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AGRICULTURE
GREENHOUSE INFRARED FILM
SWBE002-01

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MEASURE NAME

Greenhouse Infrared Film

STATEWIDE MEASURE ID

SWBE002-01

TECHNOLOGY SUMMARY

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

MEASURE CASE DESCRIPTION

This measure case is defined as a greenhouse roof with infrared (IR) inhibiting film additive on the inflated double polyethylene roof. The savings for this measure are extremely sensitive to weather; thus, savings were generated for each climate zone in California.

BASE CASE DESCRIPTION

The base case for this measure is defined as a greenhouse with an inflated double polyethylene roof without an infrared (IR) film additive.

CODE REQUIREMENTS

Greenhouses and infrared film are not governed by state or federal codes and standards.

Applicable State and Federal Codes and Standards

Code	Applicable Code Reference	Effective Date
CA Appliance Efficiency Regulations – Title 20	None.	n/a
CA Building Energy Efficiency Standards – Title 24	None.	n/a
Federal Standards	None.	n/a

NORMALIZING UNIT

Square feet of installed IR film material (ft²).

¹ Green Building Studio. 2005. *Greenhouse Baseline Study Final Report*. Prepared for Pacific Gas and Electric Company. Page 29.

PROGRAM REQUIREMENTS

Measure Implementation Eligibility

All combinations of measure application type, delivery type, and sector that are established for this measure are specified below. Measure application type is a categorization based on the circumstances and timing of the measure installation; each measure application type is distinguished by its baseline determination, cost basis, eligibility, and documentation requirements. Delivery type is the broad categorization of the delivery channel through which the market intervention strategy (financial incentives or other services) is targeted. This table also designates the broad market sector(s) that are applicable for this measure.

Note that some of the implementation combinations below may not be allowed for some measure offerings by all program administrators.

Implementation Eligibility for Investor-Owned Utilities

Measure Application Type	Delivery Type	Sector
Add-on equipment	DnDeemed	Ag

Eligible Products

The installation of infrared (IR) film must meet the following requirements:

- The IR film must be installed in an existing gas-heated greenhouse facility.
- The heating equipment type (building HVAC) must be specified in the implementation of the measure.
- The facility must be a greenhouse with the primary purpose of agricultural use.
- The film must be infrared, anti-condensate, polyethylene plastic with a minimum thickness of six thousandths of an inch.
- The IR film shall not be installed on the walls of the greenhouse.

Eligible Building Types and Vintages

This measure is applicable for existing agricultural or commercial greenhouse of any vintage for the primary purpose of the production of nursery products, horticultural specialties, or ornamental products.

Eligible Climate Zones

This measure is applicable in any California climate zones.

PROGRAM EXCLUSIONS

This measure is not eligible for new construction projects.

DATA COLLECTION REQUIREMENTS

Data requirements are to be determined.



USE CATEGORY

Building envelope (BdlgEnv)

ELECTRIC SAVINGS (KWH)

The electric unit energy savings (UES) of greenhouse infrared film was extracted directly from the Database of Energy Efficient Resources (DEER). The version used to calculate savings for this measure was DEER 2011 (D11 v4.00). The table below provides the statewide measure offering IDs and the corresponding DEER Measure IDs associated with this measure.²

Statewide Measure Offering ID and DEER Measure IDs

Statewide Measure Offering ID	DEER Measure ID	DEER Energy Impact ID
SWBE002A	Grnhs-Shell-LowIRroof	Grnhs-Shell-LowIRroof

The unit energy savings (UES) for this measure is based upon simulations of a 100' x 30' greenhouse facility with 7-foot walls.³ The model assumes an overhead gas furnace and excludes radiant heat. The specific setpoints and assumptions for the DEER model are unknown.

Model permutations were generated to derive savings for each of the 16 California climate zones. The results were reported in the Remote Ex-Ante Database Interface (READI) tool. These results have not been modified.

PEAK ELECTRIC DEMAND REDUCTION (kW)

There is no peak demand reduction expected from this measure.

GAS SAVINGS (THERMS)

The gas unit energy savings (UES) of greenhouse infrared film was extracted directly from the Database of Energy Efficient Resources (DEER). See the Electric Savings section for details.

LIFE CYCLE

Effective useful life (EUL) is an estimate of the median number of years that a measure installed through a program is still in place and operable. Remaining useful life (RUL) is an estimate of the median number of years that a technology or piece of equipment replaced or altered by an energy efficiency program would

² Itron, Inc. 2005. *2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report*. Prepared for Southern California Edison. Section 4.2.

³ Itron, Inc. 2005. *2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report*. Prepared for Southern California Edison. Section 4.2.

have remained in service and operational had the program intervention not caused the replacement or alteration. The RUL is only applicable to the first baseline period for a retrofit measure with an applicable code baseline.

As per Resolution E-4807, the California Public Utilities Commission (CPUC) defined the EUL of a retrofit add-on (REA) measure as the minimum of the EUL of the measure itself and the RUL of the host equipment.⁴ The RUL of the host equipment (which is a greenhouse for this particular measure) is calculated as one-third of the EUL of a greenhouse. The EUL of a greenhouse is not available and thus is assigned the maximum allowable EUL of 20 years, as permitted by Version 2 of the Energy Efficiency Policy Manual. The methodology to calculate the RUL of the host equipment conforms with Version 5 of the Energy Efficiency Policy Manual, which recommends “one-third of the effective useful life in DEER as the remaining useful life until further study results are available to establish more accurate values.” This approach provides a reasonable RUL estimate without the requiring any a priori knowledge about the age of the equipment being replaced.⁵

The EUL and RUL specified for a greenhouse heat curtain are specified below.⁶

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs) – IR film ^a	5.0	Itron, Inc. 2005. <i>2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report</i> . Prepared for Southern California Edison. Page 4-14. California Public Utilities Commission (CPUC). 2008. "EUL_Summary_10-1-08.xls."
EUL (yrs) – host greenhouse	20.0	California Public Utilities Commission (CPUC), Energy Division. 2003. <i>Energy Efficiency Policy Manual v 2.0</i> . Page 16.
RUL (yrs) – host greenhouse	6.67	California Public Utilities Commission (CPUC), Energy Division. 2013. <i>Energy Efficiency Policy Manual Version 5</i> . Page 32.

a. The EUL value of five years is adopted for this measure, as it is minimum of the EUL of the measure and the RUL of a greenhouse.

BASE CASE MATERIAL COST (\$/UNIT)

Estimates of base case material costs drawn from previous studies are shown below. Because these estimates are not comparable, see Measure Case Material Cost section for derivation of incremental measure cost that is used in the cost effectiveness calculation.

⁴ California Public Utilities Commission (CPUC). 2016. *Resolution E-4807*. December 16. Page 13.

⁵ KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

⁶ According to the 2008 EUL update to the Database of Energy Efficient Resources (DEER), the EUL for greenhouse IR film is based upon Pacific Gas and Electric (PG&E) program tracking data and a workpaper developed by Southern California Edison, but these sources are not identified or confirmed.

The 2005-2005 Database for Energy Efficient Resources (DEER) Update Study notes the EUL of this measure depends on the climate “Standard replacement of film is 4 years. In mild climates film may be replaced at 5-year increments or longer.”

Base Case Cost Estimates for Polyethylene Film with No Infrared Additive

Cost Estimate (\$/ft ²)	Original Source
\$0.093	Energy and Environmental Analysis, Inc. 2006. <i>Greenhouse Thermal Curtains and Infrared Films: Workpaper for PY2006-2008</i> . Prepared for the Southern California Gas Company. B-REP-06-599-17B.
\$0.250 Includes installation.	Bartok, J. 2001. <i>Energy Conservation for Commercial Greenhouses</i> . Natural Resource, Agriculture, and Engineering Service (NRAES). Ithaca, NY: Natural Resource, Agriculture, and Engineering Service.

Source: Green Building Studio. 2005. *Greenhouse Baseline Study Final Report*. Prepared for Pacific Gas and Electric Company. Page 57.

From *Greenhouse Thermal Curtains and Infrared Films: Workpaper for PY2006-2008*, base cost of \$0.093 will be used.

MEASURE CASE MATERIAL COST (\$/UNIT)

Estimates of the measure case material costs drawn from previous studies and manufacturer data are shown below. Because the material cost estimates are not comparable, the estimates of incremental measure cost are adopted for the cost effectiveness analysis.

Energy and Environmental Analysis, Inc. prepared the *Greenhouse Thermal Curtains and Infrared Films: Workpaper for PY2006-2008* for the Southern California Gas Company (SoCalGas),⁷ with incremental measure cost of \$0.021. Pacific Gas and Electric Company (PG&E) later adopted this cost evaluation in its *PGECOAGR102 Revision 3 Greenhouse IR Film* workpaper of 2012.⁸ The *2010-2012 W0017 Ex Ante Measure Cost Study* conducted by Itron, Inc reported similar results

Cost data from the SoCalGas commercial rebate program (2017 to 2018) indicate cost range from \$0.07 to \$0.16 per square foot of infrared film. These results aligned with the W0017 study results.

Measure and Installation Cost Estimates for Greenhouse Infrared Film ⁹

Cost Estimate (\$/ft ²)	Incremental Cost of IR Film	Original Source
-	\$0.02	Itron, Inc. 2014. <i>2010-2012 W0017 Ex Ante Measure Cost Study Final Report</i> . Prepared for the California Public Utilities Commission.
\$0.114	\$0.021	Energy and Environmental Analysis, Inc. 2006. <i>Greenhouse Thermal Curtains and Infrared Films: Workpaper for PY2006-2008</i> . Prepared for the Southern California Gas Company. B-REP-06-599-17B.
\$0.210 Includes installation	-	Hoogenbom, J. November 2003. This reference could not be located.
-	\$0.010	Bartok, J. 2001. <i>Energy Conservation for Commercial Greenhouses</i> . Natural Resource, Agriculture, and Engineering Service (NRAES). Ithaca, NY: Natural Resource, Agriculture, and Engineering Service.

⁷

⁸ Pacific Gas and Electric Company (PG&E). 2012. "Work Paper PGECOAGR102 Greenhouse IR Film Revision 3." August 28.

⁹ Green Building Studio. 2005. *Greenhouse Baseline Study Final Report*. Prepared for Pacific Gas and Electric Company. Page 57.



Cost Estimate (\$/ft ²)	Incremental Cost of IR Film	Original Source
-	\$0.030	Itron, Inc. 2005. <i>2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report</i> . Prepared for Southern California Edison.

BASE CASE LABOR COST (\$/UNIT)

See Measure Case Labor Cost. Base case labor cost is assumed to be the same as the measure case labor cost.

MEASURE CASE LABOR COST (\$/UNIT)

See Measure Case Material Cost section. Due to the inconsistency of cost estimates drawn from previous studies, the installation costs were not developed for this measure, but are assumed to be the same for the base case and measure case.

NET-TO-GROSS (NTG)

The net-to-gross (NTG) ratio represents the portion of gross impacts that are determined to be directly attributed to a specific program intervention. The NTG for greenhouse infrared film is based upon the evaluation of the PG&E Agriculture and Food Processing Program published by KEMA, Inc. in 2010.

Net-to-Gross Ratios

Parameter	Value	Source
NTG	0.46	KEMA, Inc. 2010. <i>2006-2008 Evaluation Report: PG&E Agricultural and Food Processing Program; Greenhouse Heat Curtain and Infrared Film Measures</i> . CALMAC Study ID: CPU0024.01. Page 60. Itron, Inc. 2011. <i>DEER Database 2011 Update Documentation</i> . Prepared for the California Public Utilities Commission. Page 9-4.

GROSS SAVINGS INSTALLATION ADJUSTMENT (GSIA)

The gross savings installation adjustment (GSIA) rate represents the ratio of the number of verified installations of the measure to the number of claimed installations reported by the utility. This factor varies by end use, sector, technology, application, and delivery method. This GSIA rate is the current “default” rate specified for measures for which an alternative GSIA has not been estimated and approved.

Gross Savings Installation Adjustment Rates

Parameter	Value	Source
GSIA	1.0	California Public Utilities Commission (CPUC), Energy Division. 2013. <i>Energy Efficiency Policy Manual Version 5</i> . Page 31.

NON-ENERGY IMPACTS

Non-energy impacts for this measure have not been quantified.

DEER DIFFERENCES ANALYSIS

This section provides a summary of DEER-based inputs and methods, and the rationale for inputs and methods that are not DEER-based.

DEER Difference Summary

DEER Item	Comment / Used for Workpaper
Modified DEER methodology	No
Scaled DEER measure	No
DEER Base Case	Yes
DEER Measure Case	Yes
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQUEST Prototypes	No
DEER Version	DEER 2011 (D11 v4.00)
Reason for Deviation from DEER	n/a
DEER Measure IDs Used	Grnhs-Shell-LowIRroof
NTG	Source: DEER 2014. The NTG of 0.46 is associated with NTG ID: <i>NonRes-sGHS-mIRF-dn</i>
GSIA	Source: DEER. The GSIA of 1.0 is associated with GSIA ID: <i>Def-GSIA</i>
EUL/RUL	Source: DEER 2014. The value of 5 years is associated with EUL ID: <i>Agr-Irfilm</i>

REVISION HISTORY

Measure Characterization Revision History

Revision Number	Revision Completion Date	Primary Author, Title, Organization	Revision Summary and Rationale for Revision Effective Date and Approved By
01	03/31/2018	Jennifer Holmes, Cal TF Staff	Draft of consolidated text for this statewide measure is based upon Workpaper PGECOAGR102 Revision 3 (August 28, 2012) Consensus reached among Cal TF members.
	06/28/2019	Andres Marquez, SoCalGas Jennifer Holmes, Cal TF Staff	Revisions for submittal of version 01.