Work Paper SCE17HC030

**Revision 0**

**Southern California Edison**

**Air-Cooled Packaged Chiller**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | AC-18678  AC-18680  AC-18679  AC-18675  AC-18677  AC-18676  AC-19134  AC-19135  AC-19136  AC-19137  AC-19138  AC-19139 |
| **Measure Description** | Air-Cooled Chillers, for use in non-residential buildings, meeting the minimum efficiency requirements listed in section 1.4.2. |
| **Base Case Description** | Air-Cooled Chillers, for use in non-residential buildings, meeting the 2016 California Title 24 minimum efficiency standards for less than and greater than 150 Tons – Refer to T24 Code Section for equipment efficiency requirements |
| **Units** | Per Ton |
| **Energy Savings** | Refer to Excel Calculation Attachment 1 |
| **Full Measure Cost ($/unit)** | Refer to Excel Calculation Attachment 2 |
| **Incremental Measure Cost ($/unit)** | Refer to Excel Calculation Attachment 2 |
| **Effective Useful Life** | 20 years (DEER EUL ID: HVAC-Chlr, DEER2017 version) |
| **Measure Installation Type** | Replace on Burnout (ROB)  New Equipment (NEW) |
| **Net-to-Gross Ratio** | 0.6 (DEER NTG ID: Com-Default>2yrs, DEER2017 version) |
| **Important Comments** | This work paper has a complementary Ex Ante Database data set that will be provided in a separate submission to the California Public Utilities Commission (CPUC). |

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Rev** | **Date** | **Author** | **Summary of Changes** |
| 0 | 01/27/2017 | Arvind Subramanya/SCE | - This work paper is an update of SCE13HC030.2  - New calculation template update for 2017 program year  - Work paper is updated with chiller efficiencies from 2016 Title-24 code requirement.  - Measure impacts have been adopted from DEER 2017  - New solution codes added replacing old solution codes.  - Baseline and Measure material costs have been updated based on manufacturers’ quotes. Labor costs are based on 2010-2012 WO017 Study Report.  - NEW program type has been added in this work paper revision.  - Work paper revised to include only “Com” building type for ROB program type.  - All (16) climate zones added for both ROB and NEW Program types.  - Two calculation templates separating ROB and NEW program types have been created. |

# Commission Staff and Cal TF Comments

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Rev** | **Party** | **Submittal Date** | **Comment Date** | **Comments** | **WP Developer Response** |
|  |  |  |  |  |  |

Cal TF website: <http://www.caltf.org/>

# Section 1. General Measure & Baseline Data

## Measure Description & Background

Measure Description: Air-Cooled Chillers, for use in non-residential buildings, exceeding the 2016 California Title 24 minimum efficiency standards.

Basecase Description: Air-Cooled Chillers, for use in non-residential buildings, meeting the

2016 California Title 24 minimum efficiency standards.

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Air-Cooled Chillers, for use in non-residential buildings, exceeding the 2016 California Title-24 minimum efficiency standards requirements listed in Section 1.4.2. |
| Existing Condition | N/A |
| Code/Standard | Air-Cooled Chillers, for use in non-residential buildings, meeting the 2016 California Title-24 minimum efficiency standards listed in Section 1.4.2. |
| Industry Standard Practice | N/A |

Measures and Solution Codes

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Measure Codes** | | | |  | **Measure Name** |
| SCG | SDG&E | SCE | PG&E | Tier |
|  |  | AC-18678 | HV356 | 1 | Air-Cooled Chiller-<150 tons- Tier 1- 10.50 EER AND 14.262 IPLV |
|  |  | AC-18680 | HV357 | 2 | Air-Cooled Chiller-<150 tons- Tier 2- 11.00 EER AND 14.941 IPLV |
|  |  | AC-18679 | HV358 | 3 | Air-Cooled Chiller-<150 tons- Tier 3- 11.50 EER AND 15.620 IPLV |
|  |  | AC-18675 | HV353 | 1 | Air-Cooled Chiller-≥150 tons- Tier 1- 10.50 EER AND 14.262 IPLV |
|  |  | AC-18677 | HV354 | 2 | Air-Cooled Chiller-≥150 tons- Tier 2- 11.00 EER AND 14.941 IPLV |
|  |  | AC-18676 | HV355 | 3 | Air-Cooled Chiller-≥150 tons- Tier 3- 11.50 EER AND 15.620 IPLV |
|  |  | AC-19134 | HV356 | 1 | Air-Cooled Chiller-<150 tons- Tier 1- 10.50 EER AND 14.262 IPLV (NEW) |
|  |  | AC-19135 | HV357 | 2 | Air-Cooled Chiller-<150 tons- Tier 2- 11.00 EER AND 14.941 IPLV (NEW) |
|  |  | AC-19136 | HV358 | 3 | Air-Cooled Chiller-<150 tons- Tier 3- 11.50 EER AND 15.620 IPLV (NEW) |
|  |  | AC-19137 | HV353 | 1 | Air-Cooled Chiller-≥150 tons- Tier 1- 10.50 EER AND 14.262 IPLV (NEW) |
|  |  | AC-19138 | HV354 | 2 | Air-Cooled Chiller-≥150 tons- Tier 2- 11.00 EER AND 14.941 IPLV (NEW) |
|  |  | AC-19139 | HV355 | 3 | Air-Cooled Chiller-≥150 tons- Tier 3- 11.50 EER AND 15.620 IPLV (NEW) |

Units are required to meet both EER and IPLV requirements. **Measure applicability requirement is based on both DEER full load (EER) “AND” lowest (less stringent) DEER part-load (IPLV) efficiencies as documented in DEER’s Technology description table in Section 1.4.1**.

There is no additional Eligibility of Implementation Requirements. All building types, climate zones, and vintages are eligible for the upstream rebate.

Refer to Section 1.4.2 Codes and Standards Analysis for Code requirements.

## 1.2 Technical Description

Chillers have two different measures of energy efficiency: 1) Full load efficiency measured in Energy Efficiency Ratio (EER) Coefficient of Performance (COP), or kW per Ton; and 2) part load efficiency measured in Integrated Part Load Value (IPLV). Full load Efficiency is the measure of energy efficiency corresponding to peak loading (kW) and part load efficiency corresponds to total energy usage (kWh). Both are important. Some manufacturers specifically design for higher IPLVs because this efficiency more closely predicts seasonal consumption and energy savings.

## 1.3 Installation Types and Delivery Mechanisms

The delivery method is:

**Up-Stream Incentive / Up-Stream Buy Down**

The install type is:

**Replace on Burnout (ROB)**

**New Equipment (NEW)**

**Installation Type Descriptions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Installation Type** | **Savings** | | **Life** | |
| 1st Baseline (BL) | 2nd BL | 1st BL | 2nd BL |
| Replace on Burnout (ROB) | Above Code or Standard | N/A | EUL | N/A |
| New Equipment (NEW) | Above Code or Standard | N/A | EUL | N/A |

A delivery mechanism is a delivery method paired with an incentive method. Delivery mechanisms are used by programs to obtain program participation and energy savings.

**Delivery Method Descriptions**

|  |  |
| --- | --- |
| **Delivery Method** | **Description** |
| Up-Stream Programs | *See Up-Stream Incentive in the Incentive Method Descriptions table.* |

**Incentive Method Descriptions**

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Up-Stream Incentive  Up-Stream Buy Down | The program gives a financial incentive to an upstream market actor (manufacturer or distributor) to encourage the manufacture, provision, or distribution of efficient measures. Buy Down means that the incentive is required to be passed down to the end-use customer. |

The **SCE Savings By Design Program** offers incentives on a wide variety of energy-saving design and technologies that encourages design teams and building owners/managers to integrate a higher level of energy efficiency for their new construction and major building renovation projects. In order to streamline incentivizing energy efficient HVAC and related technologies, SBD offers an “express” way to participate in this opportunity by way of these deemed measures.

The process will direct the customer or their designated representative (customer) to work with an SCE New Construction Representative (NCR). The NCR will determine if the Whole Building Approach (WBA) or Deemed System Approach (DSA) will provide the most benefit to the project.

If the project and equipment qualifies, the NCR will guide the customer through the application process, which will include specific instructions on applying for the incentive, identifying the required documentation and the timing for submitting documentation.

The pre-inspection and post-inspection process will follow the procedures used by SCE’s Midstream or Express programs. It should be noted, these HVAC measures were developed to ensure proper calculation methodologies for specifically new construction and major renovations. In a majority of cases there is no existing physical facility or equipment to identify.

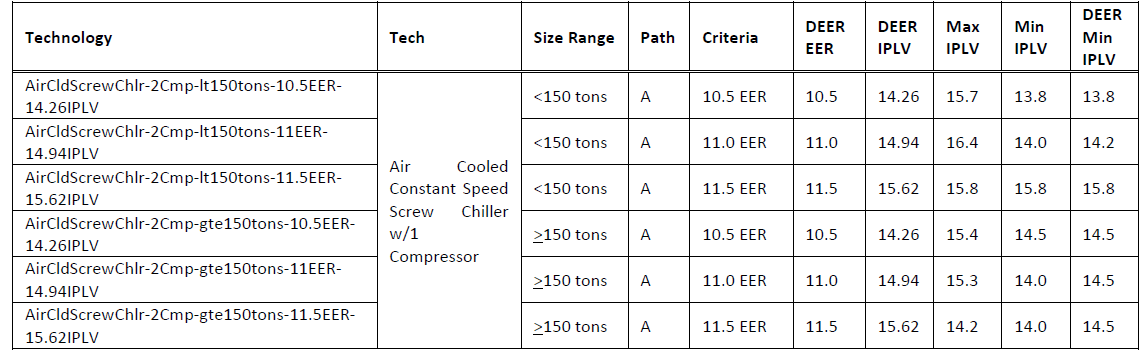
## 1.4 Measure Parameters

### 1.4.1 DEER Data

DEER air-cooled chiller measures are based on two compressor types: reciprocating and screw. There are no reciprocating air-cooled packaged chillers made by the major manufacturers. Therefore DEER data on reciprocating chillers was not used for this analysis. All measure impacts adopted in this version of the workpaper are adopted directly from DEER.

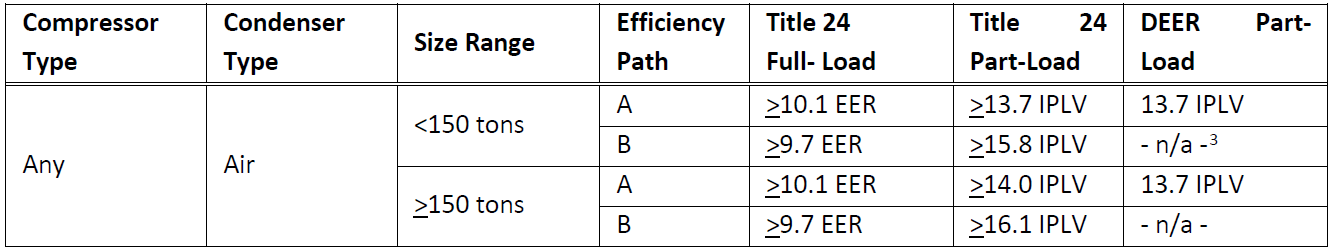
At this time, DEER includes only single sets of curve-fits for various types of water chillers. Therefore, the only input that can vary as part of the performance map is full-load efficiency. In most cases, code minimum full-load efficiencies resolve to higher IPLVs when using the current sets of performance curves for each technology type.

For air-cooled chillers, the 2017 DEER update is limited to Path A and does not include measures meeting Path B, e.g., high performance air-cooled chiller equipment. Following table lists DEER2017 updated measure definitions with corresponding DEER EER and IPLV requirements and tiers.



Baseline variations between DEER2017 and 2016 Title-24 Energy Standards

DEER and ACM manual methods can only model shifts in IPLV that are proportionate to the shift in full-load efficiency. Following table provides a comparison of minimum code requirements for IPLV and the IPLV resulting from the DEER curve-fits when using the code minimum full-load efficiency.



DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **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 | Yes |
| DEER Version | DEER 2017, READI v2.4.7 |
| Reason for Deviation from DEER | Savings are directly taken from DEER 2017, READI v2.4.7 tool. |
| DEER Measure IDs Used | N/A |

**Net-to-Gross Ratio**

The NTG values were obtained using the DEER READI tool. The relevant NTG values for the measures in this work paper are in the table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| Com-Default>2yrs | All other EEMs with no evaluated NTGR; existing EEM in programs with same delivery mechanism for more than 2 years | Com | Any | Any | 0.6 |

**Spillage Rate**

Spillage rates are not tracked in work papers; they are tracked in an external document which will be supplied to the Commission Staff.

**Installation Rate**

The IR values were obtained using the DEER READI tool. The relevant IR values for the measures in this work paper are in the table below.

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

**Effective and Remaining Useful Life**

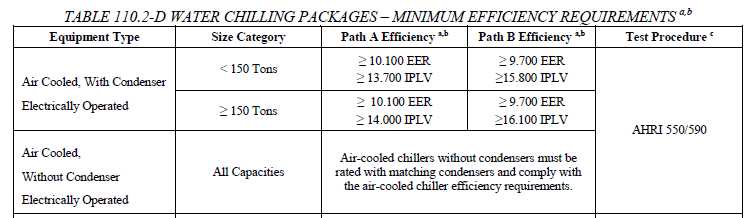
The EUL and RUL values were obtained using the DEER READI tool. DEER defines the RUL as 1/3 of the EUL value. The RUL value is only applicable to the first baseline period for an RET measure with an applicable code baseline. The relevant EUL and RUL values for the measures in this work paper are in the table below.

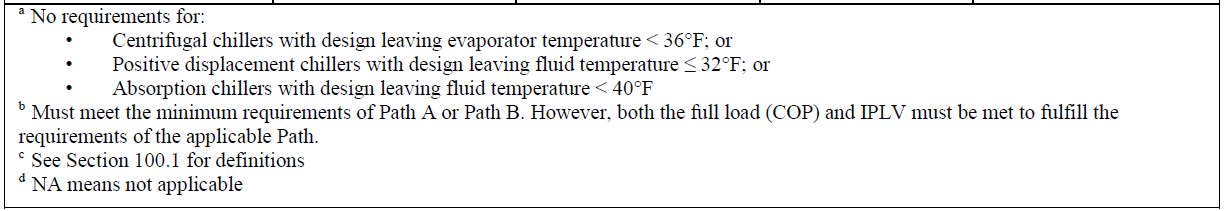
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| HVAC-Chlr (ROB) | High Efficiency Chillers | Com | HVAC | 20 | 6.7 |
| HVAC-Chlr (NEW) | High Efficiency Chillers | Com | HVAC | 20 | 6.7 |

### 1.4.2 Codes and Standards Analysis

The California Title 24 2016 [496] base case for this above-code measure is listed in section 110.2 (a), “Equipment shall meet the applicable efficiency requirements in TABLE 110.2-A through TABLE

110.2-K.” Air-cooled chillers with a leaving evaporator fluid temperature higher than 32°F shall show compliance with TABLE 110.2-D of the Energy Standards when tested or certified with water at standard rating conditions.





Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 24 (2016) | 2016 Building Energy Efficiency Standards, Section 110.2 (a), Table 110.2-D | January 1, 2017 |

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

N/A

### 1.5.1 Non-DEER Study Review

N/A

## 1.6 Data Quality and Future Data Needs

Future cycles of DEER should support tiers on high performance equipment e.g., T24 Path B. Currently, DEER does not allow Utility program to incentivize high performance equipment utilizing this path as there is inadequate chiller performance data for this equipment.

# Section 2. Calculation Methodology

DEER2017 provided latest impact values for all the chiller sizes and tiers, therefore, DEER Impact values were directly used in this workpaper update. Refer to Attachment 3 for DEER2017 energy impact values.

Calculation methodology was revised in this work paper as below:

1. Savings impacts are adopted directly without deviations from DEER2017
2. For ROB, measure impacts are based on DEER2017 AStdWBkWh for energy and AStdWBkW for demand per building type “COM” per corresponding Climate Zones for all (16) territories. The table below shows the combinations used to select the DEER impacts for the respective program type:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Program Type** | **HVAC Vintage** | **Building Type** | **PA** | **Climate Zone** |
| ROB | Ex | Com | SCE | CZ06, CZ08, CZ09, CZ10, CZ13, CZ14, CZ15, CZ16 |
| PGE | CZ01, CZ02, CZ03, CZ04, CZ05, CZ11, CZ12 |
| SDG | CZ07 |

1. For NEW, measure impacts are based on DEER2017 AStdWBkWh for energy and AStdWBkW for demand for all commercial building types under all (16) Climate Zones. The table below shows the combinations used to select the DEER impacts for the respective program type:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Program Type** | **HVAC Vintage** | **Building Type** | **PA** | **Climate Zone** |
| NEW | New | ECC, ESe, EUn, Hsp, Htl, MBT, Nrs, OfL, OfS, Rt3 | Any | CZ01-CZ16 |

1. This workpaper update is limited to DEER2017 measures excluding scaling and/or Non-DEER measures.
2. Please note that DEER standard case differs from 2016 Title-24 standards for air cooled chillers under Path-A requirements.
3. DEER 2017 update documentation excludes measure impacts on high performance equipment such as air cooled chillers meeting Path B minimum requirements.

# Section 3. Load Shapes

The ideal load shape for net benefits estimates would represent the difference between the base case and measure case. The closest load shapes that are applicable to the measures in this work paper are listed in the table below.

Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| Weighted Commercial “Com” | DEER:HVAC\_Chillers | NON\_RES |

# Section 4. Costs

## 4.1 Base Case Cost

Base case cost was taken from January 2017 Manufacturers’ quotes. Please refer to Section 4.2 below regarding the cost calculation methodology used for both the base case and measure case costs.

## 4.2 Measure Case Cost

Measure case material costs were developed as indicated below:

1. The IMC documentation was provided by collecting January 2017 pricing information from two manufacturers. Some manufacturers were able to supply the full price of the equipment while others only provided the difference in cost between multiple units of the same nominal tonnage.
2. Each unit was then classified into a tier based on DEER 2017 requirements and the Title 24 Path A requirement.
3. An average IMC for each tier was then created by averaging the IMCs calculated for each unit that met that tier requirement. The data set only contained two manufacturers and therefore had a limited number of units that qualified for Tier 2 across both size categories.
4. In order to expand pricing estimates for larger data sets, an exponential trend line was created based on the estimated gross measure cost of all the air cooled chillers. This trend line was then used to create a proposed IMC/ton for each tier (e.g., 1, 2, and 3) for capacities over and under 150 tons. The exponential curve fit had a better R squared value than the linear fit and HVAC pricing trends tend to follow an exponential curve, so an exponential function was used instead of linear interpolation. See Attachment 2 for details.

**Base Cost and Measure Cost based on Trended (Curve Fitted) Cost Data for Air-Cooled Chiller per DEER2017 Tiers.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Chiller Size** | **Proposed Measure Cost** | **Proposed Trended IMC** | **Tier** |
| <150 & >150 | $482 (Baseline) | N/A (Baseline) | 0 (Baseline) |
| <150 & >150 | $524 | $42 | 1 |
| <150 & >150 | $570 | $88 | 2 |
| <150 & >150 | $619 | $137 | 3 |

The Baseline and Measure case labor costs were developed as indicated below:

1. Labor costs were calculated based on 2010-2012 Work Order 017 Study report *“Table 4-10: Installation Cost Estimates for Other Nonresidential HVAC, Shell, and Lighting”* [475].
2. For chiller < 150 Tons:
   1. Labor Hours (Hours/Ton) were multiplied with Labor Rate ($/Hr) to calculate Labor Cost ($/Ton) for a 100-Ton ground level and 100-Ton Roof Level Chillers.
   2. To calculate the cost of chiller < 150 Tons, cost per ton of ground and roof installed chillers were averaged from Step a.
   3. Average cost per ton of chiller < 150 ton was calculated as $58.11.

|  |  |  |  |
| --- | --- | --- | --- |
| **Chiller < 150 Tons** | | | |
| **Chiller** | **Labor Hours (Hr/Ton)** | **Labor Rate ($/Hr)** | **Labor Cost ($/Ton)** |
| Air-Cooled Chillers –100 ton ground level | 0.80 | $71.30 | $57.04 |
| Air-Cooled Chillers –100 ton roof level | 0.83 | $71.30 | $59.18 |
| **Average Chiller Cost < 150 Tons** | | | **$58.11** |

1. For chiller >= 150 Tons:
   1. Labor Hours (Hours/Ton) was multiplied with Labor Rate ($/Hr) to calculate Labor Cost ($/Ton) for 200-Ton/300-Ton ground level chillers and 200-Ton/300-Ton roof level chillers.
   2. To calculate the cost of chiller >= 150 Tons, cost per ton of (2) ground and (2) roof installed chillers were averaged from Step a.
   3. Average cost per ton of chiller >= 150 ton was calculated as $30.30.

|  |  |  |  |
| --- | --- | --- | --- |
| **Chiller > 150 Tons** | | | |
| **Chiller** | **Labor Hours (Hr/Ton)** | **Labor Rate ($/Hr)** | **Labor Cost ($/Ton)** |
| Air-Cooled Chillers –200 ton ground level | 0.44 | $71.30 | $31.37 |
| Air-Cooled Chillers –300 ton ground level | 0.38 | $71.30 | $27.09 |
| Air-Cooled Chillers –200 ton roof level | 0.45 | $71.30 | $32.09 |
| Air-Cooled Chillers –300 ton roof level | 0.40 | $71.30 | $28.52 |
| **Average Chiller Cost >= 150 Tons** | | | **$30.30** |

Overall costs for chiller configurations considered in this WP including both Material and Labor Cost are summarized below:

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Size** | **Tier** | **Material Cost $/ton** | **Labor Cost $/ton** | **Total Cost $/ton** | **IMC $/ton** |
| **< 150 Tons** | 0 (Baseline) | $482.14 | 58.11 | $540.25 | (Baseline) |
| 1 | $524.07 | 58.11 | $582.18 | **$41.93** |
| 2 | $569.66 | 58.11 | $627.77 | **$87.52** |
| 3 | $619.20 | 58.11 | $677.31 | **$137.06** |
| **>= 150 Tons** | 0 (Baseline) | $482.14 | 30.30 | $512.44 | (Baseline) |
| 1 | $524.07 | 30.30 | $554.38 | **$41.93** |
| 2 | $569.66 | 30.30 | $599.96 | **$87.52** |
| 3 | $619.20 | 30.30 | $649.51 | **$137.06** |

Given the limited amount of data (total of 37 data points including both <150 ton and >150 ton chiller technology), IMC cost estimate for the curve-fitting is y = 443.56e0.0834x; R² = 0.7143 which used the whole data set yielding the same material cost on a per ton basis for capacities for both over and under 150 tons. Sampled capacities evaluated for cost average 78 tons for <150 tons and 256 tons for >150 tons.

See Attachment 2 for details

## 4.3 Full and Incremental Measure Cost

**Full and Incremental Measure Cost Equations**

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| ROB | (MEC + MLC) – (BEC + BLC) | (MEC + MLC) – (BEC + BLC) | N/A |
| NEW/NC |

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

**Full and Incremental Costs**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure** | **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| AC-18678, AC-18675 | ROB (Tier 1) | $41.93 | $41.93 | N/A |
| AC-18680, AC-18677 | ROB (Tier 2) | $87.52 | $87.52 | N/A |
| AC-18679, AC-18676 | ROB (Tier 3) | $137.06 | $137.06 | N/A |
| AC-19134, AC-10137 | NEW (Tier 1) | $41.93 | $41.93 | N/A |
| AC-19135, AC-19138 | NEW (Tier 2) | $87.52 | $87.52 | N/A |
| AC-19136, AC-19139 | NEW (Tier 3) | $137.06 | $137.06 | N/A |

# Attachments

1. SCE17HC030.0 A1 – Calculation Templates
2. SCE17HC030.0 A2 – Costing
3. SCE17HC030.0 A3 – 2017 DEER Energy Impacts

# References

1. References\_12122016\_100741.xlsx

[475]

[496]