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AGRICULTURE
GREENHOUSE HEAT CURTAIN
SWBE001-01

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MEASURE NAME

Greenhouse Heat Curtain

STATEWIDE MEASURE ID

SWBE001-01

TECHNOLOGY SUMMARY

Thermal curtains decrease conduction, convection, and radiation heat losses in greenhouses. Thermal curtains are installed inside the greenhouse and are designed to be placed horizontally above the growing zone within a greenhouse. In addition to retaining heat, thermal curtains are commonly used for shading.

There are two basic types of thermal curtain installations: flat, and slope-flat-slope.¹ The flat is under the gutter level and operates on a horizontal plane. The slope-flat-slope (or tent) installation is used with some greenhouses that have other equipment to avoid, or for growers who want to minimize the air trapped above the curtain (or maximize the area below).

Thermal curtains are made of several different materials that impact the heat retention properties.² Porous materials allow condensation to drain but are not as effective as nonporous materials for reducing energy use. However, nonporous curtains could cause the track system to fail if they become too heavy from collected moisture. The aluminized curtains typically consist of a 55% woven white polyester film.

Thermal curtains save energy by 1) trapping an insulating air film; 2) reducing the volume of space requiring heating, and/or 3) reflecting rising heat back into the growing zone (with aluminized strips). Research results indicate that outward-facing reflective surface retain heat slightly better than an inward-facing system.³ Aluminized curtains save about 10% more energy than non-aluminized curtains.

MEASURE CASE DESCRIPTION

This measure case is defined as the installation of a single-layer heat curtain with infrared film in a greenhouse area in which a heat curtain was not present, or where heat curtains were present but nonfunctional. It is assumed that the thermal curtains are deployed during nighttime hours, and open during daytime hours. The savings for this measure are extremely sensitive to weather; thus, savings for each measure offering (below) were generated for each climate zone in California.

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

² Bartok, J. 2001. *Energy Conservation for Commercial Greenhouses*. Natural Resource, Agriculture, and Engineering Service (NRAES). Ithaca, NY: Natural Resource, Agriculture, and Engineering Service.

³ Bartok, J. 2001. *Energy Conservation for Commercial Greenhouses*. Natural Resource, Agriculture, and Engineering Service (NRAES). Ithaca, NY: Natural Resource, Agriculture, and Engineering Service.

Measure Offerings

Statewide Measure Offering ID	Measure Offering Description
SWBE001A	Heat Curtain

BASE CASE DESCRIPTION

The base case for this measure is defined as greenhouse area without any heat curtains, or a greenhouse area with nonfunctional heat curtains.

CODE REQUIREMENTS

Greenhouses and the heat curtains measures 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 building floor area (ft²).

PROGRAM REQUIREMENTS 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	DeemedDn	Ag

Eligible Products

Eligible products must meet the following requirements:

- Must be a single-layer interior curtain installed for heat retention
- Must be installed in an existing gas-heated greenhouse facility
- The facility must be a greenhouse with the primary purpose of agricultural use.
- The heat curtain must be a new curtain installed where none previously existed or a new curtain that is replacing an existing curtain that is no longer functional.
- The heat curtain must be installed above the conditioned area where the gas heat source provides hot air to plant and seed species.
- The heat curtain must have a natural gas savings rating that meets or exceeds 40%.
- The heat curtain must have a warranty/product life of five years.
- The installation must allow the curtain to be automatically or manually moved into place.

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 zone.

PROGRAM EXCLUSIONS

The square footage of the new heat curtain cannot exceed the square footage of the greenhouse floor. Additionally, any overhang and overlap of curtain material cannot be included in the square footage calculation.

DATA COLLECTION REQUIREMENTS

Data collection requirements are to be determined.

USE CATEGORY

Building envelope (BldgEnv)

ELECTRIC SAVINGS (kWh)

The electric unit energy savings (UES) of a greenhouse heat curtain 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 Statewide Measure Offering ID and corresponding DEER Energy Impact ID are provided below.

DEER Measure IDs

Statewide Measure Offering ID	Measure Offering Description	DEER Energy Impact ID
SWBE001A	Heat Curtain	Grnhs-Shell-ThermCurt

According to the *2004-2005 DEER Update Study* conducted by Itron, Inc., the measure data for the DEER model were developed for a prototypical 4,000 square foot greenhouse facility and based on average characteristics for Southern California Gas Company (SCG) customer participants for Express Efficiency heat curtain measures during PY 2001.⁴ Additionally, 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)

The peak demand reduction of a greenhouse heat curtain was extracted directly from the Database of Energy Efficient Resources (DEER). See the Electric Savings section for details. Note, however, that there is no peak demand reduction expected from this measure.

GAS SAVINGS (THERMS)

The gas unit energy savings (UES) of a greenhouse heat curtain 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 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.⁵ 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

⁴ Itron, Inc. 2005. *2004-2005 Database for Energy Efficiency Resources (DEER) Update Study - Final Report*. Prepared for Southern California Edison. Section 4.2.

⁵ California Public Utilities Commission (CPUC). 2016. *Resolution E-4807*. December 16. Page 13.

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.⁶

The EUL and RUL specified for a greenhouse heat curtain are specified below. The EUL value adopted for this measure is the EUL of the heat curtain measure. The RUL is based upon the EUL of the host equipment, a cool roof. The EUL for a cool roof was adopted for the 2005 version of the Database for Energy Efficient Resources and was developed by the Lawrence Berkeley National Laboratory (LBNL).

Effective Useful Life and Remaining Useful Life

Parameter	Value	Source
EUL (yrs) – heat curtain ^a	5.0	California Public Utilities Commission (CPUC), Energy Division. 2003. Energy Efficiency Policy Manual v 2.0. Page 18, Table 4.1.
EUL (yrs) - bldg. cool roof	15.0	California Public Utilities Commission (CPUC), Energy Division. 2008. "EUL_Summary_10-1-08.xls."
RUL (yrs) – bldg. cool roof	5.0	

BASE CASE MATERIAL COST (\$/UNIT)

Because the base case is defined as no heat curtain, the base cast material cost is equal to \$0.

MEASURE CASE MATERIAL COST (\$/UNIT)

The measure case material cost for this measure was derived from the *2010-2012 W0017 Ex Ante Measure Cost Study* conducted by Itron, Inc. (See “Heat curtain installed in greenhouse that has roofs with IR film and bare wall” in Appendix F.) As shown below, the cost analysis includes data from 2013 to 2019 and assumes an annual inflation rate.

Measure Case Material and Installation Cost Inputs for a Single-Layer Greenhouse Heat Curtain

Year	Equipment Material Cost (\$/unit)	Labor Cost (\$/unit)	Misc. Cost (\$/unit)	Inflation Rate	Inflation Adder per IMC	Source
2013	\$ 0.46	\$ 0.17	\$ 0.03	3%	\$ 0.02	Itron, Inc. 2014. <i>2010-2012 W0017 Ex Ante Measure Cost Study Final Report</i> . Prepared for the California Public Utilities Commission. Appendix F.
2014	\$ 0.47	\$ 0.18	\$ 0.03	3%	\$ 0.02	
2015	\$ 0.49	\$ 0.18	\$ 0.03	3%	\$ 0.02	
2016	\$ 0.50	\$ 0.19	\$ 0.03	3%	\$ 0.02	
2017	\$ 0.52	\$ 0.19	\$ 0.03	3%	\$ 0.02	
2018	\$ 0.53	\$ 0.20	\$ 0.03	3%	\$ 0.02	
2019	\$ 0.55	\$ 0.20	\$ 0.04			

⁶ KEMA, Inc. 2008. "Summary of EUL-RUL Analysis for the April 2008 Update to DEER." Memorandum submitted to Itron, Inc.

BASE CASE LABOR COST (\$/UNIT)

Because the base case is defined as no heat curtain, the base cast labor cost is equal to \$0.

MEASURE LABOR COST (\$/UNIT)

The measure case material cost for this measure was derived from the *2010-2012 W0017 Ex Ante Measure Cost Study* conducted by Itron, Inc. (See “Heat curtain installed in greenhouse that has roofs with IR film and bare wall” in Appendix F.) As shown below, the cost analysis includes data from 2013 to 2019 and assumes an annual inflation rate.

See Measure Case Material Cost.

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 the greenhouse heat curtain measure is based upon evaluation results of the PG&E Agriculture and Food Processing Program published by KEMA, Inc. in 2010.

Table 1. Net-to-Gross Ratios

Parameter	Value	Source
NTG	0.63	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 43. 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. This installation rate reflects the fact that customers typically install the curtain rather than store the equipment after purchase.

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 BENEFITS

Non-energy benefits 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	
Scaled DEER measure	
DEER Base Case	Yes
DEER Measure Case	Yes
DEER Building Types	Yes
DEER Operating Hours	Yes
DEER eQUEST Prototypes	
DEER Version	DEER 2011 (D11 v4.00)
Reason for Deviation from DEER	n/a
DEER Measure IDs Used	Grnhs-Shell-ThermCurt
NTG	Source: DEER 2011. The NTG of 0.63 is associated with NTG ID: <i>NonRes-sGHS-mHtCrtn-dn</i>
GSIA	Source: DEER. The GSIA of 1.0 is associated with GSIA ID: <i>Def-GSIA</i>
EUL/RUL	Source: DEER 2005. The value of 5 years is associated with EUL ID: <i>Agr-GHC</i> . RUL ID: <i>BldgEnv-CoolRoof</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 PGECOAGR101 Revision 3 (August 28, 2012) WPSDGENRAG0003 Revision 0 (January 1, 2019) Consensus reached among Cal TF members.
	06/13/2019	Andres Marquez, SCG Jennifer Holmes Cal TF Staff	Revisions for submittal of version 01.