a range of humidities.

While the technical support for this measure exists in the field, the measure is not often specified by trade allies. There are a variety of newer control strategies that save even more energy than basic dew point and analog dew point controllers. These new controllers offer the potential for increasing market penetration as they will increase customer and trade ally satisfaction due to improved moisture control.

Measure Savings

UNITS: per door

Pulse Modulation Anti-Sweat Heater (ASH) Control

Interactive Savings:

Cooling Savings

ΔQ-cooling$_{svg}$ = [(watts of ASH/door) x (Average Store RH%) x (%ΔReduction)]

Where:

ΔQ-cooling$_{svg}$:	% Cooling saving, (Btu/hr/door)
Watts of ASH/door:	ASH power per door (watts/door)
Average Store RH%:	Average indoor relative humidity (%)
%ΔReduction:	%Reduction in heat gain as a function of ASH connected load

input Watts of ASH/door	200	Watts/door, **OR** 682.6 Btu/hr/door
input Average Store RH%	45%	RH
%ΔReduction:	18%	***Determined from Graph (based on SCE's test data)***
Result: **ΔQ-cooling$_{svg}$ =**	**119**	**Btur/hr/door**

Compressor Power Savings (excluding condenser power)

ΔkW = [ΔQ-cooling$_{svg}$ / EER] / 1000

Where:

ΔkW-Comp:	Compressor power savings (excluding condenser power), (kW/door)
ΔQ-cooling$_{svg}$:	Cooling savings, (Btu/hr/door)
EER:	Compressor rating given by manufacturer, (Btu/hr/watts)

Q-cooling$_{svg}$ =	119	Btu/hr/door
input EER =	5.43	Btu/hr/watts (Copeland R-502 LT, @95F SCT & -15F ST)
Result: **ΔkW-Comp =**	**0.0220**	**kW/door**

Direct Power Savings From ASH

ASH kW Reduction = [(1-%kW) x (Watts of ASH/door)]

Where:

ASH kW Reduction:	Reduction due to pulse modulation ASH, (kW/door)
%kW:	%of ASH Power, (kW/door)
Watts of ASH/door	ASH power per door (watts/door or Btu/hr/door)

%kW =	50%	**Determined from Graph based on SCE's test data**
Watts of ASH/door =	200	Watts/door
Result: **ASH kW Reduction =**	**0.100**	**kW/door**

Annual Compressor Energy Savings (excluding condenser energy)

ΔkWh-Comp = ΔkW-Comp x EFLH

Where:

ΔkWh-Comp :	Annual compressor energy savings (excluding condenser energy), (kWh/door)
ΔkW-Comp :	Compressor power savings, (kW/door)
EFLH :	Equivalent full load hours, (hours/year)

ΔkW-Comp =	0.022	kW/door
input EFLH =	5,700	hours/year
***Result:* ΔkWh-Comp =**	**125**	**Annual kWh/door**

Energy Savings From ASH

ASH kWh Reduction = (ASH kW Reduction) x h

Where:

ASH kWh Reduction :	Annual Reduction due to pulse modulation ASH, (kWh/door)
ASH kW Reduction :	Reduction due to pulse modulation ASH, (kW/door)
h :	Annual runtime of ASH, (hours/year)

ASH kW Reduction =	0.100	kW/door
Input h =	8,760	hours/year
***Result:* ASH kWh Reduction =**	**876**	**Annual kWh/door**

SUMMARY of SAVINGS:

Cooling Savings:	**119**	**Btu/hr/door**
Power Savings:	**0.12**	**kW/door**
Annual Energy Savings:	**1,001**	**Annual kWh/door**

Measure Life

12 years -- (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Incremental Cost

$56.00 – from: 2001 DEER Update Study, CCIG-CRC-01, p. 4-79, Xenergy, Oakland, CA.

Terms and Conditions

Must install a control device that senses the humidity in the air outside of the upright display cases and turns off the glass door and frame anti-sweat heaters at low-humidity conditions. Dew-point or analog dew-point controllers are recommended. Rebate is based on the linear footage (length) of the case.

Summary

	ASH CONTROLS
kWh/year-ln.ft.	343
kW/ft, non-coincident	0.04 (duty cycle)
kW/ft, coincident	0.022
Life	12 years
Cost	$56.00 / foot of Case

Application ID: J. Insulate Bare Suction Line
Measure ID: R11

Technology Description

This incentive measure provides an incentive for smaller customers to insulate bare refrigeration suction lines. Insulating suction lines decreases the heat load to the compressor, resulting in decreased compressor operating hours. To limit the measure's applicability to smaller equipment this incentive is only available for insulating pipes whose diameters are 1.5 inches or less. It is common to see the suction lines insulated on larger refrigeration systems but lines in smaller, independently owned grocery stores are not commonly insulated.

There are many companies that manufacture pipe insulation including Armstrong World, Inc., Rubatex, and Halstead. Pipe insulation can be purchased at a number of industrial supply stores including refrigeration supply houses and many plumbing supply houses.

Measure Savings

The formulas and input data for calculating the heat loss of a bare and insulated copper pipe are given below. The formulas allow inputs for temperature of refrigerant vapor, hours of compressor operation, ambient air temperature, wind speed, thickness of insulation and its *k* value (Btu-in/hr-ft^2-F), pipe diameter and length, and the efficiency (EER) of the compressor.

The formulas assume that the bare pipe will have conductive and radiant heat loss from its surface to the air. It is also assumed that the surface temperature is the same as the refrigerant vapor temperature. For insulated pipe the conductive heat loss is calculated, considering only the insulation for the heat transfer coefficient.

Calculations are performed for 3/8 inch, 1/2 inch, 3/4 inch, 1 inch, 1 1/4 inch, and 1 1/2 inch nominal diameter pipe. The savings are then averaged assuming equal participation of each diameter in the incentive program.

Assumptions

- Refrigeration vapor temperature: For both low temperature and medium temperature assume 15°F of superheat at the exit of the evaporator and an average coil to compressor rise of 5°F. Assume low temperature suction = -20°F, so use 0°F for vapor temperature, for medium temperature assume suction = 15°F, so use 35°F for medium temperature vapor.
- Compressor operates 5,700 equivalent full load hours, based on 24/7 operation of the refrigeration system.
- Average ambient temperature inside store = 75°F.
- Average wind speed = 0.5 mph (44 fpm, see ASHRAE 1989 Fundamentals, p. 13.9).

- Compressor efficiency: low temperature = 5.0 EER, medium temperature = 7.5 EER.
- 80% of participating length of pipe is for medium temperature applications, 20% of pipe is for low temperature.
- Insulation thickness, mandated in the measure requirements, is 1 inch for low temperature and 3/4 inch for medium temperature.
- Insulation material is flexible, closed-cell polyethylene foam with a thermal conductivity (*k* value) of 0.27 Btu-in/hr-ft^2-F.

Sample Data for Calculations

Vapor temperature at pipe inlet	35°F
Annual hours of operation	5700 hrs
Ambient air temperature	75°F
Tube material	Copper
Nominal tube diameter	1.5 in.
Actual tube diameter	1.625 in.
Tube length	1 ft.
Wind speed	0.5 mph
Average air temperature	55°F
Current insulation thickness	0 in.
Current insulation k value	0 Btu-in/hr-ft^2-F
Proposed insulation thickness	0.75 in.
Proposed insulation k value	0.27 Btu-in/hr-ft^2-F
Proposed insulation outside radius	1.52 in.
Proposed insulation inside radius	0.82 in.
Uninsulated Pipe Heat Gain	
Convection heat transfer coefficient	1.52 Btu/hr-ft^2-F
Radiant heat transfer coefficient	0.4115 Btu/hr-ft^2-F
Rate of conductive heat transfer	N.A.
Overall heat transfer coefficient	1.94 Btu/hr-ft^2-F
Heat gain	32.93 Btu/hr
Energy increase	25.02 kWh/yr.
Insulated Heat Gain	
Convection heat transfer coefficient	N.A.
Radiant heat transfer coefficient	N.A.
Rate of conductive heat transfer	0.24 Btu/hr-ft^2-F
Overall heat transfer coefficient	0.24 Btu/hr-ft^2-F
Heat gain	7.71 Btu/hr
Energy increase	5.86kWh/yr.
Energy Savings per year with insulation (this number is based on above data; a weighted average for this measure is given below)	19.16 kWh/yr.-ft

Equations

For bare pipe, from ASHRAE 1989 Fundamentals Handbook, page 22.15.

$$h_{cv} = C\,(1/d)^{0.2}\,(1/t_{avg})^{0.181t0.266}\,[1 + 1.277\,(wind)]^{0.5}$$

To calculate the pipe surface convective heat transfer coefficient, h_{cv}

where

C	= constant depending on shape and heat flow condition
	= 1.016 for horizontal cylinders
d	= diameter for cylinder, inches
t_{avg}	= average temperature of air film, F
t	= surface to air temperature difference, F
wind	= air speed, mph

$$h_{rad} = \frac{\varepsilon\, x\ 0.173\ x\ 10^{-8}\ [(t_a + 459.6)^4 - (t_s + 459.6)^4]}{(t_a - t_s)}$$

To calculate the pipe surface radiant heat transfer coefficient, h_{rad}

where

e	= surface emittance = 0.44 for dull bare copper pipe, page 22.18
t_a	= air temperature, F
t_s	= surface temperature, F

$$q_s = (t_i - t_s)\ /\ [r_s \ln(r_s / r_i) / k]$$

For insulated pipe, from ASHRAE 1989 Fundamentals Handbook, page 20.

where

q_s	= rate of heat transfer per unit area of insulation's outer surface
t_i	= temperature of inner surface, F (assume same as vapor temp.)
t_s	= temperature of outer surface, F
t_a	= air temperature, F

$$q_s = (t_i - t_a)\ /\ [r_s \ln\ (r_s / r_i) / k + 1 / h_s]$$

To correct for ambient temperature t_a, incorporate the surface resistance $1/h_s$

$$U = 1 / [r_s \ln(r_s / r_i) / k + 1 / h_s]$$

k	= thermal conductivity of insulation

Since Q = UAT, A = $2r_aL$, and q_S = Q/A

Provided on page 22.15, Figure 6 of ASHRAE is a graph to estimate surface resistance. Assuming a heat transmission rate of 45 Btu/h-ft^2 (based on

$$U = 1/[r_s \ln(r_s / r_i) / k + 0.65]$$

spreadsheet runs), **$1/h_S$ = 0.65 F-ft^2-h/Btu.**

Calculations

The table below shows the calculations for average of the energy savings due to insulating bare suction lines to be 16.02 kWh/ft

NOMINAL TUBE DIAMETER (IN.)		SAVINGS PER YEAR (KWH/FT)	
	Low temperature applications: 1” insulation	Medium temperature applications: 3/4” insulation	Weighted average of 20% low temp, 80% med. Temp. applications
0.38	22.06	6.42	9.55
0.50	27.70	8.24	12.13
0.75	36.98	11.03	16.22
1.00	45.61	13.62	20.02
1.25	55.45	16.82	24.55
1.50	63.34	19.16	27.99
			Average = 18.41

Note: It is believed that duty cycle demand savings do occur but that since the length of the refrigerant line and its savings are not always proportional to the size and demand rating of the compressor, the demand savings are too difficult to determine and therefore are not claimed.

Demand savings = 0 kW/ft

Measure Life

11 years -- (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Cost

The average cost of this measure was calculated using the incremental costs captured through a data search in PG&E’s MDSS database. The data reflects all insulate bare suction line purchased in 1994 that were rebated through the Retrofit Express Program.

Based on a sample size of 622 linear-feet, the average cost is calculated to be $1.72/ln.ft.

Terms and Conditions

Must insulate bare refrigeration suction lines (the larger diameter lines that run from the evaporator to the compressor). Medium temperature lines must be insulated with ¾-inch insulation, low temperature lines must be insulated with 1-

inch insulation. Insulation material must be flexible closed-cell nitrite rubber. Limited to pipe sizes of 1.5 inches or less. Rebate is not available for new equipment. Insulation exposed to outside weather must be jacketed (such as with a medium-gauge aluminum jacket) or protected from the weather in some way. Rebate is based on the linear footage of the insulation installed.

Summary

	INSULATE BARE SUCTION LINE
kWh/yr.-ln.ft.	18.4
kW/ln.ft.	0
Life	11 years
Cost	$1.72/ linear foot of line

Application ID: K. & L. Door Gaskets Coolers or Freezers, Solid or Glass Doors
Measure ID: R50/R89

Technology Description

This measure is to replace weak, worn-out gaskets with new better-fitting gaskets that reduce air infiltration into the conditioned space.

Measure Savings

Savings for this measure have been revised. Assumptions for door size and hours that infiltration occur have been updated to reflect recommendations from the M&E report for the 1995 program (Quantum 1997, B.5-14)

Baseline assumptions for measure savings:

- The cooler/freezer door may be open as much as 3,010 hours per year (estimated from 3 hr/day intentionally open or 1,915 hr/yr., plus left ajar unintentionally 25% of the remaining time, 1,915 hr/yr.) The improved gaskets save energy during the remaining 5,750 hours per year.
- We assume width, W = 3 ft and height, H = 7 feet for the average sized door.
- Cooler temperature is 40°F, freezer is 0°F, kitchen temperature is 70°F (conservative) and relative humidity is 60%.
- Weak gaskets on coolers and freezers allow loss of 3% of the open door heat loss.
- Typical cooler performance factor is 1.6kW/ton, typical freezer performance factor is 2.4 kW/ton.
- 80 % of installations are coolers, 20% are freezers.

Engineering-based savings:

- The heat loss from ill-fitting gaskets is calculated as a fraction (3%) of the heat loss from a cold space to a warmer space through an open door. We chose this model, which is described in the 1990 ASHRAE Handbook-Refrigeration, because it is based on temperature-induced (rather than pressure-induced) air flow.
- From 1990 ASHRAE Handbook-Refrigeration, 27.3 gives the basic relationship for heat gain through doorways from temperature-induced air exchange:

q_t = $q * D_t * D_f$

q = $3{,}790 * W * H^{1.5}$ (Qs/A)(I/R_S), Btu/hr

Where:

D_t = doorway open time factor

D_f = doorway flow factor

Q_S/A = sensible heat load of infiltration air per square foot of doorway opening

R_S = sensible heat ratio of the infiltration heat gain

The factors Q_S/A and $1/R_S$ are determined from 1990 ASHRAE R-26.4, Figure 3 and Table 7. Apply a doorway flow factor of 0.80 (as recommended on page R-27.5, 1990 ASHRAE Handbook), and the 3% savings assumption (D_f 0.80 * 0.03). Demand savings are initially calculated assuming that the door is open for an hour ($D_t = 1$).

Savings for the average-sized cooler are:

q_t = $3{,}790 * 3 * 7^{1.5} * 0.16 * (1/0.59) * (0.80 * 0.03)$

q_t = 1,371 Btu/h x (1 ton-hr/12,000 Btu) x (1.6 kW/ton)

= 0.183 kW

Savings for the average-sized freezer are:

q_t = $3{,}790 * 3 * 7^{1.5} * 0.61 * (1/0.63) * (0.80 * 0.03)$

q_t =4,893 Btu/h x (1 ton-hr/12,000 Btu) x (1.6 kW/ton)

= 0.979 kW

Total Non-coincident demand savings:

= (0.183 kW x 0.80)+(0.979 kW x 0.20)

= 0.342 kW

Baseline energy use = 58,400 kWh/yr. (1,752/0.03)

Annual energy savings are:

Hours Door Left Ajar = (365 day/yr. x 20 hr/day) - (1,095 hr/yr.door open)

= 6,205 hours

= 6,205 hrs x 25% chance ajar

= 1,551 hours

Hours for potential savings = 8,760 hrs - 1,551 hrs - 1,095 hrs

= 6,114 hrs/yr.

Annual Energy Savings = 0.342 kW x 6,114 hrs/yr.

= **2,091 kWh/yr.**

Coincident demand savings:

For a given hour in the year, the chance that a door will be closed is the CDF.

= 0.342 kW x (6,114 hrs/yr. door closed)/(8,760 hrs/yr.)

= **0.239 kW**

Measure Life

4 years -- (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Incremental Cost

The cost of this measure was calculated using the incremental costs found through a data search in PG&E's MDSS database. The data reflects all gaskets purchased in 1994 by customers that participated in the Retrofit Express Program. Based on a sample size of 769 gaskets, the average is $80.52 per gasket.

Gaskets may be purchased from the OEM, their representative, or other distributors who match OEM specifications. $80 per gasket (or unit). To convert this cost to that per linear foot of gasket, We divide $80 by 20 feet (3x7 foot door from savings calculations) and get $4.00 per linear foot of gasket

Terms and Conditions

Must replace a worn gasket on a walk-in cooler or freezer. Gasket must have a minimum perimeter of 16 feet. Replacement gaskets must be meet the manufacturer's specifications, specifically regarding dimensions, materials, attachment method, style, compression, and magnetism.

Summary

	DOOR GASKETS
kWh/yr.	2,091
kW, noncoincident	0.342
kW, coincident	0.239
Life	4 years
Cost	$4.00 /linear ft of gasket

Application ID: M. & N. Auto Closer on Main Cooler or Freezer Doors
Measure ID: R79/R80

Technology Description

This measure is installation of an automatic, hydraulic-type door closer on main doors to walk-in coolers or freezers.

Measure Savings

Baseline assumptions for measure savings:

- The cooler/freezer door may be open intentionally an average of three hours per day for a total of 1,095 hours per year. Of the remaining 7,665 hours per year, we assume that the door is left ajar 25% of the time. The door closer saves energy during those 1,915 hours per year.
- Typical cooler and freezer door perimeter is 20 feet; we assume a width of W = 3 ft and height of H = 7 feet.
- Cooler temperature is 40°F, freezer is 0°F, kitchen temperature is 70°F (conservative), and relative humidity is 60%.
- Coolers and freezers lose 20% of the open door heat loss when the door is slightly ajar.
- Typical cooler performance factor is 1.6 kW/ton

  1.6kW/ton x (1ton/12,000Btuh) x 1000 Watts/kW)

  = 7.5 EER (Btu/Watt)
- Typical freezer performance factor is 2.4 kW/ton.

  2.4 kW/ton x (1ton/12,000Btuh) x 1000 Watts/kW)

  = 5.0 EER (Btu/Watt)
- 80% of installations are coolers, 20% are freezers.

Engineering based savings calculations are repeated from the 1996 filing, with updated information from the M&E report for the 1995 program (Quantum 1997b, p. B.5-15):

From 1990 ASHRAE Handbook – Refrigeration, 27.3 and 27.4 give the basic relationship for heat gain through doorways from temperature induced air exchange:

$$q_t = q * D_t * D_f$$

$$q = 3{,}790 * W * H^{1.5} (Qs/A)(I/R_S)\text{, Btu/hr}$$

where:

D_t = doorway open time factor

D_f = doorway flow factor

Q_S/A = sensible heat load infiltration air per square foot of doorway

R_S = sensible heat ratio of the infiltration air heat gain

The factors Q_S/A and I/R_S are determined from 1990 ASHRAE R-26.4; Figure 3 and Table 7. Apply a doorway flow factor of 0.80 (as recommended on page R-27.5, 1990 ASHRAE Handbook), and the 20% savings assumption (Df = 0.80 * 0.20). Savings for the average-sized cooler are (assuming initially that the door is left open for an entire hour):

q_t = 3,790 * 3 * $7^{1.5}$ (0.16) (1/0.59) * (0.80 * 0.20)

q_t = 9,137 Btu/hr * (ton hr/12,000 Btu) * (1.6 kW/ton)

$\mathbf{q_t}$ **= 1.218 kW**

Savings for the average-sized freezer are (again assuming that the door is left open for an entire hour:

q_t = 3,790 * 3 * $7^{1.5}$ * 0.61 * (1/0.63) * (0.80 * 0.20)

q_t = 32,622 Btu/hr * (ton hr/12,000 Btu) * (2.4 kW/ton)

$\mathbf{q_t}$ **=6.5247 kW**

Average non-coincident demand savings are:

[(1.218 * 0.80) + (6.524 * 0.20)] kW = 2.279 kW

Annual Energy Savings:

Assuming a busy restaurant, open 20 hours a day:

Hours Door Left Ajar

= (365 day/yr. x 20 hr/day) - (1,095 hr/yr. door intentionally left open)

= 6,205 hrs x 25% chance ajar = 1,551 hrs/yr.

Hours for potential savings = 8,760 hrs - 1,551 hrs - 1,095 hrs

= 6,114 hrs/yr.

Annual Energy Savings = 0.342 kW x 6,114 hrs/yr.

= **2,091 kWh/yr.**

Coincident demand savings:

For a given hour in the year, the chance that a door will be closed is the CDF.

Coincident demand savings = 0.342 kW x (6,114 hrs/yr. door closed)/(8,760 hrs/yr.) = **0.239 kW**

Measure Life

8 years (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Incremental cost

Material cost is about $65. Since some tools are required, installation by a contractor may be desirable. Since one hour is probably the minimum service charge, $60 is allowed for cost of labor. Therefore, the total cost is $125.

Manufacturers

Casom Corporation
39-06 Cresant Sumt
Long Island, NY 11101
718/937-3737

Franklin Machine Products Corporation
3 E. Stow Road
Marlton, NJ 08053
800/257-7737

Standard Keil/Tap-Rite
Route 34 at Garden State Parkway
Allenwood, NJ 08720
800/221-0704

Terms and Conditions

The door on a walk-in cooler or freezer must have a minimum perimeter of 16 feet. The auto-closer must be able to firmly close a door that is within one inch of full closure.

Summary

	AUTO-CLOSER
kWh/yr.	3,535
kW, noncoincident	2.279
kW, coincident	0.570
Life	8 years
Cost	$125 / unit

Application ID: O. & P . Auto Closer on Glass Reach In Cooler or Freezer Doors

Measure ID: ?/?

Technology Description

This measure is installation of an automatic, hydraulic-type door closer on glass reach-in doors to walk-in coolers or freezers.

Measure Savings

Baseline assumptions for measure savings:

- The cooler/freezer door may be opened as often as 140 times per day, left ajar (unintentionally 25% of the remaining time) The auto closers save energy during the time that the doors might be left ajar or open.
- The cooler/freezer door may be open intentionally an average of one hours per day for a total of 360 hours per year along with the opening by customers of

140 x 20 seconds. Of the remaining 6,840 hours per year, we assume that the door is left ajar 25% of the time. The door closer saves energy during those 1,915 hours per year.

- Typical cooler and freezer door perimeter is 16 feet; we assume a width of W = 2 ft and height of H = 6 feet.
- Cooler temperature is 40°F, freezer is 0°F, store temperature (in the vicinity of the cases) is 70°F (conservative), and relative humidity is 60%.
- Coolers and freezers lose 20% of the open door heat loss when the door is slightly ajar.
- Typical cooler performance factor is 1.6 kW/ton

  1.6kW/ton x (1ton/12,000Btuh) x 1000 Watts/kW)

  = 7.5 EER (Btu/Watt)
- Typical freezer performance factor is 2.4 kW/ton.

  2.4 kW/ton x (1ton/12,000Btuh) x 1000 Watts/kW)

  = 5.0 EER (Btu/Watt)
- 80% of installations are coolers, 20% are freezers.

Engineering based savings calculations are repeated from the 1996 filing, with updated information from the M&E report for the 1995 program (Quantum 1997b, p. B.5-15):

From 2002 ASHRAE Handbook – Refrigeration, 12.3 and 12.4 give the basic relationship for heat gain through doorways from temperature induced air exchange:

$q_t \quad = q * D_t * D_f$

$q \quad = 3,790 * W * H^{1.5} (Qs/A)(I/R_S)$, Btu/hr

where:

D_t = doorway open time factor = $(1+P\theta_p + 60\theta_o)/3600(\theta_d)$, where:

P = number of times door way opens -- 140

θp = door open - close time, seconds per cycle 20 seconds

θo = time door is simply open, minutes -- 25% of total time -- 15 minutes per hour

θp = daily or other time period, 20 hrs

Dt = (1+140*20+60*15)/(3600*20) = .05222

D_f = doorway flow factor

Q_S/A = sensible heat load infiltration air per square foot of doorway

R_S = sensible heat ratio of the infiltration air heat gain

The factors Q_S/A and I/R_S are determined from 2002 ASHRAE R-12.4; Figure 3 and Table 7.

Qs/A for cooler: @40oF, 0.16 for freezer: @0oF, 0.61

R for cooler: @40oF, 0.59 for freezer: @0oF, 0.63

Apply a doorway flow factor of 0.80 (as recommended on page R-12.5, 2002 ASHRAE Handbook), and the 20% savings assumption (D_f = 0.80 * 0.20). Non-coincident savings for the average-sized cooler are (assuming initially that the door is left open for an entire hour):

q_c = 3,790 * 2 * $6^{1.5}$ (0.16) (1/0.59) * (0.80 * 0.20)

q_c = 4,833.75 Btu/hr * (ton hr/12,000 Btu) * (1.6 kW/ton)

q_c = 0. 6445 kW

Non-coincident savings for the average-sized freezer are (again assuming that the door is left open for an entire hour:

q_f = 3,790 * 2 * $6^{1.5}$ * 0.61 * (1/0.63) * (0.80 * 0.20)

q_f = 17,258.6 Btu/hr * (ton hr/12,000 Btu) * (2.4 kW/ton)

q_f = 3.4517 kW

Annual Energy Savings:

Assuming a busy store, open 20 hours a day, 360 days per year

Time of Door Left Ajar:

Ta = 20 hours 360 days / year Dt = 20 * 360 * 0.0522 =375.84 hours

Hours for potential savings = 375.84 hrs

=

Annual Energy Savings = kW x hrs/yr.

q_{tc} = .6445 kW * 375.84 hours / yr = **242.89 kWh/yr**

q_{tf} = 3.4517 kW * 375.84 hours /yr = **1297.29 kWh/yr.**

Coincident demand savings:

For a given hour in the year, the chance that a door will be closed is the CDF.

Coincident demand savings cooler = .6445 kW x 375.84 hrs/yr. door closed)/(7200 hrs/yr.) = **.034 kW**

Coincident Demand Savings Freezer = 3.4517 kW x375.84 / 7200 = **0.18 kW**

Measure Life

8 years (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Incremental cost

Material cost is about $240. Since some tools are required, installation by a contractor may be desirable. Since one hour is probably the minimum service charge, $60 is allowed for cost of labor. Therefore, the total cost is $300.

[I received some pricing data after I commented on the work papers. It looks like material cost run from $75 to $240. The latter is for tension rods which is used to close the door in Anthony products. Could we consider raising the price to $40 for coolers and $50 for freezers? Jim Hanna]

Manufacturers

Anthony International
12812 Arroyo Street
San Fernando, CA 91342
800 772-0900
www.anthonydoors.com

Casom Corporation
39-06 Cresant Sumt
Long Island, NY 11101
718/937-3737

Franklin Machine Products Corporation
3 E. Stow Road
Marlton, NJ 08053
800/257-7737

Standard Keil/Tap-Rite
Route 34 at Garden State Parkway
Allenwood, NJ 08720
800/221-0704

Terms and Conditions

The door on a walk-in cooler or freezer must have a minimum perimeter of 16 feet. The auto-closer must be able to firmly close a door that is within one inch of full closure.

Summary

	COOLER (Y)	FREEZER (Z)
kWh/yr.	243	1297
kW, noncoincident	0.6445	3.4517
kW, coincident	0.034	0.18
Life	8 years	8 years
Cost	$300 / unit	$300 / unit

Application ID: Q. Evaporator Fan Controller for Walk-In Coolers

Measure ID: R53

Technology Description

An evaporator fan controller is defined as a device or system that lowers airflow across an evaporator in medium-temperature walk-in coolers when there is no refrigerant flow through the evaporator (i.e., when the compressor is in an off-cycle). This is typically accomplished by lowering the speed of the fan motors during the compressor off-cycle. The controller reduces air flow rather than turning fans off completely when the compressor is not operating because a minimum airflow is required to provide defrosting and prevent the air in the cooler from stratifying into layers of higher and lower temperature.

A typical evaporator unit in a walk-in cooler contains one or more small fans with fractional horsepower motors that are operating continuously. A fan controller saves energy by reducing fan usage and by reducing the refrigeration load resulting from the heat given off by the fan.

An evaporator fan controller consists of the following components:

- A controller for reducing airflow over the evaporator coil when there is no refrigerant flow through the evaporator. This can be achieved by using an adjustable speed drive or a two-speed motor, or by staging fans. The adjustable speed drives for fractional horsepower motors typically vary the input voltage to the motor to adjust the speed.
- An input signal to the controller that indicates if refrigerant is flowing through the evaporator. This input signal could be based on compressor on/off status, temperature across the evaporator coil, or compressor head pressure.

These controllers are not applicable to low temperature walk-in coolers because they are incompatible with the operation of the defrost system in those coolers.

Market Applicability

Walk-in coolers, which maintain food and other perishable products, are often found in restaurants, convenience stores, liquor stores, supermarkets, cafeterias, warehouses, florist shops, and laboratories. It is estimated that there are around half a million of these refrigerated rooms in the United States.

Measure Savings

Energy savings are calculated for a typical application in which an evaporator fan controller for a walk-in cooler would be potentially attractive to a customer. The equipment data and other parameters used in the example are considered to be either typical or mostly in the middle range of applications. The sample calculation is shown below. The savings for this measure are highly variable and depend to a large extent on the duty cycle of the compressor, which can range from 10% to 100%.

Savings are calculated on a "per controller" basis.

Data and Assumptions

Number of evaporator fans	2
Fan horsepower	1/20 hp each
Fan motor type	shaded-pole
Fan motor efficiency at full speed	35%
Fan motor efficiency at reduced speed	5%
Existing fan operation at full speed	8,760 hrs/yr
Compressor duty cycle	50%
Fan motor speed reduction when compressor is off	75%
Electricity rate:	$0.10/kWh
Installed project cost	$300

Calculation

Total fan power at full speed

$$= \frac{(\text{number of evaporator fans}) \times (\text{fan hp each}) \times (0.746\ \text{kW/hp})}{(\text{fan motor efficiency at full speed})}$$

$$= \underline{2 \times (1/20) \times 0.746}$$

35%
= 0.21 kW

Total fan power at reduced speed = (total fan power at full speed) x (1-fan motor speed reduction) ^ 3 x (fan motor efficiency at full speed) / (fan motor efficiency at reduced speed)
= 0.21 kW x (1-0.75)^3 x 35% / 5%
= 0.023 kW

Proposed fan operation at full speed = (existing fan operation at full speed) x (compressor duty cycle)
= 8,760 hrs/yr x 50%
= **4,380 hrs/yr**

Proposed fan operation at reduced speed = (existing fan operation at full speed) - (proposed fan operation at full speed)
= 8,760 hrs/yr - 4,380 hrs/yr
= 4,380 hrs/yr

Existing fan electricity usage = (total fan power at full speed) x (existing fan operation at full speed)
= 0.21 kW x 8,760 hrs/yr
= 1,867 kWh/yr

Proposed fan electricity usage = (total fan power at full speed) x (proposed fan operation at full speed) + (total fan power at reduced speed) x (proposed fan operation at reduced speed)
= 0.21 kW x 4,380 hrs/yr + 0.023 kW x 4,380 hrs/yr
= 1,036 kWh/yr

Fan electricity savings = (existing fan electricity usage) - (proposed fan electricity usage)
= 1,867 kWh/yr - 1,036 kWh/yr
= 831 kWh/yr

Reduced refrigeration load= fan electricity savings
= 831 kWh/yr

Refrigeration system COP = 3.0
Refrigeration system electricity savings = reduced refrigeration load / refrigeration system COP
= 831 kWh/yr / 3.0
= 277 kWh/yr

Total electricity savings per Controller = (fan electricity savings) + (refrigeration system electricity savings)
= 831 kWh/yr + 277 kWh/yr
= 1,109 kWh/yr

Total electricity cost savings per Controller = (total electricity savings) x (electricity rate)
= 1,109 kWh/yr x $0.10/kWh
= $111/yr

Measure Life

5 years (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Incremental Cost

$265 per unit (from: 2001 DEER Update Study, CCIG-CRE-07, p. 4-82, Xenergy, Oakland, CA.

Terms and Conditions

Must lower air flow of evaporator fans in walk-in coolers when there is no refrigerant flow through the evaporator (i.e., when the compressor is in an off-cycle). Must control a minimum fan load of 1/20 hp where the fan(s) are currently running continuously, and must reduce fan motor power consumption by at least 75% during the compressor off-cycle.

Summary

	EVAPORATOR FAN CONTROLLER
kWh/yr.	1,109
kW, noncoincident	0
kW, coincident	0
Life	5 years
Cost	$265 / unit

Application ID: R. Air-Cooled to Evaporative Cooled Condenser *Measure ID:* R38/R90

Technology Description

Replacing air-cooled condensers with evaporative-cooled condensers is somewhat supported in the industry; concerns for maintenance, water usage, the need for plumbing, and the need for space limit this application. Over sizing evaporative-cooled condensers in the retrofit market is supported in the industry but is generally not done unless utility incentives help offset the cost.

Evaporative condensers have an optimum condensing temperature where the system is most efficient, generally when the condensing temperature is 7-10 degrees higher than the ambient wet bulb temperature. This occurs when the energy consumption of the condenser fan(s) and pumps commences to offset the energy reduction from the improved compressor efficiency as a result of lower discharge pressure operation.

Measure Savings

The energy savings for this measure were determined by using detailed computer simulations based on the DOE-2.2 energy analysis program. DOE-2.2 was developed specifically for evaluating the energy performance of commercial and residential buildings. Although DOE-2.2 is newly released, its predecessor, DOE-2, has been widely reviewed and validated in the public domain. Both programs calculate hour-by-hour building energy consumption over an entire year (8760 hours) using weather data for the location under consideration. Separate energy savings were determined for various California Energy Commission climate zones.

DOE-2.2 modeling was used to determine cumulative energy savings as new energy efficient measures were added to a base refrigeration system. Energy savings for oversized condensers varied depending on the existing system. Savings for both stand alone and parallel (Multiplex) refrigeration system were used for claimed savings.

Data and Assumptions

The study is based on a prototypical building based on a typical supermarket design of 32,000 square feet, and operating eighteen hours per day. The market contains a total of 11 display case line-ups, and 5 walk-in boxes. The display fixtures are assumed to be of mid-90's vintage, and encompass the types and range of temperatures commonly found in supermarkets. Most of the low-temperature fixtures include doors, but some are open tubs. The remainder of the display cases is meat, dairy, deli, beverage, and produce cases. The criterion for selecting the applicable climate zones was based on the ambient wet-bulb temperature. Evaporation cooled condensers perform better in low wet-bulb (drier) climates.

Base case

Each display case and walk-in cooler is served by its own compressor, for a total of 16 compressors in 16 separate refrigeration systems. The low-temperature systems use R-502, and the medium temperature systems use R-12. The systems share a single multi-circuit condenser whose fans are staged directly on outdoor drybulb temperature. A discharge-air thermostat in each fixture cycles the compressor as required to meet the load. By converting the above system to a parallel (multiplex) compressor system with air cooled condensers the base energy savings have been established. This measure is also restricted to the below listed California Energy Commission climate zones:

Baseline, Energy Usage and Savings with Evaporative Cooled Condenser

EVAPORATIVE COOLED CONDENSER	AIR-COOLED BASELINE		USAGE W/ EVAP COND.		SAVINGS FROM BASELINE	
CEC CLIMATE ZONE	KWH	KW	KWH	KW	KWH	KW
CZ09	7303	0.48	7767	1.81	461	1.33
CZ10	7180	0.49	7922	1.55	743	1.07
CZ11	7078	0.54	7713	1.65	633	1.11
CZ12	7394	0.46	7681	1.66	287	1.20
CZ13	7035	0.93	7954	2.16	917	1.23
CZ14	8040	0.73	9137	1.95	1097	1.22
CZ15	7922	1.06	10525	2.42	2603	1.36

Measure Life

The CADMAC measure life study (EMS 1993) confirms the measure lives used in previous programs, and consequently the same measure lives are used here. The previous source for measure life was the ASHRAE Journal, "Service Life of Energy Conservation Measures," (McRae et al. 1988). These service life estimates have become the industry standard. The engineering life for refrigeration condensers is 20 years. The measure life is an adjustment of engineering life as recommended by the CEC. Using the 20% discount suggested in the CADMAC measure life study, the measure life is 16 years.

Incremental Cost

$781 per ton (from: 2001 DEER Update Study, CCIG-CRE-07, p. 4-83, Xenergy, Oakland, CA).

Terms and Conditions

Replace existing air-cooled condenser with evaporative unit. Condenser should be sized under normal design practice. Refrigerant should condense at roughly 25^{o}F above ambient wet-bulb temperature. No rebate is available for California Energy Commission Climate zones # 1, 2, 3,4,5,6,7, 8 and 16.

Summary

	EVAPORATIVE COOLED CONDENSER
kWh/yr. kW, noncoincident	Dependant on CEC Climate Zone (see table)
Life	16 years
Cost	$781 / Ton R

Application ID: S. ENERGY EFFICIENT "OVERSIZED" CONDENSER *Measure ID:* R81(air cooled), R88 (evap cooled)

Technology Description

This measure is for replacing existing condensers or adding additional condensers to an existing refrigeration system so that the net condenser size and rejection of heat from the refrigerant are larger than what is normally specified. As the condenser heat transfer increases at a set compressor load, the temperature at which the refrigerant condenses will drop, correspondent to the drop in refrigerant pressure within the condenser. Along with the condenser pressure, the force (power) required to circulate the refrigerant within the system reduces. The larger condenser at the lower discharge pressure not only increases the efficiency of the compressor *but also augments its capacity (in the form of greater refrigerant effect).*

Measure Savings

The energy savings for this measure were determined by using detailed computer simulations based on the DOE-2.2 energy analysis program. DOE-2.2 was developed specifically for evaluating the energy performance of commercial and residential buildings. Although DOE-2.2 is newly released, its predecessor, DOE-2, has been widely reviewed and validated in the public domain. Both programs calculate hour-by-hour building energy consumption over an entire year (8760 hours) using weather data for the location under consideration. Separate energy savings were determined for various California Energy Commission climate zones. DOE-2.2 modeling was used to determine cumulative energy savings as new energy efficient measures were added to a base refrigeration system.

Data and Assumptions

The study is based on a prototypical building based on a typical supermarket design of 32,000 square feet, and operating eighteen hours per day. The market contains a total of 11 display case line-ups, and 5 walk-in boxes. The display fixtures are assumed to be of mid-90's vintage, and encompass the types and range of temperatures commonly found in supermarkets. Most of the low-temperature fixtures include doors, but some are open tubs. The remainder of the display cases are meat, dairy, deli, beverage, and produce cases

Base case

Parallel Compressor system:

The refrigeration loads are served by two large systems with unequally sized, multiplexed compressors. The low-temperature system has two suction groups, operating at – 32°F and –22°F respectively, and uses R-404A. The medium temperature system has three suction groups, operating at 9°F, 19°F, and 35°F respectively, and uses R-507. Each suction group has multiple compressors for improved load matching. By adding floating head pressure control the base energy savings have been established. The savings are established by the difference in savings between the Floating Head case and the Controls and Eff. Condenser case (E3 and E2, AC3 and AC2) for each climate zone in the DOE2 appendix.

Air Cooled Case

CEC CLIMATE ZONE	AIR COOLED OVERSIZED CONDENSER SAVINGS		PARALLEL SYSTEM AIRCOOLED SAVINGS		SAVINGS FROM EE OVERSIZED CONDENSER	
	KWH	kW	kWh	kW	kWh	kW
CZ01	4327	0.50	3011	0.13	1316	0.36
CZ02	4080	0.64	2609	0.46	1472	0.17
CZ03	4201	0.11	2845	-0.03	1357	0.14
CZ04	4078	0.62	2630	0.28	1448	0.35
CZ05	4137	0.46	2753	0.36	1383	0.09
CZ06	4198	0.51	2812	0.37	1386	0.15
CZ07	4145	0.81	2743	0.46	1402	0.35
CZ08	4142	0.89	2718	0.62	1424	0.27
CZ09	4190	0.39	2740	-0.50	1450	0.89
CZ10	4121	0.48	2584	0.40	1536	0.07
CZ11	4180	0.65	2643	0.47	1536	0.18
CZ12	4129	0.38	2635	0.31	1491	0.07
CZ13	4287	0.54	2780	0.36	1504	0.18
CZ14	4220	0.62	2475	0.48	1745	0.14
CZ15	4708	0.64	2895	0.50	1812	0.14
CZ16	3724	0.17	2241	0.18	1483	0.00

Evaporator Case

CEC CLIMATE ZONE	EVAP COOLED OVERSIZED CONDENSER SAVINGS		PARALLEL SYSTEM EVAP COOLED SAVINGS		SAVINGS FROM EE OVERSIZED COND.	
	KWH	kW	kWh	kW	kWh	kW
CZ01	2847	0.19	1139	0.08	1708	0.11

CZ02	2584	-0.05	885	-0.08	1700	0.03
CZ03	2488	0.46	786	0.03	1702	0.43
CZ04	2343	0.43	724	-0.35	1619	0.78
CZ05	2456	0.21	777	0.19	1678	0.03
CZ06	1960	0.24	432	0.11	1528	0.13
CZ07	2255	0.62	584	0.00	1670	0.62
CZ08	2214	0.62	617	0.03	1598	0.59
CZ09	2383	0.51	718	0.13	1665	0.38
CZ10	2453	0.27	855	0.21	1598	0.05
CZ11	2700	0.13	1080	0.03	1617	0.11
CZ12	2660	0.35	1005	0.11	1654	0.24
CZ13	2469	0.35	853	0.11	1617	0.24
CZ14	2938	0.11	1493	0.00	1445	0.11
CZ15	2477	0.38	853	-0.03	1625	0.40
CZ16	3019	0.32	1507	-0.24	1512	0.56

Measure Life

This measure has a life of 16 years.

Incremental Cost

$702 per ton (from: 2001 DEER Update Study, CCIG-CRE-07, p. 4-83, Xenerrgy, Oakland, CA).

Terms and Conditions

Must replace an existing condenser with an energy-efficient unit and additional control mechanisms. This measure cannot be used in conjunction with Measure L. and must be applied to an existing multiplex compressor system. Retrofit systems should operate at 8^{o}F temperature difference for low temperature and 13^{o}F temperature difference for medium temperature systems. EER of 105 and 240Btu/watt for air-cooled and evaporative cooled units respectively. It also includes the use of VSD, set point reset and floating head pressure controls. Must provide a minimum of 5^{o}F of sub-cooling.

Summary

	ENERGY EFFICIENT CONDENSER
kWh/yr. kW, noncoincident	Dependant on CEC Climate Zone Dependant on CEC Climate Zone
Life	16 years
Cost	$702 / Ton R air, $292/Ton R evap

Application ID: T. *High Efficiency Multiplex Compressor System with Mechanical Sub-Cooling**

Measure ID: R12(air cooled), R82 (evap cooled)

Technology Description

This measure provides an incentive to replace single compressor systems with a multiplex compressor system consisting of unequal compressors to meet varying refrigeration loads in a supermarket application. Savings result at part load conditions. Instead of having separate compressors cycling on and off to provide cooling to different loads, the loads are tied together at the equipment room. A common multiplex system rack contains three compressors, sized at a 1:2:4 ratio. This provides eight steps of capacity, while single compressor systems provide only one step. Demand savings result from near-continued operation of the largest size compressor while the smallest size cycles on and off in response to the varying load profile. The energy savings result from larger sized motors being typically more efficient than their smaller counterparts. Additionally, there is less starting torque requirement in cycling the smaller ones. Compressors are sized to account for extreme conditions, and degradation of equipment, so they are often oversized. This oversizing on several single compressors can add up.
Currently multiplex systems are more common in the new construction market. Our target markets for this program are those stores doing major remodeling. The technology and technical assistance are readily available, so the potential for increased market penetration is good.

Measure Savings

The energy savings for this measure were determined by using detailed computer simulations based on the DOE-2.2 energy analysis program, developed specifically for evaluating the energy performance of commercial and residential buildings. Although DOE-2.2 is newly released, its predecessor, DOE-2, has been widely reviewed and validated in the public domain. Both programs calculate hour-by-hour building energy consumption over an entire year (8760 hours) using weather data for the location under consideration. Separate energy savings were determined for various California Energy Commission climate zones.

DOE-2.2 modeling was used to determine cumulative energy savings as new energy efficient measures were added to a base refrigeration system. The multiplex compressor system was the first measure added to the base case so related energy savings are available directly. Related energy savings vary depending on whether the refrigeration systems condensers are air cooled or evaporative cooled.

Data and Assumptions

The study is based on a prototypical building based on a typical supermarket design of 32,000 square feet, and operating eighteen hours per day. The market contains a total of 11 display case line-ups, and 5 walk-in boxes. The display fixtures are assumed to be of mid-90's vintage, and encompass the types and range of temperatures commonly found in supermarkets. Most of the low-temperature fixtures include doors, but some are open tubs. The remainder of the display cases is meat, dairy, deli, beverage, and produce cases.

Base case

Each display case and walk-in cooler is served by its own compressor, for a total of 16 compressors in 16 separate refrigeration systems. The low-temperature systems use R-502, and the medium temperature systems use R-12. The systems share a single multi-circuit condenser whose fans are staged directly on outdoor dry bulb temperature. A discharge-air thermostat in each fixture cycles the compressor as required to meet the load.

Savings attributed to Parallel (Multiplex) Compressor System with Mechanical Sub-Cooling:

AIR COOLED CONDENSERS			EVAPORATIVE COOLED CONDENSERS	
	kWh	kW	kWh	kW

CZ01	7928	1.12	4290	0.45
CZ02	7448	0.45	3995	0.40
CZ03	7962	0.22	4102	0.58
CZ04	7512	0.69	3914	0.62
CZ05	7836	0.69	4075	0.37
CZ06	8008	0.45	3727	0.50
CZ07	7756	0.97	3968	0.87
CZ08	7542	0.48	3914	0.60
CZ09	7306	0.48	4021	0.96
CZ10	7180	0.49	3995	0.41
CZ11	7080	0.54	3941	0.49
CZ12	7397	0.46	4102	0.58
CZ13	7038	0.93	3887	0.71
CZ14	8040	0.73	3834	0.45
CZ15	7925	1.06	3673	0.61
CZ16	7072	0.35	4075	0.61

Measure Life

The life of this measure is 12 years.

	SOURCE
14 years	Competitek, p. 190, ASHRAE, Dec. '88
20 years	Competitek, p. 191, SCE
14 years	Competitek Summary, p. 241
15 years	ADM/BPA, p. 2-11
15 years	LBL Report 18543, p. 3-4
15 years	LBL Report 18543, p. 3-4
12 years	CADMAC
12 years	Best judgment

Incremental Cost

The installed cost of an efficient condenser is estimated to be $3,446 per ton, based on information provided by Design and Engineering Services. The resulting payback, depending on climate zone, is between 10 and 20 years.

Terms and Conditions

Replace inefficient single compressor per line-up system with a high efficient y, multiplex (parallel) system, equipped with floating head pressure controls and mechanical sub-cooling. In a multiplex system, multiple unequally sized compressors serve a specific suction group, and each suction group serves one or more line-ups having similar temperatures. Must replace a conventional single *compressor system sharing a multi-circuit condenser. Incentive cannot be used in conjunction with floating head pressure control incentive. Energy Efficient condensers can be used (and are recommended) in conjunction with this measure.*

Summary

	MULTIPLEX COMPRESSOR SYSTEM
kWh/yr. kW, noncoincident	Dependant on CEC Climate Zone Dependant on CEC Climate Zone
Life	12 years
Cost	$3,446 / Ton R

***Note:** Preliminary work paper calculations are being further refined**.**

Application ID: U. Floating Head Pressure Control -- Air Cooled, Evaporator Cooled

Measure ID: R19/R91

Technology Description

Traditional refrigeration systems maintain a high head pressure control set point throughout the year. This is done because it is a convenient way of avoiding certain operational problems. The main objectives are to create a pressure differential great enough to move the required amount of refrigerant around the system and to provide enough hot gas during hot gas defrosting. As ambient temperature drops, the rate of heat exchange by the condenser is increased and the condenser is shut down in stages to maintain this fixed head pressure. Two methods of control are fan cycling and condenser flooding.

Installing a floating head pressure control device allows the head pressure, and thus condensing temperature, to drop down to a lower set point as the ambient temperature drops. The difference between the evaporating temperature and the condensing temperature is the key to the efficiency of a refrigeration plant. Lowering the condensing temperature at any time saves energy. Savings from floating head pressure occur when the ambient temperature falls below design conditions and the system allows the condensing temperature to drop below a previously established minimum set point.

Most refrigeration engineering, service, and contract companies support this technology. The technology and how to implement it is foreign to some. Concerns in a retrofit situation are:

- *Providing enough hot gas in a hot gas defrost system.*
- *Making sure that the refrigerant keeps moving through the system at low ambient conditions (capacity is the product of the mass flow rate and the refrigeration effect). As the pressure differential between the system's high and low sides (condenser and evaporator) decreases, so does the potential to adequately circulate the refrigerant through the system, plus the oil develops a tendency to separate from the refrigerant gas stream when low velocity and low temperature are both evident.*
- *Invading the system (having to cut into the refrigeration piping to install a new expansion valve).*
- *Oversizing of the liquid line due to the refrigerant's increase in density; as its liquid temperature is lowered. This, in turn, transports more oil as well as refrigerant and can result in lowering crankcase oil and receiver levels.*

The most important aspect of lowering head in relation to ambient is the necessity to maintain constant liquid line subcooling; the difference between (the higher) saturated condensing temperature and (the lower) liquid line temperature. It's relatively simple to have ample subcooling at elevated pressures.; Increasing the condensing pressure, resulting in a solid liquid feed to the expansion valve easily clears The refrigerant liquid line sight glass.

Clear sight glass, i.e.; liquid integrity at the expansion valves on low head operation air-cooled condenser systems, requires properly designed receivers (surge type) or an overcharge of refrigerant. With the proper low head system components in place, a minimum head pressure set point range of 45 to 50°F saturated condensing (R-22 at approximately 80 psi) is quite common in colder climates. Systems with evaporative condensers can generally go this low in colder climates without retrofit problems.

One refrigeration engineer maintains that with evaporative condensers the greatest savings occur when the system is controlled to maintain a seven degree difference between the condensing temperature and the current ambient wet bulb temperature. It has been noted that as long as positive feed to the evaporator is maintained, savings are possible down to a minimum head pressure set point of 45°F.

Floating head pressure is becoming more common in the consumer market. The minimum set point temperature varies dramatically (the lower the set point, the bigger the savings). A common set point is 82°F. This rebate is to provide an incentive to establish a *minimum head pressure set point of 70°F for halocarbon systems and 60°F for ammonia systems.*

Measure Savings

The energy savings for this measure were determined by using detailed computer simulations based on the DOE-2.2 energy analysis program. DOE-2.2 was developed specifically for evaluating the energy performance of commercial and residential buildings. Although DOE-2.2 is newly released, its predecessor, DOE-2.1, has been widely reviewed and validated in the public domain. Both programs calculate hour-by-hour building energy consumption over an entire year (8760 hours) using weather data for the location under consideration. Separate energy savings were determined for various California Energy Commission climate zones.
DOE-2.2 modeling was used to determine cumulative energy savings as new energy efficient measures were added to a base refrigeration system. The floating head pressure measure was the first measure added to the base case so related energy savings are available directly.

Data and Assumptions

The study is based on a prototypical building based on a typical supermarket design of 32,000 square feet, and operating eighteen hours per day. The market contains a total of 11 display case line-ups, and 5 walk-in boxes. The display fixtures are assumed to be of mid-90's vintage, and encompass the types and range of temperatures commonly found in supermarkets. Most of the low-temperature fixtures include doors, but some are open tubs. The remainder of the display cases are meat, dairy, deli, beverage, and produce cases.

Base case

The refrigeration loads are served by two large systems with unequally sized, multiplexed compressors. The low-temperature system has two suction groups, operating at – 32°F and –22°F respectively, and uses R-404A. The medium temperature system has three suction groups, operating at 9°F, 19°F, and 35°F respectively, and uses R-507. Each suction group has multiple compressors for improved load matching. Floating head pressure control is the first measure added to this base case so energy savings are directly available.

Savings attributed to Floating Head Pressure Control

	Air Cooled Case		Evaporative Case	
CEC CLIMATE ZONE	KWH	KW	KWH	KW
CZ01	3011	0.13	1139	0.09
CZ02	2609	0.46	885	-0.07
CZ03	2845	-0.03	786	0.01
CZ04	2630	0.28	724	-0.34
CZ05	2753	0.36	777	0.20
CZ06	2812	0.36	432	0.12
CZ07	2743	0.46	584	-0.01
CZ08	2718	0.62	617	0.04
CZ09	2740	-0.50	718	0.13
CZ10	2584	0.40	855	0.22
CZ11	2643	0.47	1080	0.02
CZ12	2635	0.31	1005	0.10
CZ13	2780	0.36	853	0.10
CZ14	2475	0.48	1493	-0.01
CZ15	2895	0.50	853	-0.02
CZ16	2241	0.18	1507	-0.25

Measure Life

The life of this measure is 14 years.

	SOURCE
12 years	Competitek, pg. 193 FMI/EPRI
15 years	ADM/BPA, pg. 2-11
15 years	CADMAC
14 years	Best judgment

Incremental Cost

The installed cost of an efficient condenser is estimated to be $279 per ton, based on information provided by Design and Engineering Services. The resulting payback is approximately 2 years.

Terms and Conditions

Must convert the discharge pressure controls from fixed to floating. This measure is applicable to existing multiplex (parallel) compressor systems only. Incentive cannot be used in conjunction with high efficiency multiplex compressor system. Must use variable speed fans. Must provide set-point override to maintain suction control temperature set point of 70°F. Balanced port or electronic expansion valves are recommended.

Summary

	FLOATING HEAD PRESSURE CONTROL
kWh/yr. kW, noncoincident	Dependant on CEC Climate Zone Dependant on CEC Climate Zone
Life	14 years
Cost	$279 / Ton R

Application ID: V. High Efficiency Multiplex Compressor System With Mechanical Sub-Cooling and Energy Efficient Condenser*

Measure ID: R83(air cooled), R84 (evap cooled)

Technology Description

This measure provides an incentive to replace single compressor systems with a multiplex compressor system consisting of unequal compressors to meet varying refrigeration loads in a supermarket application. Savings result at part load conditions. Instead of having separate compressors cycling on and off to provide cooling to different loads, the loads are tied together at the equipment room. A common multiplex system rack contains three compressors, installed in a 1:2:4 ratio of sizes. This provides eight steps of capacity, while single compressor systems provide only one step. Demand savings result from near-continued operation of the largest size compressor while the smallest size cycles on and off in response to the varying load profile. The energy savings result from larger sized motors being typically more efficient than their smaller counterparts. Additionally, there is less starting torque requirement in cycling the smaller ones. Compressors are sized to account for extreme conditions, and degradation of equipment, so they are often oversized. This oversizing on several single compressors can add up.

Currently multiplex systems are more common in the new construction market. Our target markets for this program are those stores doing major remodeling. The technology and technical assistance are readily available, so the potential for increased market penetration is good.

Measure Savings

The energy savings for this measure were determined by using detailed computer simulations based on the DOE-2.2 energy analysis program. DOE-2.2 was developed specifically for evaluating the energy performance of commercial and residential buildings. Although DOE-2.2 is newly released, its predecessor, DOE-2.1, has been widely reviewed and validated in the public domain. Both programs calculate hour-by-hour building energy consumption over an entire year (8760 hours) using weather data for the location under consideration. Separate energy savings were determined for various California Energy Commission climate zones.

DOE-2.2 modeling was used to determine cumulative energy savings as new energy efficient measures were added to a base refrigeration system. The multiplex compressor system was the first measure added to the base case model, resulting in directly available energy savings. The energy savings vary depending on whether the refrigeration systems condensers are air cooled or evaporative cooled.

Data and Assumptions

The study is based on a prototypical building based on a typical supermarket design of 32,000 square feet, and operating eighteen hours per day. The market contains a total of 11 display case line-ups, and 5 walk-in boxes. The display fixtures are assumed to be of mid-90's vintage, and encompass the types and range of temperatures commonly found in supermarkets. Most of the low-temperature fixtures include doors, but some are open tubs. The remainder of the display cases is meat, dairy, deli, beverage, and produce cases.

Base case

Each display case and walk-in cooler is served by its own compressor, for a total of 16 compressors in 16 separate refrigeration systems. The low-temperature systems use R-502, and the medium temperature systems use R-12. The systems share a single multi-circuit condenser whose fans are staged directly on outdoor dry bulb temperature. A discharge-air thermostat in each fixture cycles the compressor as required to meet the load.

Savings attributed to Parallel (Multiplex) Compressor System with Mechanical Sub-Cooling and Energy Efficient Condenser:

	AIR COOLED COND.		EVAP. COOLED COND.	
	kWh	kW	kWh	kW
CZ01	8123	1.21	4308	0.51
CZ02	7426	0.46	4035	0.40
CZ03	8231	0.32	4102	0.59
CZ04	7855	0.80	3914	0.62
CZ05	8123	0.78	4083	0.38
CZ06	8338	0.67	3775	0.51
CZ07	8123	1.07	4016	0.97
CZ08	7909	0.59	3973	0.64
CZ09	7694	0.70	4078	0.99
CZ10	7480	0.54	4027	0.43
CZ11	7292	0.59	3973	0.51
CZ12	7614	0.51	4155	0.59
CZ13	7292	1.02	3928	0.72
CZ14	8338	0.80	3877	0.46
CZ15	8311	1.15	3718	0.64

CZ16	7319	0.38	4105	0.62

Measure Life

The life of this measure is 12 years.

	SOURCE
14 years	Competitek, p. 190, ASHRAE, Dec. '88
20 years	Competitek, p. 191, SCE
14 years	Competitek Summary, p. 241
15 years	ADM/BPA, p. 2-11
15 years	LBL Report 18543, p. 3-4
15 years	LBL Report 18543, p. 3-4
12 years	CADMAC
12 years	Best judgment

Incremental Cost

The installed cost of an efficient condenser is estimated to be $3,446 per ton, based on information provided by Design and Engineering Services. The resulting payback, depending on climate zone, is between 10 and 20 years.

Terms and Conditions

Replace inefficient single compressor per line-up system with a high efficient y, multiplex (parallel) system, equipped with floating head pressure controls and mechanical sub-cooling. In a multiplex system, multiple unequally sized compressors serve a specific suction group, and each suction group serves one or more line-ups having similar temperatures. Must replace a conventional single compressor system sharing a multi-circuit condenser. Incentive cannot be used in conjunction with floating head pressure control incentive. Energy Efficient condensers can be used (and are recommended) in conjunction with this measure.

Summary

	MULTIPLEX COMPRESSOR SYSTEM
kWh/yr. kW, noncoincident	Dependant on CEC Climate Zone Dependant on CEC Climate Zone
Life	12 years
Cost	$3,446 / Ton R

***Note:** Preliminary work paper calculations are being further refined.

Application ID: W. Efficient Evaporator Fan Motor
Electronically Commutated Motor

Measure ID: R76

Technology Description

Electronically commutated motors operate efficiently over a wide range of operating characteristics. They optimize airflow while minimizing energy usage and waste heat. Because these motors are found within the refrigeration case itself, the higher efficiency unit, with its lower waste heat production, also reduces the internal load generated within the case.

Measure Savings

Replace Standard Fan Motors with Electronically Commutated Motors (ECM)

Cooling Savings

$Q\text{-cooling}_{svg} = \Delta kW\text{-motors} \times K$

Where:

	$Q\text{-cooling}_{svg}$:		Cooling saving, (Btu/hr/ft)
	ΔkW-motors :		Reduction in motors power, (kW/ft)
	K :		Conversion factor, (3413 Btu/hr/kW)
input	ΔkW -motors =	0.016	kW/ft
	K =	3413.0	Btu/hr/kW
Result:	**$Q\text{-cooling}_{svg}$ =**	**54.949**	**Btur/hr/ft**

<u>**Compressor Power Savings**</u> **(excluding condenser power)**

$\Delta kW = [Q\text{-cooling}_{svg} / EER] / 1000$

Where:

	ΔkW-Comp :		Compressor power savings, (kW/ft)
	$Q\text{-cooling}_{svg}$:		Cooling savings, (Btu/hr/ft)
	EER :		Compressor rating given by manufacturer, (Btu/hr/watts)
	Q-coolingsvg =	54.949	Btu/hr/ft
input	EER =	8.510	Btu/hr/watts (Copeland R-502 MT, @ +95F SCT & +20F ST)
Result:	**ΔkW-Comp =**	**0.00646**	**kW/ft**

<u>**Power Savings From Efficient Fan Motors (ECM)**</u>

ΔkW-Motor = [(ΔkW/motor) x (# of Motors / case)]/L

Where:

	ΔkW-Motor:		Motors power savings, (kW/ft)
	ΔkW/motor:		Saving per retrofitted motor, (kW/motor)
	# of Motors :		Number of motors per case
	L:		Display case length (ft)
input	# of motors =	2	motor(s)/case
input	L =	8	ft
input	DkW/motor =	0.060	kW/motor

Result:	**ΔkW-Motor =**		**0.015**	**kW/ft**

<u>Annual Compressor Energy Savings</u> (excluding condenser energy)

ΔkWh-Comp = ΔkW-Comp x EFLH

Where:

		ΔkWh-Comp:	Annual compressor energy savings (kWh/ft)
		ΔkW-Comp:	Compressor power savings, (kW/ft)
		EFLH :	Equivalent full load hours, (hours/year)

	ΔkW-Comp =	0.006	kW/ft
input	EFLH =	5700	hours/year
Result:	**ΔkWh-Comp =**	**36.8**	**Annual kWh/ft**

<u>Energy Savings From Motors (ECM)</u>

ΔkWh-Motor = (ΔkW-Motor) x t

Where:

ΔkWh-Motor :	Annual motor energy savings, (kWh/ft)
ΔkW-Motor :	Motor power savings, (kW/ft)
t :	Annual runtime of motors, (hours/year)

	ΔkW-Motor =	0.015		kW/ft
input	t =		8760.	hours/year
Result:	**ΔkWh-Motor =**		**131.4**	**Annual kWh/ft**

SUMMARY of SAVINGS:

Cooling Savings:	**55**	**Btu/hr/ft OR**	**220**	**Btu/hr/motor**
Power Savings:	**0.021**	**kW/ft OR**	**0.086**	**kW/motor**
Annual Energy Savings:	**168**	**Annual kWh/ft OR**	**673**	**Annual kWh/motor**

Measure Life

16 years -- (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Incremental Cost

$161 per motor (from: <u>2001 DEER Update Study</u>, CCIG-CRE-02, p. 4-84, Xenergy, Oakland, CA).

Terms and Conditions

Applicable to existing standard efficiency shaded pole evaporative fan motor on refrigerated display cases and fan coil system of walk-in coolers or freezers. The standard efficiency fan must be replaced by an electronically commutated motor (ECM).

Summary

	ECM EVAPORATOR FAN MOTOR
kWh/yr. KW, noncoincident	673 .086
Life	16 years
Cost	$161/motor

Application ID: X. Efficient Evaporator Fan Motor

Permanent Split Capacitor (PSC) Motor

Measure ID: R9

Technology Description

Permanent Split Capacitor motors have relatively high power factor that do not vary much with motor speed. This high power factor contributes to the efficient operation of the motor. Because these motors are found within the refrigeration case itself, the higher efficiency unit, with its lower waste heat production, also reduces the internal load generated within the case.

Measure Savings

Cooling Savings

$Q\text{-cooling}_{svg} = \Delta kW\text{-motors} \times K$

Where:

$Q\text{-cooling}_{svg}$:	Cooling saving, (Btu/hr/ft)
ΔkW-motors :	Motor Pwer Reduction , (kW/ft)
K :	Conversion, (3413 Btu/hr/kW)

input	ΔkW-motors =	0.00805	kW/ft
	K =	3,413	Btu/hr/kW
Result:	**$Q\text{-cooling}_{svg}$ =**	**27**	**Btur/hr/ft**

Compressor Power Savings (excluding condenser power)

$\Delta kW = [Q\text{-cooling}_{svg} / EER] / 1000$

Where:

ΔkW-Comp:	Compressor power savings, (kW/ft)
$Q\text{-cooling}_{svg}$:	Cooling savings, (Btu/hr/ft)
EER:	Compressor rating given by manufacturer, (Btu/hr/watts)

input	$Q\text{-cooling}_{svg}$ =	27	Btu/hr/ft
input	EER =	8.51	
Result:	**ΔkW-Comp =**	**0.0032**	**kW/ft**

Power Savings From Efficient Fan Motors (ECM)

ΔkW-Motor = [(ΔkW/motor) x (# of Motors / case)]/L

Where:

ΔkW-Motor :	Motors power savings, (kW/ft)
ΔkW/motor :	Saving per motor, (kW/motor)
# of Motors :	Number of motors per case
L :	Display case length (ft)

input	Number of motors =	2	motor(s)/case
input	L =	8	ft
input	ΔkW/motor =	0.03	kW/motor
Result:	**ΔkW-Motor =**	**0.008**	**kW/ft**

Energy Savings From Efficient Fan Motors (excluding condenser energy)

ΔkWh-Comp = ΔkW-Comp x EFLH

	Where:			
		ΔkWh-Comp :	Annual compressor energy savings, (kWh/ft)	
		ΔkW-Comp :	Compressor power savings, (kW/ft)	
		EFLH :	Equivalent full load hours, (hours/year)	
	ΔkW-Comp =	0.0032	kW/ft	
input	EFLH =	5,700	hours/year	
Result:	**ΔkWh-Comp =**	**18.40**	**Annual kWh/ft**	
	Energy Savings From Motors (ECM)			
	ΔkWh-Motor = (ΔkW-Motor) x t			
	Where:			
		ΔkWh-Motor:	Annual motor energy savings, (kWh/ft)	
		ΔkW-Motor:	Motor power savings, (kW/ft)	
		t:	Annual runtime of motors, (hours/year)	
	ΔkW-Motor =	0.008	kW/ft	
input	t=	8,760	hours/year	
Result:	**ΔkWh-Motor =**	**66**	**Annual kWh/ft**	
	SUMMARY of SAVINGS:			
Cooling Savings:	**27**	**Btu/hr/ft OR**	**110**	**Btu/hr/motor**
Power Savings:	**0.011**	**kW/ft OR**	**0.043**	**kW/motor**
Annual Energy Savings:	**84**	**Annual kWh/ft OR**	**336**	**Annual kWh/motor**

Measure Life

16 years -- (from: California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Incremental Cost

$161 per motor. – (from: 2001 DEER Update Study, CCIG-CRE-02, p. 4-84, Xenergy, Oakland, CA.

Terms and Conditions

Applicable to existing standard efficiency shaded pole evaporative fan motor on refrigerated display cases and fan coil system of walk-in coolers or freezers. The standard efficiency fan must be replaced by a permanent-split-capacitor (PSC) motor.

Summary

	PSC EVAPORATOR FAN MOTOR
kWh/yr.	336
kW, noncoincident	.043

Life	16 years
Cost	$161/motor

Application ID: Y. High Efficiency Refrigeration Compressors for Low Temperature Application
Measure ID: R85

Technology Description

Copeland, Prescold and Carlyle manufacture the majority of semi-hermetic compressors used for commercial refrigeration in the 5 to 30 horsepower range. Copeland has about 70 percent of market share. Copeland markets two types of compressor models. Their older compressor model design is called Copelamtic-Reed. The Copelamtic-Reed is about 15 to 20 percent less efficient than their newer design Discus compressor. Carlyle manufacturer only one type of compressors model. Their compressor lines were redesigned in the '80s to be equivalent in efficiency to the Copeland Discus compressor model line. Prescold is no longer in business but their compressors are still in service and will remain is service from rebuilding the compressors core.

The technical reason for the increase in efficiency in Copeland's Discus and the Carlyle compressor is that both are designed with higher volumetric efficiencies and higher electric motor efficiencies than Copeland's Copelmatic-Reed or Prescold compressors.

Refrigeration compressors have an average life of 15 years. The compressor is typically remanufactured or repaired at the end of its service life. The remanufactured compressor is sent back to the compressor's manufacturer and remanufactured to its original efficiency and useful life of about 15 years. The other less costly option is a compressor rebuilder shop. This option seldom brings the compressor to its original efficiency and useful life.

Measure Savings

For low temperature applications, the most efficient Copelamtic-Reed compressor has an EER of 4.86 with an evaporator temperature of -25 F and 105 F condensing temperature (for applications using refrigerant 502). The least efficient Discus compressor has an EER of 5.2 for the same conditions.

Example:

Given:

- One-ton compressor runs 18 hour per day or 6,570 hours a year.
- kW for the compressor with the 4.86 EER would be 2.47 kW/ton
- kW for the compressor with the 5.20 EER would be 2.31 kW/ton
- Yearly savings would be $(2.47 - 2.31)\ kW \times 6{,}570\ hours = 1{,}051$ kWh/yr.- ton
- kW reduction would be $2.47 - 2.31 = 0.16$ **kW/Ton**

Computer Simulation Results:

EPRI Supermarket Simulation Tool Computer program Version 3.0 9-13-00 using San Diego weather:

- 1453 kWh/yr.-ton per ton for an air-cooled condenser
- Copeland Compass Computer Program using San Diego weather:
- 1923 kWh/yr.-ton per ton for an air-cooled condenser
- Compressor HP per ton of refrigeration at low temperature conditions.
- Copelamtic-Reed HP per Ton = $\frac{2.47}{0.7457} = 3.3 \ \textit{Horsepower}$
- Discus compressor HP per Ton = $\frac{2.31}{0.7457} = 3.0 \ \textit{Horsepower}$
- Cost premium per ton = $132

Measure Life

15 years -- Copland, Carlyle and Hussmann substantiated the 15 years life.

Cost

The average cost of this measure was calculated using the incremental costs supplied by a refrigeration wholesaler. The data reflects the cost increase to purchase a 27 discus over a 30 HP reconditions Copelamtic-Reed compressor. The Cost premium per ton equal $132.

Terms and Conditions

Customer must replace the existing 4.86 or less EER compressor with one that has 5.2 or greater EER. The EER rating is based on the compressor's manufacture data. The EER is base on compressor using R-502 as the refrigerant with the following conditions:

- Saturated Suction Temperature = -25 F
- Saturated Condensing Temperature = 105 F
- Superheat = 5 F
- Subcooling = 0
- Return Gas Temperature = 65 F
- The refrigeration system can have other types of refrigerants. But, EER for incentive is based on R-502 only. The incentive is also base on the refrigeration tons at these conditions.

Summary

	COMPRESSOR	
kWh/yr.-ton	1051	
kW/ ton	0.16	
Life	15 years	

Cost	$132/ton	

Application ID: Z. Vending Machine Controller
Measure ID: R86

Technology Description

The vending machine controller is an energy control device for refrigerated vending machines. Vending machines contain fluorescent lamps that operate continuously and refrigeration equipment that cycles continuously. The vending machine controller curtails power to the vending machine when customers are not present. In practice, vending machines only need to be operated when a customer is present or when the compressor must run to maintain the product at desired temperature. The vending machine controller must possess features to insure energy savings, maintain the product at correct temperature, and safely operate the compressor. The controller must include a passive infrared occupancy sensor to turn off the fluorescent lights and compressor when no one is around. Logic in the vendor controller should shut off the vending machine if no one is present for 15 minutes. Control logic should periodically power up the machine at two-hour intervals if no one is present to insure product is maintained at correct serving temperature. Compressor protection is another requirement of the vending machine controller. Compressor motor current sensed by the vending machine controller indicates compressor operating status to prevent power curtailment until the compressor has completed its cooling cycle.

Measure Savings

Energy savings tests on the vending machine controller include independent laboratory tests and field tests. The independent laboratory test measured the savings of the vending machine controller on a machine operated in a controlled environment. Field tests, with pre and post installation energy consumption recorded, have been performed on 62 indoor and outdoor vending machines at 50 customer sites. The field tests indicated average energy savings of 1590 kWh/year [1]. The laboratory test was performed at a controlled ambient temperature of 90 F without surrounding activity to confirm the ability of the controller to maintain product within beverage manufacturers recommended serving temperature range.

Measure Life

The warranty period for vending machine controllers should be at least 3 years.

Cost

Unit price is $160. Including tax and installation the installed price would be approximately $200

Summary

Unit savings	**1590 kWh/year**
Life	3 years
Unit Cost	*$200*

End Notes

1. Bayview Technology Group Inc., Application VMSavingsComparison.XLS All-Savings worksheet tab

Refrigeration and Food Services References

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EPRI 1988. “Foodservice Industry Presentation Package.” Electric Power Research Institute, Publication No. 6148, December.

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Foodservice Application

Terms and Conditions: Foodservice

All equipment must be new. Used or rebuilt equipment is not eligible.

A. Pressureless Steamers

Must replace existing electric steamer. Pressureless electric steamers with full load efficiency of 50 percent or greater and idle energy rate of 0.4 kW or less qualify. Full load efficiency (potato cooking test) and idle energy rate (single compartment steamer) must be in accordance with the American Society for Testing and Materials (ASTM) Standard F1484.

B. Insulated Hot Food Holding Cabinets

Must replace existing electric hot food holding cabinet. The insulated electric hot food holding cabinets qualify if the operating energy rate is:

- For full size cabinets, less or equal to 0.8 kW
- For three-quarter size cabinets, less or equal to 0.6 kW
- For half size cabinets, less or equal to 0.4 kW

All operating energy rates must be in accordance with the American Society for Testing and Materials (ASTM) Standard F2140.

2003 Foodservice Application

Equipment Type	Quantity Purchase A	Rebate/Unit B	Rebate C = A x B
A1. Pressureless Steamers (full load efficiency 50% or greater and idle energy rate 0.4 kW or less)		**$500/unit**	
A2. Pressureless Steamers (full load efficiency 70% or greater and idle energy rate 0.2 kW or less)		**$600/unit**	
B1. Insulated Holding Cabinets (full size cabinets energy rate less or equal to 0.8 kW)		**$250/unit**	
B2. Insulated Holding Cabinets (full size cabinet energy rate less or equal to 0.5 kW)		**$400/unit**	
B3. Insulated Holding Cabinets (three-quarter size cabinet energy rate less or equal to 0.6 kW)		**$200/unit**	
B4. Insulated Holding Cabinets (three-quarter size cabinet energy rate less or equal to 0.4 kW)		**$300/unit**	
B5. Insulated Holding Cabinets (half size cabinet energy rate less or equal to 0.4 kW)		**$150/unit**	
B6. Insulated Holding Cabinets (half size cabinet energy rate less or equal to 0.3 kW)		**$200/unit**	

PRESSURELESS STEAMER ENERGY SAVINGS
Baseline Steamer
Full load efficiency = 30%
Idle energy rate = 0.6 kW
Annual energy usage = 11,600 kWh

Energy Efficient Steamer: 50% efficiency

Full load efficiency = 50%
Idle energy rate = 0.4 kW
Annual energy usage = 4,980 kWh
Annual Energy Savings = 11,600 – 4,980 = 6,620 kWh

Energy Efficient Steamer: 70% efficiency
Full load efficiency = 70%
Idle energy rate = 0.2 kW
Annual energy usage = 3,820 kWh
Annual Energy Savings = 11,600 – 3,820 = 7,780 kWh

Energy usage calculations are based on 12 hours a day, 365 days per year, with one preheat and cooking 100 pounds per day of food. The steamers' efficiency and idle rate were obtained in accordance with the American Society for Testing and Materials (ASTM) Standard F1484.

INSULATED HOT FOOD HOLDING CABINET ENERGY SAVINGS

Full Size Holding Cabinets

Baseline Full Size Hot Food Holding Cabinet

Operating energy rate = 1.5 kW
Annual energy usage = 8,300 kWh

Energy Efficient Full Size Hot Food Holding Cabinet: 0.8 kW

Operating energy rate = 0.8 kW
Annual energy usage = 4,400 kWh
Annual Energy Savings = 8,300 – 4,400 = 3,900 kWh

Energy Efficient Full Size Hot Food Holding Cabinet: 0.5 kW

Operating energy rate = 0.5 kW
Annual energy usage = 2,800 kWh
Annual Energy Savings = 8,300 – 2,800 = 5,500 kWh

Three-Quarter Size Holding Cabinets

Baseline Three-Quarter Size Hot Food Holding Cabinet

Operating energy rate = 1.1 kW
Annual energy usage = 6,090 kWh

Energy Efficient Three-Quarter Size Hot Food Holding Cabinet: 0.6 kW

Operating energy rate = 0.6 kW
Annual energy usage = 3,300 kWh
Annual Energy Savings = 6,090 – 3,300 = 2,790 kWh

Energy Efficient Three-Quarter Size Hot Food Holding Cabinet: 0.4 kW

Operating energy rate = 0.4 kW
Annual energy usage = 2,240 kWh
Annual Energy Savings = 6,090 – 2,240 = 3,850 kWh

Half Size Holding Cabinets

Baseline Half Size Hot Food Holding Cabinet

Operating energy rate = 0.75 kW
Annual energy usage = 4,150 kWh

Energy Efficient Half Size Hot Food Holding Cabinet: 0.4 kW

Operating energy rate = 0.4 kW
Annual energy usage = 2,200 kWh
Annual Energy Savings = 4,150 – 2,200 = 1,950 kWh

Energy Efficient Half Size Hot Food Holding Cabinet: 0.3 kW

Operating energy rate = 0.3 kW
Annual energy usage = 1,400 kWh
Annual Energy Savings = 4,150 – 1,400 = 2,750 kWh

Energy usage calculations are based on 15 hours a day, 365 days per year operation at a typical temperature setting of 150°F. Note that the different sizes for the holding cabinets (half size and three-quarter size) have proportional operating energy rates. Operating energy rate for the full size holding cabinets was obtained in accordance with the American Society for Testing and Materials (ASTM) Standard F2140.
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EXPRESS Gas Measure Workpapers

Prepared by SoCalGas Per 2002 Operations (reflects final technical requirements and therm savings calculation methodologies used during the PY; where applicable, equipment characteristics are based on full-year PY 2001 applicable records*)

H8 (Application Code A)
Measure(s): Commercial H-axis Washer

Measure Description

Horizontal-axis commercial washers reduce energy consumption primarily through reduced [natural gas] water heating usage, as h-axis washers clean laundry using approximately one-half the water of a conventional vertical-axis washer. H-axis washers also reduce energy consumption associated with natural gas clothes drying, as clothes are spun dry at high RPM speeds to extremely low water content.

Market Applicability

This measure is applicable to commercial laundromat facilities.

Terms and Conditions

Commercial clothes washers must be classified as ~~category~~ Tier 2, 3, 4a, or 4b~~A2, B2, or C2~~ by the Consortium for Energy Efficiency (CEE). The qualified commercial clothes washer ~~Equipment~~ must replace existing vertical-axis commercial clothes washers and be used in conjunction with gas water heating and gas drying. Customers must submit an invoice clearly identifying the brand and model number of the washer.

Cost Effectiveness Modeling Measure Data

Measure data for cost effectiveness modeling have been developed based on typical operational characteristics for Southern California laundry facilities, and based on average equipment characteristics for SoCalGas customer participants for commercial h-axis washer incentives during PY 2001. Unitized cost effectiveness determinants are summarized in the table below. Energy savings data are based on water heating-related ~~savings only (~~ and gas dryer savings~~ are not included)~~. The assumed measure lifetime is based on the October 2001 Energy Efficiency Policy Manual for insulation measures. The assumed net-to-gross ratio is based on the October 2001 Energy Efficiency Policy Manual for express efficiency. Non-energy savings data are based on lifecycle water savings using DWP commercial customer water rates and 3% annual inflation. Tax credit data are associated with business compliance with ADA laws (since h-axis washers qualify owing to front access and control panels), and allow for a tax credit of 50% for up to $10,000 of qualifying expenditures.

	Commercial H-axis Washers
Incremental Measure Cost per avg. unit	*$407*
Annual Energy Savings per avg. unit	148.9 ~~87.6~~ therms; 0 ~~21.9~~ kWh[1]
Incentive Amount per avg. unit	*$150*
Non Energy Savings per avg. unit	$1,011
Tax Credit per avg. unit	$239
Measure Lifetime	10 years
Net-to-Gross Ratio	.96
MDSS Measure Code	H8
Application Code	A

[1] Annual energy savings per average unit are updated based on *CEE Clothes Washer Savings Estimates* from the 2002 CEE Initiative Description, for Tiers 4a and 4b. California commercial Laundromats use Tier 4a and 4b H-axis washers almost exclusively.

*H8 Commercial Washer Measure Reference
Prepared for the Express Efficiency Planning Group by SoCalGas

	Value	Notes:
Incentive/unit	$200	Incentive paid directly to customers (primarily coin-op laundries), but promoted through equipment distributors
# incented	1,123	Program begun in June 2001, closed in December 2001
Therm saved/unit	148.92~~87.6~~	.068~~40~~ therms/cycle, 6 cycle/day, 365 day/yr [.040/cycle based on .053/cycle figure from SD Co. Water Authority, 1/30/01, for gas water heater & gas clothes dryer, assuming hot water wash; SD City figure]
KWh saved/unit	0 ~~21.9~~	~~motor/controls: base unit = .15 kwh/cycle; incented = .14 kwh/cycle; 6 cycle/day, 365 day/yr [base model = GE; incented model = assumed to be a 50/50 mix of Maytag and Speed Queen models (.16 & .12 kwh/cycle, respectively); data are per SCE Leisure World report, 12/00, p. vi; 6 cycles/day is per CEE web site for laundromat units; total is 22 kwh saved/year]~~ Per CEE, No electric savings due to increased work to spin dry.
Measure life	10	CALMAC measure 263
Net-to-gross	.96	Express Efficiency value
Incremental measure cost/unit	$401	Base model was assumed to be a 1/3-1/3-1/-3 blend of the following models: GE WCCD2050Y ($640); Maytag MAT12CS ($750); & Maytag MAT12PD ($830) = $740 (GE data are per SCE Leisure World report, 12/00, p. iv, while Maytag data are per Best Maytag Home Appliance Center Online Mall web site, 5/25/01). Incented model was assumed to be a 1/3-1/3-1/3 blend of the Speed Queen SWR 261 ($1250), the Maytag MAH20PD ($1450), and the Staber HXW 2901 ($1599) = $1433; Speed Queen data are per SCE report, p. iv; Maytag data are per above-mentioned web site, 5/25/01; Staber data are per company web site, 6/12/01. Of incented models, 80% were assumed to take the $250 MWD rebate while 20% do not (owing to service territory issues, customers falling through promotional cracks, customer inertia, etc.); resulting IMC/unit is .8 * ($1433 - $740 - $250) + .2 * ($1433 - $740) = $493. IMC ratio to baseline cost is .4 = $493/$1233, where $1233 is the incented unit cost minus $200 average MWD incentive payment. Actual 2001 values for incented units were lower ($1003), hence IMC lowered to $401 = .4 * 1003.
Tax credit/unit	$239	Credit is for business compliance with ADA laws, and allows for a tax credit of 50% for up to $10,000 of qualifying expenditures. Per Form 8826 instructions, $ spent on modifying equipment or devices for individuals with disabilities qualifies; h-axis washers qualify owing to front access and control panels.
TRC Benefit/Cost	1.4	3.9 with non-energy (water savings) benefits
Water saving/unit	NPV= $992	19.7 gal/cycle, 6 cycle/day, 365 day/yr, 748 gal/CCF, $1.493/CCF [19.7 gal/cycle is per SD Co. Water Authority, 1/30/01; 6 cycles/day is per CEE web site for laundromat units; $2.1215 is DWP avg monthly rate for schedule C for <2" meter for Jan-Jun 2001; 3% inflation assumed thereafter]

H6 (Application Code B)
Equipment Measure(s): Storage Water Heaters

Measure Description

Energy efficient storage water heaters used in commercial or industrial applications of domestic hot water. Energy efficient units typically have features such as relatively large heat exchange surfaces and/or extra thick amounts of tank insulation.

Market Applicability

These measures are applicable to any small or medium storage water heater domestic hot water application; cannot be used for process end uses. Applicable building/business types include (but are not limited to) offices, restaurants, retail, schools, colleges, hotels, motels, and recreational facilities.

Terms and Conditions

Water heaters must have an energy factor of .58+ - .61+ (small units; depends on tank volume) or thermal efficiency of 82+% (large units). Only storage (i.e., non-instantaneous) water heaters qualify. The incentive applies only to gas-for-gas equipment replacement (i.e., neither new construction nor fuel switching applications are eligible). Water heaters used for pool or spa do not qualify. The manufacturer name and equipment model number must be provided. If necessary, customers must provide proof of unit efficiency (e.g., manufacturer equipment specification sheets).

Cost Effectiveness Modeling Measure Data

Measure data for cost effectiveness modeling have been developed based on average equipment characteristics for SoCalGas customer participants for Express Efficiency storage water heater measures (those large units with efficiencies of 82+%; all small units) during PY 2001. Unitized cost effectiveness determinants are summarized in the table below. The assumed measure lifetime is based on the October 2001 Energy Efficiency Policy Manual for water heater measures. The assumed net-to-gross ratio is based on the October 2001 Energy Efficiency Policy Manual for express efficiency.

	Storage Water Heaters
Rated Input (MBTUH per avg. unit)	251
Incremental Measure Cost per avg. unit	$1,701
Annual Energy Savings per avg. unit	440 therms
Incentive Amount per unit ($2/MBTUH)	*$502*
Measure Lifetime	15 years
Net-to-Gross Ratio	.96
MDSS Measure Code	H6
Application Code	B

X1/X2/X3 (Application Code C)
Equipment Measure(s): Space Heating Boilers

Measure Description

Space heating boilers are pressure vessels that transfer heat to water for use primarily in space heating applications. Boilers heat water using a heat exchanger that works like an instantaneous water heater or by the addition of a separate tank with an internal heat exchanger that is connected to the boiler. Energy efficient units often feature high efficiency and/or low NOX burners, and typically have features such as water tubes, power burners, relatively large heat exchange surfaces, and/or utilize heat recovery from stack gases.

Market Applicability

These measures are applicable to any small or medium commercial boiler application used primarily for space heating and cannot be used primarily for process end uses or for domestic hot water. Applicable building/business types include (but are not limited to) offices, restaurants, retail, schools, colleges, hotels, motels, and recreational facilities.

Terms and Conditions

Boilers must have a combustion efficiency of 82+% (large units) or AFUE of 77+% (small steam units) or 82+% (small water units). Only boilers used primarily for space heating uses qualify. The incentive applies only to gas-for-gas equipment replacement (i.e., neither new construction nor fuel switching applications are eligible). Boilers used for pool or spa do not qualify. The manufacturer name and equipment model number must be provided. If necessary, customers must provide proof of unit efficiency (e.g., manufacturer equipment specification sheets).

Cost Effectiveness Modeling Measure Data

Measure data for cost effectiveness modeling have been developed based on average equipment characteristics for SoCalGas customer participants for Express Efficiency space heating boiler measures (those units with efficiencies of 82+%) during PY 2001. Unitized cost effectiveness determinants are summarized in the table below. The assumed measure lifetime is based on the October 2001 Energy Efficiency Policy Manual for boiler measures. The assumed net-to-gross ratio is based on the October 2001 Energy Efficiency Policy Manual for express efficiency.

	Space Heating Boilers
Rated Input (MBTUH per avg. unit)	*1,269*
Incremental Measure Cost per avg. unit	*$2,845*
Annual Energy Savings per avg. unit	814 therms
Incentive Amount per avg. unit ($2/MBTUH)	*$2,537*
Measure Lifetime	20 years
Net-to-Gross Ratio	.96
MDSS Measure Code	X1, X2, X3
Application Code	C

B2 (Application Code D)
Equipment Measure(s): Hot Water Boilers

Measure Description

Hot water boilers are pressure vessels that transfer heat to water. Boilers heat domestic hot water using a heat exchanger that works like an instantaneous water heater or by the addition of a separate tank with an internal heat exchanger that is connected to the boiler. Energy efficient units often feature high efficiency and/or low NOX burners, and typically have features such as water tubes, power burners, relatively large heat exchange surfaces, and/or utilize heat recovery from stack gases.

Market Applicability

These measures are applicable to any small or medium commercial domestic hot water boiler application and cannot be used for process end uses. Applicable building/business types include (but are not limited to) offices, restaurants, retail, schools, colleges, hotels, motels, and recreational facilities.

Terms and Conditions

Boilers must have rated capacity of >75 MBTUH and have a thermal efficiency of 82+%. Only boilers used primarily for domestic hot water uses qualify. The incentive applies only to gas-for-gas equipment replacement (i.e., neither new construction nor fuel switching applications are eligible). Boilers used for pool or spa do not qualify. The manufacturer name and equipment model number must be provided. If necessary, customers must provide proof of unit efficiency (e.g., manufacturer equipment specification sheets).

Cost Effectiveness Modeling Measure Data

Measure data for cost effectiveness modeling have been developed based on average equipment characteristics for SoCalGas customer participants for Express Efficiency hot water boiler measures (those units with efficiencies of 82+%) during PY 2001. Unitized cost effectiveness determinants are summarized in the table below. The assumed measure lifetime is based on the October 2001 Energy Efficiency Policy Manual for boiler measures. The assumed net-to-gross ratio is based on the October 2001 Energy Efficiency Policy Manual for express efficiency.

	Hot Water Boilers
Rated Input (MBTUH per avg. unit)	*976*
Incremental Measure Cost per avg. unit	*$1,671*
Annual Energy Savings per avg. unit	2,937 therms
Incentive Amount per avg. unit ($2/MBTUH)	*$1,952*
Measure Lifetime	20 years
Net-to-Gross Ratio	.96
MDSS Measure Code	B2
Application Code	D

H9/H10/H14 (Application Code E)
Measure(s): Instant Water Heaters

Measure Description

Tankless water heater units have become available in recent years for a variety of commercial sector domestic hot water applications. Such units feature sufficiently large efficient burners to heat water immediately to commercial temperature requirements. Instantaneous water heaters thereby provide users with "endless" supplies of heated water. Such units are highly energy efficient, as standby losses are effectively eliminated. Despite cost advantages relative to traditional storage water heaters (e.g., associated with elimination of the tank), this technology requires financial incentives to increase market share beyond current niche applications. These incentives offset 1) user general lack of technology familiarity and 2) perceived concerns about utility system water pressure variability.

Market Applicability

These measures are applicable to any small or medium commercial domestic hot water application; cannot be used for process end uses. Applicable building/business types include (but are not limited to) offices, restaurants, retail, schools, colleges, hotels, motels, and recreational facilities.

Terms and Conditions

Instantaneous water heaters must have an energy factor of .63+ (<=200 MBTUH units) or thermal efficiency of 82+% (>200 MBTUH units). Only instantaneous water heaters (as defined by the California Energy Commission) used for domestic hot water applications qualify. The incentive applies only to gas-for-gas equipment replacement (i.e., neither new construction nor fuel switching applications are eligible). The manufacturer name and equipment model number must be provided. If necessary, customers must provide proof of the tankless nature of the water heater (e.g., manufacturer equipment specification sheets).

Cost Effectiveness Modeling Measure Data

Cost effectiveness calculations applicable to PY 2002 Express Efficiency instantaneous water heater equipment measures have been developed based on the 2001 Deer study, comparable cost manuals (e.g., R.S. Means), and the CEC instant water heater equipment database. Unitized cost effectiveness determinants are summarized in the table below. The assumed measure lifetime is based on the CPUC's Energy Efficiency Policy Manual for water heater measures. The assumed net-to-gross ratio is based on the October 2001 Energy Efficiency Policy Manual for express efficiency.

	Large Units (> 200 MBTUH)	**Medium Units (75.1-200 MBTUH)**	**Small Units (<= 75 MBTUH)**
Rated Input (MBTUH per avg. unit)	1229	*139*	*42*
Incremental Measure Cost per avg. unit	-$1,627	*-$1,080*	*-$326*
Annual Energy Savings per avg. unit	1,733 therms	196 therms	222 therms
Incentive Amount per unit ($2/MBTUH)	*$2,458*	*$278*	*$84*
Measure Lifetime	15 years	15 years	15 years
Net-to-Gross Ratio	.96	.96	.96
MDSS Measure Code		H9	H14
Application Code		E	E

H11/H15/H16 (Application Code F)
Equipment Measure(s): Process Boilers (including Direct Contact Water Heaters)

Measure Description

Process boilers are pressure vessels that transfer heat to water for use in industrial applications. Boilers heat process-related water using a heat exchanger that works like an instantaneous water heater or by the addition of a separate tank with an internal heat exchanger that is connected to the boiler. Energy efficient units often feature high efficiency and/or low NOX burners, and typically have features such as water tubes, power burners, relatively large heat exchange surfaces, and/or utilize heat recovery from stack gases.

Direct contact water heaters are units in which flame heat comes into direct contact with small droplets of cold water, thereby heating the water directly.

Market Applicability

These measures are applicable to any small or medium process boiler application; they cannot be used primarily for domestic hot water or space heating end uses. The main applicability is in the industrial sector, but also includes commercial laundry, dry cleaning, agricultural, and miscellaneous process uses.

Terms and Conditions

Boilers must have a combustion efficiency as installed of 82+%. Only process boilers (i.e., units not primarily used for domestic hot water or space heating uses) qualify. The incentive applies only to gas-for-gas equipment replacement (i.e., neither new construction nor fuel switching applications are eligible). The manufacturer name and equipment model number must be provided. If necessary, customers must provide proof of unit efficiency (e.g., manufacturer equipment specification sheets).

Cost Effectiveness Modeling Measure Data

Measure data for cost effectiveness modeling have been developed based on average characteristics among customer participants in the SoCalGas Process Energy Consumption boiler measure (those units with efficiencies of 82+%) during PY 2001. Unitized cost effectiveness determinants are summarized in the table below. The assumed measure lifetime is based on the CPUC’s Energy Efficiency Policy Manual for boiler measures. The assumed net-to-gross ratio is based on the October 2001 Energy Efficiency Policy Manual for express efficiency.

	Process Boilers
Rated Input (MBTUH per avg. unit)	*3,093*
Incremental Measure Cost per avg. unit	*$6,704*
Annual Energy Savings per avg. unit	7,074 therms
Incentive Amount per avg. unit ($2/MBTUH)	*$6,185*
Measure Lifetime	20 years
Net-to-Gross Ratio	.96
MDSS Measure Code	H11, H15, H16
Application Code	F

E3/E4 (Application Code G)
Measure(s): Foodservice Equipment – Power Burner Technology

Measure Description
In certain commercial gas food service equipment applications such as fryers and conveyor ovens, power burners have begun to displace traditional atmospheric burners. The power burner consists of a blower used in conjunction with a natural gas burner to facilitate convection cooking efficiencies. Typically, power burner technology food service equipment can reduce energy consumption by 25% relative to corresponding baseline atmospheric burner units.

Market Applicability
This measure is applicable to any small commercial cooking application. Includes (but is not limited to) sit down and fast food restaurants, hotels, motels, schools, colleges, and recreational facilities.

Terms and Conditions
Only fryers and conveyor ovens with power burner technology qualify. The incentive applies only to gas-for-gas equipment replacement (i.e., neither new construction nor fuel switching applications are eligible). Customers must provide proof of power burner technology on the invoice and/or manufacturer equipment specification sheets. The equipment model number also must be provided.

Cost Effectiveness Modeling Measure Data
Measure data for cost effectiveness modeling have been developed based on average equipment characteristics for SoCalGas customer participants for Express Efficiency power burner cooking measures during PY 2001. Unitized cost effectiveness determinants are summarized in the table below. The assumed measure lifetime is based on the October 2001 Energy Efficiency Policy Manual for cooking measures. The assumed net-to-gross ratio is based on the October 2001 Energy Efficiency Policy Manual for express efficiency.

	Power Burner Fryer	**Power Burner Conveyor Oven**
Rated Input (MBTUH per avg. unit)	*148*	180
Incremental Measure Cost per avg. unit	*$1,646*	$2,895
Annual Energy Savings per avg. unit	709 therms	863 therms
Incentive Amount per avg. unit ($5/MBTUH)	*$738*	*$898*
Measure Lifetime	12 years	12 years
Net-to-Gross Ratio	.96	.96
MDSS Measure Code		E4
Application Code		G

E1/E5/E7 (Application Code H)
Measure(s): Foodservice Equipment – Infrared Technology

Measure Description
In certain commercial gas food service equipment applications, infrared burners have begun to displace traditional atmospheric burners. The infrared burner is made of ceramic plates or metal screens. Combustion of premixed air and gas takes place on the burner surface, which can reach $1{,}800^{o}$ F. The high surface temperatures cause the material to emit radiant heat. Typically, infrared technology food service equipment can reduce energy consumption by 40-50% relative to corresponding baseline atmospheric burner units.

Market Applicability
This measure is applicable to any small commercial cooking application. Includes (but is not limited to) sit down and fast food restaurants, hotels, motels, schools, colleges, and recreational facilities.

Terms and Conditions
Only fryers, conveyor ovens, and rotisseries with infrared technology qualify. The incentive applies only to gas-for-gas equipment replacement (i.e., neither new construction nor fuel switching applications are eligible). Customers must provide proof of infrared technology on the invoice and/or manufacturer equipment specification sheets. The equipment model number also must be provided.

Cost Effectiveness Modeling Measure Data
Measure data for cost effectiveness modeling have been developed based on average equipment characteristics for SoCalGas customer participants for Express Efficiency infrared cooking measures during PY 2001. Unitized cost effectiveness determinants are summarized in the table below. The assumed measure lifetime is based on the October 2001 Energy Efficiency Policy Manual for cooking measures. The assumed net-to-gross ratio is based on the October 2001 Energy Efficiency Policy Manual for express efficiency.

	Infrared Fryer	**Infrared** **Conveyor Oven**	**Infrared** **Rotisseries**
Rated Input (MBTUH per avg. unit)	*79*	200	171
Incremental Measure Cost per avg. unit	*$1,749*	$2,049	$3,679
Annual Energy Savings per avg. unit	652 therms	1,573 therms	1,347 therms
Incentive Amount per avg. unit ($10/MBTUH)	*$786*	*$2,000*	*$1,713*
Measure Lifetime	12 years	12 years	12 years
Net-to-Gross Ratio	.96	.96	.96
	E1	E5	E7
	H	H	H

H12/H13/H17/H18(Application Code I & J)
Measure(s): Insulation (Pipe and Tank)

Measure Description

Owing to first cost sensitivity and/or a low level of awareness, many commercial and industrial customers – particularly smaller, hard to reach businesses – configure tanks and piping systems with sub-optimal amounts of insulation. These measures address cost-effective energy efficiency opportunities in the tank and pipe insulation areas, and encompass both fiberglass and heavier duty insulation systems. Tank insulation primarily has industrial sector applicability (e.g., brine, plating solutions). Pipe insulation applications in the industrial sector include brine, plating solutions, steam, condensate, hot water, chilled water, and refrigerant; in the commercial sector they include steam, hot water, chilled water, and refrigerant. The Express Efficiency program's rebate mechanisms partially offset first cost premiums associated with these measures, and also simplify the incentive process for targeted customers.

Market Applicability

These measures are applicable to any small or medium commercial or industrial pipe/tank insulation retrofit (i.e., non new construction) application. They cannot be used for domestic (i.e., residential) purposes. The main applicability for tank insulation is in the industrial sector, whereas pipe insulation is applicable across both the commercial and industrial sectors.

Terms and Conditions

A minimum of 2 inches of insulation must be added to existing bare commercial or industrial tank/pipe system applications. For pipe insulation, the bare pipe must be at least one inch in diameter. The following types of applications are not eligible: new construction; new pipe/tank system replacement; fuel switching; residential. The manufacturer name and insulation material number must be provided. If necessary, customers must provide proof of insulating values (e.g., manufacturer specification sheets).

Cost Effectiveness Modeling Measure Data

Measure data for cost effectiveness modeling have been developed based on average cost characteristics among customer participants in SoCalGas' PY 1995 pipe and tank insulation incentive programs (adjusted for inflation); energy savings data assume the following:

- Tank insulation, high temperature application: 180 degree F solution, 2 inches of insulation over bare tank; tank operated 4,200 hours/year.
- Tank insulation, low temperature application: 120 degree F solution, 2 inches of insulation over bare tank; tank operated 4,200 hours/year.
- Pipe insulation, hot water application: 130 degree water, 2 inches of insulation over 2 inch bare pipe; pipe system operated 4,200 hours/year.
- Pipe insulation, low pressure steam application: 250 degree steam, 2 inches of insulation over 2 inch bare pipe; pipe system operated 4,200 hours/year.

Unitized cost effectiveness determinants are summarized in the table below. The assumed measure lifetime is based on the October 2001 Energy Efficiency Policy Manual for insulation measures. The assumed net-to-gross ratio is based on the October 2001 Energy Efficiency Policy Manual for express efficiency.

	Pipe Insulation – hot water application	**Pipe Insulation – low pressure steam application**	**Tank Insulation – low temperature application**	**Tank Insulation – high temperature application**
Units	*LF*	*LF*	*sq ft*	*sq ft*
Incremental Measure Cost per avg. unit	*$4.39/LF*	*$4.39/LF*	*$4.07/sq ft*	*$4.07/sq ft*
Annual Energy Savings per avg. unit	3.0 therms/LF	15.2 therms/LF	4.1 therms/sq ft	11.4 therms/sq ft
Incentive Amount per avg. unit	*$1.00/LF*	*$1.00/LF*	*$1.00/sq ft*	*$1.00/sq ft*
Measure Lifetime	20 years	20 years	20 years	20 years
Net-to-Gross Ratio	.96	.96	.96	.96
MDSS Measure Code	H12	H17	H13	H18
Application Code	I	I	J	J

A10 (Application Code K)
Measure(s): Greenhouse Heat Curtains

Measure Description

Thermal blankets installed in greenhouses decrease heat losses resulting from radiation and convection. They also reduce infiltration through broken and poorly fitted windowpanes in the roof of the greenhouse. It is assumed that the heat curtains are deployed during nighttime hours, and furled during daytime hours.

Market Applicability

This measure is applicable to agricultural or commercial greenhouses involved in the production of nursery products, horticultural specialties, or ornamental products.

Terms and Conditions

Only installation of interior curtains for heat retention in gas-heated commercial greenhouses qualify. Neither new construction nor fuel switching applications are eligible. The manufacturer name and insulation material number must be provided. If necessary, customers must provide proof of insulating values (e.g., manufacturer specification sheets).

Cost Effectiveness Modeling Measure Data

Measure data for cost effectiveness modeling have been developed for a prototypical 4,000 square foot greenhouse facility, and based on average characteristics for SoCalGas customer participants for Express Efficiency heat curtain measures during PY 2001. Unitized cost effectiveness determinants are summarized in the table below. The assumed measure lifetime is based on the October 2001 Energy Efficiency Policy Manual for insulation measures. The assumed net-to-gross ratio is based on the October 2001 Energy Efficiency Policy Manual for express efficiency.

	Greenhouse Heat Curtains
Units	*sq ft.*
Incremental Measure Cost per avg. unit	*$.49*
Annual Energy Savings per avg. unit	.39 therms
Incentive Amount per avg. unit	*$.10*
Measure Lifetime	5 years
Net-to-Gross Ratio	.96
MDSS Measure Code	A10
Application Code	K

Agricultural Measures

The agricultural measures in the Express Efficiency Program include the following measures from 1997 REO Agricultural Program.

- Low Pressure Sprinkler Nozzles
- Sprinkler to Micro-Irrigation Conversion
- Greenhouse Heat Curtains (covered under gas workpapers)

Net-To-Gross Ratio

Net-to-gross ratio is 0.96 in conformance with the CPUC's October 2001 *Energy Efficiency Policy Manual*.

Calculation Methodology

Energy and demand savings are based on the differential between baseline and efficient equipment. The baseline measure varies, depending on the application. The low-pressure sprinkler nozzle measures were evaluated using data from field studies. The details of the efficiency and savings assumptions are given in each technical assessment.

Two types of capacity savings estimates were done for this analysis: peak savings achieved by the measure (non-coincident) and demand reduction coincident with system peak. The non-coincident demand savings achieved by the measure are estimated from engineering analyses or measured savings, as discussed above. Coincident demand savings are the product of the non-coincident demand savings and the coincident diversity factor. The coincident diversity is based on load shape data and determines what fraction of the savings occur during the factor system peak. The coincident diversity factor is:

Ag Coincident diversity factor

= Ag Demand at System Peak / Maximum Ag Demand Load

= 0.78

The CDF is an annual average based on PG&E's 1992–95 agricultural rate load research data (Quantum 1996).

Measure Life

Measure lifetimes for agricultural technologies vary by technology and are based on industry standards.

Incremental Measure Cost

Incremental costs are used to evaluate the economics of each retrofit. For measures where there is choice between two levels of efficiency, the incremental cost is the difference between the two products. Labor costs are included for the low-pressure sprinkler nozzles measure.

Reference

Quantum. 1996. Memo dated 9/25/96 from John Cavalli (Quantum) to Mary Dimit (PG&E). Berkeley, CA.

A40, A41, A42, A43 LOW PRESSURE SPRINKLER NOZZLES

Technology Description

Standard, impact-driven, sprinkler heads for agricultural irrigation utilize relatively high water pressure in conjunction with smoothbore nozzles. The high water velocity through the nozzles results in a breakup of the water stream into an acceptable distribution of small, medium, and large droplet sizes. The distribution of droplet sizes then results in an acceptable uniformity of water application, assuming correct sprinkler head spacing.

"Low-pressure" impact sprinkler nozzles use various orifice shapes (square, rectangular, octagonal, round with notches) and configurations so that the desired stream breakup will occur at a significantly lower operating pressure. A conversion to low-pressure nozzles should be investigated for any irrigation system now using standard, smoothbore, high-pressure nozzles.

Market Applicability

Low-pressure sprinkler nozzles are applicable in any situation where standard, impact-driven agricultural or turf sprinkler heads are used for irrigation. These may be in:

- Portable, hand-move systems are systems consisting of aluminum or PVC pipe that can be moved from field to field and typically where the actual sprinklers are moved several times within a field during an irrigation cycle.
- Permanent solid-set systems are systems where the sprinklers are in one place throughout a growing season.

Calculation Methodology

This measure encourages system operators to convert to low-pressure nozzles, thus reducing the amount of energy required to apply the same amount of water. The amount of energy saved per nozzle will depend on the actual operating pressure decrease, the pumping plant efficiency, the amount of water applied, and the number of nozzles converted. The reduction in demand per nozzle will depend on the pump flow, the operating pressure decrease, the pumping plant efficiency, and the number of nozzles converted.

Energy use by an irrigation system can be calculated using the equation:

[1] kWh/yr = kWh/AF x AF/yr.

where: kWh/yr = Total annual energy use.

kWh/AF = Amount of energy required to pump an acre-foot of water.

AF/yr = Total acre-feet pumped annually.

The amount of energy required per acre-feet, kWh/acre-feet, can be determined using the equation:

[2] kWh/AF = 1.0241 x TDH / OPE.

where: kWh/AF = Amount of energy required to pump an acre-foot of water in the irrigation system.

TDH = Total dynamic head required to pump water through the irrigation system in feet.

OPE = Overall pumping plant efficiency expressed as a decimal (0 - 1.0).

Converting to low-pressure nozzles allows a reduction in the TDH, thus a reduction in kWh/AF, thus a reduction in kWh/yr.

The basis for the following assumptions is developed in Low Pressure Sprinkler Nozzles (Canessa 1994). Assumptions were developed based on the average acre.

- Operating pressure decrease = 20 psi (46.2 feet)
- Overall pumping plant efficiency = 55%
- Net water applied = Varies with region (matrix ; Canessa 1994)
- Irrigation efficiency = 70% - Irrigation efficiency is defined as the ratio of applied irrigation water that is beneficially used to the total amount of applied irrigation water.
- Nozzles converted = Varies with irrigation system type, (matrix ; Canessa, 1994)
- Pump flow = 7.56 gpm/acre

Energy savings per nozzle per year:

To determine energy savings per nozzle, equation [2] is first used to determine the reduction in kWh/AF:

[2] kWh/AF = 1.0241 x TDH / OPE

= 1.0241 x 46.2 / .55

= 86 kWh/AF

A weighted average water application was determined using crop acreages as reported by the California Department of Food and Agriculture, net crop evapotranspirations calculated using data supplied by the UC Extension, and an average 70% irrigation efficiency. Equation [1] is then used to determine kWh/nozzle-year:

Initially there were three scenarios developed for the number of nozzles required to complete the retrofit:

A standard, portable, hand move system with 4 nozzles/acre, referred to as “Low-Density Portable”.

A standard, portable, hand move system with 21 nozzles/acre, referred to as “High-Density Portable”.

A solid-set system with 35 nozzles/acre, referred to as “Solid-Set”.

Having the different kWh/acre-yr developed using equation [2] for the different climate regions and having the number of nozzles per acre required to make the conversion allows a calculation of kWh savings per nozzle:

[3] kWh/nozzle-yr = (kWh/acre-yr) / (nozzles/acre)

A weighted average kWh/nozzle-yr was determined for all portable systems using the results from the Low-Density and High-Density portable systems.

kWh/nozzle-yr savings for two major climate regions and two system types:

SYSTEM/REGION	Portable	Solid-Set
Central Valley	55 kWh	14 kWh
Coast and Coastal Valleys	12 kWh	10 kWh

Non-coincident demand savings per nozzle:

Horsepower savings per acre are determined with the standard equation:

[4] HP = TDH x Q / (3960 x OPE)

where: HP = Motor horsepower requirements per acre.
TDH = Reduction in total dynamic head in the system in ft of water.
Q = Pump flow in gallons/minute - acre.
OPE = Overall pumping plant efficiency as a decimal.

Q can be determined if it is assumed that a flow will be in place that is required to satisfy the crop evapotranspiration demands at peak daily water use. A weighted average Q is determined based on the different crops and their acreages within the climate regions.

The TDH reduction is 20 psi (46.2 feet) as before.

The average overall pumping plant efficiency is assumed to be 55%.

Kilowatt demand savings per nozzle are calculated as:

[5] kW/nozzle = (HP/acre x 0.746 kW/HP)/ (nozzles/acre)

kW/nozzle-yr savings for two major climate regions and two system types:

SYSTEM/REGION	Portable	Solid-Set
Central Valley	0.0349 kW	0.004 kW
Coast and Coastal Valleys	0.0082 kW	0.0029 kW

Measure Life

8 years (California Measurement Advisory Committee Public Workshops on PY 2001 Energy Efficiency Programs)

Measure Incremental Cost

Material cost: Material cost is $0.57/nozzle based on the average of three manufacturer's retail pricing.

Labor cost of retrofit: It is assumed that the nozzle conversion will take place in the field. The laborer has to walk to each nozzle, remove the old nozzle and insert a new nozzle. This is expected to take five minutes. At a "fully-loaded" cost of $7.50 ($5/hour + 50% burden), this equals $0.63/nozzle.

Total cost: The total installed cost of a low-pressure nozzle retrofit is $1.20/nozzle.

Terms and Conditions

Customers must provide proof of acreage amount, crop type, number and gpm of nozzles purchased and installed.

References

Canessa. 1992. *Low Pressure Sprinkler Nozzles*, San Luis Obispo, CA, August 1992; updated November 1994.

Charles McMillen. 1991. Rain Bird Service Center, Glendora, CA .

PG&E. 1992. Program database, Table TA-2.12, San Francisco, CA, February.

A48 thru A59 SPRINKLER IRRIGATION TO MICRO-IRRIGATION SYSTEM CONVERSION

Technology Description

Micro-irrigation systems consist of systems of above and below ground pipelines/hoses, delivering water under pressure, to specialized emission 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 a constant, comparatively high, rootzone soil moisture. In addition, micro-irrigation provides opportunities for very precise control of fertilizer applications. Other advantages may include reduced weed growth and diseases and increased flexibility in timing cultural operations.

Energy may be saved by converting from a sprinkler irrigation system to a micro-irrigation system in two ways:

The system operating pressure will be reduced.

Micro-irrigation irrigation systems have a higher potential irrigation efficiency (IE) for many reasons. When compared to sprinkle systems a) they are not as sensitive to wind and b) they usually do not result in as much evaporation losses. Thus, converting to a micro-irrigation system will tend to reduce the amount of required water pumping.

Market Applicability

Some form of micro-irrigation is operationally adaptable to any crop type. Examples of common situations for adaptation of micro-irrigation include:

Permanent orchards and vineyards which may have been irrigated by flood or sprinkle systems. The grower may be looking for better yields due to higher potential water and fertilizer effectiveness. Micro-irrigation may also reduce disease and weed pressure.

Areas with a current or anticipated loss of water supplies due to current or anticipated administrative actions by State and Federal agencies in response to environmental concerns, challenges to existing water rights, or transfers of water from agricultural uses to urban areas. The value of remaining supplies, regardless of the actual cost to the grower, is increased. Thus, the grower is primarily interested in the higher potential irrigation efficiency of micro-irrigation.

The primary water supply is ground water pumping and continual over drafting of an aquifer has increased the cost of pumping to the point where the economics of micro-irrigation become attractive.

High-value vegetable crops that have adapted very well to micro-irrigation, resulting in better yields and, just as important in this highly competitive area, better uniformity at harvest.

Calculation Methodology

Annual energy use by an irrigation system can be calculated using the equation:

[1] kWh/yr = kWh/AF x AF/yr.

where: kWh/yr = Total annual energy use.

kWh/AF = Average amount of energy required to pump an acre-foot of water.

AF/yr = Total acre-feet pumped annually.

kWh/AF can be calculated using the equation:

[2] kWh/AF = 1.0241 x TDH / OPE

where:

TDH = Total dynamic head required to pump water through the irrigation system in feet.

OPE = Overall pumping plant efficiency expressed as a decimal (0 - 1.0).

kWh/AF may be the summation of two or more pumps in the system. For the purposes of this measure, two "types" of kWh/AF will be identified, 1) the kWh/AF required to deliver water to the start of the actual field irrigation system ($kWh_{delivery}$/AF), and 2) the boost kWh/AF required to operate the irrigation system itself (kWh_{boost}/AF).

The acre-feet of pumped water required by a cropped field per year (AF/yr) can be determined using the equation:

[3] AF/yr = CL + (ACRES x ((ETc - RAIN) / ((1 - LR) x IE))

where: AF/yr = Annual water pumping required to irrigate a field as acre-feet per year.

ACRES = Net cropped acres in the field.

ETc = Annual net water use as acre-feet/acre per year.

RAIN = Annual rainfall effective in satisfying ETc or required leaching as acre- feet/acre per year.

LR = Leaching requirement for maintaining a salt balance in the rootzone as a decimal (0.0 - 1.0).

IE = Irrigation efficiency as a decimal (0.0 - 1.0)

CL = Conveyance losses while delivering water to the irrigation system as acre feet per year.

1.0241= kWh required to lift one acre-foot of water one foot

The annual energy savings are calculated as follows:

[4] kWh_{saved}/year = kWh_{base}/year - $kWh_{project}$/year

Where: kWh_{saved}/year = Annual energy savings.

kWh_{base}/year = Current annual energy usage.

$kWh_{project}$/year = Predicted annual energy usage.

kWhbase/year and kWhproject/year are both calculated by a form of equation [1], incorporating equations [2] and [3].

As noted, kWh/AF consists of $kWh/AF_{delivery}$ and kWh/AF_{boost}. $kWh/AF_{delivery}$ remains constant, i.e., the primary water source and method of delivery for the field will not change. There will be savings in annual $kWh_{delivery}$ due to the reduction in applied water but this will be disregarded for all cases except those with a well as the water source.

A survey of the major manufacturers, see attached report Micro-Irrigation for Energy-Use Reduction (Canessa 1995), identified average required device operating pressures for different types of micro-irrigation and sprinkler irrigation devices. The following major assumptions were made:

Field and Vegetable crops would only be converted to drip tape or one of the three identified in-line hose products.

Orchards and Vineyards would only be converted to on-line emitters, jets/foggers/misters, or mini-sprinklers.

The required operating pressures of all sprinklers were averaged assuming the following weighting: sprinkler conversions would be 5% from Big Gun systems, 75% from High Pressure systems, and 20% from Low Pressure systems.

Eight pound-per-square-inch pressure (psi) for filters, two psi for valves, and four psi for pipeline friction losses, a total of fourteen psi, would be added to the device operating pressure to calculate total required micro-irrigation system pressure.

Four psi for filters, two psi for valves, and six psi for pipeline friction losses, a total of twelve psi, would be added to the device operating pressure for sprinkler systems.

Table 1 summarizes the total required system pressure, TDH in equation [2], for the two types of micro-irrigation system and sprinkler systems as averaged.

TABLE 1 - Estimated required system operating pressures for various irrigation system types[1]

System	Required Operating Pressure (psi / feet)
Sprinklers (5% Big Gun, 65% High Pressure, 30% Low Pressure)	64.5 / 149.0
Field/Vegetable Crop Micro	28.8 / 66.5
Orchard/Vineyard Micro	34.1 / 78.7

1. Source - see report "Micro-Irrigation for Energy-Use Reduction" (Canessa 1995)

Since the conversion to micro-irrigation will usually involve either a new pump or a retrofit of an existing installation, the overall pumping plant efficiency of the micro system is 67.5%. This assumes a 90% motor efficiency and a 75% bowl efficiency.

The OPE of the existing pumping plant is assumed to be 55.1%. This is the average of 17,672 pump tests that are contained in the 1993-1994 agricultural pump test database.

With the sprinkler and micro-irrigation TDHs identified in Table 1, and the assumed OPEs, equation [2] can be used to calculate the reduction in kWh/AFboost for the conversion to micro-irrigation.

Equation [3] for calculating required annual water pumping, AF/yr, can be solved by examining the separate components of the equation:

Conveyance Losses (CL) - Since micro-irrigation systems generally result in less water applied to the field, this means less water being pumped through the conveyance system and the conveyance losses in equation [3] (CL) should logically decrease. Another reason that CL could decrease is that micro-irrigation systems generally are a totally piped system and, many times, there are open ditches associated with water conveyance to flood irrigation systems. As a conservative assumption then, CL will not be considered in the annual energy use calculations.

Net water requirements (ETc - RAIN) / (1- LR) - As fully explained in the report, Micro-Irrigation for Energy-Use Reduction (Canessa 1995), weighted average water applications were calculated for four types of crops in two major climate regions. Important data included a) crop acreages as reported by the California Department of Food and Agriculture, b) net crop evapotranspirations calculated using data supplied by the UC Extension, c) a 3% leaching ratio, and d) an assumed 33% of average annual gross rainfall as effective. The weighted averages are based on assumptions regarding the percentage of any one crop's total acreage that might be drip irrigated. Crops were grouped by type. The weighted average applications for the different combinations of crop type and climate region are termed NET and are seen in Table 2 below.

Irrigation efficiencies (IE) - average irrigation efficiencies for the various system types are assumed as per University of California Cooperative Extension recommendations contained in Publication #21454, Irrigation Scheduling (UCCE 1989). They are contained in Table 3.

In summary, the preceding assumptions regarding equation [3] result in the reduced equation:

[5] AF/yr = ACRES x NET / IE

where: AF/yr = Required annual pumping in acre-feet.

ACRES = Net cropped acres.

NET = Net required pumping, acre-feet/acre per year, as identified for the major climate regions and crop type in Table 2.
IE = Irrigation efficiency for the different irrigation system types as identified by Table 3.

TABLE 2 - Cropped acreages, required net annual irrigation, and pump flow on a per acre basis for two major climate regions and four different crop types - micro-irrigated acreage only[1].

REGION	CROP	ACRES	AF/Ac[2]	ETmax[3]	FLOW[4]
				(in / day)	(gpm/ac)
Central Valleys	total	769,679	2.59	0.32	6.41
Central Valleys	Field/Vege	135,616	1.92	0.38	7.73
Central Valleys	Trees	433,289	2.94	0.36	7.42
Central Valleys	Grape	200,774	2.38	0.25	5.11
Coastal	total	122,827	1.41	0.25	5.13
Coastal	Field/Vege	57,943	1.22	0.28	5.86
Coastal	Trees	22,290	1.96	0.27	5.62
Coastal	Grape	42,593	1.37	0.19	3.87

Source: see report "Micro-Irrigation for Energy-Use Reduction" (Canessa 1995)

AF/Ac: the acreage-weighted, average, annual, net irrigation requirement. Note that the irrigation requirement for vegetable crops was doubled to reflect the double-cropping common to this crop rotation.

ETmax: the maximum expected daily crop water use, inches/day. This will set the required pump flow. This was calculated as the peak crop coefficient times 1.1 times the maximum monthly ETc divided by 31 days.

FLOW: this is the net required pump flow, gallons/minute per acre as calculated using equation [5].

TABLE 3 - Estimated irrigation efficiencies for various irrigation system types

SYSTEM	IRRIGATION EFFICIENCY (%)
Micro-Irrigation	80
Sprinklers	70

1. Source - UC Cooperative Extension publication #21454, Irrigation Scheduling (UCCE 1989)

With results and data as noted in Tables 1, 2, and 3 the annual kWh/acre savings are calculated and reported in Table 4a. Note that the calculations in Table 4 disregard any savings due to applying a decrease in AF/yr against the kWh/AF required for water delivery.

The 1993-1994 PG&E agricultural pump test database was evaluated to estimate average kWh/AF for wells pumping water to the surface with a discharge pressure of 8 psi or less. The average for wells in the Central Valley Divisions was 274.6 kWh/AF, for wells in the Coastal Divisions, 316.6 kWh/AF. These numbers were used in conjunction with the results and data in Tables 1, 2, and 3 to calculate annual kWh/Acre savings when the water source is a delivery well. These are reported in Table 4b.

TABLE 4a - Annual kWh/Acre-Year savings for converting from sprinkler systems to micro-irrigation - projects with a water supply other than a well[1]

REGION	FIELD/VEGs	TREES	GRAPE

Central Valleys	579	819	663
Coastal	368	546	381

1. Source - see report “Micro-Irrigation for Energy-Use Reduction” (Canessa 1995)

TABLE 4b - Annual kWh/Acre-Year savings for converting from sprinkler systems to micro-irrigation for two climate regions and four crop types - projects with a well as the water supply[1]

REGION	FIELD/VEGs	TREES	GRAPE
Central Valleys	615	868	703
Coastal	400	593	415

1. Source - see report “Micro-Irrigation for Energy-Use Reduction” (Canessa 1995)

Changes in Peak kW

During the identification of annual net crop water requirements, the average, maximum daily crop water use was also identified. If a crop’s water use is to be satisfied by an irrigation system at the maximum daily use rate, the following equation is used to identify the required system flow on a per acre basis:

[6] FLOW = 452.5 x ETmax / (IE x HOURS)

where: FLOW = Gallons/minute per acre to replace maximum daily crop water use.
ETmax = Maximum daily crop water use in inches/day (see Table 2).
IE = Irrigation efficiency as a decimal (0.00 - 1.00) (see Table 3).
HOURS = Daily hours of operation.

For this measure, the maximum daily crop water uses in Table 2 and the irrigation efficiencies in Table 3 were used, along with an assumed 22 hour/day operation. (The net calculated FLOWs, IE = 1.0, are reported in Table 2.)

The required connected load on a per acre basis can be calculated the equation:

[7] kW/Ac = .746 x FLOW x TDH / (3960 x OPE)

where: kWh/Ac = KiloWatt-hours required per acre.
FLOW = Gallons per minute per acre in pumping plant, as calculated by Equation [6].
TDH = Total dynamic head of pumping plant in feet as identified in Table 1.
OPE = Overall pumping plant efficiency as a decimal (0 - 1.).

The connected load reduction is calculated as follows:

[8] kW_{saved} = kW_{base}/ - $kW_{project}$

where: kW_{saved} = kiloWatt load reduction
kW_{base} = Base connected load in kiloWatts
$kWh_{project}$ = Predicted connected load in kiloWatts

kW_{base} and $kWh_{project}$ are calculated by equations [6] and [7] respectively, incorporating some of the assumptions regarding equations [2] and [3].

With required FLOWs calculated with equation [6], the assumptions concerning overall pumping plant efficiency, and the required system operating pressure (TDH, see Table 1), the kW savings on a per acre basis were identified using equations [7] and [8] and are reported in Table 5:

TABLE 5 - kW/Acre savings for converting from sprinkler systems to micro-irrigation[1]

REGION	FIELD/VEGs	TREES	GRAPE
Central Valleys	0.429	0.380	0.262
Coastal	0.325	0.288	0.198

1. Source - see report “Micro-Irrigation for Energy-Use Reduction” (Canessa 1995)

Note: The savings in Table 5 are peak kW savings since the systems are typically sized to operate continuously and therefore use the lowest capital cost pump and piping.

Measure life

Micro-irrigation systems are a combination of many sub-systems, including a pumping plant, filters, mainline and manifold piping, and the system of distribution tubing and emission devices. It is assumed that the system life is that of the pumping system and main pipelines, 20 years.

Incremental cost

The incremental cost of a micro-irrigation system over the cost of a sprinkler system will vary with the situation. PG&E agricultural consultants estimate an average incremental cost of $300/acre.

Terms and Conditions

Customers must provide proof of acreage amount, crop type, number and gpm of nozzles purchased and installed.

References

Canessa. 1995. *Micro-Irrigation for Energy-Use Reduction*. San Luis Obispo, CA, September.

University of California Cooperative Extension. 1989. Publication #21454, Irrigation Scheduling. Division of Agriculture and Natural Resources. Davis, CA.

P11 VFDs for Dairy Pumps

Technology Description

Adjustable speed drives (VFDs) have the potential to save significant amounts of energy when implemented in dairy vacuum milking systems. These drives can be used for both vacuum and milk pumps. Vacuum pumps are generally oversized and run at a constant speed in order to accommodate for any unexpected airflow stemming from things like milking units falling off udders. A VFD allows the pump to run at a reduced speed most of the time and can increase the speed when necessary. Milk pumps are more efficient with VFDs since it enables the motor to speed up or slow down depending on the amount of milk in the receiver. This also allows a more uniform flow through the plate cooler which increases its effectiveness.

Market Applicability

The dairy industry in California is very important. Roughly 18% of the nation's milk comes from California, with annual milk sales in excess of $3.6 billion. Because dairy producers have little control over the market price of dairy products, an effective way of increasing profits is to decrease production costs.

Assumptions

1. Estimated cost for VFD is $340/hp.
2. Pumps are reasonably sized and thus the VFD provides no demand reduction.
3. Estimated average annual energy savings provided by a VFD system is 3730 kWh/hp.

Calculation Methodology

The calculations for the estimated annual energy savings were performed using data from the Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), the PG&E Standard Performance Contract (SPC) program, and the Southern California Edison (SCE) Savings by Design (SBD) program. Each data set assumes the dairy operates between 20 and 22 hours each day. Cost estimates for VFDs come from information provided in these reports and dairy equipment retailers. The average cost for a VFD system is estimated at $340/hp.

Table 1.Estimated annual energy savings per kWh when VFD is implemented. (From Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET) study)

Dairy	Pump Power hp	Savings KWh/yr-hp
A	8	1742
B	5	2140
C	15	4257
D	20	5550
E	10	2468
F	10	7321
G	10	9653
H	8	5186
I	16	3713
J	20	5250
Average	12	4728

The variation in the table developed using information from CADDET is due to the method used in sizing the pumping system. The average pump size for the sample group is 12 hp and ranges from 5 to 20 hp.

Table 2.Estimated annual energy savings per kWh when VFD is implemented. (From PG&E SPC Program)

PGE SPC Program		
Dairy	**Pump hp**	**Savings kWh/hp**
1	15	5142
2	10	3530
	10	3867
3	20	3891
4	15	1869
	Average =	3660

Table 3.Estimated annual energy savings per kWh when VFD is implemented. (From Southern California Edison's "Energy Savings Estimator v1.0" used for its SBD Program)

SCE SBD Program	
Dairy	**Savings kWh/hp**
Model	2800

Using the data from the previous tables an average annual energy savings value of 3730 kWh/hp was calculated.

Economics

The following economic analysis estimates the rebate level required to provide a two to three year simple payback period for a VFD investment. An energy rate of $0.128/kWh is used to determine the payback period. This rate is based on an average of Rates A and

B in the AG-1 schedule. The VFD is assumed to provide no demand reduction. The following displays how the simple payback period is calculated for this application.

$$\textit{Payback Period} = (\textit{VFD Cost - Rebate}) \div \textit{Annual Energy Saved} \div \textit{Energy Rate}$$

$$\textit{Payback Period} = (\$340/hp - \$100/hp) \div 3730\ kWh/yr/hp \div \$0.128/kWh$$

$$\textit{Payback Period} = 0.5\ years$$

Table 4.Estimated simple payback period for various rebate levels.

VFD Cost ($/hp)	Rebate ($/hp)	Rebate (% VFD Cost)	Rebate ($/kWh)	Simple Payback Period (years)
340	113	33%	0.030	0.47
340	100	30%	0.027	0.50
340	85	25%	0.023	0.53
340	34	10%	0.009	0.64

Table 4 summarizes the simple payback periods for various rebate levels. The data suggests that the payback period will be less than one year regardless of the rebate level. The actual payback would vary from dairy to dairy depending upon the method used to size the pumps and the milking schedule used. Most of the literature regarding this topic estimates the payback to be between one and two years without incentives. All of the rebate levels shown in the table are lower than the $0.05/kWh currently offered by Southern California Edison as part of the Savings by Design program. The $34/hp level is similar to what is currently offered by many of the Utility Cooperatives in the state of Wisconsin.

Example Programs

Southern California Edison

As part of the Agricultural/Industrial side of the Savings by Design program, several dairy system retrofits were performed. The rebate was based on annual kWh reduction estimated with software developed by SCE. An incentive rate of $0.05/kWh was used.

Wisconsin Electric Cooperative

Many of the Cooperative Electricity providers in Wisconsin have offered a VFD rebate for dairy farms of $30/hp. In order to be eligible for the rebate the drive must be installed in a 4-wire location.

P1 VFDs for Injection Molding Machines

Technology Description

Variable frequency drives (VFDs) have the potential to save significant amounts of energy when implemented in injection molding machines (IMMs). An IMM operates with a hydraulic pumping system. The requirements of this system vary throughout the production cycle and include "idle" periods where essentially no pumping power is required. When a VFD is installed it allows the pump power to track the requirements of the production cycle. This is very critical during the idle periods of the cycle, which on average compose 20% of the total cycle time.

Market Applicability

Many different plastic parts are produced using IMM technology. Given the size of the plastics industry, this equates to a significant market. A large number of IMMs currently in use are only 10 to 25 percent efficient. The use of VFDs can reduce there energy consumption by 20-60%.

Assumptions

4. Estimated cost for equipment and installation of VFD is $216/hp.
5. Estimated industry average idle time is 20% of total cycle time.
6. Estimated average demand savings is 0.22 kW/hp.

Calculation Methodology

The calculations for the estimated average demand savings were performed using data from the San Francisco State University Industrial Assessment Center (SFSU IAC), the San Diego State University Industrial Assessment Center (SDSU IAC), Pacific Gas & Electric Standard Performance Contract program, and Magnum LLC, a VFD manufacturer. Each data set assumes the IMM operates with an idle time of 20% the total cycle time. Cost estimates for VFDs were calculated based on information provided by the previously listed sources. The average cost for a VFD system is estimated at $216/hp.

Table 5.Estimated average demand savings per hp when VFD is implemented. (From San Francisco State University Industrial Assessment Center study)

Table 6. Estimated average demand savings per hp when VFD is implemented. (From PG&E Standard Performance Contract (SPC) program)

Table 7. Estimated average demand savings per hp when VFD is implemented. (From San Diego State University Industrial Assessment Center study)

Table 8. Estimated average demand savings per hp when VFD is implemented. (Magnum LLC VFD manufacturer)

Using the data from the previous tables a combined average demand savings of 0.22 kW/hp was calculated.

Table 9. Estimated equipment and labor cost for VFD implementation.

Source	PUMP (hp)	Equipment and Labor Cost ($)	$/hp
PG&E SPC	375	55813	149
	250	30416	122
SDSU IAC	120	30480	254
Savage Engineering	20	5787	289
	25	6656	266
	30	7525	251
	40	9263	232
	50	11001	220
	60	12738	212
	75	15345	205
	100	19690	197
	120	25477	212
	150	30691	205
		Average =	216

Economics

The following economic analysis displays the simple payback period for various rebate levels and annual operation periods. An energy rate of $0.128/kWh is used to determine the payback period. This rate is based on an average of Rates A and B in the AG-1 schedule. It is significant to the note that the economic analysis is based on data with an idle time of 20% the total cycle time. This is assumed to be the industry average. Applications with idle times less than 20% would experience longer payback periods and those with times greater than 20% would experience shorter payback periods. Using an average idle time allows the rebates to be simplified for the purposes of the Express Efficiency Program. The following explains how the payback period is calculated,

$$\text{Payback Period} = \frac{(\text{VFD Cost - Rebate})}{(\text{Average Demand Savings} \cdot \text{Annual Operation}) \cdot \text{Energy Rate}}$$

$$\text{Payback Period} = (\$216/\text{hp} - \$65/\text{hp}) \div (0.22\ \text{kW/hp} \cdot 7000\ \text{hr/yr}) \div \$0.128/\text{kWh}$$

$$\text{Payback Period} = 0.77\ \text{years}$$

Table 10. Estimated simple payback period for 6000 hrs/yr of operation at various rebate levels.

Total Annual Hours, 6000 hrs					
VFD Cost ($/hp)	Rebate ($/hp)	Savings (kW/hp)	Savings ($/hp yr)	Rebate in % of VFD Cost	Simple Payback Period (years)
216	72	0.22	168.96	33%	0.85
216	65	0.22	168.96	30%	0.89
216	54	0.22	168.96	25%	0.96
216	22	0.22	168.96	10%	1.15

Table 11. Estimated simple payback period for 7000 hrs/yr of operation at various rebate levels.

Total Annual Hours, 7000 hrs					
VFD Cost ($/hp)	Rebate ($/hp)	Savings (kW/hp)	Savings ($/hp yr)	Rebate in % of VFD Cost	Simple Payback Period (years)
216	72	0.22	197.12	33%	0.73
216	65	0.22	197.12	30%	0.77
216	54	0.22	197.12	25%	0.82
216	22	0.22	197.12	10%	0.99

Table 12. Estimated simple payback period for 8000 hrs/yr of operation at various rebate levels.

Total Annual Hours, 8000 hrs					
VFD Cost ($/hp)	Rebate ($/hp)	Savings (kW/hp)	Savings ($/hp yr)	Rebate in % of VFD Cost	Simple Payback Period (years)
216	72	0.22	225.28	33%	0.64
216	65	0.22	225.28	30%	0.67
216	54	0.22	225.28	25%	0.72
216	22	0.22	225.28	10%	0.86

Tables 6, 7, and 8 summarize the simple payback periods for various rebate levels. The data suggests that the payback period will be roughly one year or less for annual operation greater than 6000 hours regardless of the rebate level. The actual payback period would vary depending upon the application and the specific part being molded.

Example Programs

Southern California Edison

SCE has in the past offered a 30% of the total VFD cost as an incentive.

Pacific Gas & Electric

The 2001 SPC program offered $150 per saved kW. In the example provided this equated to rebates of $24/hp for one machine and $14/hp for the other. These machines were running roughly 7000 hrs per year, which translates to a 0.98 year payback and 1.02 year payback respectively.