Work Paper PGECOAGR102
Greenhouse IR Film
Revision 0

Pacific Gas & Electric Company

Customer Energy Efficiency Department

Greenhouse IR Film

Measure Code A102

April 4, 2008

At a Glance Summary: IR Film

Applicable Measure Codes:	A102
Measure Description:	Polyethylene allows more radiant heat loss than other greenhouse glazing materials. IR films are a common additive to polyethylene plastics that help reduce the heat loss from greenhouses and improve the U-value of double layer polyethylene by nearly 30% (from 0.7 to 0.5).
Energy Impact Common Units:	Therms per Square feet
Base Case Description:	Source: PG&E Greenhouse Baseline Study, 2005. **Roof:** double-inflated polyethylene <u>without</u> IR inhibiting film. **Wall:** single layer polycarbonate **Thermal Curtains**: None **Heat setpoint:** 55F
Base Case Energy Consumption:	Source: PG&E Calculations. 0.511 therms per sq. ft. of greenhouse floor area per year
Measure Energy Consumption:	Source: PG&E Calculations. 0.374 therms per sq. ft. of greenhouse floor area per year
Energy Savings (Base Case – Measure)	Source: PG&E Calculations 0.137 therms per year This is a weighted average for climate zones 1, 2, 3, 4, 5, 11, 12, and 13. Refer to the table on the following page for details.
Costs Common Units:	$ per sq. ft of greenhouse floor area per year
Base Case Equipment Cost ($/unit):	Source: *Greenhouse Thermal Curtains and Infrared Films Workpaper for PY2006-2008* prepared for Southern California Gas Co. by Energy and Environmental Analysis, Inc. (B-REP-06-599-17B) $0.093
Measure Equipment Cost ($/unit):	Source: *Greenhouse Thermal Curtains and Infrared Films Workpaper for PY2006-2008* prepared for Southern California Gas Co. by Energy and Environmental Analysis, Inc. (B-REP-06-599-17B) $0.114
Measure Incremental Cost ($/unit):	Source: *Greenhouse Thermal Curtains and Infrared Films Workpaper for PY2006-2008* prepared for Southern California Gas Co. by Energy and Environmental Analysis, Inc. (B-REP-06-599-17B) $0.021
Effective Useful Life (years):	Source: DEER. 5 years
Program Type:	Mass Market Small Business
Net-to-Gross Ratios:	Source: DEER. 0.96
Important Comments:	Energy consumption and savings are based upon weighted average for climate zones 1, 2, 3, 4, 5, 11, 12, and 13. Results are extremely sensitive to temperature setpoints for heating. For example, changing the temperature setpoint from 55F to 80F increases gas usage by an average of more than 200%. Due to the enormous variability in conditions needed for various crops, no attempt was made to capture the variability with additional crop or temperature setpoint tiers. This analysis uses a 55F set point.[1]

Measure Code	DEER RunID	Measure Description	Building Type	Building Vintage	Climate Zone	Peak Electric Demand Reduction (kW/sq,ft.)	Annual Electric Savings (kWh/sq.ft.)	Annual Gas Savings (therms/sq.ft.)	Base Case Cost ($/sq.ft.)	Measure Cost ($/sq.ft.)	Measure Incremental Cost ($/sq.ft.)	Effective Useful Life (years)
A102	CFRM01AVIRFlm	Infrared Film for Greenhouses (55F)	FRM	AV	Z01	0	0.040	0.204	$0.093	$0.114	$0.021	5
A102	CFRM02AVIRFlm	Infrared Film for Greenhouses (55F)	FRM	AV	Z02	0	0.031	0.160	$0.093	$0.114	$0.021	5
A102	CFRM03AVIRFlm	Infrared Film for Greenhouses (55F)	FRM	AV	Z03	0	0.027	0.137	$0.093	$0.114	$0.021	5
A102	CFRM04AVIRFlm	Infrared Film for Greenhouses (55F)	FRM	AV	Z04	0	0.026	0.134	$0.093	$0.114	$0.021	5
A102	CFRM05AVIRFlm	Infrared Film for Greenhouses (55F)	FRM	AV	Z05	0	0.024	0.121	$0.093	$0.114	$0.021	5
A102	No DEER runs performed for this Climate Zone	Infrared Film for Greenhouses (55F)	FRM	AV	Z11	0	0.022	0.170	$0.093	$0.114	$0.021	5
A102	No DEER runs performed for this Climate Zone	Infrared Film for Greenhouses (55F)	FRM	AV	Z12	0	0.022	0.167	$0.093	$0.114	$0.021	5
A102	No DEER runs performed for this Climate Zone	Infrared Film for Greenhouses (55F)	FRM	AV	Z13	0	0.014	0.128	$0.093	$0.114	$0.021	5
A102	No DEER runs performed for weighted averages	Infrared Film for Greenhouses (55F)	FRM	AV	Weighted average	0	0.026	0.137	$0.093	$0.114	$0.021	5

:

Work Paper Approvals

Ed Mah Date
Manager, Forecast, Analysis, and Product Performance

Grant Brohard Date
Manager, Technical Product Support

Keith Reed or Greydon Hicks Date
Manager, Mass Market or Target Market

Document Revision History

Revision #	Date	Description	Author (Company)
Revision 0	**04/04/08**	**Original work paper: Greenhouse IR Film PGECOAGR102 R0.doc**	**Marjorie Stein, Green Building Studio**

Table of Contents

List of Tables

List of Figures

Section 1. General Measure & Baseline Data

1.1 Measure Description & Background: IR Film

Catalog Description:

Infrared Film for Greenhouses A102

Installations of infrared anti-condensate polyethylene plastic with a minimum 6 mil. thickness for heat retention on existing heated greenhouses will qualify. A manufacturer's specification sheet must be included.

Program Restrictions and Guidelines: IR Film

Terms and Conditions

Installations of infrared anti-condensate polyethylene plastic with a minimum 6 mil. thickness for heat retention on existing heated greenhouses will qualify. A manufacturer's specification sheet must be included.[ii]

Market Applicability

This measure is applicable to agricultural or commercial greenhouses involved in the production of nursery products, horticultural specialties, or ornamental products.

Technical Description: IR Film

Polyethylene allows more radiant heat loss than other greenhouse glazing materials. IR films are a common additive to polyethylene plastics that help reduce the heat loss from greenhouses and improve the U-value of double layer polyethylene by nearly 30% (from 0.7 to 0.5).

1.2 DEER Differences Analysis: IR Film

DEER Measure (ID D03-980) Infrared Film for Greenhouses[iii] is based upon simulations of a 100' x 30' greenhouse facility with 7' walls. This is per section 4.2 of the DEER Update Study Final Report. The estimated savings from the DEER study is 0.057 therms/square foot of installed film in Oxnard and 0.049 therms/square foot of installed film in San Diego. The specific setpoints and assumptions for the DEER analysis are unknown; however using the assumed baseline setpoints for this study, our model estimated a savings of 0.058 therms per square foot of installed film for Oxnard—our results essentially agree with the DEER results. Given that the results for this measure are sensitive to weather and extremely sensitive to temperature setpoints the difference of 0.009 therms/square foot between this paper and the DEER Study is not unreasonable.

Please note that the DEER Study savings values are per square foot of installed film; this workpaper is using the convention of savings per square foot of greenhouse floor area.

The incremental cost cited by DEER ($0.03) is higher than that cited by vendors in the 2005 Greenhouse Baseline Study conducted by PG&E ($0.01) as well as the 2006 Workpaper prepared for Southern California Gas Co. ($0.021).

According to DEER, "Standard replacement of film is 4 years. In mild climates film may be replaced at 5-year increments or longer." Vendors interviewed for the PG&E Greenhouse Baseline Study cited useful life of 3-4 years. The Southern California Gas Co. Workpaper used a value of 3 years. This workpaper has adopted the DEER useful life of 5 years.

1.3 Codes & Standards Requirements Analysis: IR Film

Greenhouses and the heat curtains measures are not governed by either state or federal codes and standards.

1.4 EM&V, Market Potential, and Other Studies

Based upon the PG&E Greenhouse Baseline Study (page 19), the most common type of roofing material for greenhouses within PG&E's service territory in double-inflated polyethylene with IR inhibiting film. The study interviewed 22 greenhouse owners—ten of the facilities used this material on some, if not all, of their structures.

Table 1. Use of IR Inhibiting Film on Greenhouse Roofs

Bin	Never Use	Rarely Use	Sometimes Use	Typically Use
TOTAL	5	4	3	10

Three of the greenhouse owners with polyethylene houses do not have the IR film additive on the glazing material. Two of the greenhouse owners who reported never using IR films indicated that either they, "don't feel it adds any value," or they are "not convinced it works." However, a majority of owners interviewed for this study using polyethylene glazing do use IR films.

Generally the vendors and consultants indicated that IR films make polyethylene last longer so are commonly used in polyethylene structures, however one consultant indicated that there was a time when people used IR films but now people are not convinced they actually work. The following table contains the comments from the vendors and consultants:

Table 2. Use of IR Inhibiting Films, Vendor and Consultant Comments

How Common are IR Inhibiting Films
very common
sometimes, if rebate is available.
There was a time when people used them but now people not convinced they actually work.
very common on polyethylene houses
films make polyethylene last longer so are commonly used in those structures
Small portion of polyethylene roofs use. May soon be integrated into polycarbonate material but otherwise film not used elsewhere.
don't sell much
very common

Delta Therms Assumption (ΔT): Source: PG&E Calculations.
Baseline therms usage: 0.511 therms/square foot/yr.
IR Film: 0.374 therms/square foot/yr.

Net-to-Gross Assumption: *0.96. Source: DEER value, assumes Express Efficiency Rebates program.*

In-service factor/first year installation rate: *From the PG&E Greenhouse Baseline Study (page 30).*[iv]
Five of the 22 (23%) greenhouse owners participating in the study reported using no IR film at all. Ten of the facilities (45%) use IR film on most or all of their greenhouses. The remaining 32% either rarely or sometimes use IR film.

Hours of Operation: *From the PG&E Greenhouse Baseline Study (page 50[v]).*
The interviews with the greenhouse owners revealed that while many crops are seasonal in nature, the greenhouses rarely sit idle. Crops are usually rotated through the nursery during the entire year. Based upon this finding, the baseline schedule of operations will be assumed to be 24-hours per day, 7 days per week.

Effective Useful Life: *5 years. Source: DEER.*

1.5 Base Cases for Savings Estimates: Existing & Above Code

The base case for the infrared film for greenhouses measure is no infrared film.

No state or federal codes apply to either of these measures.

1.6 Base Cases & Measure Effective Useful Lives

Based upon DEER data an effective useful life of five years is. DEER source 2004-05, Version 2.01 -- Measure ID D03-981.

1.7 Net-to-Gross Ratios for Different Program Strategies

The Net-to-Gross (NTG) ratios are estimated based on whole building energy efficiency program approaches and strategies. They are summarized in the CPUC Energy Efficiency Policy Manual and on the DEER web site. If there are new EM&V studies with more recent NTG estimates, they may be cited here.

Table 1 below summarizes all applicable Net-to-Gross ratios for programs that may be used by this measure.

Table 3 Net-to-Gross Ratios

Program Approach	NTG
Name of Program	0.96

Section 2. Calculation Methods

2.1 Electric Energy Savings Estimation Methodologies

See section 2.3 for the methodology. No kWh savings were identified with this measure.

2.2. Demand Reduction Estimation Methodologies

There is no anticipated demand reduction associated with this measure.

<u>Energy and Demand Savings Results</u>

Δ*Watts/unit: IR Film measures have no demand savings.*

Annual Electric Savings:

Energy Savings [kWh/Unit] = 0.026kWh/square foot[1]

[1] Refer to the appendix for information on the savings calculations.

2.3. Gas Energy Savings Estimation Methodologies

A computer simulation model has been developed using the PG&E Green House Analysis Tool. The program is a Windows™ application that acts as an interface to the eQuest™/DOE 2.2 hourly energy simulation engine. DOE-2.2 was developed by the U.S. Department of Energy and J.J. Hirsch and Associates, specifically for evaluating the energy performance of commercial and residential buildings, and has been widely reviewed and validated in the public domain. DOE-2.2 calculates hour-by-hour building energy consumption over an entire year (8760 hours) using weather data for the location under consideration. eQUEST is a graphical user interface to DOE-2.2 developed by J.J. Hirsch and Associates and others.

Input to the program consists of a detailed description of the building being analyzed, including glazing specifications, cooling and heating systems, hourly scheduling of equipment, and thermostat settings.

The baseline greenhouse building consists of the following features:

Roofs: Double-inflated poly[vi] without IR film (U-value 0.70, Visible Transmittance 0.78, and Shading Coefficient 0.85).

Walls: Single layer polycarbonate: U-value 1.14, R-Value 0.91, Visible Transmittance 0.90, Shading Coefficient 0.95.

Floors: Uninsulated bare soil

Thermostats: Temperature sensors are assumed to be located at crop level (approximately four feet above the floor) near the middle of each greenhouse range. Baseline heaters are assumed to be located overhead.

Heating: The baseline heating system in California greenhouses consists of overhead gas-fired unit heaters with an 80% heating efficiency.

Cooling: For coastal areas, the baseline cooling system is passive natural ventilation with ridge & vent design (upper vents sized at 20% of floor area, lower vents same size). For inland valley areas the baseline cooling system is fan and pad. This evaporative cooling system is assumed to be 80% effective.

Fans and Airflow: For the non-coastal areas, exhaust fans are simulated to provide 60 air changes per hour of ventilation whenever the greenhouse temperature exceeds 75 F. Based upon Energy Conservation for Commercial Greenhouses, it is assumed that the target rate is eight CFM/square foot, and the fans are assumed to deliver 20,000 cfm per hp. For coastal locations, no exhaust fans are assumed in the baseline model—only passive natural ventilation.
Horizontal airflow fans are used to mix the air and reduce mold and mildew growth when the greenhouse is being ventilated. The model assumes HAF fans with a capacity of 0.25 cfm/sq.ft, based upon recommendations from Energy Conservation for Commercial Greenhouses for greenhouses.

Lighting: No supplemental lighting has been assumed in the analysis.

Infiltration: A rate of 1.1 air changes per hour is assumed in the model. Energy Conservation for Commercial Greenhouses cites an average of 0.75 – 1.5 air changes per hour for new Construction glass, fiberglass, polycarbonate, or acrylic sheets.

Orientation: According to Energy Conservation for Commercial Greenhouses[vii], locations above 40°N latitude should have the ridge of multi-span greenhouses running north to south, and the ridge of single bay greenhouses running east to west. All houses below 40°N should have the ridges running north to south to optimize the light.

Schedule: 24 hours per day, 7 days per week.

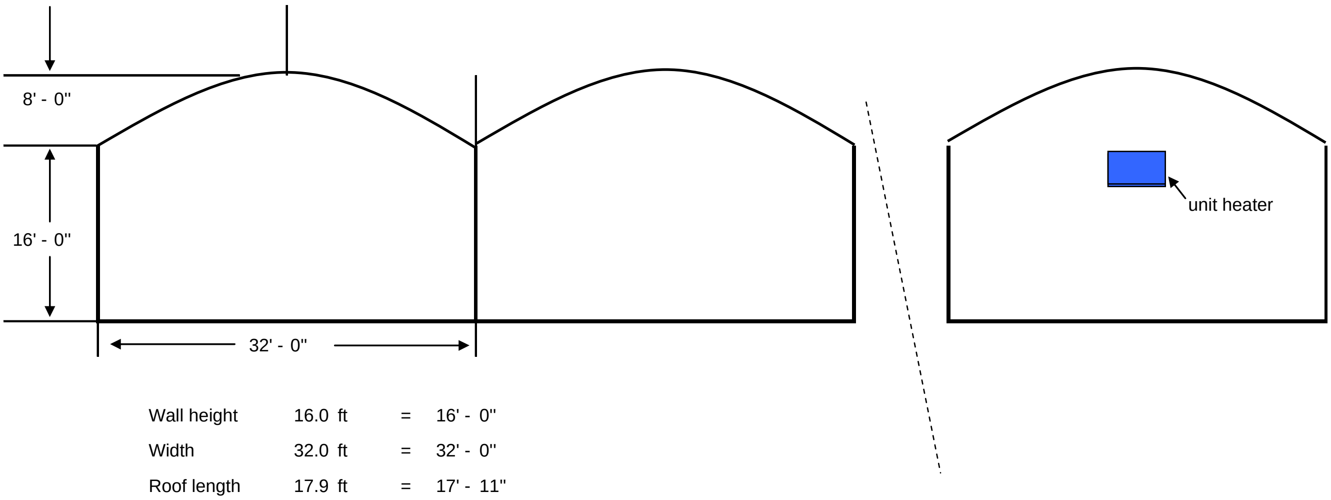
Utility Rates: Assumes PG&E's AG-5 rate for electricity and GNR-1 rate for gas.

IR Film: Assumes an IR inhibiting film additive on the inflated double polyethylene roofing material. (U-value 0.50, Visible Transmittance 0.78, and Shading Coefficient 0.85).

Greenhouse Geometry Assumptions: See Figure 1 below.

Figure 1. Greenhouse Geometry Assumptions

Greenhouse Structure



Wall height	16.0	ft	=	16' - 0"
Width	32.0	ft	=	32' - 0"
Roof length	17.9	ft	=	17' - 11"
Attic height	8.0	ft	=	8' - 0"

Description

Design	gutter connected bays with hoop roofs
Roof Material	double inflated PE without IR film
Wall Material	single layer polycarbonate
Floor	uninsulated bare soil
Thermal Curtains	NONE

Surface Area and Volume Calculations

Dimensions		
Number of Bays		14
Width (each bay)	ft	32
Wall Height (each bay)	ft	16
Length	ft	256
Roof Pitch, rise to run (**x** in 12)		6.0
Peak Height (gutter to peak)	ft	8.0
Roof Width (gutter to peak)	ft	17.9
Surface Area		
Side Walls	ft^2	8,192
End Wall (without gable)	ft^2	14,336
Total Wall (below gutter)	ft^2	22,528
End Gable	ft^2	3,584
Roof	ft^2	128,225
Floor	ft^2	114,688
Interior Volume		
Total	ft^3	2,293,760
Gable (above gutter)	ft^3	458,752
Main (below gutter)	ft^3	1,835,008

Annual Gas Savings:
Baseline therms usage: 0.511 therms/square foot.[2]
IR Inhibiting Film usage: 0.374 therms/square foot.

Savings are the difference between baseline and IR usage

Section 3. Load Shapes

Load Shapes are an important part of the life-cycle cost analysis of any energy efficiency program portfolio. The net benefits associated with a measure are based on the amount of energy saved and the avoided cost per unit of energy saved. For electricity, the avoided cost varies hourly over an entire year. Thus, the net benefits calculation for a measure requires both the total annual energy savings (kWh) of the measure and the distribution of that savings over the year. The distribution of savings over the year is represented by the measure's load shape. The measure's load shape indicates what fraction of annual energy savings occurs in each time period of the year. An hourly load shape indicates what fraction of annual savings occurs for each hour of the year. A Time-of-Use (TOU) load shape indicates what fraction occurs within five or six broad time-of-use periods, typically defined by a specific utility rate tariff. Formally, a load shape is a set of fractions summing to unity, one fraction for each hour or for each TOU period. Multiplying the measure load shape with the hourly avoided cost stream determines the average avoided cost per kWh for use in the life cycle cost analysis that determines a measure's Total Resource Cost (TRC) benefit.

3.1 Base Cases Load Shapes

The base case load shape would be expected to follow a typical non-residential greenhouse end use load shape.

3.2 Measure Load Shapes

For purposes of the net benefits estimates in the E3 calculator, what is required is the load shape that ideally represents the *difference* between the base equipment and the installed energy efficiency measure. This *difference* load profile is what is called the Measure Load Shape and would be the preferred load shape for use in the net benefits calculations.

The measure load shape for this measure is determined by the E3 calculator based on the applicable non-residential market sector and the greenhouse end-use.

Section 4. Base Case & Measure Costs

4.1 Base Case(s) Costs

The most current data available for the base cost (clear double-inflated polyethylene film, no IR enhancements) is from the 2006 Workpaper prepared for Southern California Gas Co. This study took an average of costs from three manufacturers for a cost of $0.093 per square foot. This workpaper will also use this value. It is not clear from the 2006 Workpaper if this cost includes labor, but the labor cost can reasonably be assumed to be identical for the IR and baseline products. The PG&E Greenhouse Baseline

[2] Refer to the appendix for information on the savings calculations.

Study showed measures costs which were substantially higher. It is presumed that the $0.093 value is for material only and does not include installation costs.

4.2 Measure Costs

At this time, IR film cannot be purchased and/or installed independent of polyethylene film. See the following section for incremental vs. full measure costs for polyethylene with IR film.

4.3 Incremental & Full Measure Costs

Cost information on the incremental costs of IR film from three sources cites a range from $0.01 up to $0.03. This workpaper will use the value of $0.021; it represents an average of the three sources plus will be consistent with the value used for the Southern California Gas Co. Workpaper.

Table 4. Measure Costs: IR Inhibiting Film

Full Measure IR Enhanced PE	Base Case Clear PE	Incremental cost of IR film	Source	Date
$0.114	$0.093	$0.021	*Greenhouse Thermal Curtains and Infrared Films Workpaper for PY2006-2008* prepared for Southern California Gas Co. by Energy and Environmental Analysis, Inc. (B-REP-06-599-17B)	Sept. 2006
$0.21 Installed			John Hoogenbom	Nov. 2003
	$0.25 Installed		John W. Bartok, *Energy Conservation for Commercial Greenhouses*	2001
		$0.01	John W. Bartok, *Energy Conservation for Commercial Greenhouses*	2001
		$0.03	DEER Database	Oct. 2005

Index

Appendix

Table 5 outlines how the savings realized with the addition of IR inhibiting film to double-inflated polyethylene is much more sensitive to the greenhouse temperature setpoint than the weather. For example, with a 55F setpoint, there is only a 14% difference in the annual natural gas savings between the coastal versus the inland greenhouse. However; there is a difference of 276% in savings between a 55F versus a 80F temperature setpoint for a coastal greenhouse.

	55F Setpoint	80F Setpoint	% Difference
Coastal weighted average (55F)	0.135	0.49	263%
Inland (weighted average (55F)	0.158	0.45	185%
% Difference	14.6%	8%	

Table 5. Annual Natural gas savings (per square foot) with IR Film. Location versus Temperature Setpoint

Results

The following table presents the annual natural gas usage and savings, based upon weighted averages of the coastal climate zones (climate zones 1, 2, 3, 4 and 5) ; the weighted averages of the inland climate zones (climate zones 11, 12, and 13); and the weighted average of all zones together. Refer to the appendix for data on square footage of greenhouses by county and climate zone. Because less than one percent of California greenhouse space is in climate zone 16, this region has been ignored. As can be seen, while the gas usage is significantly different between the inland and the coastal greenhouses, the savings are comparable. Refer to Table 10 for annual electricity use savings. The electricity savings is from the fan energy consumed by the heaters. There is no peak demand savings. The savings in the following table have been grouped by the weighted average of the five coastal zones (0.135 therms/sq ft); by the three inland climate zones (0.158 therms/sq ft); and for all climate zones (0.137 therms/sq ft).

		Coastal Climate Zones Usage					**Coastal zones, weighted averages**		**Inland Climate Zones Usage**			**Inland zones, weighted averages**		**All zones, weighted averages**	
		cz 01	cz 02	cz 03	cz 04	cz 05			cz 11	cz 12	cz 13				
	% of total greenhouse area (grouped by coastal vs inland)	1.1%	1.3%	53.9%	28.3%	15.3%	**100%**		2.8%	74.3%	22.9%	**100%**		N/A	
	% of total greenhouse area (all zones)	1.0%	1.2%	47.7%	25.1%	13.6%	**88%**		0.3%	8.3%	2.8%	**12%**		**100%**	
Alt	Description	**Use**	**Use**	**Use**	**Use**	**Use**	**Use**	**Saving**	**Use**	**Use**	**Use**	**Use**	**Saving**	**Use**	**Saving**
0	Double Inflated Poly no IR, 55F	0.844	0.633	0.515	0.492	0.384	0.493	N/A	0.762	0.702	0.474	0.651	N/A	0.511	N/A
1	Alt 0 + IR Film	0.640	0.473	0.378	0.358	0.263	0.358	**0.135**	0.592	0.535	0.346	0.493	**0.158**	0.374	**0.137**
	Savings by Climate Zone	0.204	0.160	0.137	0.134	0.121			0.170	0.167	0.128				

Table 6. Annual Natural Gas Usage and Savings (therms per square foot)

Baseline Roof Material

There is a significant difference in savings with applying heat curtains between double-inflated roofs with and without IR film; however the Greenhouse Baseline Study found that the majority of greenhouse roofs consist of double-inflated polyethylene <u>with</u> IR film (see Figure 2). While this study was based upon a small sample size (22 greenhouse facilities), the findings are backed up by anecdotal information from the vendors.

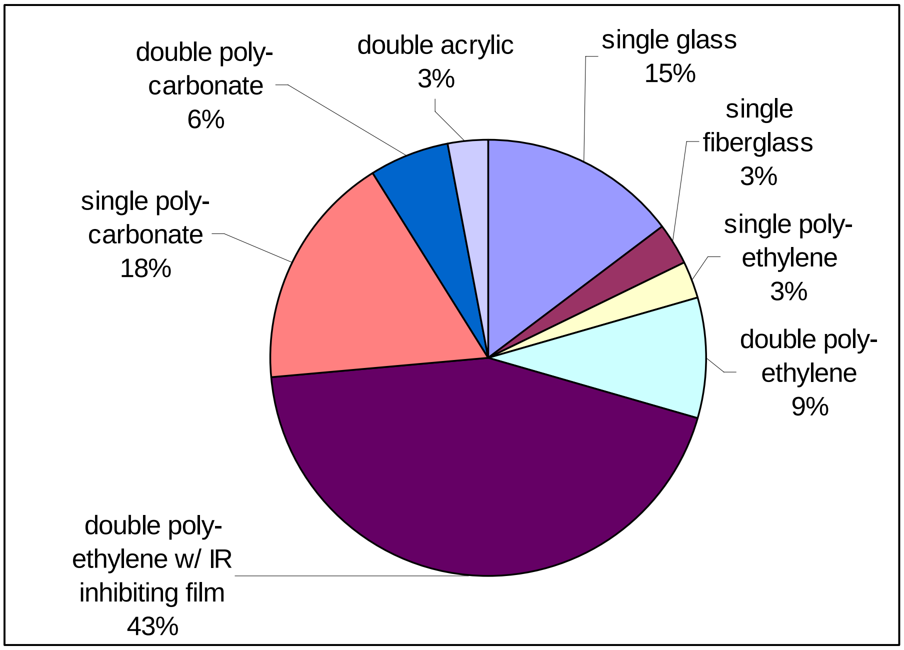


Figure 2. Distribution of Greenhouse Roof Materials (Source: PG&E Greenhouse Baseline Study)

Climate Zones

The original Greenhouse Baseline Study conducted for PG&E stratified the data into three different geographic regions: coastal, coastal valley, and inland valley. This aggregation was based upon conversations with PG&E project manager John Blessent and PG&E meteorologist Woody Whitlatch. The geographical segregation was accomplished by mapping the greenhouse locations with the California Energy Commission climate zones (see Figure 7 in the appendix). Refer to Table 7 for the assignment of the geographic regions by climate zone. Because less than one percent of California greenhouse space is in climate zone 16, this region has been ignored.

Climate Zones	Category
2, 4, and 12	Coastal Valley
1, 3, and 5	Coastal
11 and 13	Inland Valley

Table 7. Grouping of Greenhouses by Climate Zones for the PG&E Greenhouse Baseline Study.

Based upon feedback from PG&E, this workpaper does not segregate results by climate zones or regions into separate deemed savings tiers. Rather a weighted average of the results will be applied to all greenhouses within PG&E's service territory. Refer to **Error! Reference source not found.** for a summary of the square footage of crops grown under cover (by County and climate zones), based upon 2002 Census data.

Results indicate that natural gas usage is higher in climate zone 12, which may seem counter-intuitive. However, climate zone 12 has colder temperatures than climate zone 3, as can be seen in Figure 3 and Table 8. The data presented in

Table 8 is from the California Energy Commission weather files for climate zones 3 (Oakland is the reference city) and 12 (Sacramento is the reference city). The results compare the number of heating degree days (HDD) and shows that climate zone 12 is colder than climate zone 3. The weather files used in the analysis have been approved by the California Energy Commission.

	CZ 03 (Oakland)	CZ 12 (Sacramento)
Average Daily Max Tdb	67.4	73.7
Average Daily Min Tdb	49.2	47.5
Avg. Annual Tdb	57.5	59.5
Annual Max Tdb	91	103
Annual Min Tdb	34	27
HDD (24 hours/65F)	3107	3351

Table 8. Summary of California Energy Commission Climate Zone HDD Calculations

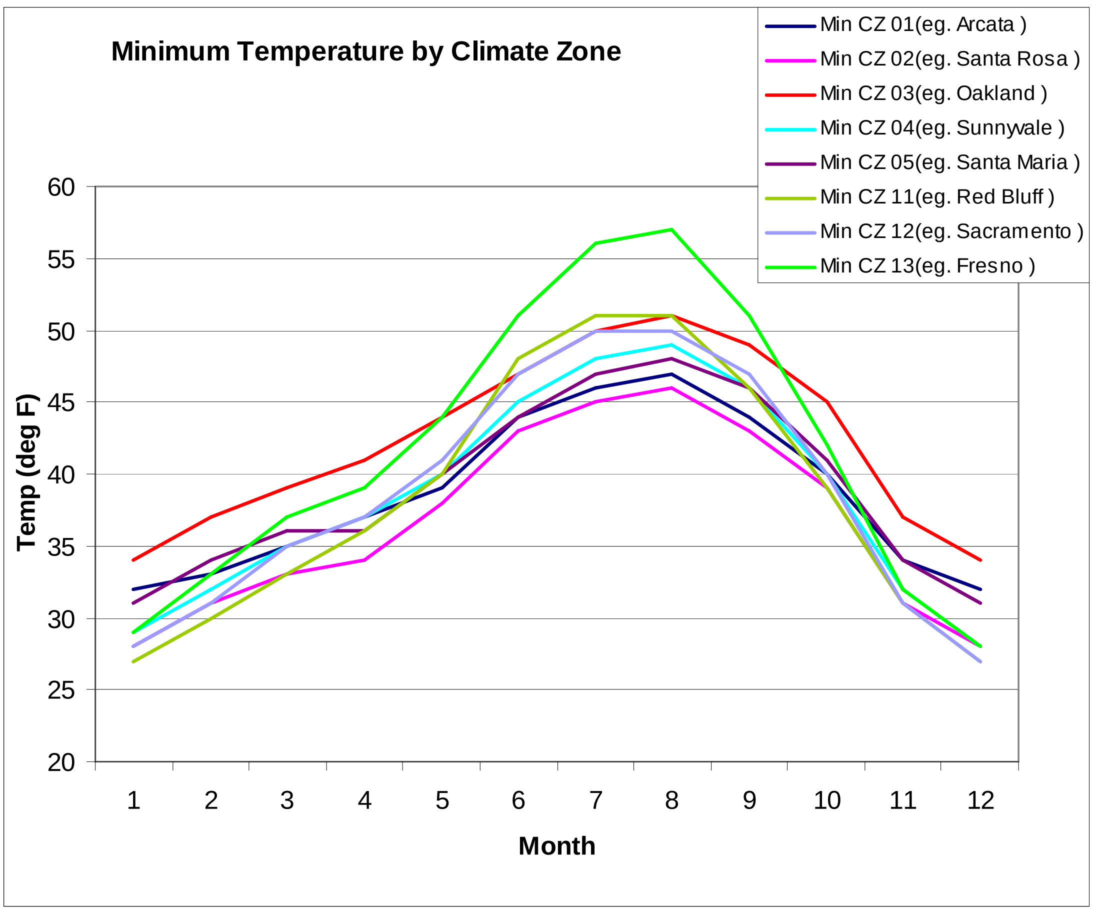


Figure 3. Monthly Minimum Temperatures

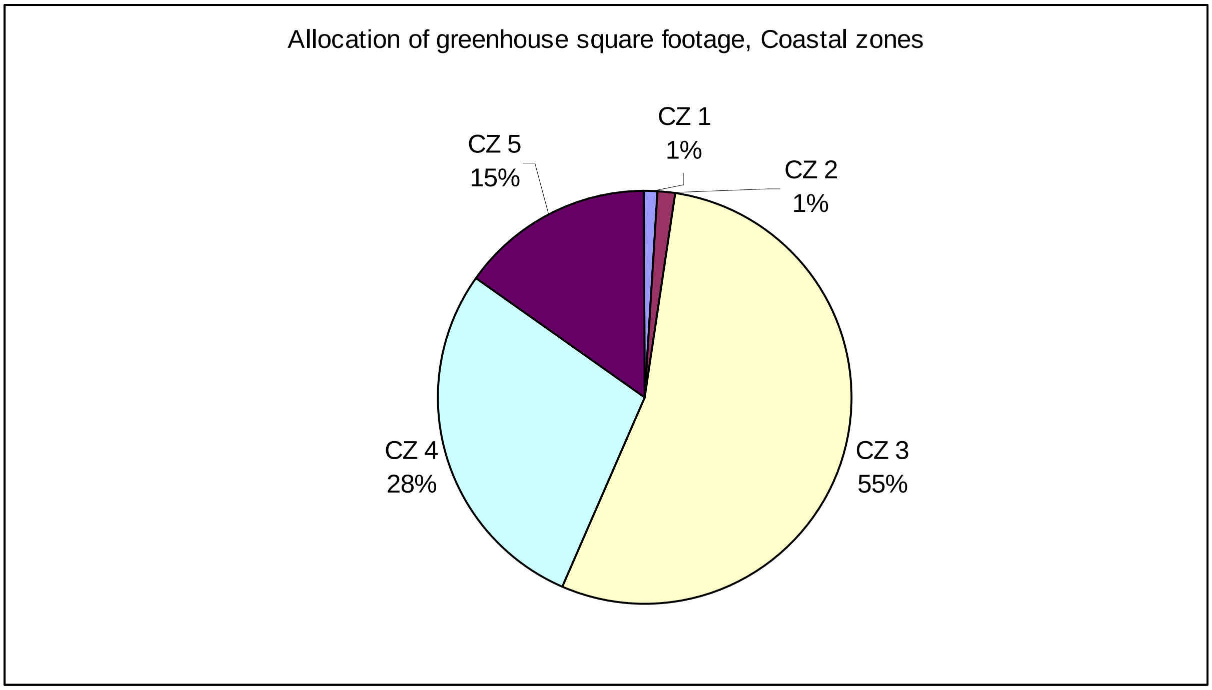


Figure 4. Allocation of greenhouse square footage, coastal climate zones.

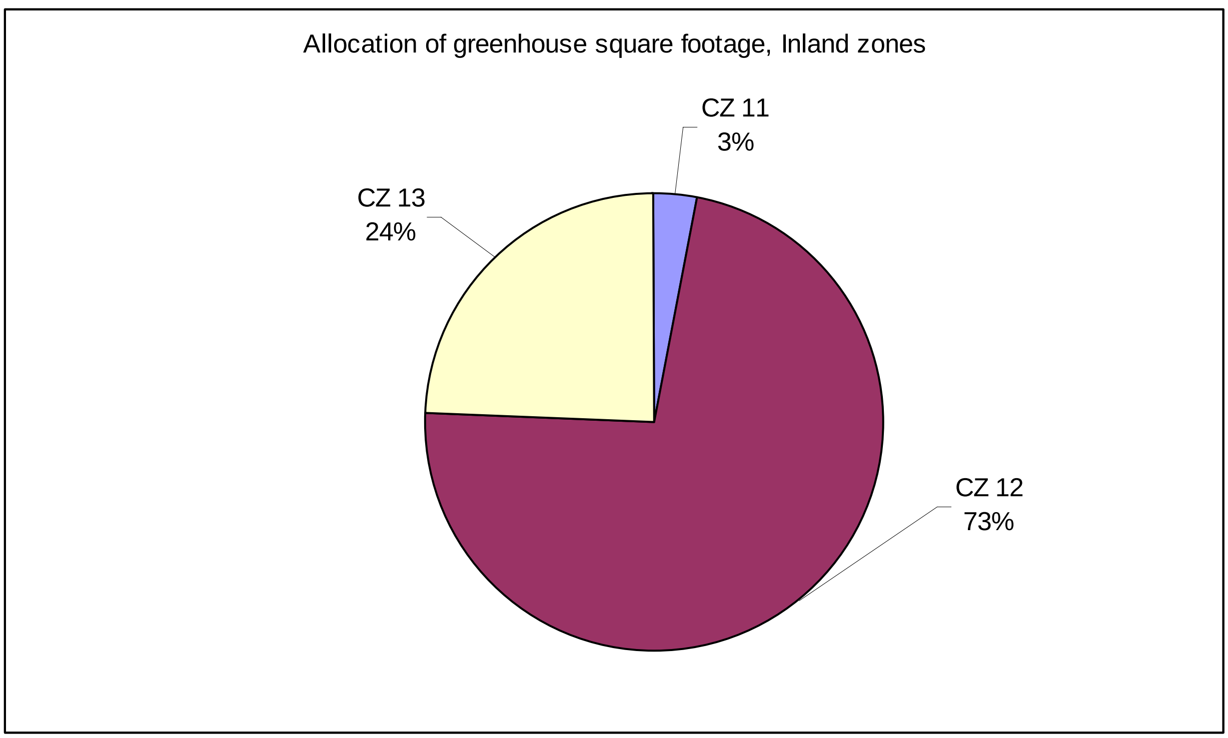


Figure 5. Allocation of greenhouse square footage, inland climate zones.

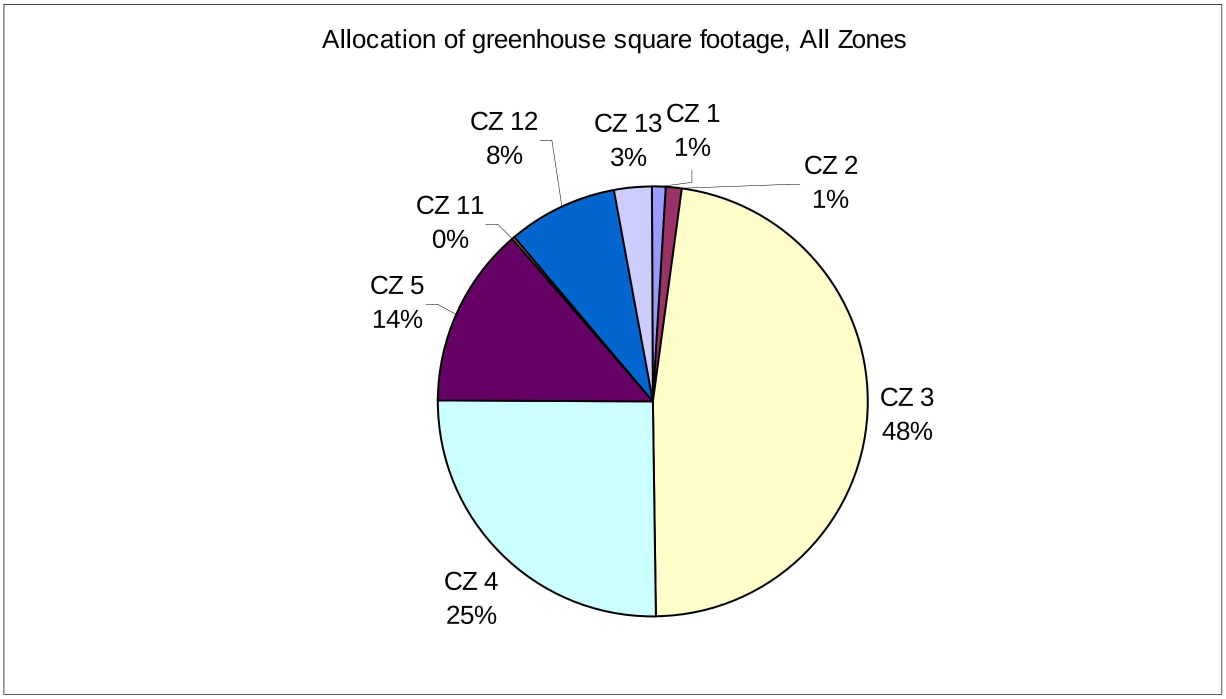


Figure 6. Allocation of greenhouse square footage, all climate zones.

Table 9. Square Footage of Greenhouses by County and Climate Zones.

County	Climate Zone(s)	sq ft of greenhouses	% of total
Alameda	12	478,560	0.3%
Butte	11/16	864,063	0.5%
Contra Costa	3/12	3,682,708	2.0%
El Dorado	12/16	77,352	0.0%
Fresno	13/16	1,877,395	1.0%
Humboldt	1	1,514,335	0.8%
Kern	13/14/16	309,354	0.2%
Lake	2	47,396	0.0%
Lassen	16	93,400	0.1%
Madera	13/16	124,400	0.1%
Marin	2/3	60,576	0.0%
Mendocino	1/2/3/16	746,950	0.4%
Monterey	3/4	51,680,374	28.6%
Napa	2	6,050	0.0%
Nevada	11/16	67,280	0.0%
Sacramento	12	2,811,632	1.6%
San Benito	4	29,464	0.0%
San Francisco	3	114,039	0.1%
San Joaquin	12	9,434,276	5.2%
San Luis Obispo	4/5	13,773,982	7.6%

County	Climate Zone(s)	sq ft of greenhouses	% of total
San Mateo	3	17,192,804	9.5%
Santa Barbara	4/5/6	25,918,293	14.3%
Santa Clara	4	14,663,782	8.1%
Santa Cruz	3	25,638,304	14.2%
Shasta	11/16	64,692	0.0%
Siskiyou	16	70,156	0.0%
Solano	3/12	25,828	0.0%
Sonoma	2/3	5,148,121	2.8%
Stanislaus	12	299,478	0.2%
Sutter	11	113,000	0.1%
Tehama	11/16	34,310	0.0%
Trinity	2/11/16	3,046	0.0%
Tulare	13/16	3,591,573	2.0%
Yolo	12	316,948	0.2%

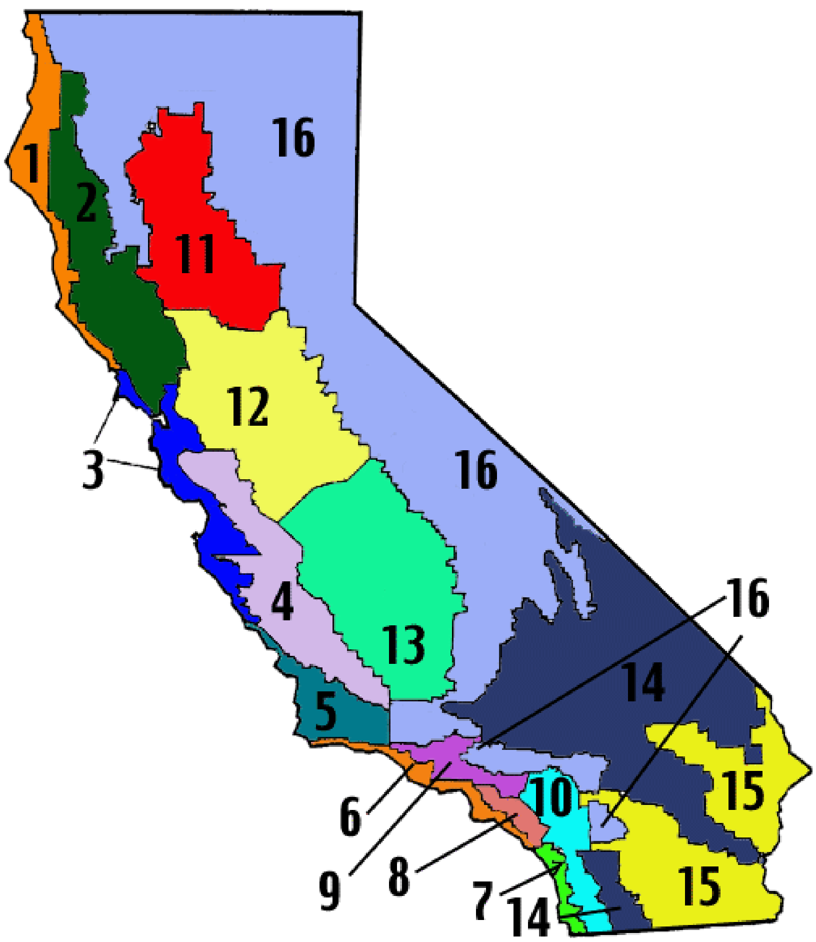


Figure 7. California Climate Zones Map

Electricity Savings

The following table outlines the annual electricity use and annual electricity savings, per square foot, for only climate zones 3 and 12. The electricity savings is from the fan energy consumed by the heaters. There is no peak demand savings.

		Coastal Climate Zones Usage					**Coastal zones, weighted averages**		**Inland Climate Zones Usage**			**Inland zones, weighted averages**		**All zones, weighted averages**	
		cz 01	cz 02	cz 03	cz 04	cz 05			cz 11	cz 12	cz 13				
% of total greenhouse area (grouped by coastal vs inland)		1.1%	1.3%	53.9%	28.3%	15.3%	**100%**		2.8%	74.3%	22.9%	**100%**		N/A	
% of total greenhouse area (all zones)		1.0%	1.2%	47.7%	25.1%	13.6%	**88%**		0.3%	8.3%	2.8%	**12%**		**100%**	
Alt	Description	**Use**	**Use**	**Use**	**Use**	**Use**	**Use**	**Saving**	**Use**	**Use**	**Use**	**Use**	**Saving**	**Use**	**Saving**
0	Double Inflated Poly no IR, 55F	0.270	0.225	0.204	0.199	0.177	0.199	N/A	0.344	0.320	0.328	0.323	N/A	0.214	N/A
1	Alt 0 + IR Film	0.230	0.194	0.177	0.173	0.153	0.173	**0.026**	0.322	0.298	0.314	0.302	**0.020**	0.188	**0.026**
	Savings by Climate Zone	0.040	0.031	0.027	0.026	0.024			0.022	0.022	0.014				

Table 10. Annual Electricity Usage and Savings (kWh per square foot)

References

[1] The PG&E Greenhouse Baseline Study found that the greatest majority of crop types grown within PG&E service territory greenhouses is cut flowers (47%). This figure is based upon 2002 Census data. According to Bond, T.E. et. al. 1985. Reducing Energy Costs in California Greenhouses. University of California Cooperative Extension. (http://ohric.ucdavis.edu/Newsltr/GreenhouseEnergy.pdf) typical cut flowers can be grown at 55F or less.

[ii] Copied from PG&E "Energy Efficiency Rebates For Your Business" brochures. http://www.pge.com/includes/docs/pdfs/catalogs/biz_catalog.pdf

[iii] Southern California Edison. December 2005. *2004-2005 Database for Energy Efficiency Resources (DEER) Update Study Final Report*. Prepared by Itron, Inc., Vancouver, Washington. http://www.energy.ca.gov/deer/

[iv] Greenhouse Baseline Study, prepared for PG&E by Green Building Studio, December 2005. .

[v] *ibid*

[vi] Peter Fryn of System USA Inc. is a major vendor to greenhouse owners. His experience is that the baseline roof material for coastal greenhouses is single-layer Dynaglas (Polycarbonate) and not double-inflated polyethylene. Our 2005 baseline study for PG&E found that of the 20 greenhouse facilities in coastal locations interviewed for the study, the largest number (7) had double-polyethylene roofs, 5 had glass roofs, and 3 had single polycarbonate roofs. The remaining roof types were distributed among other materials.

[vii] Bartok, John W., Jr. 2001. *Energy Conservation for Commercial Greenhouses*.NRAES-3. Ithaca, NY: Natural Resource, Agriculture, and Engineering Service.