Work Paper PGECOAPP129

**Revision 0**

**Program Administrator**

**Residential Clothes Dryers**

# At-a-Glance Summary

|  |  |  |
| --- | --- | --- |
| **Measure Codes** | ApgCld001 | AP011 |
| **Measure Description** | ENERGY STAR gas clothes dryer | ENERGY STAR Emerging Technology Award electric clothes dryer |
| **Base Case Description** | Federal code compliant standard size gas clothes dryer | Federal code compliant standard size electric clothes dryer |
| **Units** | Per clothes dryer | Per clothes dryer |
| **Energy Savings** | Refer to Excel Calculation Attachment | Refer to Excel Calculation Attachment |
| **Full Measure Cost ($/unit)** | Refer to Excel Calculation Attachment | Refer to Excel Calculation Attachment |
| **Incremental Measure Cost ($/unit)** | Refer to Excel Calculation Attachment | Refer to Excel Calculation Attachment |
| **Effective Useful Life** | 12 years – Appliance Magazine | 12 years – Appliance Magazine |
| **Measure Installation Type** | Replace on Burnout (ROB) | Replace on Burnout (ROB) |
| **Net-to-Gross Ratio** | 0.55 (DEER NTGR ID: Res-Default>2) | 0.7 (DEER NTGR ID: All-Default<=2yrs) |
| **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

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| --- | --- | --- | --- |
| **Revision #** | **Revision Date** | **Author and Affiliation** | **Summary of Changes** |
| 0 | 9/18/15 | Jia Huang (PG&E) | New measures for ENERGY STAR gas clothes dryers and ENERGY STAR Emerging Technology Award electric clothes dryers. |
|  |  |  |  |

# Commission Staff Review and Comment History

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| --- | --- | --- | --- |
| **Revision #** | **Date Submitted to Commission Staff** | **Date Comments Received** | **Commission Staff Comments** |
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|  |  |  |  |

# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

ENERYGY STAR certified clothes dryers use 20 percent less energy than conventional models. A tier above ENERGY STAR, the ENERGY STAR Emerging Technology Award recognizes innovative products that have the potential to significantly reduce greenhouse gas emissions but fact certain barriers to U.S. market entry or acceptance. As of 2015, ENERGY STAR Emerging Technology Award winning dryers all utilize heat pump technology.

**Base, Standard, and Measure Cases**

|  |  |
| --- | --- |
| **Case** | **Description of Typical Scenario** |
| Measure | Residential Clothes Dryer: ENERGY STAR rated or above |
| Existing Condition | N/A |
| Code/Standard | CEC Title 20 code minimum |
| Industry Standard Practice | N/A |

Measures and Codes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Measure Codes** | | | | **Measure Name** |
| SCG | SDG&E | SCE | PG&E |
| ApgCld001 |  |  |  | ENERGY STAR gas clothes dryer |
|  |  |  | AP011 | ENERGY STAR Emerging Technology Award electric clothes dryer |

## 1.2 Technical Description

Electric Clothes Dryer: A cabinet-like appliance designed to dry fabrics in a tumble-type drum with forced air circulation. The heat source is electricity and the drum and blower(s) are driven by an electric motor(s).

Gas Clothes Dryer: A cabinet-like appliance designed to dry fabrics in a tumble-type drum with forced air circulation. The heat source is gas and the drum and blower(s) are driven by an electric motor(s).

Standard size Clothes Dryer: A clothes dryer with a drum capacity of 4.4 cubic feet or greater.

Combined Energy Factor (CEF): The clothes dryer test load weight in pounds divided by the sum of the per cycle standby and off mode energy consumption and either the total per-cycle electric dryer energy consumption or the total per-cycle gas dryer energy consumption expressed in kilowatt hours (kWh).

Residential clothes dryers are appliances designed to dry clothes by tumbling the load in a heated drum to remove moisture by means of evaporation. Because a horizontal axis of rotation is required to create the tumble action, residential clothes dryers are generally front-loading. Front-loading clothes dryers have an opening on the front of the unit, covered by a door, which gives access to an inner cylindrical drum where the load to be dried is placed. The inner drum is perforated and is surrounded by a larger outer housing which collects the moisture-laden air. The clothes dryer uses electricity to power an electric motor that rotates the drum within the housing, which is contained inside a cabinet. Vanes and/or surface textures may be incorporated into the inner surface of the drum to facilitate separation of the clothing to expose surface areas for drying.

Air is drawn through the drum by means of an electrically driven blower. This air stream is heated prior to entering the drum in order to evaporate the moisture in the clothing with which the air comes in contact. Heating may be provided by an electrically energized resistive element. Alternatively, hot air in the drum may be supplied by means of a gas burner system whose combustion products are directed into the drum by the electrically powered blower.

In the case of vented clothes dryers, the moisture-laden air is exhausted from the drum through a length of ducting, and as it exits, freshly heated room air is drawn in. For ventless clothes dryers, moist air in the drum is routed through an air- or water-cooled heat exchanger where water vapor is removed from the air by condensation. Ventless systems may either open-loop, in which the relatively dry air from the drum is exhausted into the room, or closed-loop, in which the dry air is recirculated back to the heater and subsequently to the drum inlet.

Some high efficiency clothes dryers in the market today are capable of modulating the amount of heat entering the drum, allowing for energy efficient settings involving rotating the drum at a lower temperature. This reduces the amount of energy required to heat the drum at the cost of longer dryer run times. The most efficient electric dryers currently in the market are heat pump dryers. Heat pump dryers function by recirculating the exhaust air back to the dryer while moisture is removed by a refrigeration-dehumidification system. No heating element is needed. The warm and damp exhaust air of the dryer enters the evaporation coil where it cools down below the dew point, and sensible and latent heat are extracted. The heat is transferred to the condenser coil and reabsorbed by the air, which is moving in a closed cycle.

## 1.3 Installation Types and Delivery Mechanisms

**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 Construction (NEW/NC) | Above Code or Standard | N/A | EUL | N/A |
| Retrofit or Early Replacement (RET/ER) | Above Customer Existing | Above Code or Standard | RUL | EUL-RUL |
| Retrofit First Baseline Only (REF) | Above Customer Existing | N/A | EUL | N/A |
| Retrofit Add-on (REA) | Above Customer Existing | N/A | EUL | N/A |

The installation type for these measures is Replace on Burnout (ROB). Customers are incented to purchase high efficiency clothes dryers when they replace their old units.

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** |
| Appliance Turn-in and Recycling | The program motivates customers, through financial incentives, to recycle appliances that are functional but inefficient. This prevents the continued use of those appliances, by both the current owner and potential future owners. |
| Audit/Information/Testing Services | The program performs a free assessment of a customer’s facility and provides the customer with information and guidance on energy efficiency opportunities. |
| Commissioning and Retrocommissioning | The program modifies or repairs existing equipment to ensure that it works as intended. |
| Financial Support | The program motivates customers, through financial incentives such as rebates or low interest loans, to implement energy efficient measures or projects. |
| Innovative Design | The program funds new ideas that meet reasonable scientific scrutiny for potential energy savings. These innovative measures typically have small market penetration (less than 5%) or are targeted toward relatively unreached market segments. |
| New Construction | The program offers financial incentives and/or design assistance to customers involved with new building construction. This is intended is to motivate customer to exceed Title 24 building energy efficiency requirements (residential or nonresidential). |
| Partnership | The program implements projects through a partnership between the utility and an institutional, government, or community-based organization. |
| Performance Based | The program offers financial incentives that vary based on the energy efficiency performance of specific projects. |
| Up-Stream Programs | See Up-Stream Incentive and Up-Stream Buy Down in the Incentive Method table. |

The delivery method is Financial Support.

**Incentive Method Descriptions**

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Direct Install | The program implements energy efficiency measures for qualifying customers, at no cost to the customer. |
| Down-Stream Incentive | The customer installs qualifying energy efficient equipment and submits an incentive application to the utility program. Upon application approval, the utility program pays an incentive to the customer. Such an incentive may be deemed or customized. |
| Mid-Stream Incentive | The program gives a financial incentive to a midstream market actor, such as a retailer or contractor, to encourage the promotion of efficient measures. The incentive may or may not be passed on to the end-use customer. |
| Up-Stream Incentive | The program gives a financial incentive to an upstream market actor, such as a manufacturer or distributor, to encourage the manufacture, provision, or distribution of an efficient measure. The incentive may or may not be passed on to the end-use customer. |
| Up-Stream Buy Down | The program gives a financial incentive to an upstream market actor, such as a manufacturer or distributor, with specific requirements to pass down the incentive to the end use customer. Such an incentive buys-down the cost of an efficient measure for the end-use customer by at least the amount of the financial incentive. |
| Giveaway | The program provides customers with energy efficiency equipment or services for free. |
| Exchange/Replacement | The utility program holds events where customers can trade functional equipment for similar but more energy efficient equipment, free of charge. |
| On-bill Finance/Loan | The program offers financing for the cost an efficient measure as part of the utility bill. This can be an add-on option to an existing program or can serve as an organizing principle for its own program. |

These measures are delivered as a down-stream incentive.

## 1.4 Measure and Base Case Cost Effectiveness Data

### 1.4.1 DEER Data

DEER Difference Summary

|  |  |
| --- | --- |
| **DEER Item** | **Used for Workpaper?** |
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | No |
| DEER Measure Case | No |
| DEER Building Types | No |
| DEER Operating Hours | No |
| DEER eQUEST Prototypes | No |
| DEER Version | DEER 2016, READI v2.3.0 |
| Reason for Deviation from DEER | DEER does not contain this type of measure. |
| 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.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Measure** | **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| ENERGY STAR gas clothes dryer | Res-Default>2 | All other EEM with no evaluated NTGR; existing EEM with same delivery mechanism for more than 2 years | Any | Any | Any | 0.55 |
| ENERGY STAR Emerging Technology Award electric clothes dryer | All-Default<=2yrs | All other EEM with no evaluated NTGR; new technology in program for 2 or fewer years | All | Any | Any | 0.70 |

A net-to-gross ratio of 0.70 is appropriate for ENERGY STAR Emerging Technology Award (ETA) clothes dryers because this is a new class of technology that has yet to gain traction in the U.S. market. According to the EPA, “the ENERGY STAR Emerging Technology Award was created to raise the profile of innovative technologies that may not yet meet key principles associated with the ENERGY STAR program (e.g. widely available, cost-effective), but have the potential to significantly reduce greenhouse gas emissions once they are more widely adopted.” Eligible technologies are required to have <5% market share. In order to meet stringent requirements for the EPA’s emerging technology award specification, ETA dryer winners all incorporate new technologies that are not commonly available. All 2014 ENERGY STAR ETA dryers incorporated heat pumps into their designs whereas almost all other electric dryers in the U.S. market use electric resistance to heat the drum. While more common in the European market, heat pump clothes dryers have limited market share in the U.S. market due to high cost and cultural resistance to long drying times.

**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**

DEER does not contain effective useful life for clothes dryers. Appliance Magazine cites an average measure life of 12 years for clothes dryers.[[1]](#endnote-1)

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)** |
| N/A | Clothes Dryers | Res | AppPlug | 12 | 4 |

### 1.4.2 Codes and Standards Analysis

The California 2015 Appliance Efficiency Regulations (Title 20) and Title 10 of Electronic Code of Federal Regulations for clothes dryers are consistent.

Code Summary

|  |  |  |
| --- | --- | --- |
| **Code** | **Reference** | **Effective Dates** |
| Title 20 (2015) | Section 1605.1(q) Clothes Dryers | January 1, 2015 |
| Code of Federal Regulations | 10 CFR 430.32(h)(3) | January 1, 2015 |

Title 10, Chapter II, Subchapter D, Part 430 of the Code of Federal Regulations requires clothes dryers to be tested under either appendix D1 or appendix D2 to comply. Minimum efficiency requirements effective January 2015 were finalized with the intent that dryers would be tested under appendix D1, but before appendix D2 was adopted. The ENERGY STAR specification for clothes dryers requires all qualifying dryers to be tested under appendix D2. Minimum requirements tested under appendix D1 are crosswalked to their equivalent values as tested under appendix D2 using three data sets comprising of a total of 12 standard size electric dryers and 8 gas dryers. The data sets are DOE’s January 2013 Notice of Proposed Rulemaking[[2]](#endnote-2), Oak Ridge National Lab’s study on *Residential Clothes Dryer Performance Under Timed and Automatic Cycle Termination Test Procedures[[3]](#endnote-3)*, and Pacific Northwest National Lab’s *Clothes Dryer Automatic Termination Sensor Evaluation, Volume 1[[4]](#endnote-4)*.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Product Type | Size | Voltage (V) | Minimum Combined Energy Factor (lbs/kWh) measured using appendix D1 | Minimum Combined Energy Factor (lbs/kWh) measured using appendix D2 |
| Ventless or Vented Electric | Standard | Any | 3.73 | 3.10 |
| Ventless or Vented Electric | Compact | 120 | 3.61 | 2.94 |
| Vented Electric | Compact | 240 | 3.27 | 2.66 |
| Ventless Electric | Compact | 240 | 2.55 | 2.07 |
| Vented Gas | Any | Any | 3.30 | 2.76 |

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

### 1.5.1 Analysis of Potential Energy Savings from Heat Pump Clothes Dryers in North America[[5]](#endnote-5)

This study was completed in March 2013 and funded by CLASP as a part of the Super Efficient Dryer Initiative (SEDI). The aim of the study was to evaluate the energy savings potential of heat pump dryers, a technology that has made significant market gains in Europe, but is not yet sold in North America. Tests were conducted on 3 conventional, electric resistance dryers and 4 heat pump dryers. Test runs were conducted using DOE test cloths as well as with IEC and AHAM test cloths which better approximate real world clothing. The study found that:

1. Heat pump dryers use only 40-50% as much as energy as conventional dryers, but took twice as long to dry the same amount of laundry.

2. Drying time and energy consumption increased for all dryers when drying test loads that more closely resemble real-world clothing.

3. Conventional dryers had peak power consumption roughly five times as high as heat pump dryers.

# Section 2. Calculation Methodology

**ENERGY STAR Vented Gas Dryers**

Unit energy savings for ENERGY STAR gas clothes dryers is calculated using the following equation:

where

UES = unit energy savings in therms

cycles = 274 cycles per year

C = drum capacity, 8.45 pounds of laundry dried per cycle

0.03413 = conversion from kWh to therms

= combined energy factor tested under appendix D2

The assumptions for cycles per year and drum capacity were obtained from the 2011 DOE Clothes Dryers Technical Support Document and the DOE test procedure respectively. The combined energy factors for the base and measure cases are the federal code minimum and ENERGY STAR specification requirements respectively. The DOE test procedure requires that for gas dryers, the quantity of gas consumed be measured and converted to units of kWh. That number is then added to the actual electricity use of the dryer to calculate a combined energy factor. To simplify the energy savings calculation, we omit the analysis of electricity use by the gas dryer and assume that the dryer only consumes natural gas. This is reasonable because 1) electricity consumed by a gas dryer is small (<5%) compared to total energy use and 2) electricity consumption is unlikely to change significantly between gas dryers of different efficiency levels.

**ENERGY STAR Emerging Technology Award Electric Clothes Dryers**

where

UES = unit energy savings in kWh

cycles = 283 cycles per year

C = drum capacity, 8.45 pounds of laundry dried per cycle

UCEF = utility combined energy factor

The assumptions for cycles per year and drum capacity were obtained from the 2011 DOE Clothes Dryers Technical Support Document and the DOE test procedure respectively. PG&E and NEEA, in collaboration with other utility stakeholders, created a Utility Test Protocol and a new metric called the utility combined energy factor (UCEF). In addition to the DOE appendix D2 test, this test protocol requires four supplemental tests: small, large, eco (the dryer’s most efficient low heat setting), and fast (the least efficient high heat setting) modes. Equal weighting of the five tests produces the UCEF for the tested dryer. In contrast to the 50/50 cotton/polyester blend test cloths prescribed by the DOE test procedure, the supplemental tests require actual articles of clothing. To encourage the use of more efficient settings, an additional UCEF credit of 0.10 is given to dryers that automatically return to the eco mode setting within 2 hours of the last run cycle. The impetus for the use of the Utility Test Protocol are that 1) the utility test clothes better approximate real world clothing and 2) it is common for the most efficient electric dryers in the market to have multiple efficiency settings. The DOE test procedure only prescribes a single setting of either high heat or automatic cycle termination, and thus is unable to capture the effects of a variety of settings that are available to the consumer. The equivalent UCEF for a standard size electric dryer is derived from a set of 11 baseline dryers tested under both the DOE appendix D2 test procedure and the Utility Test Protocol. ENERGY STAR Emerging Technology Award winning dryers are tested both by the EPA using appendix D2 and by NEEA using the Utility Test Protocol.

Peak demand savings for electric dryers are calculated using the following:

where

UES = unit energy savings

cycles = 283 cycles per year

50 minutes = average dryer cycle run time per lab tests conducted by PG&E and NEEA

CDF = coincident demand factor of 0.095.

The coincident demand factor for clothes dryers is assumed to be similar to that of clothes dryers. SCE’s data collection efforts for clothes washers in multifamily common area laundry facilities show an average CDF of 0.367. We’ve scaled this number by the number of washing cycles per year (1095 cycles for multifamily and 283 cycles for single-family) to arrive at a CDF of 0.095 for single-family laundry use.

# 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** |
| Res | PGE:Residential:32 = Res. Clothes Dry | N/A |

# Section 4. Costs

Base and measure costs are derived from a representative sample of clothes dryers sold by three major online retailers: Home Depot, Lowes and Sears. Incremental cost for an ENERGY STAR gas clothes dryer is determined by comparing ENERGY STAR certified dryers with similar non-ENERGY STAR models by size, color, and features.

The incremental measure cost for an electric heat pump clothes dryer is determined by summing the incremental cost of an ENERGY STAR certified electric dryer and the incremental cost of a heat pump dryer over an ENERGY STAR dryer. ENERGY STAR models used as a comparison to heat pump models are higher end, newer models with similar quality and features as the heat pump models. This is consistent with the definition of incremental measure cost as the only the cost attributed to features that enable energy efficiency. Heat pump clothes dryers are the most expensive dryers on the market and therefore are expected to have the build quality and features common in the higher end price point.

## 4.1 Base Case Cost

|  |  |
| --- | --- |
| Measure | Base Case Material Cost |
| ENERGY STAR gas Clothes dryer | $848.53 |
| ENERGY STAR Emerging Technology Award electric clothes dryer | $895.25 |

## 4.2 Measure Case Cost

|  |  |
| --- | --- |
| Measure | Measure Case Material Cost |
| ENERGY STAR gas Clothes dryer | $898.03 |
| ENERGY STAR Emerging Technology Award electric clothes dryer | $1430.30 |

## 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 |
| RET/ER | (MEC + MLC) – (BEC + BLC) | MEC + MLC | (MEC + MLC) – (BEC + BLC) |
| REF | (MEC + MLC) – (BEC + BLC) | MEC + MLC | N/A |
| REA | MEC + MLC | MEC + MLC | N/A |

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

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

**Full and Incremental Costs**

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| ROB | $49.50 | $49.50 | N/A |
| ROB | $535.05 | $535.05 | N/A |

# References

1. Appliance Magazine, U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture for 2005-2012, Jan. 2011, p. 11-12 for service and average lifetimes and units to be replaced [↑](#endnote-ref-1)
2. U.S. Department of Energy (2013, January 2). *Energy Conservation Program: Test Procedures for Residential Clothes Dryers; Notice of Proposed Rulemaking*. Retrieved from <http://www.regulations.gov/#!documentDetail;D=EERE-2011-BT-TP-0054-0006>

   [↑](#endnote-ref-2)
3. Kyle Gluesenkamp, Oak Ridge National Lab (October 2014). *Residential Clothes Dryer Performance Under Timed and Automatic Cycle Termination Test Procedures*. Retrieved from <http://web.ornl.gov/sci/buildings/docs/2014-10-09-ORNL-DryerFinalReport-TM-2014-431.pdf> [↑](#endnote-ref-3)
4. W. TeGrotenhuis, *Pacific Northwest National Lab (September 2014). Clothes Dryer Automatic Termination Sensor Evaluation Volume 1: Characterization of Energy Use in Residential Clothes Dryers*. Retrieved from <http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-23621.pdf> [↑](#endnote-ref-4)
5. CLASP and Ecova (March 2013). *Analysis of Potential Energy Savings from Heat Pump Clothes Dryers in North America*. Retrieved from <http://clasp.ngo/en/Resources/Resources/PublicationLibrary/2013/Clothes-Dryer-Heat-Pump-Technology-Offers-Substantial-Cost-and-Energy-Savings-for-North-America> [↑](#endnote-ref-5)