**Work Paper PGE3PAGR115**

**Revision 2**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**Compressor Heat Recovery Unit – Electric and Gas Water Heaters**

**Measure Code H324 and H325**

***EnSave Inc.***

# At a Glance Summary

|  |  |  |
| --- | --- | --- |
| Applicable Measure Codes: | **H324** | **H325** |
| **Measure Description:** | Compressor Heat Recovery Unit (CHR), Gas | Compressor Heat Recovery Unit (CHR), Electric |
| **Energy Impact Common Units:** | Compressor Heat Recovery Unit Installed. | Compressor Heat Recovery Unit Installed. |
| **Base CaseDescription:** | No Compressor Heat Recovery | No Compressor Heat Recovery |
| **Base Case Energy Consumption:** | Source: EnSave Calculations | Source: EnSave Calculations |
| **Measure Energy Consumption:** | Source: EnSave Calculations | Source: EnSave Calculations |
| **Energy Savings ((Base Case – Measure) x Interactive Effects)** | Source: EnSave Calculations | Source: EnSave Calculations |
| **Costs Common Units:** | Compressor Heat Recovery Unit Installed. | Compressor Heat Recovery Unit Installed. |
| **Base Case Equipment Cost ($/unit):** | $0 | $0 |
| **Measure Equipment Cost ($/unit):** | $4,734, per Measure Cost Data CHR PGE3PAGR115 | $4,734, per Measure Cost Data CHR PGE3PAGR115 |
| **Measure Incremental Cost ($/unit):** | $4,734, per Measure Cost Data CHR PGE3PAGR115 | $4,734, per Measure Cost Data CHR PGE3PAGR115 |
| **Effective Useful Life (years):** | 14 years, per SPTdata\_ format-v0.97 | 14 years, per SPTdata\_ format-v0.97 |
| **Program Type:** | Retrofit Add On (REA) | Retrofit Add On (REA) |
| **Net-to-Gross Ratios:** | NTGR = 0.6:  Agric-Default>2yrs “All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years”  (DEER2011\_NTGR\_2012-05-16.xls Cell T58)  Source2: DEER 2011 V4.01 | NTGR = 0.6:  Agric-Default>2yrs “All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years”  (DEER2011\_NTGR\_2012-05-16.xls Cell T58)  Source2: DEER 2011 V4.01 |

# Work Paper Approvals

The following Manager(s) approved this workpaper through the PG&E Electronic Data Routing System under Routing Requisition # \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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| |  | | --- | | **Grant Brohard**  Manager, Technical Product Support | | **Carolyn Weiner**  Principal, CES Products and Programs | |
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# Document Revision History

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| --- | --- | --- | --- |
| **Revision #** | **Date** | **Original short form work paper.** | **Author (Company)** |
| Revision 1 | 4/4/08 | Updated for initial DEEP 2009-2011 Submission | EnSave, Inc. |
| Revision 2 | 5/16/08 | Updated to standard Long Form. | EnSave, Inc. |
| Revision 3 | 8/25/08 | Updated to include gas fired water heaters. | EnSave, Inc. |
| Revision 4 | 8/13/09 | Updated for revised DEEP 2009-2011 post Bridge Funding Period. Net-to-Gross and source of energy savings shown in E3 updated. | EnSave, Inc. |
| Revision 5 | 9/24/09 | Minor updates to have the written kWh formula figures exactly match electronic calculations (e.g., default water temperature changed from 66 to 65 degrees). | EnSave, Inc. |
| Revision 6 | 11/17/09 | Updated with references to the most recent EM&V study conducted on the 2004-2005 CA Multi Measure Farm Program. | EnSave, Inc. |
| Revision 7 | 11/24/09 | Updated Sections 1-4 to include more complete reference source descriptions. | EnSave, Inc. |
| Revision 8 | 12/22/09 | Corrected common unit definitions, EUL, and gas savings values; revised text descriptions. | EnSave, Inc. |
| Revision 9 | 3/8/10 | Redefined and corrected common unit definitions and associated data and text descriptions; updated At A Glance table format. | EnSave, Inc. |
| Revision 10 | 2/3/12 | Updated measure equipment costs, measure incremental costs, measure installed costs, and installation labor costs. Changed costs common units. | EnSave, Inc. |
| Revision 11 | 6/8/12 | Updated work paper for 2013-2014. | EnSave, Inc. |
| Revision 12 | 2/8/2013 | Updated from hybrid measure based on 100 gallons per day of milk production to deemed measure based on average kWh savings per Compressor Heat Recovery Unit Installed. Includes changes at:   * At a Glance Summary * Section 2.1.1 Energy Savings Estimation Methodologies - Electric * Section 2.1.2 Energy Savings Estimation Methodologies – Natural Gas * Section 2.2 Demand Reduction Estimation Methodologies   Updated format for both Summary At A Glance pages.  Updated NTG value and reference at A-A-G pages and Section 1.7.  Added signature page.  Removed embedded files, now to be separate files, updated file names & references.  Various formatting updates. | EnSave, Inc. |
| PGE3PAGR115  Revision 0 | 2/14/2013 | Re-named from WPenNRPR0002, Rev 12 as per PG&E review request | EnSave, Inc. |
| PGE3PAGR113  Revision 1 | 5/7/2014 | Updated to new compliance template. Updated designation to Retrofit Add On (REA) | Mark Tiemens, PG&E |
| PGE3PAGR113 Revision 2 | 1/1/2016 | Ex ante format only | Linda Wan, PG&E |

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# Section 1. General Measure & Baseline Data

## Product Measure Description & Background

The compressor heat recovery (CHR) unit saves energy by preheating water using heat from the hot vapor exiting milk cooling system’s compressor. The heated water is used for cow udder cleaning and final milk system cleaning. The measure is applicable if the currently installed water heater is either an electrical resistance heater or a natural gas fired water heater.

## Product Technical Description

Compressor heat recovery units (CHR) are add-on components to a milk refrigeration system. These devices are insulated storage tanks with heat exchangers that use the heat extracted from the milk through the hot gas refrigerant line from the refrigeration system’s compressors, to pre-heat the water to approximately 110 °F before it enters the conventional water heaters.

## Measure Application Type

Table  Measure Application Type[[1]](#endnote-1)

*Identifies the measure application type in the Measure Implemenation table in DEER2014.*

|  |  |  |
| --- | --- | --- |
| **Code** | **Description** | **Comment** |
| ER | Early retirement | *Measure is more efficient than code/std; Dual baseline, full measure costs required* |
| ROB | Replace on Burnout | *Single baseline (above code), incremental or full costs* |
| NC | New Construction | *Single baseline (above code), incremental or full costs* |
| REA | Retrofit Add On | *Single baseline (above pre-existing), full measure costs required* |

This measure is considered Retrofit Add On (REA) as there is only a single baseline used for savings evaluation.

## Product Base Case and Measure Case Information

## DEER Base Case and Measure Case Information

Refer to Compliance work paper template for all applicable DEER IDs.

Table 1. DEER USE and Technology Table



Net-to-Gross ratio for this work paper is based on DEER2011\_NTGR\_2012-05-16.xls from DEER Database for Energy-Efficient Resources; Version 2011 4.01[[2]](#endnote-2). 2 below shows the description of the applicable Net-to-Gross ratiofor this measure.

Table 2: Net-to-Gross Ratios

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| NTGR\_ID | Description | Sector | NTGR | Documentation |
| Agric-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Ag | 0.6 | 2011 DEER Update Report - Section 15 Table 15-3 T58 |

**Effective Useful Life: DEER Version and Impact IDs**

The Effective Useful Life estimates are taken from SPTdata\_ format-v0.97 for “Compressor Heat recovery (w/electric water heater)” at line 94, Index #79 and match the intended measure.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Building type** | **Bldg Vintage** | **Climate Zone** | **EUL (yrs)** | **RUL (yrs)** | **DEER Version** | **Impact IDs** |
| Com | n/a | n/a | 14 | 4.7 | DEER2011 | n/a |

## 1.4.2 Codes & Standards Requirements Base Case and Measure Information

There are no applicable state or federal codes that dictate or restrict the energy saving potential of this measure.

## 1.4.3 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information

An EM&V study was completed for this measure as part of the California Multi Measure Farm Program by kW Engineering, and was summarized in a report dated March 15, 20072. This study focused on the installation of high efficiency options for five measures associated with milking at small, independent dairies. Evaluation results are based on calculations completed using data collected through end-use metering.

## 1.4.4 Assumptions and Calculations from other sources—Base and Measure Cases

There are no further data or calculations provided for the support of the measures in this workpaper.

# Section 2. Calculation Methods

Information is provided for CHR applications involving both electric and gas water heating. Only one fuel type is typically applicable per dairy site.

## 2.1.1. Electric Energy Savings Estimation Methodologies

Value: 14,523 annual kWh / Compressor Heat Recovery Unit Installed.

Value was derived using the equation below for the California 2006-2008 Dairy Energy Efficiency Program and averaging the results across all installations.

Since on a typical dairy farm, the energy removed from the milk far exceeds the energy needed to heat water, CHR units typically only remove the superheat and a small amount of vaporization heat from the hot refrigerant vapor. A normal condenser is still needed to reject the remaining heat. CHR units typically can heat water to about 110F.

The savings calculation equation used for this measure is as follows:



Where:

Site annual water use (gallons of water/year) =   
Daily water use (typically 0.5 – 1.0 gallons/cow/day) \* 365 days/year

d,water = density of water = 8.34 lbs/gallon

Cp,water = specific heat of water = 1.0 Btu/lb/F

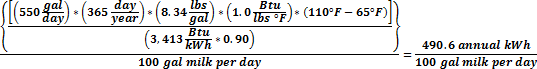
Tout = Temperature of water exiting the CHR (default 110F)

Tin = Temperature of water entering the CHR (default 65F)

3,413 = conversion factor from Btu to kWh

N = Efficiency of electric resistance water heater; assume 0.90 (per http://www.aceee.org/consumerguide/waterheating.htm)

Illustrative site-specific example (which approximates, but does not match precisely the average site value discerned from the 2006-2008 Dairy Energy Efficiency Program): for a 550 cow dairy with 550 gallons daily hot water use, operating for 16 hours/day, with 65F well water temperature, and with 50 hundreds of gallons per day of milk production:



Derivation of the actual 2006-2008 Dairy Energy Efficiency Program average of 500.57 annual kWh savings / 100 gallons per day of milk production per dairy site is provided as referenced Excel object in the References section.

This annual 500.57 kWh savings per 100 gallons per day of milk production is then multiplied by the average daily milk production per CHR unit, 29.012 hundred gallons per day, in the DEEP Measures Installed 06-08 CHR PGE3PAGR115 data provided in the Excel object listed in the References section,



This value is also seen in the Excel object referenced above.

Note that the calculation method has not been adjusted to reflect EM&V results because the EM&V for the 2004-2005 California Multi Measure Farm Program (by KW Engineering, dated March 15, 2007) discerned a gross realization rate of 100% for kWh savings (Exhibit 2, page 2).

## 2.1.2. Natural Gas Energy Savings Estimation Methodologies

Value: 742.7 annual therms / Compressor Heat Recovery Unit Installed.

Natural gas savings are expressed in therms using a savings calculation equation similar to the equation utilized in Section 2.1.1 (except that values are converted from Btu’s to therms and utilize gas unit efficiency, rather than to kWh and utilizing electric unit efficiency).

The savings calculation equation used for this measure is as follows:



Where:

Site annual water use (gallons of water/year) =   
Daily water use (typically 0.5 – 1.0 gallons/cow/day) \* 365 days/year

Cp,water = specific heat of water = 1.0 Btu/lb/F

d,water = density of water = 8.34 lbs/gallon

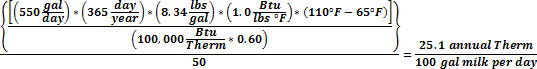
Tout = Temperature of water exiting the CHR (default 110F)

Tin = Temperature of water entering the CHR (default 65F)

100,000 = conversion factor from Btu to therms

N2 = Efficiency of natural gas fired water heater; assume 0.60 (per http://www.aceee.org/consumerguide/waterheating.htm)

Illustrative site-specific example (which approximates, but does not match precisely the average site value discerned from the 2006-2008 Dairy Energy Efficiency Program): for a 550 cow dairy with 550 gallons daily hot water use, operating for 16 hours/day, with 65F well water temperature, and with 50 hundreds of gallons per day of milk production:



Derivation of the actual 2006-2008 Dairy Energy Efficiency Program average (as converted to gas water heating system applicability) for annual therm savings / 100 gallons per day of milk production per dairy site is provided as referenced Excel object in the References section.

This annual 25.6 Therms savings per 100 gallons per day of milk production is then multiplied by the average daily milk production per CHR unit, 29.012 hundred gallons per day, in the DEEP Measures Installed 06-08 CHR PGE3PAGR115 data provided in the Excel object listed in the References section,



Note that the calculation method has not been adjusted to reflect EM&V results because the EM&V for the 2004-2005 California Multi Measure Farm Program (by KW Engineering, dated March 15, 2007) discerned a gross realization rate of 100% for kWh savings (Exhibit 2, page 2); the kWh gross realization rate is assumed applicable to therms savings as well.

## 2.2. Demand Reduction Estimation Methodologies

Value: 0.0 peak kW savings

There is no anticipated demand reduction associated with this measure.

The heat recovered from the bulk tank refrigeration unit is utilized to pre-heat the incoming water at the water heating unit thereby reducing the kWh consumption to heat the water to the set point temperature. However, the existing electric water heater is unchanged by this measure. Thus the peak demand kW when the water heater is on is the same as the peak demand kW prior to the installation of the Compressor Heat Recovery Unit.

# Section 3. Load Shapes

## 3.1 Base Cases Load Shapes

Base case Load Shape is not applicable since the base case is no CHR.

## 3.2 Measure Load Shapes

Measure is an agricultural measure so the agricultural load shape is assumed in the E3 calculator

# Section 4. Base Case & Measure Costs

## 4.1 Base Case Costs

Base case costs are not applicable since the base case is no CHR.

## 4.2 Measure Case Costs

Value: $4,734 per compressor heat recovery unit installed.

The measure cost is derived as the average cost taken from a sample of 17 installations in DEEP 2006-2012, NYSERDA, MAESTRO, and NY Disaster Relief Programs.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| ***Measure Code*** | **Measure Application Type** | **Baseline** | **Equipment Cost** | **Labor / Installation Cost** | **Maintenance / Other Cost** | **Total Measure Case Cost** |
| H325 | REA | Average cost for Compressor Heat Recovery units installed | $3,677 | $1,057 | n/a | $4,734 |

*All costs are noted as $ per measure unit*

*Note*: Material costs from sample were found to be $3,667 per compressor heat recovery unit installed. Labor and installation costs from sample were found to be $1,057.

Data used to determine average costs is found in referenced Excel file.

## 4.3 Incremental & Full Measure Costs

Full measure costs are used for this measure since the base case is always no CHR.

# References

1. KW Engineering, Inc., Evaluation, Measurement and Verification Report California Multi Measure Farm Program 1354-04 and 1360-04 – March 15, 2007.
2. “CHR Measure Data” - Excel-based derivation of CHR measure data per 2006-2008 installations.
3. “Measure Cost Data CHR PGE3PAGR115” – Measure cost information from DEEP 2006-2012, NYSERDA, MAESTRO, and NY Disaster Relief programs.
4. “DEEP Measures Installed 06-08 CHR PGE3PAGR115” Excel-based analysis of measure installations in 2006-2008.
5. SPTdata\_ format-v0.97 Excel file

1. The DEER Measure Cost Data Users Guide found on [www.deeresources.com](http://www.deeresources.com) under *DEER2011 Database Format* hyperlink, DEER2011 for 13-14, spreadsheet *SPTdata\_format-V0.97.xls.* [↑](#endnote-ref-1)
2. *DEER2011\_NTGR\_2012-05-16.xls* from DEER Database for Energy-Efficient Resources; Version 2011 4.01 found at :<http://www.deeresources.com/index.php?option=com_content&view=article&id=68&Itemid=60> Under: DEER2011 Update Documentation linked at: [DEER2011 Update Net-To-Gross table](http://www.deeresources.com/DEER2011/download/DEER2011_NTGR_2012-05-16.xls)

   Cells: (Table 15-3 T58) [↑](#endnote-ref-2)