Commercial Clothes Dryers

Codes and Standards Enhancement (CASE) Initiative
For PY 2013: Title 20 Standards Development

Analysis of Standards Proposal for
Commercial Clothes Dryers

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Prepared for:

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We would like to thank all of those who contributed to the development of this report. We would particularly like to thank Gary Fernstrom and Rafik Sarhadian for reviewing the report.

[1] As of January 1, 2013 the HMG has been acquired by TRC COMPANIES, INC. (TRC)

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1 Executive Summary

The Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), Southern California Gas (SCG), San Diego Gas & Electric (SDG&E) Codes and Standards Enhancement (CASE) Initiative Project seeks to address energy efficiency opportunities through development of new and updated Title 20 standards. Individual reports document information and data helpful to the California Energy Commission (CEC) and other stakeholders in the development of these new and updated standards. The objective of this project is to develop CASE Reports that provide comprehensive technical, economic, market, and infrastructure information on each of the potential appliance standards. This CASE report covers standard options for commercial clothes dryers.

Commercial clothes dryers are used in three types of applications including multi-family laundromats (MFLs), coin-operated Laundromats (COLs), and on-premise laundromats (OPLs). The first two are self-explanatory and serve people who do not have their own laundry equipment. The third one refers to on-site laundry equipment for serving particular types of facilities, such as hospitals, hotels and motels, restaurants, health clubs, fire stations, and law enforcement facilities. Nearly all dryers in these commercial applications are tumble-type dryers, which remove moisture by blowing hot air through damp clothes tumbling in a rotating drum. Residential clothes dryers are based on the same working mechanism. For this reason, commercial and residential clothes dryers have very similar designs and controls. The majority of commercial dryers installed in California are natural gas models, which burn natural gas to provide hot air to dry clothes, as compared to electric models, which provide hot air through resistance heating.

The three different commercial laundry applications utilize dryers with a wide range of capacities: 5.4 to 175 cubic feet in terms of drum volume; or 18 to 464 lb in terms of dry clothes weight. Most dryers used in MFLs are similar to residential dryers and are in the low end of the capacity spectrum. For this reason, these dryers are typically called MFL or residential-style dryers. Their drum volumes are between 5.6 and 7.4 cubic feet, and heat input ratings are between 20 and 25 kBtu/hr for gas models, and between 4.75 and 6 kW for electric models. The most popular dryer models used in COLs are the ones with about 30 lb weight capacity. OPLs utilize the broadest range of dryers due to diversified facility laundry needs.

There are currently no federal or California energy efficiency testing and minimum energy performance standards for commercial clothes dryers. The United States Department of Energy (U.S. DOE) has established both testing standards and minimum energy performance standards for residential clothes dryers. Commercial clothes dryers have very similar designs and controls as residential clothes dryers. The predominant difference between the two is capacity, other than many commercial clothes dryers have coin slots. Therefore, the CASE study team proposes the adoption of the U.S. DOE test standard for residential dryers as a Title 20 test method for commercial dryers. The proposal changes the product classes specified in the U.S. DOE test method for residential dryers in order to accommodate different capacity ranges found in commercial dryers, as shown in **Error! Reference source not found.**. The CASE study team onducted laboratory tests to evaluate the feasibility of using the U.S. DOE residential dryer test standards to assess the efficiency of commercial clothes dryers. The tests investigated the dependence of dryer energy performance on different operational parameters, including load weight, fabric type, cycle temperature settings, initial moisture content (IMC), and remaining moisture content (RMC). These parametric tests demonstrated that the U.S. DOE residential dryer test method can be used to quantify the energy performance dependence on various commercial dryer testing parameters and, therefore, is feasible as a test method for commercial clothes dryers. Efficiencies of several gas and one electric MFL dryers and several 30 lb gas dryers were assessed under a set of recommended rating conditions.

The CASE study team modified the U.S. DOE residential dryer test method to make it suitable for testing commercial clothes dryers. The CASE study team recommends the CEC to adopt this modified test method into the Title 20 Appliance Efficiency Standards as the test method for all tumble-type commercial clothes dryers. The CASE study team also recommends that Title 20 Appliance Efficiency Standards require manufacturers to test commercial clothes dryer models to be sold in California after January 1, 2015 and to report the test results to the CEC for publication in the CEC Appliance Efficiency Database.

Based on test results, the CASE study team also proposes minimum energy performance standards for the two most popular product classes for COL and OPL applications in California. The proposed minimum standards, as shown in Table 1.1 are cost effective, because the average cost of high-efficiency dryers is similar to those with lower efficiencies.

Table 1.1 Commercial Clothes Dryer Proposed Minimum Energy Factors (lb/kWh)

Drum Capacity	Fuel Type	Proposed Minimum Energy Factor (lb/kWh)
< 7.5 ft^3	Natural Gas	3.65
>= 7.5 ft^3 and < 13 ft^3	Natural Gas	3.00

2 Product Description

Tumble-type clothes dryers represent nearly all of the clothes dryers used for commercial laundry applications. A typical tumble-type dryer uses hot air to dry clothes placed in a rotating drum. Forced hot air circulation and the tumbling motion enhance water evaporation and removal so that clothes can be dried in relatively short times. In an electric clothes dryer, air is heated by electric resistance elements, whereas in a gas clothes dryer, air is heated through mixing ambient air with gas combustion flue gases.

Hot air provides the thermal energy required for water evaporation. Air at higher temperatures also allows higher vapor pressures, so that it is capable of carrying more moisture than air at lower temperatures. An air circulation fan maintains the forced convective flow to enhance the heat and moisture transfer between the air and wet textiles, and to move the moist air out of the dryer. The tumbling motion makes the clothes mixture spread out so that the contact area between the textiles and the hot air can be maximized to enhance heat and moisture transfer. Drum rotation and air blower are driven by an electric motor.

Figure 2.1 and Figure 2.2**Error! Reference source not found.** below present some randomly selected commercial dryer models. In Figure 2.2Error! Reference source not found., two dryers ay be configured for stacking installation so that the total floor footprint can be reduced. In this case, the two dryers together are treated as one unit, and each dryer is called a pocket. The following sections provide detailed descriptions of commercial clothes dryer classifications and applications.

Figure 2.1 Commercial Dryer Examples: multi-family dryer, 30, 50, 120 and 310 lb capacity dryers (from left to right)

Figure 2.2 Stacked Dryers 2x multi-family (left) and 2x 30 lb (right) dryers

2.1 PRODUCT CLASSIFICATIONS

Dryers are commonly categorized by the drum volume size measured in cubic feet (cu. ft.), or by the dryer weight capacity measured in pounds (lb) of dry clothes. Small commercial dryers have similar sizes and designs to residential (consumer) dryers and they are used mostly in multi-family laundromats (MFLs). For this reason, they are often called multi-family (MF) or residential-style dryers. For these commercial dryers, manufacturers tend to provide drum volume size specifications, as for residential dryers, but not weight capacity specifications. Large commercial clothes dryers are usually categorized by weight capacity, although manufacturer specifications also provide drum size information. Large commercial dryers are mostly used in coin-operated laundromats (COLs) and on-premise laundromats (OPLs) and, therefore, they are referred as COL/OPL dryers in this document. The next section will provide detailed descriptions of the three types of laundromats mentioned above.

Table A.1 in the Appendix A provides a list of commercial dryer models from all major commercial dryer manufacturers in the United States. Key product specifications listed in the table were based on product specification sheets obtained from manufacturer websites. Figure 2.3 shows that, in general, dryer weight capacity is linearly proportional to dryer volume size for all commercial clothes dryers. However, a more close review of dryer specification reviewed that these two specifications do not have one-to-one correlation for all dryers. This is clearly shown in Figure 2.4, which presents weight capacity and drum volume only for dryers with drum less than 25 cubic feet. For example, drum volume size for 30 lb dryers range from 7.7 to 12.5 cubic feet. Similarly, dryers with the same or very similar drum volumes can have different weight capacities.

Weight capacity of MFL dryers is usually not provided in product specification sheets. Maytag MFL dryers have a specified weight capacity of 18 lb. According to industry experts, this weight capacity is the typical weight capacity suggested for MFL dryers. Therefore, all MFL dryers are designated with a weight capacity of 18 lb in Figure 2.3 and Figure 2.4.

Drum volume, as a physical property of dryers, can be measured with reasonable precision. Dryer weight capacity, on the other hand, cannot be preciously determined. Drum filling factor, defined as the ratio of load weight, in kilograms, to drum volume, in liters, can be used to indicate how full the drum is loaded. When a drum is filled with large pieces of clothes, there will be less empty space for clothes to spread out and for hot air to pass through. For this reason, using a smaller filling ratio is suggested for drying larger pieces of clothes than for drying smaller pieces of clothes. A filling factor between 1:18 (3.47 lb/cu.ft.) and 1:25 (2.50 lb/cu.ft.) is used in some product specification sheets to indicate product weight capacity. These two filling factor limits are shown in Figure 2.3 and Figure 2.4 to compare weight capacities specified by manufacturers.

From the above discussion, it can be seen that dryer weight capacity provides a reference to the size of a dryer. It does not represent the absolute maximum amount of clothes that can be handled by a dryer in one cycle. A dryer with one or two pounds of clothes over the weight capacity specification can still run well, although the drying time will be longer than normal and there could be extra wear and tear on drum bearings due to the excess weight. Therefore, dryer weight capacity is not a suitable metric to classify commercial dryers.

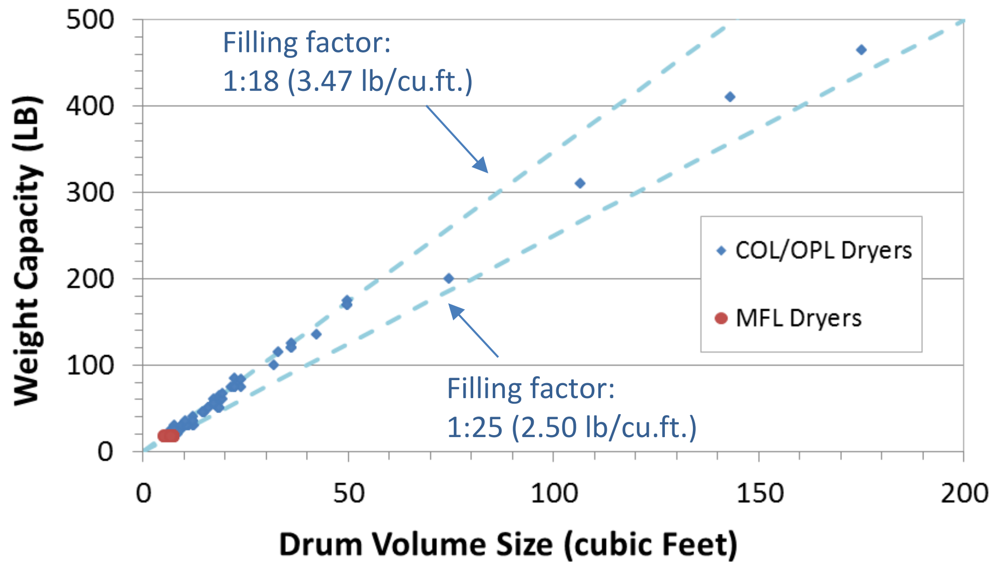

Figure 2.3 Correlation between Dryer Weight Capacity and Drum Volume (all sizes)

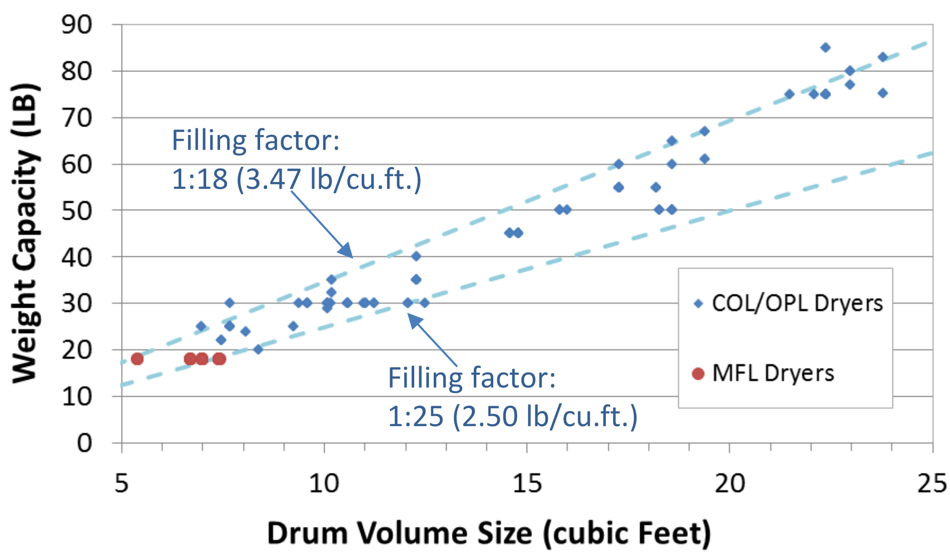

Figure 2.4 Correlation between Dryer Weight Capacity and Drum Volume (<25 cu. ft.)

The U.S. Department of Energy's (U.S. DOE) energy efficiency standards classify residential clothes dryers according to the drum volume size. Dryers with drum sizes less than 4.4 cubic feet are deemed as "compact sized" and dryers with drum sizes equal to or large than 4.4 cubic feet are classified as "standard sized." Since all commercial dryers have drum volume size specifications, drum volume size may be used to differentiate commercial dryer products as well.

Dryer heat input rate, in Btu/hr for gas dryers and kW for electric dryers, may also be used as a product classification metric. In general, the dryer heat input rate is proportional to the dryer drum volume size, as shown in Figure 2.5. Figure 2.6, showing heat input of a smaller range of dryers, indicates that dryers with the same or similar drum sizes can have large variations in gas heat input.

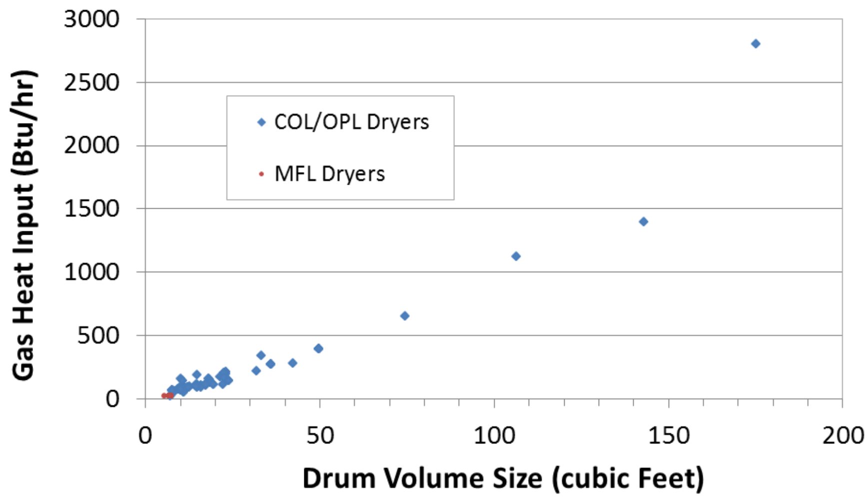

Figure 2.5 Correlation between Gas Dryer Heat Input and Drum Volume (All Size)

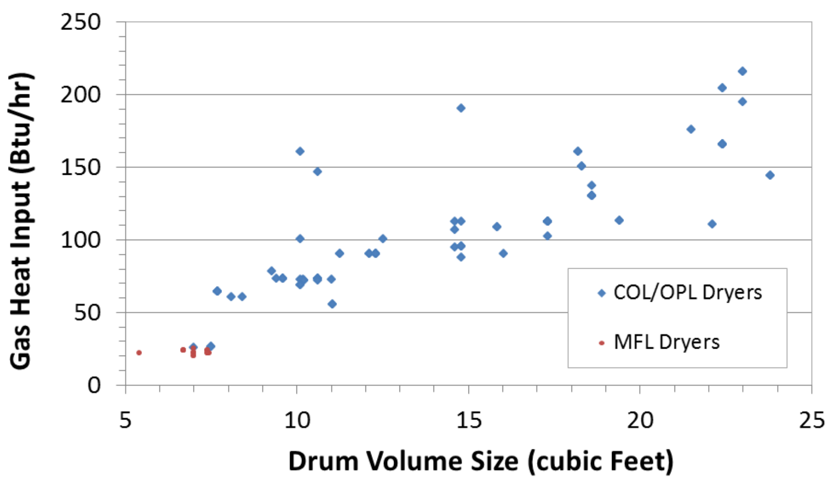

Figure 2.6 Correlation between Gas Dryer Heat Input and Drum Volume (< 25 cu. ft.)

As shown in Figure 2.3 and Figure 2.4, there is no clear distinction between large MF dryers and small COL/OPL dryers in terms of drum volume and weight capacities. In terms of gas heat input rates, Figure 2.6 shows that most COL/OPL dryers have a gas heat input rate larger than 50 kBtu/hour. However, there are three COL/OPL dryers, ADC AD-22, Continental Girbau Econ-o-dry, and Continental Girbau Econ-o-dry, with heat inputs similar to those of MLF dryers.

2.2 PRODUCT APPLICATIONS

Most commercial clothes dryers are used in three distinct sectors: multi-family laundromats (MFLs), coin-operated laundromats (COLs), and on-premise laundromats (OPLs). Each sector is characterized by a different market size and types of dryers used. In general, MFLs use small-sized residential-style dryers. Larger dryers, e.g. 30 lb dryers, may also be used in some multi-family buildings, to allow occupants to combine several washing loads into one drying load to reduce overall laundry time. COL dryers generally have a larger weight capacity, ranging from approximately 20 to 75 lbs. The weight capacities for OPL applications have the largest variation and covering all weight capacity classes.

2.2.1 Multi-family Laundromats (MFLs)

MFLs are located in multi-family buildings and certain hospitality facilities (Figure 2.7), serving domestic laundry needs. For this reason, MFLs usually deploy small commercial dryers that have similar volume sizes and heat inputs to residential clothes dryers. These small-sized commercial dryers are usually called multi-family dryers by the industry. Table A.1 in Appendix A shows that multi-family dryers have a drum volume size between 5.6 and 7.4 cubic feet and a heat input rating between 20 and 25 Btu/hr for gas models and between 4.75 and 6 kW for electric models. For easy comparison, **Error! Reference source not found.** presents specifications of some tandard-sized residential clothes dryers. While in general, standard-sized residential dryers have similar drum sizes and heat inputs to those of multi-family dryers, drum sizes of some residential dryers are beyond the size range of multi-family dryers. As indicated in Section **Error! Reference ource not found.** Product Classifications, multi-family dryers usually do not provide weight capacity specifications. Maytag MFL dryers are specified to have a weight capacity of 18 lb. Based on discussions with manufacturers; other MFL dryers also have similar weight capacities.

It should be noted that MFL dryers may also be used in COLs and OPLs, because they can provide the same services as COL and OPL dryers, just with smaller load sizes. Similarly, some MFLs also deploy large commercial dryers that are more commonly used in COLs and OPLs.

Figure 2.7 A Multi-family Laundromat

2.2.2 Coin-Operated Laundromats (COL)

COLs are the most visible of the laundromat applications in the market (Figure 2.8). These facilities cater to consumers who do not have washer and dryer equipment at their residence, and the washers and dryers are usually operated by coins, thus the name coin-operated. According to manufacturer representatives, Coin Laundromats Association representatives, and commercial dryer distributors, the most popular dryers used in COLs are 30 lb weight capacity models, in both single pocket and stacked two-pocket configurations. Other sizes of dryers have much smaller market shares in the COL sector.

Figure 2.8 Coin-Operated Laundromat with Stacked Configuration

2.2.3 On Premise Laundromats (OPL)

OPLs (see Figure 2.9) cover laundry services in a broad range of facilities such as health care facilities, fire stations, hotels and motels, universities, prisons and laundry services companies. Some of these facilities outsource their laundry needs to private laundry service companies which may use very large dryers, e.g. dryers with capacities larger than 100 lbs, to increase productivity. For this reason, very large dryers are also categorized as industrial applications. As each of these commercial applications has unique laundry service needs, the OPL market is fragmented. In response to diverse market needs, manufacturers offer products with a broad range of capacities. Some OPL applications use small dryers while others need dryers with much larger capacities. As shown in Table A.1 in Appendix A, dryer capacities for OPL applications can be larger than 400 lb.

Figure 2.9 On-Premise Laundromat

3 Manufacturing and Market Channel Overview

The CASE study team utilized a number of methods to collect product and market information on commercial dryers in California. These data collection methods included:

- Market study literature reviews
- Interviews with manufacturer representatives

- Interviews with distributors and industry associations
- Manufacturer product lines and specification sheet reviews

The CASE study team engaged manufacturers and industry associations at the beginning of the study period to inform study objectives. The CASE study team contacted and interviewed major manufacturers and distributors to obtain information about market characteristics, and to solicit input to potential efficiency standards, including dryer test methods.

Table 3.1 Commercial Clothes Dryer Manufacturers and Products

Manufacturer	Commercial Clothes Dryers
Alliance Laundry Systems (Includes Cisell, Huebsch, IPSO, SpeedQueen, Unimac)	MFL dryers, 25-170 lb
American Dryer Corporation	20 – 464 lb
Continental Girbau	25 – 175 lb
Dexter	30 – 83 lb
Electrolux	29 - 135 lb
General Electric (GE)	MFL dryers
Maytag (Include brand names of Maytag and Whirlpool)	MFL dryers, 30-75 lb
Wascomat	30 – 135 lb

Table 3.1 shows the major commercial clothes dryer manufacturers in the United States and their product ranges in weight capacity. The information was collected through review of manufacturer product literature obtained from manufacturer websites. Some manufacturers have several subsidiaries or brand names. For example Cisell, Huebsch, IPSO, SpeedQueen and Unimac all belong to Alliance Laundry Systems.

The CASE study team was unable to find any published data of annual sales, shipments, or market share of sales by manufacturer, or by the industry as a whole. Manufacturers deemed such information sensitive and confidential, and therefore would not provide even very rough estimates to the CASE study team. Based on input from different manufacturers, it seemed that some manufacturers, e.g. Alliance Laundry Systems, represented larger shares of the commercial dryer market than others. However, for purposes of this study, the market shares by manufacturer and by application (MFL, COL or OPL markets) are unknown.

In terms of dryer sales by fuel type, market survey results indicate that in California gas dryers account for most MFL dryers and nearly all large dryers sold to COLs and OPLs. However, there is not enough market information to provide a quantitative estimate of the breakdown between gas and electric clothes dryers.

Commercial dryers have relatively simple distribution channels. Dryers are typically sold through local and regional distributors. Small quantities of the MFL commercial dryers can also be purchased directly from specialty retail stores. Most distributors indicated that they typically enter agreements with manufacturers to only carry products from selected manufacturers.

Based on interviews with manufacturers and distributors, the useful life of commercial dryers is about 14 years. However, distributors believe that owners of commercial dryers often opt to fix old dryers rather than replace them with new ones for cost considerations. Therefore, the effective equipment life including service time after repairs is longer.

4 Energy Usage

4.1 Test Methods

Energy use of clothes dryers varies with load conditions and cycle control settings. A standardized test method allows dryer energy use to be assessed under uniform operating conditions to compare dryer energy performance. The test results can also be used to estimate dryer annual energy use.

4.1.1 Current Test Methods

There are currently no federal or California energy efficiency testing and minimum energy performance standards for commercial clothes dryers. The U.S. DOE has established both test standards and minimum energy performance standards for residential dryers. In August 2011, the U.S. DOE updated the existing standard (DOE 1994 Standard), with new test procedures and minimum energy performance requirements. The new standard will take effect on January 1, 2015, and is referred to as DOE 2015 Standard. Besides the DOE standard, there are a number of test standards established by various domestic and international agencies for residential clothes dryers, as listed below:

- Australian/New Zealand Standards: AS/NZS 2442.1
- American National Standard Institute (ANSI)/ Association of Home Appliance Manufacturers (AHAM): ANSI/AHAM HLD-1: 1992
- International Electrotechnical Commission (IEC) 1121:1991

Table 4.1 below summarizes the differences between these standards. Both of the DOE test standards for residential dryers are included in Table 4.1 as well.

The DOE, AS/NZS and IEC standards have been adopted as energy efficiency test standards in the U.S., Australia/New Zealand and the European Union (EU) respectively. In contrast, the ANSI/AHAM standard was intended to evaluate characteristics deemed significant to dryer functional performance, such as clothes temperature and wrinkling level. While the DOE and ANSI/AHAM standards were designed for evaluation of both natural gas and electric dryers, the AS/NZS and IEC standards only cover electric tumble dryers.

Table 4.1 Comparison of Different Residential Clothes Dryer Test Methods[2]

Rating Condition	DOE 1994 Standard (Effective May 14, 1994)	DOE 2015 Standard (Effective Jan 1, 2015)	AS/NZS 2442.1:1996	ANSI/AHAM HLD-1:1992	IEC 1121:1991
Ambient Air Temperature	24 ±3°C	24 ±3°C	20 ±2°C	24 +3°C	20 ±2°C
Ambient Humidity	50 ±10%	50 ±10%	60 ±5%	50 ±10%	65 ±5%
Load Material	50% cotton & 50% polyester		Mixed load	Mixed load	Towels and sheets
Load Weight[3]	7.00 ±0.7 lb	8.45 ± .085 lb	--	--	--
Initial Moisture Content (IMC)[4]	70 ±3.5%	57.5 ±3.5%	90% ±20g	100 ±1%	70 ±5%
Residual Moisture Content (RMC)	2.5 ±0.5%	2.5 ±0.5%	6%	5 ±1%	0 ~3%
Clothes Temperature Measurement	No	No	Yes	Yes	No
Wrinkling Test	No	No	No	Yes	Under consideration

[2] Adopted from Australian Energy Rating's website

[3] For standard size residential dryers. load weight is measured at bone dry condition. A load reaches the bone dry condition when its weight changes less than one percent after being dried for a minimum of 10 minutes, at the maximum dryer temperature setting.

[4] IMC and RMC are measured as percentages of load weight.

The DOE 1994 standard uses an energy factor (EF) to measure dryer energy efficiency, which is defined as pounds of clothes dried per kWh power consumption. For gas dryers, natural gas energy consumption in Btus is converted to kWh to support the EF calculation. The DOE 2015 standard establishes an expanded EF measure, a combined energy factor (CEF), to include energy use associated with both drying cycles and standby[5] energy use. Both of the two efficiency measures are defined as the pounds of clothes dried per kWh of energy input. Minimum efficiency requirements from both the DOE 1994 and 2015 standards are listed in Table 4.2. The DOE 1994 standard sets separate minimum EF requirements for two size categories of residential clothes dryers, standard size and compact size. Minimum energy performance requirements in the DOE 2015 standard were updated to incorporate new testing parameters as well as the inclusion of standby energy use. For the first time, the updated DOE standards set efficiency requirements for ventless dryers and combination washer-dryers.

Table 4.2 DOE Efficiency Standards for Residential Clothes Dryer[6]

DOE 1994 Standard - Effective May 14, 1994	**EF (lb/kWh)**
i. Electric, Standard (4.4 ft^3 or greater capacity)	3.01
ii. Electric, Compact (120V) (less than 4.4 ft^3 capacity)	3.13
iii. Electric, Compact (240V) (less than 4.4 ft^3 capacity)	2.90
iv. Gas	2.67
DOE 2015 Standard - Effective January 1, 2015	**CEF (lb/kWh)**
i. Vented Electric, Standard (4.4 ft3 or greater capacity)	3.73
ii. Vented Electric, Compact (120V) (less than 4.4 ft3 capacity)	3.61
iii. Vented Electric, Compact (240V) (less than 4.4 ft3 capacity)	3.27
iv. Vented Gas	3.30
v. Ventless Electric, Compact (240V) (less than 4.4 ft3 capacity)	2.55
vi. Ventless Electric, Combination Washer-Dryer	2.08

[5] "Standby mode" means any mode where the product is connected to a main power source and offers user-oriented or protective functions by remote switch, internal sensor, or timer; or continuous functions including information or status displays, including clocks, for regularly scheduled tasks, or sensor-based functions.

[6] Federal Register / Vol. 76, No. 164 / Wednesday, August 24, 2011 / Rules and Regulations, DEPARTMENT OF ENERGY, 10 CFR Part 430, [Docket Number EERE–2007–BT–STD– 0010], RIN 1904–AA89, Energy Conservation Program: Energy Conservation Standards for Residential Clothes Dryers and Room Air Conditioners

4.1.2 Proposed Test Methods

Commercial tumble-type clothes dryers have very similar designs and controls as residential clothes dryers. The predominant difference between the two types of dryers is size, in terms of drum volume. Therefore, the test procedures prescribed in the DOE residential clothes dryer standards can be used for commercial dryers as well. The only testing parameter needing adjustment for commercial dryers is the test load weight in order to accommodate the large range of capacities of commercial dryers.

The CASE study team conducted a laboratory tests to evaluate the feasibility of using the DOE test standards to assess efficiency of commercial clothes dryers. The CASE study team discussed the scope of the tests with a group of stakeholders, including representatives of commercial dryer manufacturers, the Coin Laundry Association, and AHAM (Association of Home Appliance Manufacturers). AHAM and some manufacturers suggested that the majority of the commercial dryer market was represented by MF dryers and 30 lb dryers. They also stated that dryers with very large capacities were used in applications with large variations of load conditions, and that the testing materials used in the DOE test standard were not able to reflect the variations in fabrics and materials dried by those large commercial dryers. With the consideration of stakeholder input, market study results from the CASE study, and available project resources, the CASE study team performed laboratory tests on MF dyers and 30 lb dryers.

The team contacted all major manufacturers asking about model numbers best representing the manufacturers' product lines and soliciting donations of dryers for testing. For those manufacturers who did not provide feedback, the team selected and procured dryers that were representative of manufacturer models available on the market, based on the knowledge gained from local distributors.

The laboratory test report, titled "Commercial Clothes Dryer Tests Report", documents the detailed methodology and results of the testing efforts. The tests included two components: performance sensitivity investigation; and performance rating assessment. The former investigated the dependence of dryer energy performance on different operational parameters, including load weight, fabric type, cycle temperature settings, IMC, and RMC. The latter component assessed dryer efficiencies under a set of recommended test conditions, to support the development of minimum energy performance standards. The study tested gas and electric MF dryers, and 30 lb gas dryers.

Results of a sensitivity investigation provided important information to support adaptation of the DOE residential dryer test standard for commercial dryers. The testing parameter matrix used for the sensitivity investigation is shown below in Table 4.3.

The s verified that the test method provided in the DOE residential dryer test standard could be used for commercial clothes dryers with some modifications according to specifications of commercial dryers. Items requiring modifications are discussed in following sections.

Table 4.3 Dryer Testing Parameter Matrix for Sensitivity Investigation

Dryer	Load Weight	Fabric Type	IMC	RMC	Temp Setting
MF Dryers (Gas & electric)	8.45 lb ±.085 lb	Standard Test Material	47% ± 2.3%	4.5% ± 0.25%, 2.5% ± 0.25%	High
30 lb Dryers (Gas)	20.0 lb ±.20 lb	Standard Test Material	47% ± 2.3%	4.5% ± 0.25%, 2.5% ± 0.25%	High

Product Class

Product analysis in Section 2.1 shows that there is a wide range of dryers available in the market. From an application point of view, there are MFL, COL, and OPL dryers. From a dryer physical specification point of view, MFL dryers are generally smaller than COL and OPL dryers. Large dryers tend to be used more in OPLs than in COLs. For general purposes of product classification, the overall market may be roughly divided into the following product classes:

- MFL dryers (weight capacity less than 20 lb)
- Dryers with weight capacity between 20 and 45 lb
- Dryers with weight capacity between 45 and 70 lb
- Dryers with weight capacity between 70 and 90 lb
- Dryers with weight capacity between 90 and 150 lb
- Dryers with weight capacity between 150 and 250 lb
- Dryers with weight capacity larger than 250 lb

However, these product classifications may not be the best choice for developing efficiency regulations for several reasons. First, Section 2.1 indicated that MFL dryers cannot easily be differentiated from small COL/OPL dryers. Second, the boundaries between the above OPL/COL product classes are not very clear, as shown in Figure 2.3. Future market changes may make the above classifications less practical. Third, within each of the COL/OPL dryer classes above, there is still a variety of dryers with different drum sizes and weight capacities. It will be hard to create a performance metric for all products within a product class.

Given the wide range of available dryer products in the market, and the reasons indicated above, the CASE study team recommends to not use the general product classifications above, to define testing parameters. Instead, it is recommended that the test standards do not include specific product classes. The proposed test load is defined according to dryer drum volume, as discussed below. With this approach, dryer performance is characterized by drum volume. Potential Title 20 dryer performance requirements will be defined by drum volume.

Test Load

The test load is the amount of dry test fabric used in one drying cycle. It is measured as the weight (in pounds) of the test fabric in dry conditions. Test loads were developed according to drum volume.

In the 2015 DOE test standards, the test load for standard-sized residential dryers is 8.45 lb. MFL dryers have similar drum sizes to standard-sized residential dryers and therefore should have the same test load. This amount of test load is smaller than the typical weight capacity of 18 lb for MFL dryers and it therefore represents a "part-load" condition. The laboratory tests indicated that using a "part-load" condition could better reveal the effects of air flow and temperature control optimization.

The average drum volume for available MFL dryers in the market is 7.1 cubic feet. Using the test load of 8.45 lb for this average drum volume leads to a drum filling factor of 1.2 lb/cu.ft. It is recommended that this filling factor be used to define the test load. Therefore for all commercial clothes dryers, the test load (lb) is defined as 1.2×Drum Volume, in cubic feet.

Standby Energy Use

The CASE study team conducted laboratory tests of commercial dryers before U.S. DOE began the rulemaking process to develop the DOE 2015 standard, which included standby energy use in measuring residential dryer efficiency. Therefore, the CASE study team did not investigate standby energy use of commercial dryers. However, measurements of standby energy use for commercial dryers can be performed using the same tool and setup for measuring electrical power consumption during drying cycles. Therefore, the CASE study team recommends that standby energy use be measured following the DOE 2015 test method. The results can be used in the future to develop a combined energy factor (CEF) based performance requirements.

Efficiency Metric

Because the standby energy use for commercial dryers was not tested, the CASE study team recommends that commercial dryer efficiency be measured using EF, instead of CEF. The CASE study team also recommends that natural gas and electric energy consumption be explicitly reported to provide complete energy consumption information.

4.2 Energy Use per Unit for Non-Qualifying Products

Baseline energy use is defined as the average annual energy use by commercial clothes dryers with current energy efficiency performance. Dryers used in different market sectors and with different capacities are expected to have different uses, and therefore have different annual energy use baselines. The team evaluated the baseline energy use for two classes of dryers, MFL dryers and 30 lb dryers, because their efficiencies were obtained from laboratory tests. Baseline energy use for other dryers was not assessed, because their efficiencies were not available.

Table 4.4 below summarizes the baseline energy use, along with the supporting parameters used for the calculation, for the two product classes that minimum efficiency standards are proposed. The product class with drum capacity less than 7.5 cubic feet represents MFL dryers and the other one represents COL dryers. The team tested three classes of commercial dryers: gas MFL dryers, one electric MFL dryer, and gas 30 lb dryers. The average energy factor (EF) by type of dryer was obtained by averaging the test results of dryers. Assumptions on average frequency of use (loads/day) are from the literature referenced in the corresponding footnote. The Consortium for Energy Efficiency (CEE) study on commercial laundries provided the average frequency of use, (loads per day) for MFL washing machines, which was used to estimate the annual energy use for MFL dryers, since all washed clothes are assumed to be dried using dryers. For MFL dryers, the average load weight is assumed to be the same as the test load size specified in DOE's 2015 residential dryer test standards. Since the majority of dryers are used in COLs, the average annual energy consumption of 30 lb dryers is based on annual usage information provided by the Coin Laundry Association for COL dryers, and is assumed to be 20 lb, the same as the proposed test weight.

Table 4.4 Baseline Energy Use for MFL and 30 lb Dryers

Dryer Class	Average EF (lb/kWh)	Average Frequency of Use (loads/day)	Average Load Size (lbs/load)	Unit Electricity Consumption[3] (kWh/yr)	Unit Gas Consumption[3] (therm/yr)
Drum Capacity < 7.5 ft^3,Gas	3.59	3.51	8.45	350	147
Drum Capacity >= 7.5 ft^3 and < 13 ft^3, Gas	2.80	5.52	20	700	732

1. Consortium for Energy Efficiency, 2007
2. CoinLaundry.org: Coin Laundry Industry Overview, average of "3 ~ 8 turns per day"
3. Accordingly to lab testing results, electric and gas respectively accounted for 7.5% and 92.5% of the total energy consumption for MFL gas dryers. Electric and gas energy respectively accounted for 3.2% and 96.8% of the total energy consumption for 30 lb gas dryers accordingly to test results

The 2015 DOE residential dryer standards for the first time include energy consumption associated with standby and off-modes to calculate a Combined Energy Factor (CEF) and mandated minimum levels of CEF. The laboratory tests was conducted before the new DOE test method was developed and, therefore, did not measure dryer energy consumption under standby or off modes. As a result, the above baseline energy use estimation does not include standby energy use.

4.3 Efficiency Measures

The CASE study team conducted literature reviews to provide the following summary of available efficiency measure options. In general, there were two types of efficiency improvement strategies identified: optimization of normal dryer designs and utilization of innovative technologies.

4.3.1 Optimization of Normal Dryer Designs

In general, dryer energy performance is affected by test fabric type, load weight, initial and final moisture content levels, and temperature settings. A typical drying cycle consists of three main phases: transient period, constant-rate drying, and falling rate drying (Lambert 1991). The transient period is characterized by the initial heating of the damp clothes, drum, and chassis, and the rapid increase in the evaporation rate. This period has the highest energy consumption rate among all three phases, as continuous heating is required to bring the whole system to the set temperature. During the constant-rate drying period, drum temperature is maintained and the maximum evaporation rate is achieved and sustained. There is enough moisture in the system so that gradual moisture reduction does not have large impact on the overall evaporation rate, which remains relatively constant during this period. The falling rate period starts after the bulk of the moisture has been removed. This period is marked by a declining evaporation rate as much less moisture is left in the fabric. At the end of a drying cycle, dryer controls may stop heating the air to allow the heat contained in the fabric and drum to evaporate the remaining moisture. This process is called the cool-down period and can be used to reduce energy use. Clothes are cool to the touch after the cool-down period. Optimization of dryer design is based on an understanding of the above operational phases.

Optimization of Operational Parameters

Several researchers investigated the effects of operational variables, such as the heat input, tumble speed, airflow, initial moisture content, and load weight on dryer energy efficiency. Bassily and Colver conducted comprehensive laboratory tests and computer modeling studies to assess opportunities for drying process optimization. They tested dryer performance by varying individual operational variables, while keeping others the same (Bassily 2003). They found that operational variables have large impacts on dryer energy consumption and drying time. They also found air leakage could be a major source of heat loss. Optimum settings of fan speed, drum speed and heat input also exist, depending on load weight and the phase of the dryer cycle. Upon further investigation, Bassily and Colver (2005) found that optimum drum speed decreases as heater input increases, and optimum fan speed increases as heat input increases (if load is held constant). By optimizing heat input and installing a fan speed controller, savings of 20% to 37% could be achieved (Bassily 2005). Since optimum settings depend on load conditions, further research of consumer behavior and operation would be useful, to better understand these interactive effects on dryer efficiencies and performance.

Automatic Termination Controls (ATC)

Automatic Termination Controls (ATCs), based on moisture sensors and or temperature sensors, are available and improve the energy efficiencies of both residential and commercial dryers. ATC technologies reduce energy waste by automatically stopping heat input when the clothes are sensed to be dry and, therefore reduce over-drying. Current federal appliance standards provide credits for ATC functions in the form of either moisture or temperature controls. According to a report published by the U.S. DOE Office of Scientific and Technology Information, General Electric (GE) lab tests have shown a typical automatic cycle dryer over-dries clothing considerably, in some cases, by over 100%, particularly at small and medium load sizes (Richter, 2005). Reducing over-drying with ATC technologies helps to reduce energy use and avoid fabric damage.

Reliability of moisture sensors is key to the performance of ATC technologies. Numerous studies have been dedicated to advancing more reliable sensing technologies and more accurate end-of-cycle moisture content estimation. In general, ATC technologies based on moisture sensors can perform better than those based on temperature sensors. Moisture rods are among the most advanced moisture sensor technologies. They detect clothes moisture content by measuring the conductivity of the clothes in the dryer drum. They can accurately measure middle-range clothes moisture content and can be further improved to measure low-range, i.e. below 15%, moisture content. Measuring exhaust air relative humidity is another moisture sensing technology and their performance can also be impacted by condensation, lint trapping and sensitivity issues. A study shows that these issues can be partially mitigated by incorporating a control scheme with measurements of ambient humidity levels to reduce dryer operating time further by 13% (Deng, 2007).

Possible penetration barriers to applying ATC technologies in commercial dryers are mainly due to the common practices of the market. Coin-operated laundromats currently provide a set amount of time for a set price. Dryer run times are determined by the purchased time regardless of whether the clothes are dried or not. Implementing ATC in coin-operated dryers allows users to know when the clothes are dried and to allow them to retrieve the dried clothes earlier. Users can have the option of applying the un-used time to the next load of clothes. At the least, consumers should be given ATC as an option.

Local weights and measures regulations treat purchased drying time as a commodity, and are sometimes considered to be the reason for not implementing ATC for coin-operated dryers. As previously discussed, this technology does to take away purchased drying time from consumers. It simply gives consumers the option to get dry clothes earlier. Consumers can use any remaining drying time for the next load, continue the current load, or leave it for the next customer. Currently, consumers have the option to stop dryers before the timer stops. The ATC will give them another option, with the benefits of dry clothes with less waiting time, avoiding over-drying, and saving overall energy and drying expenses. This option does not violate any weights and measures regulations.

4.3.2 Utilization of Innovative Technologies

Gas Modulation

Energy savings can be achieved through matching (or modulating) the heat input rate to the moisture content of the load. All commercial dryers currently on the market are equipped with constant heat input burners and with a fixed-speed fan. Depending on the cycle settings and the exhaust flow temperatures, the burner only operates in an on/off fashion. Modulating gas dryer technologies enable the burner heat input rate to better match the load. To provide good feedback to the modulating heat input rate (along with the airflow rate), more advanced moisture sensors are preferred to indicate not just air moisture content, but also fabric moisture content. The technology has yielded encouraging results from preliminary research. Pescatore's report (Pascatore, 2005) shows up to a 25% reduction in energy consumption for small to medium loads, and a 10-15% energy reduction, and up to 35% time savings for large loads. Delicate loads resulted in 18% energy reduction, along with reduced fabric temperatures and dry times. Even though gas modulation is a relatively mature technology, gas modulation-based clothes dryers are not currently available in the market. This might be due to the cost of this technology. Adoption of this technology can bring substantial energy savings since the majority of commercial dryers sold in the California market are natural gas models.

Air Recirculation

Air recirculation is commonly used in industrial processes as a way to reclaim waste heat. This technology has been tested for commercial dryer applications (Williamson, 2004). But test results show that this technology is not easily applicable to clothes dryer applications without additional technology improvements. Unless moisture is removed from the heated dryer air and exhaust gas, the recirculated gas, after mixing with heated air (from either the combustion chamber or the heating element), will recirculate moisture back into the drum. Test results based on commercial dryers show that simple air recirculation strategies exhibited a low moisture evaporation rate, low energy efficiency, and even longer dry times (Williamson, 2004). Further improvement of this technology is needed.

Condensing Dryer

Normal tumble-dryers use ducts to release hot and humid exhaust air to the outside. Condensing dryers eliminate ducts to the outside, by condensing the moisture content in the exhaust using an ambient air-cooled condensing coil. Once the moisture is removed or reduced from the exhaust, the exhaust air can be cycled back to the dryer. This closed loop design is especially attractive to spaces that do not have the option of venting to the outside. Obviously, closed loop design is not applicable to gas clothes dryers, because combustion exhaust needs to be discharged out of the facility for safety consideration. By reusing the exhaust air, closed loop condensing dryers are inherently more efficient than normal electric dryers because some exhaust heat is recovered. Bansal, Braun and Groll's study (2001) showed a closed-loop condensing dryer to be about 7% more efficient than air-vented electric dryers. Studies have also been conducted to investigate refined condensing dryer design options such as open-loop condensing dyers with a heat recovery feature, leakage prevention, high efficiency heat exchangers, and better control systems (Berghel, 2001).

Heat Pump Dryer

Heat pump clothes dryer technology has been in existence for years as an alternative to electric resistance heating models. While heat pump dryers currently account for only 4% of residential market share in most European countries (Nipkow, 2009), the market presence of this technology remains insignificant in the United States as well. The low adoption rate in the United States is probably due to the higher cost of this technology as compared to resistance heating-based dryers. Heat pump dryers may have longer drying times than resistance heating models, because a smaller heat pump is usually used for cost and efficiency considerations.

Heat pump dryers, with an integrated heat recovery exhaust condenser, would be more efficient, because exhaust heat is captured and reused. Under a demonstration project funded by the U.S. DOE and led by TIAX, a modified heat pump clothes dryer delivered 40-50% energy savings with 35oF lower fabric temperatures and similar drying times for regular loads. Delicate loads benefitted from a 10-30° F reduction in temperature with up to 50% energy savings and 30-40% time savings (Pescatore, 2005).

Mechanical Steam Compression Dryer

The French Center for Energy Studies has been developing and demonstrating mechanical steam compression dryers since 1996. Exhaust air is compressed and condensed to remove moisture from the exhaust air. In a 2003 study, French researchers reported that this technology consumes half the energy used by a standard European residential dryer (Palandre, 2003).

Microwave Dryer

Another new dryer technology is microwave clothes dryers. Microwave clothes dryers have the same working principle of a microwave oven. Laboratory prototype testing conducted by the Electric Power Research Institute (EPRI) confirmed that high energy efficiency, shorter drying times, and lower fabric temperatures could be achieved (Kesselring, 1996). However, due to the danger of arcing and overheating caused by voltage differences induced by an electromagnetic field, much research and development work is still needed before the commercialization of microwave dryers (Gerling, 2003).

4.4 Energy Use per Unit for Qualifying Products

The CASE study team considered the following two options for Title 20 Standards improvement:

- Standards Option 1: Establish a standardized test methodology and require selected classes of dryers to be tested, with test results reported to the Energy Commission
- Standards Option 2: Establish minimum energy efficiency performance standards for selected classes of commercial dryers

Standard Option 1 above only requires dryers to be tested, reported and listed and, therefore, may not lead to immediate improvements in dryer efficiencies. Since there have been no former test methods or minimum efficiency requirements for commercial dryers, adoption of a test standard will serve to equip the manufacturers with the testing and energy performance rating procedures to prepare for minimum efficiency requirements in the future.

Standards Option 2 above will have an immediate impact on overall commercial dryer energy uses by forcing less efficient dryer models to meet minimum efficiency levels. Based on the laboratory test results, CASE study team proposes minimum efficiency requirements for two product classes, as shown in Table 4.5. The first product class with drum volume less than 7.5 cubic feet represents MFL dryers. The other product class covers dryers larger than MFL dryers and having a weight capacity less than 45 lbs. This product class presents most of the dryers used in COLs, including the popular 30-lb dryers. No minimum energy performance standards are proposed for electric dryers and for gas dryers with drum volume larger than 13 cubic feet, because the CASE study team did not perform comprehensive performance assessments of these dryers.

Table 4.5 below provides a summary of the proposed minimum EF and the associated energy uses for the two classes of gas dryers. The assumptions of average frequency of use and average load size are the same as those used for the baseline energy use in Table 4.4. The proposed minimum EFs of

3.65 and 3.00 represent a 1.6% and 6.6% improvement over average tested EFs of the corresponding product class, respectively.

Table 4.5 Proposed Energy Use by Class of Dryer

Drum Capacity / Primary Energy Source	Proposed Minimum EF (lb/kWh)	Average Frequency of Use (load/day)	Average Load Size (lb/load)	Unit Electricity Consumption (kWh/yr)	Unit Gas Consumption (therm/yr)
< 7.5 ft^3, Natural Gas	3.65	3.5	8.45	350	143
>= 7.5 ft^3 and < 13 ft^3, Natural Gas	3.00	5.5	20	700	676

5 Market Saturation & Sales

5.1 Current Market Situation

5.1.1 Total Shipments and Stock

The CASE study team was not able to find market studies that provided a comprehensive assessment of installed commercial dryers in California. The team requested product shipment data from manufacturers, but did not receive any responses from manufacturers. Since washers and dryers are installed with matching capacities, the study researched and reviewed market study results for commercial clothes washers in order to estimate annual shipments and stocks of commercial clothes dryers. The estimation results are summarized in Table 5.1, and details of the estimation are included in the following sections.

Table 5.1 Estimated Commercial Dryer Stock and Sales in California

Applications	Annual Shipment		Estimated Current Stock	
	Gas	Electric	Gas	Electric
MFL				
MF Dryers	17,100	900	239,800	12,600
COL				
MF Dryers	3,400	0	47,500	0
30 lb Dryer	8,800	0	122,900	0
OPL				
30 lb Equivalent	4,100	0	58,000	0
Total				
MF Dryers	20,500	900	287,300	12,600
30 lb Equivalent	12,900	0	180,900	0

The CAE study team found two data sources that provide historical shipment information related to commercial clothes washers. The Consortium for Energy Efficiency (CEE) Commercial, Family-Sized Washer Initiative (CEE 2007) reported that approximately 2-3 million commercial family-sized washers were installed in the United States in 2007. The annual shipment was approximately 265,000 units, of which about 42,000, or 16% of the annual sales, were sold to COLs. In a document provided by AHAM to support US DOE standard development for commercial clothes dryers[7], annual shipments of commercial clothes washers were shown to vary between 175,187 and 190,720 units per year for the period 2002–2005. The differences between the two data sources

[7] http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/home_appliances_tsd/appendix_5a.pdf

could be because AHRI data only represents shipments from AHRI members, not the total annual sales.

Based on the CEE data, it was assume that about 2.5 million family-size commercial washers were installed in the United States in 2007. Assuming that California represents 12% of the national laundry appliance market (as California has 12% of the national population), there would be approximately 300,000 family-size commercial washers installed in California in 2007. Again, based on CEE data, 16% of them or 47,500 units were installed in COLs and the remainder, or 84% of 252,400 units, were installed in MFLs. The AHRI's multi-year data shows fluctuating annual shipments without any clear trend of shipment increases or decreases over time. Therefore, the CASE study assumes that the annual shipments in 2013 are similar to those provided by CEE for 2013.

It should be further noted that the above data is only for family-size commercial washers. Other high-capacity commercial clothes washers and washer extractors are widely used in COLs and OPLs. The CASE study team was not able to find any market data related to high-capacity commercial clothes washers and washer extractors.

MFL Applications

MFLs mostly use family-size washers and MF (or residential-style) dryers. These washers and dryers have equivalent capacities and are installed in pairs. The above analysis indicates that there are approximately 252,400 washers installed in California MFLs. Therefore, there are equal numbers of MF dryers installed in MFLs. Manufacturers and distributors indicated that the majority of MFL dryers installed in California were natural gas models. Based on this information, the CASE study team assumed that 95% of MF dryers, or 239,800 units, were gas models and 5%, or 12,600 units, were electric models. Using an average expected useful life of 14 years (see detailed explanation in section 7.2), the stock would be on average replaced with new dryers every 14 years. The annual shipments are estimated to be 17,100 units for gas models and 900 units for electric models.

A very small fraction of the MFLs use large dryers, especially those with capacities around 30 lb. The total number of large dryers in MFLs is expected to negligible compared to those in the COLs and OPLs.

COL Applications

Coin-operated laundromats (COLs) are the most visible laundromat types in the market. According to the Coin Laundry Association (CLA), there are about 35,000 COLs in the United States. California would have about 4,200 of them, based on its population ratio (12% of the nation). There is no definitive market data on the number of dryers installed in these COLs.

The CEE data indicated that about 16% of the commercial family-size washers were installed in COLs. Following the same assumptions used for MFL applications above, there are approximately 47,500 MF dryers installed in COLs in California and the annual shipment to this market sector is about 3,400 units. The majority, if not all, of them are expected to be gas model, because it is much more economical for COL owners to operate gas dryers than electric dryers.

COLs also deploy many large capacity washers and dryers so customers can process large loads easily. Based on communications with manufacturer and CLA representatives, the majority of these large capacity dryers are expected to be 30-lb dryers. According to the CLA, in a mature market, COLs and MFLs evenly split the self-service laundry business, which serve people living in rental housing. Assuming California can be considered a mature market for the self-service laundry business, MFLs and COLs should have equal amounts of clothes drying capacities. The above analysis, based on CEE data, showed 204,900 more MF dryers installed in MFLs than in COLs. To provide the same total capacity, COLs are estimated to have 122,900 units of 30-lb dryers(weight capacity of MF dryers is 18 lb.). The annual shipment is estimated to be 8,800 units, based on an assumption of average expected useful life of 14 years. All of these dryers are expected to be gas models for the reasons explained above.

OPL Applications

On Premise Laundromat (OPL) applications include very diversified end uses. Without detailed market study information, the CASE study team could not use a relatively simple approach to estimate the installed stock for this market sector. The California Urban Water Conversation Council (CUWCC) conducted a study on OPLs to address water use. The CUWCC study reported laundry loads for different types of on-premise facilities in California. Based on these results, the CASE study estimated the number of dryers needed to meet the load according to OPL design guidelines.

The CASE team adopted the calculation method and many of the assumptions made by the CUWCC report. However, the team modified the daily load numbers for universities from 20 to 5 lbs/person/day using our judgment, in an attempt to make the estimation relatively conservative. We added the two public services applications, law enforcement and fire departments, to the table. The results in Table 5.2 show that hotels and motels represented the majority of the total OPL laundry needs, about 60%. A large fraction of hospitality laundry load consists of towels, which require more energy to dry than most other domestic textiles. As a result, the hospitality sector is a more dominant dryer energy consumer.

The CASE study team further estimated the commercial dryer stock utilizing the estimated annual laundry load and an industry dryer design (sizing) guide[8]. OPL facilities use a broad range of commercial dryers and there is no market data that reveals the breakdown of difference types of dyers in each OPL market sector. However, communications with manufacturers and distributors indicated that a 30-lb dryer is a popular model for many market sectors. Therefore, we use it as a proxy to illustrate the overall size of the OPL application. If all OPL market sectors were served by 30 lb dryers, there would be around 47,000 dryers in California OPLs. The corresponding annual shipment to these market sectors is estimated to be 3400 units. Utilizing the reference industry design (sizing) guide placed the low end of the range at 40,000. The high end of the range, 72,000, was obtained when applying the simplistic assumption that the total annual load was served by 30 lb dryers with 20 lbs per load, and 16 cycles per day.

[8] On-Premise Laundromat design guide: http://www.twsystems.citymax.com/f/SpeedQueenDesignIdeas.pdf

Table 5.2 Total Laundered Poundage by Application Type [1]

OPL Market Sector	Facility Capacity		Occupancy %	Daily load (lb/room or person)	Annual load		Number Room or People per Dryer
	Rooms	Population			million lb	% total	
Hotels	225,000		70%	36	2,070	23.2%	40
Motels	750,000		60%	22.5	3,696	41.4%	40
Nursing Homes	160,000		98%	25	1,431	16.0%	20
Hospitals	4,375		70%	25	28	0.3%	20
State Prison		160,000	100%	12	701	7.8%	20
County Jail		87,000	100%	10	318	3.6%	20
Universities						1.3%	40
CSU		46,000	75%	5	63	0.7%	40
UC		18,000	75%	5	25	0.3%	40
Private		20,000	75%	5	27	0.3%	40
Law Enforcement[2]		116,000	100%	5	212	2.4%	20
Fire Department[3]		29,000	100%	5	53	0.6%	20
Health Club[4]	3,660	6,120,000		0.14	319	3.5%	1
TOTAL					8,622	100.0%	

1. The table is adopted(with modifications) from the document Potential Best Management Practices, Chapter IV on Commercial Laundry Facilities prepared for the California Urban Water Conservation Council in Jan 2006.
2. In 2000, California had about 116,000 full-time State and local law enforcement employees (US Dept. of Justice).
3. 29,000 firefighters and inspectors in California (2000 US Census).
4. Number of health clubs is 30,500 the United State in 2012, serving (http://www.ihrsa.org/about-the-industry/.

5.1.2 Market Share of High Efficiency Options

The CASE study team was not able to obtain market share data from commercial dryer manufacturers and distributors, and therefore the study is not able to include an accurate estimate of market penetration of dryers that meet the proposed minimum performance standards. The team tested three MFL gas dryers and four 30 lb gas dryers. If we simply assume each model has equal representation of the corresponding product class, the estimated market penetration of high efficiency models is 30% and 25% respectively, for MFL and 30 lb gas dryers.

5.2 Future Market Adoption of High Efficiency Options

Commercial clothes dryers are not currently required to meet minimum energy efficiency standards. Because of this, the efficiencies of the machines have been largely gone unnoticed by the market. In selecting dryers, owners consider multiple factors including cost, durability, warranty and service, drying speed, and sometimes energy efficiency. Several manufacturers promote energy efficiency as an important feature of their products.

During this study, some manufacturer representatives have expressed concerns to the CASE study team that higher efficiencies could lead to longer drying times. The laboratory tests results did show that dryers with higher efficiencies require slightly longer times to complete the whole drying cycle. It is not clear how the market considers the two factors. Because revenues from coin-operated dryers are based on the "drying time," a fast-drying dryer would not help the owner make more money. On the other hand, an efficient model will help the owner by lowering the utility bills. Once a minimum efficiency standard is established, it becomes possible for dryer owners to compare energy consumption between different dryers, and consideration of energy efficiency on the overall product will increase accordingly. Users of coin-operated dryers are not sensitive to slight changes of drying speed. This is because users tend to fully load the dryer to reduce the number of cycles needed, and therefore cycle times are typically going to be longer. Also, users cannot manage their drying time by small increments (e.g. by one minute increments), because drying time has to be purchased with at least five minute intervals for 30 lb dryers, and ten minutes for MF dryers. It should be further noted that the observation of an inverse correlation between drying speed and energy efficiency is mostly associated with dryers with normal design and control practices. If advanced efficiency technologies, as those discussed in Section 4.3, are incorporated, energy efficiency and drying speed can both be improved. For example, optimized air flow pattern designs can enhance heat and mass transfer in the drum to improve efficiency and increase drying speed. Using heat recovery can effectively increase the total heat input rate into the drum, and therefore improve both energy efficiency and drying speed.

6 Savings Potential

6.1 Statewide California Energy Savings

Statewide baseline energy consumption and the energy consumption according to the proposed standard are calculated following these approaches:

- Energy consumption (stock) = Unit annual energy consumption x dryer stock
- Energy consumption (First year sales) = Unit annual energy consumption x First Year Sales

Unit annual energy consumption values are presented in Sections 3.2 and 3.4 for the baseline and the propose standards, respectively. The annual baseline energy consumption results are presented below in Table 6.1.

Table 6.1 California Statewide Baseline Energy Use

Dryer Product Classification	Total Dryer Stock Annual Electric Energy Consumption (GWh/yr)	Annual Gas Energy Consumption (million therms/yr)
Drum Capacity < 7.5 ft^3 Gas	86	36
Drum Capacity >= 7.5 ft^3 and < 13 ft^3, Gas	149	155
CA Total	235	191

Energy savings resulting from the proposed standard is the difference between the baseline energy consumption and the energy consumption in the proposed standard. The CASE team followed the calculation methodology and spreadsheet tool developed by the IOUs' Title 20 team to calculate the statewide net energy savings. The estimated statewide savings resulting from the proposed standard, following an assumed effective date of 2015 are presented in Table 6.2. Energy savings from "first-year sales" are roughly equal to the "after entire stock turnover" numbers, divided by the equipment useful life of 14 years (See Section **Error! Reference source not found.**, DESIGN IFE). Electricity demand (kW) energy savings are not included in the table because they are expected to be very small. The proposed minimum energy performance standards are only applicable to gas dryers.

Table 6.2 Estimated California Statewide Energy Savings

Product Class	First-Year Sales Annual Electric Consumption (GWh/yr)	First-Year Sales Annual Gas Consumption (million therms/yr)	After Entire Stock Turnover (14 years) Annual Electric Consumption (GWh/yr)	After Entire Stock Turnover (14 years) Annual Gas Consumption (million therms/yr)
Drum Capacity < 7.5 ft^3 Gas	NA	0.06	NA	0.83
Drum Capacity >= 7.5 ft^3 and < 13 ft^3, Gas	NA	0.8	NA	10.9
CA Total	NA	0.86	NA	11.7

6.2 Other Benefits and Penalties

The proposed Standards Option 2 (discussed in Section **Error! Reference source not found.**) ill result in natural gas savings. These savings have been converted to metric tons of CO2 equivalent savings, using a conversion of 5.32e-8 MMTCO2e[9] per 1 MMBtu of natural gas. The results are displayed in Table 6.3 below.

Table 6.3 Estimated California Statewide Greenhouse Gas (GHG) Emission Savings

Design Options	Annual GHG Emission Savings by 2020 (MMT of CO2e/ yr)	Total GHG Emission Savings by 2020 (MMT of CO2e)
Standard Option 2	0.005	0.062

[9] http://www.arb.ca.gov/cc/scopingplan/document/appendices_volume2.pdf

7 Economic Analysis

7.1 Incremental Cost

The CASE study team surveyed various commercial dryer distributors for cost information of the tested dryers. It was found that prices of commercial clothes dryers are not correlated with tested dryer efficiencies. The dryers that performed better, based on the laboratory tests, did not cost more than those that were tested to be less efficient. Dryers with better brand name recognition or higher heat input ratings (kBTU/hr for gas and kW for electric dryers) tend to have higher prices, even though higher heat inputs may lead to lower efficiencies, but faster drying time.

As discussed above, dryer efficiencies are determined by heat exchange and moisture removal processes in the drum, which depends on optimization of air flows, drum speed, and temperature control. These factors can be adjusted through design improvements using the same or similar hardware and other parts. Given that dryers are commodity products, their prices depend heavily on material costs. Since high-efficiency dryer designs do not necessarily have increased material uses, incremental costs for high-efficiency models are expected to be negligible.

7.2 Design Life

Based on interviews with stakeholders, commercial clothes dryer expected useful life (EUL) is expected to be between 13 and 15 years. In contrast, The California Database for Energy Efficient Resources (DEER) sets the residential dryer EUL at 15 years. For the following lifecycle cost analysis, the EUL for commercial clothes dryers is assumed to be 14 years.

7.3 Lifecycle Cost / Net Benefit

Error! Reference source not found. below displays the lifecycle costs and benefits for the roposed minimum performance standard. The present value (PV) of benefits from natural gas energy savings is calculated using the Energy Commission's current forecast (CEC 2010) of average statewide energy rates with a discount rate assumption of 3%.

Table 7.1 Costs and Benefits per Unit for Proposed Standard

Dryer Classification	**EUL** (years)	**Lifecycle Costs per Unit** (PV $)			**Lifecycle Energy Savings Benefits per Unit** (PV $)
		Incremental Cost	Additional Costs	PV Costs	
Drum Capacity < 7.5 ft^3, Gas	14	$0	$0	$0	$63
Drum Capacity >= 7.5 ft^3 and < 13 ft^3, Gas	14	$0	$0	$0	$820

PV = Present Value

Net present values (NPV) of energy savings for first year sales, and after entire stock turnover after 14 years, are calculated based on the statewide energy savings of the proposed standard in Table 6.2. The results are displayed in Table 7.2.

Table 7.2 Lifecycle Costs and Benefits for the Proposed Standards

Product Class	**Lifecycle Benefit/Cost Ratio**[a]	**Net Present Value ($)**[b]		
		Per Unit	First Year Sales	After Entire Stock Turnover [c]
Drum Capacity < 7.5 ft^3, Gas	>1.0	$63	$69,000	$950,000
Drum Capacity >= 7.5 ft^3 and < 13 ft^3, Gas	>1.0	$820	$838,000	$11,460,000

a. Positive value indicates a reduced total cost of ownership over the life of the appliance.
b. This calculation assumes a constant NPV for each year's sales until entire stock turnover (14 years).

8 Acceptance Issues

8.1 Infrastructure issues

For dryers that do not meet the recommended minimum efficiency standards, improvements in system design and control optimizations are required. Such improvements will not require production and market infrastructure changes. Implementing automatic termination controls for coin-operated dryers will require changes to control logics built into the coin collector. Additional display information is needed to inform users that the clothes are dry. Users may need some time to get used to this new feature, which gives them the option to retrieve dried clothes sooner than the drying time based on coin input. These changes do not require infrastructure change, either.

8.2 Existing Standards

There are no state or federal testing or minimum energy performance standards for commercial clothes dryer. Energy performance of residential clothes dryers is regulated by federal standards.

8.3 Stakeholder Positions

The CASE study team presented the recommendation of adopting a Title 20 test method for commercial clothes dryers based on the US DOE test method for residential clothes dryers and minimum efficiency standards for MFL and COL dryers in previous Title 20 scoping workshops. During initial discussions with manufacturers and AHAM, their representatives commented that energy efficiency testing was not suitable for large dryers for OPLs because load conditions in these applications have very large variations.

9 Recommendations

9.1 Recommended Standards Proposal

The CASE study team recommends the following changes to Title 20 Appliance Standards:

- Establish test procedures for all commercial clothes dryers and require manufacturers to report test results to the CEC.
- Establish minimum energy performance standards in terms of energy factors (EF) for MFL and COL gas dryers.

9.2 Proposed Changes to the Title 20 Code Language

The proposed changes will expand existing sections in Title 20 for residential clothes dryers to include commercial clothes dryers as well. The proposed test method is based on the federal test standard for consumer (residential) clothes dryers. The following proposed Title 20 language specifies the necessary changes to the federal test standard (CRF PART 430 SUBPART B APPENDIX D1) to make it suitable for commercial clothes dryers.

The proposed changes to Title 20 language are provided in the following subsections, in which additions to the original language are shown underlined and deletions are shown in strikeout.

Section 1601 (q) Clothes dryers that are federally-regulated consumer products<u> and commercial clothes dryers</u>

Section 1602 (q) Clothes dryers.
Add the following definitions:

<u>“Commercial clothes dryer” means a clothes dryer that is used in multi-family, coin operated, or on-premise laundromats and is not covered by 10 CFR 430.32(h)(3).</u>

<u>“Consumer clothes dryer” means a clothes dryer that is federally-regulated as a consumer product according to 10 CFR 430.32(h)(3).</u>

Section 1604 (q) Clothes dryers.

(1) The test methods for consumer and commercial clothes dryers are shown in Table Q-1~~is 10 CFR Section 430.23(d) (Appendix D to Subpart B of Part 430) (2008)~~.

Table Q-1

Clothes Dryer Test Methods

Appliance	**Test Method**
Consumer clothes dryers	10 CFR Section 430.23(d1) (Appendix D1 to Subpart B of Part 430) (2008)
Commercial clothes dryers	Section 1604 (q) (2)

(2) **Commercial clothes dryers**. The test method for commercial clothes dryers is as follows and is based on the test standard for consumer clothes dryers with modifications according to sizes of commercial clothes dryers:

(A) Definitions

1. “Active mode” means a mode in which the clothes dryer is connected to a main power source, has been activated and is performing the main function of tumbling the clothing with or without heated or unheated forced air circulation to remove moisture from the clothing, remove wrinkles or prevent wrinkling of the clothing, or both.
2. “AHAM” means the Association of Home Appliance Manufacturers.
3. “AHAM HLD–1” means the test standard published by the Association of Home Appliance Manufacturers, titled “Household Tumble Type Clothes Dryers” (2009), AHAM HLD–1–2009 (incorporated by reference; see §430.3).
4. “Automatic termination control” means a dryer control system with a sensor which monitors either the dryer load temperature or its moisture content and with a controller which automatically terminates the drying process. A mark, detent, or other visual indicator or detent which indicates a preferred automatic termination control setting must be present if the dryer is to be classified as having an “automatic termination control.” A mark is a visible single control setting on one or more dryer controls.
5. “Bone dry” means a condition of a load of test clothes which has been dried in a dryer at maximum temperature for a minimum of 10 minutes, removed, and weighed before cool down, and then dried again for 10-minute periods until the final weight change of the load is 1 percent or less.

~~"Compact" or "compact size" means a clothes dryer with a drum capacity of less than 4.4 cubic feet.~~

6. "Conventional clothes dryer" means a clothes dryer that exhausts the evaporated moisture from the cabinet.

7. "Cool down" means that portion of the clothes drying cycle when the added gas or electric heat is terminated and the clothes continue to tumble and dry within the drum.

8. "Cycle" means a sequence of operation of a clothes dryer which performs a clothes drying operation, and may include variations or combinations of the functions of heating, tumbling, and drying.

9. "Drum capacity" means the volume of the drying drum in cubic feet.

10. "IEC 62301" means the test standard published by the International Electrotechnical Commission ("IEC"), titled "Household electrical appliances–Measurement of standby power," Publication 62301 (first edition June 2005) (incorporated by reference; see §430.3).

11. "Inactive mode" means a standby mode that facilitates the activation of active mode by remote switch (including remote control), internal sensor, or timer, or that provides continuous status display.

12. "Moisture content" means the ratio of the weight of water contained by the test load to the bone-dry weight of the test load, expressed as a percent.

13. "Moisture sensing control" means a system which utilizes a moisture sensing element within the dryer drum that monitors the amount of moisture in the clothes and automatically terminates the dryer cycle.

14. "Off mode" means a mode in which the clothes dryer is connected to a main power source and is not providing any active or standby mode function, and where the mode may persist for an indefinite time. An indicator that only shows the user that the product is in the off position is included within the classification of an off mode.

~~"Standard size" means a clothes dryer with a drum capacity of 4.4 cubic feet or greater.~~

15. "Standby mode" means any product modes where the energy using product is connected to a main power source and offers one or more of the following user-oriented or protective functions which may persist for an indefinite time:
(a) To facilitate the activation of other modes (including activation or deactivation of active mode) by remote switch (including remote control), internal sensor, or timer.
(b) Continuous functions, including information or status displays (including clocks) or sensor-based functions. A timer is a continuous clock function (which

may or may not be associated with a display) that provides regular scheduled tasks (e.g., switching) and that operates on a continuous basis.

16. "Temperature sensing control" means a system which monitors dryer exhaust air temperature and automatically terminates the dryer cycle
17. "Ventless clothes dryer" means a clothes dryer that uses a closed-loop system with an internal condenser to remove the evaporated moisture from the heated air. The moist air is not discharged from the cabinet.

(B).Testing Conditions

1. Installation. Install the clothes dryer in accordance with manufacturer's instructions. For conventional clothes dryers, as defined in (A) 6, the dryer exhaust shall be restricted by adding ~~the AHAM~~ an exhaust simulator based on the one described in 3.3.5.1 of AHAM HLD–1 ~~(incorporated by reference; see §430.3)~~. The exhaust simulator shall consist of a straight section of 13.5 inches (344 mm) and a tapered section of 13.25 inches (338 mm). The straight section shall have an inside diameter matching the exhaust pipe diameter of the dryer being tested. The tapered section shall have a linear diameter reduction from the diameter of the straight section to 2 and 9/16 inches (65mm). For ventless clothes dryers, as defined in (A) 21, the dryer shall be tested without the AHAM exhaust simulator. Where the manufacturer gives the option to use the dryer both with and without a duct, the dryer shall be tested without the exhaust simulator. All external joints should be taped to avoid air leakage. If the manufacturer gives the option to use a ventless clothes dryer, as defined in (A) 21, with or without a condensation box, the dryer shall be tested with the condensation box installed. For ventless clothes dryers, the condenser unit of the dryer must remain in place and not be taken out of the dryer for any reason between tests. For drying testing, disconnect all console lights or other lighting systems on the clothes dryer which do not consume more than 10 watts during the clothes dryer test cycle. For standby and off mode testing, the clothes dryer shall also be installed in accordance with section 5, paragraph 5.2 of IEC 62301 (incorporated by reference; see §430.3). For standby and off mode testing, do not disconnect console lights or other lighting systems.
2. Ambient temperature and humidity.
   2.1. For drying testing, maintain the room ambient air temperature at 75 ±3 °F and the room relative humidity at 50 ±10 percent relative humidity.
   2.2. For standby and off mode testing, maintain room ambient air temperature conditions as specified in section 4, paragraph 4.2 of IEC 62301 (incorporated by reference; see §430.3).
3. Energy supply.
   3.1. Electrical supply. Maintain the electrical supply at the clothes dryer terminal block within 1 percent of 120/240 or 120/208Y or 120 volts as applicable to the particular terminal block wiring system and within 1 percent of the nameplate

frequency as specified by the manufacturer. If the dryer has a dual voltage conversion capability, conduct the test at the highest voltage specified by the manufacturer.

3.1.1. Supply voltage waveform. For the clothes dryer standby mode and off mode testing, maintain the electrical supply voltage waveform indicated in section 4, paragraph 4.4 of IEC 62301 (incorporated by reference; see §430.3)

3.2. Gas supply.

3.2.1. Natural gas. Maintain the gas supply to the clothes dryer immediately ahead of all controls at a pressure of 7 to 10 inches of water column. If the clothes dryer is equipped with a gas appliance pressure regulator for which the manufacturer specifies an outlet pressure, the regulator outlet pressure shall be approximately that recommended by the manufacturer. The hourly Btu rating of the burner shall be maintained within ±5 percent of the rating specified by the manufacturer. The natural gas supplied should have a heating value of approximately 1,025 Btus per standard cubic foot. The actual heating value, Hn2, in Btus per standard cubic foot, for the natural gas to be used in the test shall be obtained either from measurements made by the manufacturer conducting the test using a standard continuous flow calorimeter as described in (B) 4.6 or by the purchase of bottled natural gas whose Btu rating is certified to be at least as accurate a rating as could be obtained from measurements with a standard continuous flow calorimeter as described in (B) 4.6.

3.2.2. Propane gas. Maintain the gas supply to the clothes dryer immediately ahead of all controls at a pressure of 11 to 13 inches of water column. If the clothes dryer is equipped with a gas appliance pressure regulator for which the manufacturer specifies an outlet pressure, the regulator outlet pressure shall be approximately that recommended by the manufacturer. The hourly Btu rating of the burner shall be maintained within ±5 percent of the rating specified by the manufacturer. The propane gas supplied should have a heating value of approximately 2,500 Btus per standard cubic foot. The actual heating value, Hp, in Btus per standard cubic foot, for the propane gas to be used in the test shall be obtained either from measurements made by the manufacturer conducting the test using a standard continuous flow calorimeter as described in (B) 4.6 or by the purchase of bottled gas whose Btu rating is certified to be at least as accurate a rating as could be obtained from measurement with a standard continuous calorimeter as described in (B) 4.6.

4. Instrumentation. Perform all test measurements using the following instruments as appropriate.

4.1. Weighing scale for test cloth. The scale shall have a range of 0 to a maximum ~~of~~ that is at least 10% higher than the dryer load defined in 7.1. ~~30 pounds~~ ~~with a~~ The resolution ~~of~~shall be at least 0.2 ounces for dryer load less than or equal to 75 pounds and at least 0.4 ounces for dryer load large than 75 pounds. The ~~and a~~ maximum error shall be no greater than 0.3 percent of the~~any~~ measured value ~~within the range of 3 to 15 pounds~~.

4.1.1. Weighing scale for drum capacity measurements. The scale should have a range of 0 to a maximum that is larger than 20% of the net weight of the test dryer and is not more than 2500 pounds. ~~of 500 pounds with~~The resolution ~~of~~shall be 0.50 pounds and ~~a~~the maximum error shall be no greater than 0.5 percent of the measured value.

4.2. Kilowatt-hour meter. The kilowatt-hour meter shall have a resolution of 0.001 kilowatt-hours and a maximum error no greater than 0.5 percent of the measured value.

4.3. Gas meter. The gas meter shall have a resolution of 0.001 cubic feet and a maximum error no greater than 0.5 percent of the measured value.

4.4. Dry and wet bulb psychrometer. The dry and wet bulb psychrometer shall have an error no greater than ±1 °F.

4.5. Temperature. The temperature sensor shall have an error no greater than ±1 °F.

4.6. Standard Continuous Flow Calorimeter. The calorimeter shall have an operating range of 750 to 3,500 Btu per cubic feet. The maximum error of the basic calorimeter shall be no greater than 0.2 percent of the actual heating value of the gas used in the test. The indicator readout shall have a maximum error no greater than 0.5 percent of the measured value within the operating range and a resolution of 0.2 percent of the full-scale reading of the indicator instrument.

4.7. Standby mode and off mode watt meter. The watt meter used to measure standby mode and off mode power consumption of the clothes dryer shall have the resolution specified in section 4, paragraph 4.5 of IEC 62301 (incorporated by reference; see §430.3). The watt meter shall also be able to record a "true" average power as specified in section 5, paragraph 5.3.2(a) of IEC 62301.

5. Lint trap. Clean the lint trap thoroughly before each test run.

6. Test Clothes.

6.1. Energy test cloth. The energy test cloth shall be clean and consist of the following:
(a) Pure finished bleached cloth, made with a momie or granite weave, which is a blended fabric of 50-percent cotton and 50-percent polyester and weighs within +10 percent of 5.75 ounces per square yard after test cloth preconditioning, and has 65 ends on the warp and 57 picks on the fill. The

individual warp and fill yarns are a blend of 50-percent cotton and 50-percent polyester fibers.
(b) Cloth material that is 24 inches by 36 inches and has been hemmed to 22 inches by 34 inches before washing. The maximum shrinkage after five washes shall not be more than 4 percent on the length and width.
(c) The number of test runs on the same energy test cloth shall not exceed 25 runs.

6.2. Energy stuffer cloths. The energy stuffer cloths shall be made from energy test cloth material, and shall consist of pieces of material that are 12 inches by 12 inches and have been hemmed to 10 inches by 10 inches before washing. The maximum shrinkage after five washes shall not be more than 4 percent on the length and width. The number of test runs on the same energy stuffer cloth shall not exceed 25 runs after test cloth preconditioning.

6.3. Test Cloth Preconditioning.
A new test cloth load and energy stuffer cloths shall be treated as follows:
(1) Bone dry the load to a weight change of ±1 percent, or less, as prescribed in section 1.5.
(2) Place the test cloth load in a standard clothes washer set at the maximum water fill level. Wash the load for 10 minutes in soft water (17 parts per million hardness or less), using 60.8 grams of AHAM standard test detergent Formula 3. Wash water temperature is to be controlled at 140 ° ±5 °F (60 ° ±2.7 °C). Rinse water temperature is to be controlled at 100 ° ±5 °F (37.7 ±2.7 °C).
(3) Rinse the load again at the same water temperature.
(4) Bone dry the load as prescribed in section 1.5 and weigh the load.
(5) This procedure is repeated until there is a weight change of 1 percent or less.
(6) A final cycle is to be a hot water wash with no detergent, followed by two warm water rinses.

7. Test loads.

~~Compact size dryer load. Prepare a bone-dry test load of energy cloths which weighs 3.00 pounds ±.03 pounds. Adjustments to the test load to achieve the proper weight can be made by the use of energy stuffer cloths, with no more than five stuffer cloths per load. Dampen the load by agitating it in water whose temperature is 60 °F ±5 °F and consists of 0 to 17 parts per million hardness for approximately 2 minutes in order to saturate the fabric. Then, extract water from the wet test load by spinning the load until the moisture content of the load is between 54.0–61.0 percent of the bone-dry weight of the test load.~~

7.1. ~~Standard size d~~Dryer load. Prepare a bone-dry test load of energy cloths which weighs ~~8.45 pounds ±.085~~1.2×(drum volume) pounds. Adjustments to the test load to achieve the proper weight can be made by the use of energy stuffer cloths, with no more than five stuffer cloths per load. Dampen the load by agitating it in water whose temperature is 60 °F ±5 °F and consists of 0 to 17 parts per million hardness for approximately 2 minutes in order to saturate the fabric. Then, extract water from the wet test load by spinning the load until the moisture content of the load is between 54.0–61.0 percent of the bone-dry weight of the test load.

7.2. Method of loading. Load the energy test cloths by grasping them in the center, shaking them to hang loosely, and then dropping them in the dryer at random.

8. Clothes dryer preconditioning.

8.1. Conventional clothes dryers. For conventional clothes dryers, before any test cycle, operate the dryer without a test load in the non-heat mode for 15 minutes or until the discharge air temperature is varying less than 1 °F for 10 minutes—whichever is longer—in the test installation location with the ambient conditions within the specified test condition tolerances of 2.2.

8.2. Ventless clothes dryers. For ventless clothes dryers, before any test cycle, the steady-state machine temperature must be equal to ambient room temperature described in 2.2.1. This may be done by leaving the machine at ambient room conditions for at least 12 hours between tests.

(C) Test Procedures and Measurements

1. Drum Capacity. For dryer with a net weight less than 2000 pounds, ~~M~~measure the drum capacity by sealing all openings in the drum except the loading port with a plastic bag, and ensuring that all corners and depressions are filled and that there are no extrusions of the plastic bag through the opening in the drum. Support the dryer's rear drum surface on a platform scale to prevent deflection of the drum surface, and record the weight of the empty dryer. Fill the drum with water to a level determined by the intersection of the door plane and the loading port. Record the temperature of the water and then the weight of the dryer with the added water and then determine the mass of the water in pounds. Add or subtract the appropriate volume depending on whether or not the plastic bag protrudes into the drum interior. The drum capacity is calculated as follows:
   C = w/d

   C = capacity in cubic feet.

   W = weight of water in pounds.

   D = density of water at the measured temperature in pounds per cubic feet.

   Dryers with a net weight equal or larger than 2000 pounds are not required to test drum capacity. For these dryers, use the drum capacity specified by the manufacturer for the following test procedures.

2. Dryer Loading. Load the dryer as specified in (B) 7.

3. Test cycle Operate the clothes dryer at the maximum temperature setting and, if equipped with a timer, at the maximum time setting and dry the load until the moisture content of the test load is between 2.5 and 5 percent of the bone-dry

weight of the test load, but do not permit the dryer to advance into cool down. If required, reset the timer or automatic dry control. If the dryer automatically stops during a cycle because the condensation box is full of water, the test is stopped, and the test run is invalid, in which case the condensation box shall be emptied and the test re-run from the beginning. For ventless dryers, as defined in (A) 21, during the time between two cycles, the door of the dryer shall be closed except for loading (and unloading).

4. Data recording. Record for each test cycle:

   4.1. Bone-dry weight of the test load described in (B) 7.

   4.2. Moisture content of the wet test load before the test, as described in (B) 7.

   4.3. Moisture content of the dry test load obtained after the test described in (C) 3.

   4.4. Test room conditions, temperature, and percent relative humidity described in (B) 2.1.

   4.5. For electric dryers—the total kilowatt-hours of electric energy, Et, consumed during the test described in (C) 3.

   4.6. For gas dryers:

      4.6.1. Total kilowatt-hours of electrical energy, Ete, consumed during the test described in (C) 3.

      4.6.2. Cubic feet of gas per cycle, Etg, consumed during the test described in (C) 3.

      4.6.3. Correct the gas heating value, GEF, as measured in (B) 3.2.1 and (B) 3.2.2, to standard pressure and temperature conditions in accordance with U.S. Bureau of Standards, circular C417, 1938.

~~5 Test for automatic termination field use factor. The field use factor for automatic termination can be claimed for those dryers which meet the requirements for automatic termination control, defined in (A) 4.~~

5. Standby mode and off mode power. Establish the testing conditions set forth in Section (B) "Testing Conditions" of this appendix, omitting the requirement to disconnect all console light or other lighting systems on the clothes dryer that do not consume more than 10 watts during the clothes dryer test cycle in section (B) 1. If the clothes dryer waits in a higher power state at the start of standby mode or off mode before dropping to a lower power state, as discussed in section 5, paragraph 5.1, note 1 of IEC 62301 (incorporated by reference; see §430.3),wait until the clothes dryer passes into the lower power state before starting the measurement. Follow the test procedure specified in section 5, paragraph 5.3 of IEC 62301 for testing in each possible mode as described in (C) 6.1 and (C) 6.2, except allow the product to stabilize for 30 to 40 minutes and use an energy use measurement period of 10 minutes. For units in which power varies over a cycle, as described in section 5, paragraph 5.3.2 of IEC 62301, use the average power approach described in

paragraph 5.3.2(a) of IEC 62301, except allow the product to stabilize for 30 to 40 minutes and use an energy use measurement period not less than 10 minutes.

5.1. If a clothes dryer has an inactive mode, as defined in (A) 11, measure and record the average inactive mode power of the clothes dryer, PIA, in watts.

5.2. If a clothes dryer has an off mode, as defined in (A) 15, measure and record the average off mode power of the clothes dryer, POFF, in watts.

(D) Calculation of Derived Results From Test Measurements

1. Total Per-cycle electric dryer energy consumption. Calculate the total electric dryer energy consumption per cycle, Ece, expressed in kilowatt-hours per cycle and defined as:

   Ece= [53.5/(Ww−Wd)] × Ett× field use,

   Where:

   53.5 = an experimentally established value for the percent reduction in the moisture content of the test load during a laboratory test cycle expressed as a percent.

   field use = field use factor.

   = 1.18 for clothes dryers with time termination control systems only without any automatic termination control functions.

   = 1.04 clothes dryers with automatic control systems that meet the requirements of the definition for automatic control systems in 1.4, 1.14 and 1.18, including those that also have a supplementary timer control, or that may also be manually controlled.

   Ww= the moisture content of the wet test load as recorded in (C) 4.2.

   Wd= the moisture content of the dry test load as recorded in (C) 4.3.

2. Per-cycle gas dryer electrical energy consumption. Calculate the gas dryer electrical energy consumption per cycle, Ege, expressed in kilowatt-hours per cycle and defined as:
   Ege= [53.5/(Ww−Wd)] × Ete× field use,
   Where:
   Ete= the energy recorded in (C) 4.6.1 field use, 53.5, Ww, Wdas defined in (D) 1.

3. Per-cycle gas dryer gas energy consumption. Calculate the gas dryer gas energy consumption per cycle, Ege, expressed in Btus per cycle as defined as:
   Egg= [53.5/(Ww− Wd)] × Etg× field use × GEF
   Where:
   Etg= the energy recorded in (C) 4.6.2
   GEF = corrected gas heat value (Btu per cubic feet) as defined in (C) 4.6.3, field use, 53.5, Ww, Wdas defined in (D) 1.

4. Total per-cycle gas dryer energy consumption expressed in kilowatt-hours. Calculate the total gas dryer energy consumption per cycle, Ecg, expressed in kilowatt-hours per cycle and defined as:
   Ecg= Ege+ (Egg/3412 Btu/kWh)
   Where:
   Ege as defined in (D) 2
   Egg as defined in (D) 3
5. Per-cycle standby mode and off mode energy consumption. Calculate the dryer inactive mode and off mode energy consumption per cycle, ETSO, expressed in kWh per cycle and defined as:
   ETSO= [(PIA× SIA) + (POFF× SOFF)] × K/283
   Where:
   PIA= dryer inactive mode power, in watts, as measured in section (C) 6.1;
   POFF= dryer off mode power, in watts, as measured in section (C) 6.2.
   If the clothes dryer has both inactive mode and off mode, SIA and SOFF both equal 8,620 ÷ 2 = 4,310, where 8,620 is the total inactive and off mode annual hours;
   If the clothes dryer has an inactive mode but no off mode, the inactive mode annual hours, SIA, is equal to 8,620 and the off mode annual hours, SOFF, is equal to 0;
   If the clothes dryer has an off mode but no inactive mode, SIA is equal to 0 and SOFF is equal to 8,620
   Where:
   K = 0.001 kWh/Wh conversion factor for watt-hours to kilowatt-hours; and
   283 = representative average number of clothes dryer cycles in a year.
6. Per-cycle combined total energy consumption expressed in kilowatt-hours. Calculate the per-cycle combined total energy consumption, ECC,expressed in kilowatt-hours per cycle and defined for an electric clothes dryer as:
   ECC= Ece+ ETSO
   Where:
   Ece= the energy recorded in (D) 1, and
   ETSO= the energy recorded in (D) 7, and defined for a gas clothes dryer as:
   ECC= Ecg+ ETSO
   Where:
   Ecg= the energy recorded in (D) 4, and
   ETSO= the energy recorded in (D) 7.
7. Energy Factor in pounds per kilowatt-hour. Calculate the energy factor, EF, expressed in pounds per kilowatt-hour and defined for an electric clothes dryer as:
   EF = Wbonedry/Ece
   Where:
   Wbonedry= the bone dry test load weight recorded in (C) 4.1, and
   Ece= the energy recorded in (D) 1, and
   and defined for a gas clothes dryer as:
   EF = Wbonedry/Ecg

Where:
Wbonedry= the bone dry test load weight recorded in <u>(C) </u>4.1, and
Ecg= the energy recorded in <u>(D) </u>4,

8. Combined Energy Factor in pounds per kilowatt-hour. Calculate the combined energy factor, CEF, expressed in pounds per kilowatt-hour and defined as:
   CEF = Wbonedry/ECC
   Where:
   Wbonedry= the bone dry test load weight <u>(C) </u>4.1, and
   ECC= the energy recorded in <u>(D) </u>6

Section 1605.1 (q) Clothes dryers

Add the following at the end of the section:

<u>Commercial clothes dryers are not regulated by federal energy efficiency standards.</u>

Section 1605.2 (q) Clothes dryers

No change.

Section 1605.3 (q) Clothes dryers

See Section 1605.1(q) for energy efficiency standards and energy design standards for clothes dryers that are federally-regulated consumer products.

<u>The energy factor for commercial clothes dryers with weight capacity less than 40 lb, and manufactured on or after January 1, 2015 shall be greater than the applicable values shown in Table Q-2.</u>

<u>Table Q-2</u>

<u>Standards for Commercial Clothes Dryers</u>

<u>Product Class</u>	**<u>Minimum Energy Factor (lbs/kWh)</u>**
<u>Drum Capacity <7.5 ft^3, Gas</u>	<u>3.65</u>
<u>Drum Capacity >= 7.5 ft^3 and < 13 ft^3, Gas</u>	<u>3.00</u>

Section 1606 . Clothes Dryers

Modify section Q in Table X:

	Appliance	Required Information	Permissible Answers
Q	Residential Clothes Dryers	Energy Source	Natural Gas, Electric
		Drum Capacity	Cubic feet (ft^{3})
		Voltage	120 v, 240 v, other (specify)
		Combination Washer/Dryer	Yes, No
		Automatic Termination Control	Yes, No
		Energy Factor	
		Constant Burning Pilot Light (Gas Model only)	Yes, No
	Commercial Clothes Dryers	Energy Source	Natural Gas, Electric
		Drum Capacity	Cubic feet (ft^{3})
		Voltage	120 v, 240 v, other (specify)
		Automatic Termination Control	Yes, No
		Total Per-cycle electric dryer energy consumption (Ece)	kWh
		Per-cycle gas dryer electrical energy consumption (Ege)	kWh
		Per-cycle gas dryer gas energy consumption (Egg)	Btu
		Per-cycle standby mode and off mode energy consumption (ETSO)	kWh
		Energy Factor	
		Combined Energy Factor	
		Constant Burning Pilot Light (Gas Model only)	Yes, No

10 References

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Appendix A: List of Dryer Products

Table A.1 Commercial Clothes Dryer Models[10]

Commercial Clothes Dryer Models	Weight Capacity (lb of dry clothes)	Drum Size (cubic feet)	Heat Input Btu/h (gas)	Heat Input kW (Electric)	Air Flow (cfm)	Motor Power (hp)
ADC AD-285	30	10.2	72	NA	375	0.50
ADC AD-30V	30	12.5	100	20-24 kW	460	0.5
ADC AD-50V	50	18.3	150	20-30 kW	750	0.75
ADC AD-78	75	22.4	204	23 - 36 kW	1200	1
ADC AD-758V	75	21.5	175	30	1000	1
ADC AD-22	22	7.5	26	4.1 - 5.4	220	0.333
ADC AD-24	24	8.1	60	18-24	400	0.5
ADC AD-25V	25	9.3	78	15-24	460	0.5
ADC AD-115	115	33.1	343	60-72	2100	0.75
ADC AD-200	200	74.5	650	NA	5300	3
ADC AD-310	310	106.5	1125	NA	6500	5
ADC AD-410	410	143.0	1400	NA	9200	7.5
ADC AD-464	464	175.0	2800	NA	13000	7.5
ADC AD-320	20x2	8.4	60	15	400	0.333

[10] Products presented in this table are based on market survey conducted in 2012.

ADC AD-222	22x2	7.5	26	5.4	220	0.333
Commercial Clothes Dryer Models	**Weight Capacity (lb of dry clothes)**	**Drum Size (cubic feet)**	**Heat Input Btu/h (gas)**	**Heat Input kW (Electric)**	**Air Flow (cfm)**	**Motor Power (hp)**
ADC AD-333	30x2	10.1	72	NA	400	0.50
ADC AD-330	30x2	10.1	68	15	400	0.333
ADC AD-30x2	30x2	11.0	72	NA	450	0.24
ADC AD-236	30x2	10.1	160	NA	400	0.5
ADC AD-4545	45x2	14.6	112	NA	600	0.75
ADC AD-444	45x2	14.6	106	NA	530	0.75
Cissell-CT025	25	7.7	64	12	500	NA
Cissell-CT030	30	9.4	73	21	500	NA
Cissell-CT035	35	12.3	90	24	650	NA
Cissell-CT055	55	17.3	112	27	700	NA
Cissell-CT050	50	18.6	130	30	750	NA
Cissell-CT075	75	22.4	165	30	920	NA
Cissell-CT120	120	36.1	270	118.5	1600	NA
Cissell-CT170	170	49.7	395	187.7	2450	NA
Cissell-CT 55 LB	55	17.3	112	27	700	0.5
Continental Girbau-Econ-o-dry	NA	7	25	4.75	220	0.333
Continental Girbau-E-Series	25	7	25	NA	220	0.333
Continental Girbau-CG20-30	30	7.7	64	12	500	0.25

Continental Girbau-CG30-40	40	12.3	90	24	650	0.25
Commercial Clothes Dryer Models	**Weight Capacity (lb of dry clothes)**	**Drum Size (cubic feet)**	**Heat Input Btu/h (gas)**	**Heat Input kW (Electric)**	**Air Flow (cfm)**	**Motor Power (hp)**
Continental Girbau-CG55-65	60	17.3	112	27	700	0.5
Continental Girbau-CG50-60	65	18.6	130	30	750	0.5
Continental Girbau-CG75-85	85	22.4	165	30	920	0.75
Continental Girbau-CG115-125	125	36.1	270	60	1600	0.75
Continental Girbau-CG165-175	175	49.7	395	NA	2450	0.75
Continental Girbau-KTT30	30	10.6	73	21	400	0.25
Continental Girbau-KTT45	45	14.8	95	NA	600	0.5
Continental Girbau-KTT030	30	9.6	73	21	500	0.25
Continental Girbau-KTT055	55	17.3	112	27	700	0.5
Continental Girbau-KTT075	75	22.4	165	30	920	0.75
Dexter-DCTD30KC	30	12.1	90	24-30	830	NA
Dexter-DCWD55KC	55	18.2	160	24-30	910	NA
Dexter-DCWD80KC	80	23	215	30-36	1200	NA
Dexter-DDBD50KC	50	15.84	108	NA	600	NA
Dexter-DCTD30HC	30	12.1	90	20-30	830	NA
Dexter-DCWD55HC	55	18.2	160	24-30	910	NA
Dexter-DCWD80HC	80	23	215	30-36	1200	NA
Dexter-DDAD30HC	30	11.25	90	20-24	600	NA

Dexter-DDBD50HC	50	15.84	108	NA	600	NA
Commercial Clothes Dryer Models	**Weight Capacity (lb of dry clothes)**	**Drum Size (cubic feet)**	**Heat Input Btu/h (gas)**	**Heat Input kW (Electric)**	**Air Flow (cfm)**	**Motor Power (hp)**
Electrolux-T4290	29	10.1	71.7	18	406	1.36
Electrolux-T5290	32.3	10.2	71.7	18	359	1.22
Electrolux-T4530	60	18.6	136.5	30	683	1.36
Electrolux-T5550	61.15	19.4	112.7	32	553	3.06
Electrolux-T4650	77	23	194.4	36	883	2.72
Electrolux-T5675	75.1	23.8	143.4	40	671	3.06
Electrolux-T4900	100	31.8	218.4	60	1354	4.49
Electrolux-T41200	135	42.4	279.9	72	1471	4.49
Huebsch-HT025	25	7.7	64	12	430	NA
Huebsch-HT030	30	9.6	73	21	430	NA
Huebsch-HTT30	30	10.6	73	21	340	NA
Huebsch-HT035	35	12.3	90	24	550	NA
Huebsch-HTT45	45	14.8	87	NA	500	NA
Huebsch-HTT055	55	17.3	102	27	600	NA
Huebsch-HTT120	120	36.1	270	NA	1600	NA
Huebsch-HTT170	170	49.7	395	NA	2450	NA
Huebsch-HTT050	50	18.6	130	30	750	NA
Huebsch-HTT075	75	22.4	165	30	750	NA

IPSO-IPD30ST	30	10.6	73	21	400	NA
Commercial Clothes Dryer Models	**Weight Capacity (lb of dry clothes)**	**Drum Size (cubic feet)**	**Heat Input Btu/h (gas)**	**Heat Input kW (Electric)**	**Air Flow (cfm)**	**Motor Power (hp)**
IPSO-IPD45ST	45	14.8	95	NA	600	NA
IPSO-IPD50	50	18.6	130	30	750	NA
IPSO-IPD75	75	22.4	165	30	920	NA
IPSO-IPD120	120	36.1	270	NA	1600	NA
IPSO-IPD170	170	49.7	395	NA	2450	NA
Maytag-MDG31PD	30	11.04	55	NA	360	0.25
Maytag-MDG50PCCWW	50	18.3	150	NA	750	0.75
Maytag-MDG76PC	75	22.4	204	NA	1200	1
Maytag-MDG51PD	50	16.02	90	NA	525	1
Maytag-MDG77PD	75	22.1	110	NA	560	1
Maytag-MLG31PC	30	10.1	68	NA	400	0.333
Maytag-MLG33PD	30	11.04	55	NA	360	0.25
Maytag-MLG45PBD	45	14.8	112	NA	600	0.75
SpeedQueen-55 lb Vended Single Pocket	55	17.3	112	27	700	0.5
SpeedQueen-ST025	25	7.7	64	12	500	0.25
SpeedQueen-ST030	30	9.6	73	21	500	0.25
SpeedQueen-ST035	35	12.3	90	24	650	0.25
SpeedQueen-ST055	55	17.3	112	27	700	0.5

SpeedQueen-ST050	50	18.6	130	30	750	0.5
Commercial Clothes Dryer Models	**Weight Capacity (lb of dry clothes)**	**Drum Size (cubic feet)**	**Heat Input Btu/h (gas)**	**Heat Input kW (Electric)**	**Air Flow (cfm)**	**Motor Power (hp)**
SpeedQueen-ST075	75	22.4	165	30	920	0.75
SpeedQueen-STT30	30	10.6	146	21	400	0.25
SpeedQueen-STT45	45	14.8	190	NA	600	0.5
UniMac-25	25	7.7	64	12	500	0.25
UniMac-30	30	9.6	73	21	500	0.25
UniMac-35	35	12.3	90	24	650	0.25
UniMac-55	55	17.3	112	NA	700	0.5
UniMac-T30	30	10.6	73	24	400	0.25
UniMac-T45	45	14.8	95	NA	600	0.5
Wascomat-TD30x30	30	10.6	71.7	18	354	NA
Wascomat-TD45x45	45	14.6	94	18	n/a	NA
Wascomat-TD35	35	10.2	71.7	13.5	325	NA
Wascomat-TD67	67	19.4	112.7	24	550	NA
Wascomat-TD83	83	23.8	143.4	24	670	NA
MFL Dryer Models						
Huebsch-LEZ27/LGZ27	NA	7	22.5	5	NA	0.333
Maytag-MLE/MLG20PDB	NA	6.7	24	5.6	230	0.333
Maytag-MLE/MLG20PRB	NA	6.7	24	5.6	230	0.333

IPSO-BDG909,BDE907	NA	7	NA	NA	NA	0.333
Commercial Clothes Dryer Models	**Weight Capacity (lb of dry clothes)**	**Drum Size (cubic feet)**	**Heat Input Btu/h (gas)**	**Heat Input kW (Electric)**	**Air Flow (cfm)**	**Motor Power (hp)**
IPSO-PSG909, BSE907	NA	7	NA	NA	NA	0.333
Maytag-MDE/MDG17CS	18	7.4	24	5.6	230	0.33
Maytag-MDE/MDG17PD	18	7.4	24	5.6	230	0.33
Maytag-MDE/MDG17PR	18	7.4	24	6	230	0.33
Maytag-MDE/MDG25PD	18	6.7	24	5.6	230	0.333
Whirlpool-CEM2940TQ	NA	7	NA	5.6	NA	0.333
Whirlpool-CGM2941TQ	NA	7	22	NA	NA	0.333
Whirlpool-CEM2750TQ	NA	7.4	NA	5.6	NA	
Whirlpool-CGM2751TQ	NA	7.4	22	NA	NA	0.333
Whirlpool-CED8990XW/CDG8990XW/YCED8990XW	NA	6.7	24	5.6	NA	0.333
Whirlpool-GCEM2990TQ	NA	7	NA	5.6	NA	0.333
Whirlpool-GCGM2991TQ	NA	7	22	NA	NA	0.333
Whirlpool-CEM2760TQ / YCEM2760TQ	NA	7.4	NA	5.6	NA	0.333
Whirlpool-CGM2761TQ	NA	7.4	22	NA	NA	0.333
Whirlpool-CET8000XQ / CGT8000XQ	NA	6.7	24	5.6	NA	0.25
Whirlpool-CSP2760TQ	NA	7.4	NA	5.6	NA	2x0.333
Whirlpool-CSP2761TQ	NA	7.4	22	NA	NA	2x0.333

GE-DCCB330GJ	NA	7	20	NA	NA	NA
Commercial Clothes Dryer Models	**Weight Capacity (lb of dry clothes)**	**Drum Size (cubic feet)**	**Heat Input Btu/h (gas)**	**Heat Input kW (Electric)**	**Air Flow (cfm)**	**Motor Power (hp)**
GE-DMCD30GJ	NA	7	20	NA	NA	NA
GE-DDC4400T	NA	5.4	NA	5.6	NA	NA
GE-DCCB330EJ	NA	7	NA	5.6	NA	NA
GE-DDC4500T	NA	5.4	22	NA	NA	NA
GE-DMCD330EJ	NA	7	NA	5.6	NA	NA
GE-DNCD450EG/GG	NA	7	NA	5.6	NA	NA

Table A.2 Examples of Residential Clothes Dryer Models[11]

Model	Weight Capacity (lb of dry clothes)	Drum Size (cubic feet)	Heat Input		Air Flow (cfm)	Motor Power (hp)
			Btu/h (gas)	kW (Electric)		
Electrolux-EIMED55I	NA	8.0	NA	5.4	NA	NA
Electrolux-EIMGD55I	NA	8.0	20	NA	NA	NA
GE-GTDP180EDWW	NA	6.8	NA	5.6	NA	NA
GE-GTDL200GMWW	NA	7	22	NA	NA	NA
GE-PTDN805GMMS	NA	7.3	25	NA	NA	NA
LG-DLE2250W	NA	7.1	NA	7.2	NA	NA
LG-DLEX8000V	NA	9	NA	7.2	NA	NA
Samsung-DV210AEW/XAA	NA	7.3	NA	5.3	NA	NA

[11] Products presented in this table are based on market survey conducted in 2012.