**Work Paper PGECOAGR120**

**Agricultural Pump System Overhaul for Pumps Less Than or Equal to 25hp**

**Revision 2**

**Pacific Gas & Electric Company**

**Customer Energy Solutions**

**Agricultural Pump System Overhaul for Pumps Less Than or Equal to 25hp**

**Measure Codes IR001, IR002, IR003, IR004, IR005**

**3/15/2019**

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# At-A-Glance Summary Table

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Applicable Measure Codes:** | **IR001** | **IR002** | **IR003** | **IR004** | **IR005** |
| Measure Description: | This measure details the overhaul of existing, inefficient centrifugal booster pumps used for agricultural applications and which have motors less than or equal to 25 horsepower (hp). The measure is a pump that is overhauled for improved pumping efficiency to better match the design of the pump to the actual system operating conditions. | This measure details the overhaul of existing, inefficient submersible well pumps used for agricultural applications and which have motors less than or equal to 25 horsepower (hp). The measure is a pump that is overhauled for improved pumping efficiency to better match the design of the pump to the actual system operating conditions. | This measure details the overhaul of existing, inefficient submersible booster pumps used for agricultural applications and which have motors less than or equal to 25 horsepower (hp). The measure is a pump that is overhauled for improved pumping efficiency to better match the design of the pump to the actual system operating conditions. | This measure details the overhaul of existing, inefficient turbine booster pumps used for agricultural applications and which have motors less than or equal to 25 horsepower (hp). The measure is a pump that is overhauled for improved pumping efficiency to better match the design of the pump to the actual system operating conditions. | This measure details the overhaul of existing, inefficient turbine well pumps used for agricultural applications and which have motors less than or equal to 25 horsepower (hp). The measure is a pump that is overhauled for improved pumping efficiency to better match the design of the pump to the actual system operating conditions. |
| Energy Impact Common Units: | per rated hp | per rated hp | per rated hp | per rated hp | per rated hp |
| Base Case Description: | The base case is an existing centrifugal booster pump that is operating inefficiently due to general wear and tear or pump operation that has deviated from the original design conditions. | The base case is an existing submersible well pump that is operating inefficiently due to general wear and tear or pump operation that has deviated from the original design conditions. | The base case is an existing submersible booster pump that is operating inefficiently due to general wear and tear or pump operation that has deviated from the original design conditions. | The base case is an existing turbine booster pump that is operating inefficiently due to general wear and tear or pump operation that has deviated from the original design conditions. | The base case is an existing turbine well pump that is operating inefficiently due to general wear and tear or pump operation that has deviated from the original design conditions. |

**At-A-Glance Summary Table** (Continued)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Applicable Measure Codes:** | **IR001** | **IR002** | **IR003** | | **IR004** | | **IR005** | |
| Base Case Energy Consumption: | Varies based on climate zone. | Varies based on climate zone. | Varies based on climate zone. | | Varies based on climate zone. | | Varies based on climate zone. | |
| Measure Energy Consumption: | Varies based on climate zone. | Varies based on climate zone. | Varies based on climate zone. | | Varies based on climate zone. | | Varies based on climate zone. | |
| Energy Savings (Base Case – Measure) | Varies based on climate zone. | Varies based on climate zone. | Varies based on climate zone. | | Varies based on climate zone. | | Varies based on climate zone. | |
| Costs Common Units: | Cost per hp | Cost per hp | Cost per hp | | Cost per hp | | Cost per hp | |
| Base Case Equipment Cost ($/unit): | Existing equipment.  $0.0 | Existing equipment.  $0.0 | Existing equipment.  $0.0 | | Existing equipment.  $0.0 | | Existing equipment.  $0.0 | |
| Measure Equipment Cost ($/unit): | Source: cost data obtained from various implemented pump overhaul projects. | Source: cost data obtained from various implemented pump overhaul projects. | Source: cost data obtained from various implemented pump overhaul projects. | | Source: cost data obtained from various implemented pump overhaul projects. | | Source: cost data obtained from various implemented pump overhaul projects. | |
| Measure Incremental Cost ($/unit): | Source: cost data obtained from various implemented pump overhaul projects. | Source: cost data obtained from various implemented pump overhaul projects. | Source: cost data obtained from various implemented pump overhaul projects. | | Source: cost data obtained from various implemented pump overhaul projects. | | Source: cost data obtained from various implemented pump overhaul projects. | |
| Effective/Remaining Useful Life (years): | 3 years,  NonRes-RCx-Operational | 3 years,  NonRes-RCx-Operational | | 3 years,  NonRes-RCx-Operational | | 3 years,  NonRes-RCx-Operational | | 3 years,  NonRes-RCx-Operational | |
| Source: Resolution E4952 | | | | | | | |
| Measure Application Type (MAT): | Retrocommissioning (RC) | Retrocommissioning (RC) | Retrocommissioning (RC) | | Retrocommissioning (RC) | | Retrocommissioning (RC) | |
| Net-to-Gross (NTG) Ratio: | Source: DEER 2016:  Agric-Default>2yrs, 0.6 | Source: DEER 2016:  Agric-Default>2yrs, 0.6 | Source: DEER 2016:  Agric-Default>2yrs, 0.6 | | Source: DEER 2016:  Agric-Default>2yrs, 0.6 | | Source: DEER 2016:  Agric-Default>2yrs, 0.6 | |

# Document Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Revision #** | **Date** | **Section by Section Description of Revisions** | **Author (Company)** |
| Revision 0 | 12/1/2014 | Original Work paper based on SCE WP SCE13PR003.0 Agricultural Pump System Overhaul for Pumps Less Than or Equal to 25 hp | Mark Ritchie  (BASE Energy, Inc) |
| Revision 1 | 2/26/2016 | Ex-ante format update for 2016. No values were changed. | Linda Wan (PG&E) |
| Revision 2 | 3/15/2019 | Changed MAT to RC and EUL to 3 years, per Resolution E4952. | Randy Kwok (PG&E) |

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# Section 1. General Measure & Baseline Data

## 1.1 Product Measure Description & Background

Agricultural Irrigation Pump Overhaul (≤25 hp)

***Program Restrictions and Guidelines***

Only the following pump types may qualify for the rebate in this work paper:

1. Centrifugal Booster
2. Submersible Well
3. Submersible Booster
4. Turbine Booster
5. Turbine Well

Restricted to agricultural pumps. Specialty pumps with pre-determined low load factors such as fire pumps and storm water pumps do not qualify for an incentive. This work paper only considers cases where existing pumps that are overhauled before they break down. New pump curves clearly showing the design conditions must be submitted with the application. The application must include a detailed scope of work of the overhaul.

***Terms and Conditions:***

Only operational pumps less than or equal to 25hp qualify for this rebate. The customer application scope of work must include at least one of the following:

1. Replacing pump bowl assembly/impeller
2. Adjusting bowl and impeller on a deep well pump. Field adjustments include: a) for semi-open impellers, all impellers in the bowl assembly must be running in close proximity (0.003 – 0.007 in) to the next lower bowl. Thus, careful adjustment in the field is required. Shaft stretch determines the final position of the impellers. Also, it directly varies with discharge head. Therefore, it has to be set to a proper specification to perform well at a given discharge head. Multistage units may require that the impellers be trimmed (reduction in diameter) to obtain proper fitting and clearance in the assembly bowl. For enclosed impellers, with a principal seal that is parallel to the centerline of the shaft, a close axial adjustment is not necessary. Therefore, this type of impeller is suited for operation under variable head conditions. Capacity and horsepower requirements can be controlled by raising the impeller until the skirts are out of the wear rings.
3. Trimming the existing impeller on a booster pump

***Market Applicability:***

This measure is applicable to agricultural pumps in the PG&E service territory that rely on electric pumping to water crops. Pumps with horsepower above 25 hp must be considered under the Advanced Pumping Efficiency Program (APEP).

## 1.2 Product Technical Description

This work paper details the overhaulof existing inefficient agricultural pumps with motors less than or equal to 25 horsepower (hp). The measure is a pump that is overhauled for improved efficiency to better match the design of the pump to the actual system operating conditions. Doing so will improve the overall plant efficiency (OPE) of the pump. The base case is an existing pump that is operating inefficiently, which can be caused by general wear and tear or pump operation that has deviated from the original design conditions. Operators typically look for large reductions in flow rate or discharge pressure delivered by the pump to gauge the condition of the equipment. While these techniques do not provide an accurate description of the pump, they are good indicators that the pump is in need of repair.

The following table provides a brief overview of the measures included in this work paper.

**Table 1 Measure Names**

|  |  |
| --- | --- |
| **Measure Code** | **Measure name** |
| IR001 | Centrifugal Booster Pump System Overhaul (<=25hp) |
| IR002 | Submersible Well Pump System Overhaul (<=25hp |
| IR003 | Submersible Booster Pump System Overhaul (<=25hp) |
| IR004 | Turbine Booster Pump System Overhaul (<=25hp) |
| IR005 | Turbine Well Pump System Overhaul (<=25hp) |

Note that there was not any pump test data available for submersible booster pumps. For this work paper it is assumed that the analysis results for turbine booster pumps will be similar to that for submersible booster pumps since submersible booster pumps are similar in design to turbine pumps with multiple stages and SCE data for turbine booster pumps and submersible booster pumps show similar operating discharge pressures. Therefore, the findings for turbine booster pumps have been applied to submersible booster pumps.

## 1.3 Measure Application Type

Table  Measure Application Type

|  |  |  |
| --- | --- | --- |
| **Code** | **Description** | **Comment** |
| RC | Non-Res Retro-commissioning | Single baseline (above pre-existing), full measure costs required |

The Base Case of this work paper is considered to be existing inefficient agricultural pumps with motors less than or equal to 25 horsepower. The Measure Case is considered to be a pump that is overhauled for improved efficiency to better match the design of the pump to the actual system operating conditions. The measure application type is considered to be retro-commissioning, per Resolution E4952.

## 1.4 Product Base Case and Measure Case Data

## 1.4.1 DEER Base Case and Measure Case Information

The Database for Energy Efficient Resources (DEER) 2016 does not address pump overhaul measures.

**Table 3 DEER Difference Summary**

|  |  |
| --- | --- |
| **DEER Difference Summary Table** | |
| Modified DEER Methodolgy | No |
| Scaled DEER Measure | No |
| DEER Building Prototypes Used | No |
| Deviation from DEER | N/A |
| DEER Version | Measures are not included in DEER 2016 |
| DEER Run ID and Measure Name (Sample) | N/A |

The Effective Useful Life is an estimate of the median number of years that the measures installed under the program are still in place and operable.

These measures are not in the DEER database. Per Resolution E-4952 guidance the EUL for the pump overhaul activities shall be 3 years. Table 4 below identifies the value used for the measures in this work paper.

Table 4 EUL Value/Methodology

Table Effective and Remaining Useful Life

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Code** | **EUL ID** | **Measure** | **EUL (Years)** | **RUL (Years)** |
| IR001 | NonRes-RCx-Operational | Ag Pump – Centrifugal Booster | 3 | - |
| IR003 | NonRes-RCx-Operational | Ag Pump – Submersible Booster | 3 | - |
| IR002 | NonRes-RCx-Operational | Ag Pump – Submersible Well | 3 | - |
| IR004 | NonRes-RCx-Operational | Ag Pump – Turbine Booster | 3 | - |
| IR005 | NonRes-RCx-Operational | Ag Pump – Turbine Well | 3 | - |

The NTG value was obtained from the DEER2016 documentation. The relevant NTGR for this measure is shown in Table 5 below.

Table 5: Net-to-Gross Ratios

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| NTGR\_ID\* | Description\* | Sector\* | BldgType\* | ProgDelivID\* | NTG\* |
| Agric-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | All | Any | All | 0.6 |

\*Denotes that the column is taken from the DEER NTG Table.

**Installation Rate**

The IR value was obtained using the DEER READI tool. The relevant IR value for the measures in this work paper is in the table below.

Table 6 Installation Rate

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **GSIA ID** | **Description** | **Sector** | **BldgType** | **ProgDelivID** | **GSIAValue** |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |

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

***Title 20:*** These measures do not fall under Title 20 of the California Energy Regulations.

***Title 24:*** These measures do not fall under Title 24 of the California Energy Regulations.

***Federal Standards:*** These measures do not fall under Federal DOE or EPA Energy Regulations.

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

The measure of overhauling agricultural pumps is also evaluated and/or discussed in the following studies:

* *Agricultural Pump System Overhaul for Pumps Less Than or Equal to 25hp*, Southern California Edison Company, Work Paper SCE13PR003 Rev. 0, June 1, 2012.
* *Agricultural Water Energy Efficiency,* Prepared for the California Energy Commission, Prepared by the Irrigation Training and Research Center, December 2011, CEC-500-2011-049

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

The Peak kW adjustment factor is taken to be the same for this work paper as that developed for PG&E’s Advanced Pumping Efficiency Program (APEP). Please refer to section 2.2 Demand Reduction Estimation Methodologies for more detail.

# Section 2. Calculation Methods

## 2.1 Electric Energy Savings Estimation Methodologies

The following variables must be estimated to quantify the savings resulting from overhauling pumps with motors that are less than or equal to 25hp:

1) Pump size

2) Annual hours of operation

3) Motor loading

4) Baseline Operating Plant Efficiency (OPE)

5) Post Operating Plant Efficiency

The Pacific Gas & Electric (PG&E) pump test database was used to obtain average values of the variables listed above. Data going back eight years were used in estimating the averages [Attachment B]. As more data becomes available the averages provided in this work paper may need to be revised for accuracy.

The data was disaggregated according to the following pump types for each climate zone within PG&E’s service territory:

1. Centrifugal Booster
2. Submersible Well

2) Submersible Booster

4) Turbine Well

5) Turbine Booster

The following table shows a sample breakdown of average values from CZ13. Average value calculations for the other PG&E climate zones are provided in the “PGECOAGR120 R1 Ag Pump Overhaul Measure Savings.xlsm“ file in the “Attachments” section [Attachment A].

**Table 8 Estimation of Variables for CZ 13**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Pump Type** | **Average Annual Hours of Operation (AOH)** | **Average Pump Size (Nominal Motor hp)** | **Average Baseline OPE (%)** | **Average Proposed OPE (%)** | **Average Motor Loading** |
| Centrifugal Booster | 1,783.9 | 25.0 | 35.9% | 60.4% | 86% |
| Submersible Booster | 1,405.3 | 25.0 | 45.8% | 61.1% | 100% |
| Submersible Well | 1,353.5 | 23.1 | 39.6% | 56.6% | 108% |
| Turbine Well | 1,436.2 | 24.5 | 46.8% | 61.0% | 112% |
| Turbine Booster | 1,405.3 | 25.0 | 45.8% | 61.1% | 100% |

Equation 1

Equation 2

## 2.2 Demand Reduction Estimation Methodologies

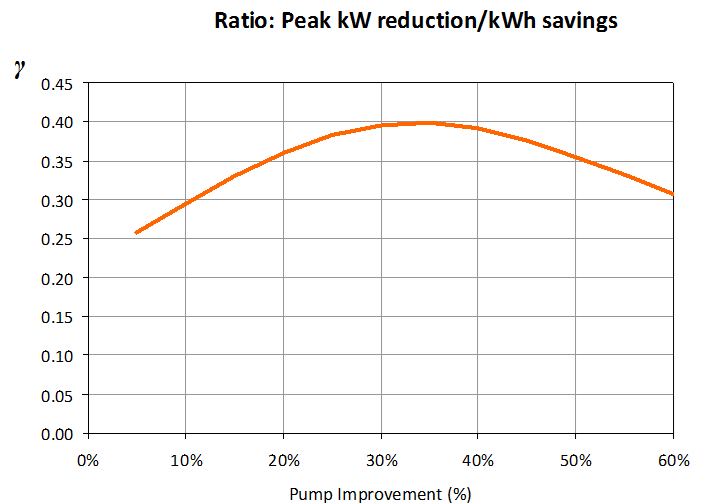
Demand reduction for this measure is based on PG&E’s Advanced Pumping Efficiency Program (APEP) demand reduction methodology as presented in Attachment C. APEP’s methodology is based on billing data analysis for pump customers for a period of one year with the formulation shown below.

Equation 3

Where,

𝛾 = ratio of average Peak power draw to average Off Peak power draw (analysis of billing

data for pump customers), function of percent pump improvement according to Figure 1 below.



**Figure 1** – Overhauled Pump Improvement Percentage Versus Peak Demand Reduction (Attachment C)

Table 9 Average Savings per Pump Type for CZ 13

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Pump Type** | **kWh Savings (kWh/yr)** | **Pump Improvement**  **%** | **𝛾** | **kW Savings** |
| Centrifugal Booster | 13,173.50 | 24.5% | 37.6% | 2.78 |
| Submersible Booster | 13,173.50 | 24.5% | 37.6% | 2.78 |
| Submersible Well | 8,985.73 | 17.0% | 34.5% | 2.29 |
| Turbine Well | 7,672.40 | 14.2% | 32.9% | 1.76 |
| Turbine Booster | 7,374.08 | 15.3% | 33.6% | 1.76 |

Equation 4

## 2.3. Gas Energy Savings Estimation Methodologies

There will not be any natural gas savings for this measure.

# Section 3. Load Shapes

This section of the work paper explains the measure’s load shape, which indicates what fraction of annual energy usage and savings occurs in each time period of the year.

The difference between the base case load shape and the measure load shape would be the most appropriate load shape; however, only end-use profiles are available. Therefore, the closest load shape chosen for this measure is the Agricultural load shape based on E3 calculators. See table below for the measure Load Shape. Please refer to Attachment A for reference regarding the load shapes for this measure.

Table 10 Load Shapes

|  |  |  |
| --- | --- | --- |
| **E3 Target Sector** | **Load Shape** | **Code** |
| Agricultural | 14 = Agricultural | PGE:AGRICULTURAL:14 = Agricultural |

# Section 4. Base Case & Measure Costs

## 4.1 Base Case(s) Costs

For this measure category, the base case cost is assumed to be zero because these are discretionary modifications (retrofit) to the customers’ existing equipment. Their alternative is not to make any changes to their existing system.

## 4.2 Measure Case Costs

Per the E3, the Full Measure Cost (FMC) is the cost to install an energy efficient measure. This definition implies two different meanings depending on the install type. In the case of RET and REA, FMC means the full cost of the measure to purchase and install. In the case of ROB and NEW, FMC means the cost premium required to install the energy efficient measure over a less efficient piece of equipment. Being that RET, REA, ROB, and NEW have different definitions, there is a clear distinction between the equations for the various install types.

For **RET** and **REA**, FMC is represented by the equation below:

*FMC = Measure Equipment Cost + Measure Labor Cost*

For this deemed measure, cost data was obtained from existing program data. The cost is based on implemented pump overhaul projects and is equal to $603.85 per nominal horsepower rating of pump motor (Attachment B).

Equation 5

The above cost estimate, per unit cost was derived using actual project implementation cost and average pump size. The equation below shows the estimated project costs formulation:

Equation 6

The table below provides an example of typical costs involved in overhauling pumps.

**Table 11 Full Measure Cost**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure Description** | **CZ** | **Average Pump Size (Nominal motor hp)** | **kWh Savings (kWh/yr)** | **Full Measure Cost($/hp)** | **Cost of Retrofit ($)** |
| Centrifugal Booster Pump System Overhaul (<=25hp) | 2 | 25.0 | 10,985.53 | $603.85 | $15,096.25 |
| Centrifugal Booster Pump System Overhaul (<=25hp) | 3 | 25.0 | 7,286.64 | $603.85 | $15,096.25 |
| Centrifugal Booster Pump System Overhaul (<=25hp) | 4 | 25.0 | 5,117.42 | $603.85 | $15,096.25 |
| Centrifugal Booster Pump System Overhaul (<=25hp) | 5 | 25.0 | 4,929.98 | $603.85 | $15,096.25 |
| Centrifugal Booster Pump System Overhaul (<=25hp) | 11 | 25.0 | 3,650.82 | $603.85 | $15,096.25 |
| Centrifugal Booster Pump System Overhaul (<=25hp) | 12 | 25.0 | 8,045.50 | $603.85 | $15,096.25 |
| Centrifugal Booster Pump System Overhaul (<=25hp) | 13 | 25.0 | 13,173.50 | $603.85 | $15,096.25 |

## 4.3 Incremental & Full Measure Costs

Incremental Measure Cost (IMC) is the premium cost to install an energy efficient measure over a standard efficiency measure or code baseline measure. The incremental cost is only used to help determine program incentives. It is not affected by the first and second baseline periods and may differ from the cost used for cost effectiveness calculations.

However, for this measure, the base case is an existing pump that is not operating efficiently. Therefore, the base case equipment cost is $0.00 for this measure. For this measure, the IMC will be equal to the FMC.

# References

*[1] Agricultural Pump System Overhaul for Pumps Less Than or Equal to 25hp*, Southern California Edison Company, Work Paper SCE13PR003 Rev. 0, June 1, 2012.

*[2] Agricultural Water Energy Efficiency,* Prepared for the California Energy Commission, Prepared by the Irrigation Training and Research Center, December 2011, CEC-500-2011-049

[3] 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

[4] 2004-2005 Database for Energy Efficiency Resources (DEER) Update Study, Prepared for Southern California Edison, Prepared by Itron, Inc., December 2005.

# Attachments

[A] PGECOAGR120 R2 Ag Pump Overhaul Measure Savings.xlsm

[B] APEP Peak Demand Analysis\_101210.ppt