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# NEEA Dryer Test Procedure Version 2.0 – Summary of Changes and Rationale

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# Table of Contents

## List of Tables



## List of Figures

## Glossary of Terms and Acronyms

| Term/Acronym | Definition/Meaning |
|---|---|
| **AHAM** | Association of Home Appliance Manufacturers |
| **AHAM Cotton** | Association of Home Appliance Manufacturers (AHAM) 100% cotton load of sheets, pillowcases, and towels as specified by AHAM HLW-2-2020 and IEC 60456 (2010), Annex C. |
| **Appendix D2** | U.S. DOE's Appendix D2 for amended test procedure for clothes dryers, specified in 10 CFR Part 430, Subpart B. |
| **Appendix J2** | U.S. DOE's Appendix J2 for amended test procedure for consumer clothes washers, specified in 10 CFR Part 430, Subpart B. |
| **CEF** | combined energy factor |
| **CFR** | Code of Federal Regulations |
| **cu ft** | cubic foot or cubic feet |
| **DOE** | U.S. Department of Energy |
| **DOE 50/50** | DOE-designated textiles for Appendix D2 and other laundry test procedures; comprised of standard-sized momie cloths made of 50 percent cotton, 50 percent polyester. |
| ***eco*** | A dryer test run with an 8.45 lb load and other parameters as listed in Table 1. |
| **ENERGY STAR® program** | A partnership between private and public sector organizations and the federal government. The name and mark are registered trademarks owned by the U.S. EPA. Through this partnership, organizations may receive authorization to use one or more of the ENERGY STAR trademarks to identify and promote their certified products and/or to highlight their partnership with ENERGY STAR. |
| **EPA** | U.S. Environmental Protection Agency |
| ***fast*** | A dryer test run with an 8.45 lb load and other parameters as listed in Table 1. |
| **FMC** | final moisture content: the ratio of the weight of water contained by the dry test load (i.e., after completion of the drying cycle) to the bone-dry weight of the test load, expressed as a percent. |
| **IEC** | International Electrotechnical Commission |
| **IMC** | initial moisture content: the ratio of the weight of water contained by the damp test load (i.e., prior to completion of the drying cycle) to the bone-dry weight of the test load, expressed as a percent. |
| ***large*** | A dryer test run with a large-sized load. |
| **lb** | pound or pounds |
| **NEEA** | Northwest Energy Efficiency Alliance |
| **NPCC** | Northwest Power and Conservation Council |
| **PG&E** | Pacific Gas & Electric |
| **QPL** | qualified product list |
| **RBSA** | Residential Building Stock Assessment |
| **ESRPP** | ENERGY STAR Retail Products Platform |
| **RTF** | Regional Technical Forum (Advisory Committee of the NPCC) |
| ***small*** | A dryer test run with a 4.2 lb load. |
| **UCEF** | utility combined energy factor |

## Executive Summary

In 2022, the Northwest Energy Efficiency Alliance (NEEA) updated its Clothes Dryer Test Procedure Version 1.2 to Version 2.0. Key changes included:

1. Adopting the Association of Home Appliance Manufacturers (AHAM) / International Electrotechnical Commission (IEC) 100% cotton test load (AHAM Cotton) as the supplemental load,
2. Reducing the number of total tests from five to three,
3. Changing the definition of utility combined energy factor (UCEF), and
4. Making other minor adjustments to improve the protocol.

Table ES-1 details the list of Version 2.0 tests that replace those found in Version 1.2. Test Procedure Version 2.0 also uses manufacturer-reported Appendix D2 combined energy factor (CEF) values to calculate the UCEF. Changes from similar Version 1.2 tests are highlighted in bold.

***Table ES - 1. Test Runs in Test Procedure Version 2.0***

| Test | Test Name | Load Type | Cycle Setting | Cycle Temp | Initial Dryness Setting | Load Weight (lb) | IMC | FMC |
|---|---|---|---|---|---|---|---|---|
| One | *small* | **AHAM Cotton** | Normal | Medium | Middle | 4.22 | 62% | **6%** |
| Two | *large* | **AHAM Cotton** | Normal | Medium | Middle | **< 4.4 cu ft:** 10.2<br>≥ **4.4 cu ft:** 16.9 | 62% | **6%** |
| Three | *fast* | **AHAM Cotton** | Heavy Duty | High | Highest | 8.45 | 62% | 4% |

Notes: Changes to similar test runs relative to Version 1.2 of the test procedure are shown **in bold**.
IMC = initial moisture content, FMC = final moisture content

Compared to Version 1.2, Version 2.0 is more reasonable (i.e., it lowers the test burden) and also improves repeatability, reproducibility, and representativeness. NEEA developed a crosswalk methodology to translate Version 1.2 results into Version 2.0 results. The estimated regional energy savings increased only slightly (7%) with the application of this new test procedure to the existing Northwest Power and Conservation Council (NPCC) Regional Technical Forum (RTF) savings methodology. Given this, the regional energy savings methodology update is unlikely needed on an accelerated timetable.

## 1. Introduction

In 2022, the Northwest Energy Efficiency Alliance (NEEA) updated its Clothes Dryer Test Procedure Version 1.2 (Dymond 2017) to Test Procedure Version 2.0 (NEEA 2022a). Version 1.2 (Table 1), originally developed by NEEA and Pacific Gas and Electric (PG&E), was designed to supplement the U.S. Department of Energy (DOE) Appendix D2 test procedure (CFR 2021a) to enhance understanding of the realistic energy efficiency of residential clothes dryers. Version 1.2 revealed significant opportunities to improve the energy efficiency of dryers that otherwise would have remained opaque. The list of five required Version 1.2 tests is shown in Table 1 below.

***Table 1.*** ***Tests Runs in Test Procedure Version 1.2***

| Test | Test Name | Load Textile Type | Cycle Setting | Cycle Temp | Initial Dryness Setting | Load Weight (lb) | IMC | FMC |
|---|---|---|---|---|---|---|---|---|
| DOE [a] | DOE | DOE 50/50 | Default | Highest available [b] | Middle | 8.45 | 57.5% | 2% |
| One | *small* | Lands' End[c] | Normal | Medium | Middle | 4.22 | 62% | 4% |
| Two | *large* | Lands' End | Normal | Medium | Middle | 16.9 | 62% | 4% |
| Three | *eco* | Lands' End | Mfr Defined | Mfr Defined | Middle | 8.45 | 62% | 4% |
| Four | *fast* | Lands' End | Heavy Duty | High | Highest | 8.45 | 62% | 4% |

[a] Version 1.2 requires this independent test for all dryers with a 4.0 cu ft and larger drum. This differs from Appendix D2, which uses a 3.0 lb load for dryers up to 4.4 cu ft and an 8.45 lb for 4.4 cu ft and larger.
[b] Highest available by default is usually a lower "eco" temperature for ENERGY STAR qualified dryers.
[c] See www.landsend.com.

Notes: DOE = U.S. Department of Energy, DOE 50/50 = DOE-designated textiles for Appendix D2 and other laundry test procedures (comprised of standard-sized momie cloths made of 50 percent cotton, 50 percent polyester), Mfr = Manufacturer, lb = pound, IMC = initial moisture content, FMC = final moisture content

Over the last five years, NEEA applied Version 1.2 to test more than 60 dryers—most of them electric—to gather information on dryer energy efficiency and qualify heat pump dryers for its market transformation program.[1] NEEA's data revealed five key opportunities for test procedure improvement, specifically: improving the reproducibility of the test textile load, eliminating multiple "eco mode" tests, eliminating duplicate Appendix D2 runs, improving the representation of the compact dryer load size, and changing the FMC approach. Each opportunity is detailed below.

***Improving reproducibility of the test textile load.*** To increase NEEA's confidence that efficient dryers perform as expected in homes, Version 1.2 uses a more realistic test load made up of bath towels, jeans, and other articles of clothing purchased from Lands' End. Clothing styles change over time, and loads lose lint with each run. Manufacturers have expressed concern over the fair comparison of the efficiency of a competitor product, especially for dryers that are tested months or years apart.

[1] NEEA Launches Super-Efficient Dryer Initiative. Portland, Oregon: NEEA. Article available at: https://neea.org/news/neea-launches-super-efficient-dryer-initiative.

***Eliminating multiple "eco mode" tests.*** As a result of the ENERGY STAR® program (EPA 2017), many dryers now operate in "eco mode" by default and are, therefore, tested in this efficient mode for the DOE Appendix D2 test (EPA 2017). While eco mode was not commonly the default setting when NEEA and PG&E developed the protocol, Test Procedure Version 1.2 contains two test runs with eco mode, which is more than needed to represent the field use of this mode. Therefore, eliminating the eco reduces testing costs.

***Eliminating duplicate Appendix D2 test runs to reduce unnecessary costs.*** Version 1.2 requires the dryer to be tested nearly identically (but not exactly) to DOE's Appendix D2 test. The key difference is the load size for compact-sized dryers between 4.0 cu ft and 4.4 cu ft. The Appendix D2 test load size is 3.0 lb for that drum volume range, but Test Procedure Version 1.2. calls for an 8.45 lb load instead. Simply adopting the manufacturer-reported Appendix D2 value eliminates multiple tests and aligns better with ENERGY STAR and DOE testing.

***Improving the representation of the compact dryer load size.*** Some compact dryers struggle to completely dry the *large* 16.9 lb load required in Version 1.2. For example, 2021 testing revealed two of three compact heat pump dryers could only dry the load to 7.6% - 10% FMC, even with the highest dryness setting. Further NEEA research revealed this *large* load size is not very representative of real-world use, as it exceeds the capacity of all three of the paired washers. Version 1.2 requires a mathematical adjustment of the combined energy factor (CEF) to compare these high moisture content tests to other tests. Given the difficulty of drying the load and the washing capacity of the paired washer, NEEA concludes that the 16.9 lb load is not representative of real-world use of compact dryers.

***Changing the final moisture content (FMC) approach.*** There are four key opportunities for improvement to the FMC content approach found in Version 1.2:

- **The 4% FMC threshold is difficult to achieve on the middle dryness setting, contributing to increased testing costs.** For many dryers tested with Version 1.2, seven to eight tests must be performed to yield five valid results. This is because the dryers do not always achieve the maximum FMC in the test procedure, and the test must be performed again with the highest dryness setting. This higher cost has contributed to manufacturer reluctance to cover the cost of testing for qualifying products. Consequently, NEEA has paid for most of the testing to date for both the heat pump dryers and gas dryers. In either case, stakeholders fare better with lower testing costs.
- **The 4% FMC threshold does not fully align with industry dryer test procedures.** The FMC threshold of 4% in Version 1.2 may be overly stringent relative to the AHAM protocol, which suggests an FMC for normal loads should be in the range of 4% to 6 % (AHAM 2010, p. 6). Version 1.2's requirement of 4% FMC at the end of the test is likely to be contributing to more repeat testing with the highest dryness setting, given some dryers may terminate in the 4% to 6% FMC range with the middle setting per the industry guidance given in AHAM's dryer test procedure.

- **The FMC thresholds and mathematical adjustment approach are unclear.** Section 4.2 of Version 1.2 is unclear and open to interpretation, resulting in an inconsistent application of FMC thresholds and dryness settings in NEEA's current dataset.
- **The mathematical adjustment of the CEF with higher FMCs may not create an effective manufacturer incentive for accurate automatic cycle termination.** Version 1.2 allows adjustment of CEF with FMC values up to 8% FMC. This mathematical adjustment approach may not provide enough incentive for accurate auto termination, particularly for gas dryers,[2] resulting in more overall energy use in the real world as consumers may run a second dryer cycle for a load that isn't fully dry.

The outcome of these improvement opportunities is NEEA Dryer Test Procedure Version 2.0. This effort focused on balancing four critical aspects of effective test procedure design:

- Is it repeatable (the measured result is consistent within one lab)?
- Is it reproducible (the measured result is consistent across different labs)?
- Is it representative (the measured result predicts real-world use accurately)?
- Is it reasonable (the measurement value matches the test burden)?

The test runs for Version 2.0 are summarized in Table 2. Version 2.0 includes three supplementary tests and references manufacturer-reported Appendix D2 CEF values (DOE Test in Table 2). These Appendix D2 CEF values are found in the DOE compliance database (DOE 2022) and are used to calculate the utility CEF (UCEF) metric. Changes to similar Version 1.2 tests are highlighted **in bold.**

*Table 2. CEF Measurements Included in Test Procedure Version 2.0*

| Test | Test Name | Load Type | Cycle Setting | Cycle Temp | Initial Dryness Setting | Load Weight (lb) | IMC | FMC |
|---|---|---|---|---|---|---|---|---|
| DOE [a] | D2 | DOE momie | Default | Highest available [b] | Middle | **< 4.4[c] cu ft:** 3.0<br>≥ **4.4[c] cu ft:** 8.45 | 57.5% | 2% |
| One | *small* | **AHAM Cotton** | Normal | Medium | Middle | 4.22 | 62% | **6%** |
| Two | *large* | **AHAM Cotton** | Normal | Medium | Middle | **< 4.4[b] cu ft:** 10.2<br>≥ **4.4[b] cu ft:** 16.9 | 62% | **6%** |
| Three [d] | *fast* | **AHAM Cotton** | Heavy Duty | High | Highest | 8.45 | 62% | 4% |

[a] This test is not independently performed in Version 2.0, but instead, the protocol references the manufacturer-reported value from the DOE compliance database (DOE 2022). Test details are included here for comparison to Version 1.2 and are identical to Appendix D2 requirements.

[b] Highest available by default is usually a lower "eco" temperature for ENERGY STAR qualified dryers.

[c] Version 1.2 of the test procedure uses an 8.45 lb load for dryers with 4.0 cu ft or greater drum size. Version 2.0 aligns with the DOE test procedure using 4.4 cu ft as the boundary for load size changes.

[d] Modified from test run Four in the current Version 2.0 of the test protocol.

Notes: Changes to test runs relative to Version 1.2 of the test procedure are shown **in bold**.

[2] One of the challenges uncovered by NEEA's Version 1.2 gas dryer testing is that 75% of the eight models tested do not reach 4% FMC on at least one of the test runs even when on the "most dry" dryness setting.

This report includes a synopsis for each key test procedure change. It details the rationale, crosswalk methodology,[3] and impacts (i.e., shifts in dryer efficiency rank and qualification levels) to NEEA's heat pump clothes dryer qualified product list (QPL) (NEEA 2022b) and concludes with a discussion of implications.

## 2. Rationale for Key Changes from Test Procedure Version 1.2 to 2.0

### 2.1. Adoption of the AHAM (IEC) 100% Cotton Test Load as the Supplemental Load

For Version 1.2, NEEA developed its own test load using a variety of textiles from Lands' End. Although more realistic than DOE's specified load (50% cotton 50% synthetic momie test cloths 24" by 26" in size) (DOE 50/50), it had its own set of challenges with reproducibility. For Version 2.0, NEEA considered developing a new supplemental test load; however, this approach is costly and has other significant barriers to adoption (i.e., mainly convincing manufacturers and DOE of the merits of a new supplemental load and encouraging its use).

Therefore, NEEA elected to utilize an established test load (AHAM Cotton) specified in ANSI/AHAM HLD-1-2010 and IEC 61121:2012 for Version 2.0.[4] It is similar to the Version 1.2 Lands' End load, has better reproducibility, and is already widely accepted and used by industry. Detailed benefits of this test load include:

- **Three different article sizes and thicknesses.** AHAM Cotton articles include small hand towels, bedsheets, and pillowcases, which increases the challenge for a dryer's automatic termination technology compared to the single small textile size in the DOE 50/50 load.
- **A 100% cotton fabric load.** AHAM Cotton contains similar cotton content to the Lands' End load.[5]
- **Excellent repeatability and reproducibility.** DOE confirmed repeatability and reproducibility of the AHAM Cotton are similar to its 50/50 load. Test-to-test standard error of the AHAM Cotton load averages 2.07%, close to DOE's 50/50 standard error average of 1.87%. Lab-to-lab reproducibility of the AHAM Cotton load averages 4.7%, compared to DOE's 50/50 average of 3.0%.[6]
- **Existing manufacturer acceptance.** Some manufacturers already utilize AHAM Cotton for both washer and dryer energy efficiency testing under IEC 60456: 2010 and IEC 61121: 2012, respectively. Additionally, AHAM HLW-2-2020 and AHAM HLD-1-2010 reference this test load for performance testing of washers and dryers. Widespread use of the load may enable manufacturers to employ in-house testing with NEEA's

[3] The crosswalk methodology used lab data to translate Version 1.2 results to Version 2.0 results.

[4] The other options for standard test loads include a 100% synthetic fiber test load with pillowcases and men's dress shirts described in section 6.5.6.2 of IEC 61121:2012 and the 100% cotton 24" by 36" test cloths used for safety testing and described in section 5.1.6 of ANSI Z21.5.1-2017 (CSA 7.1-2017). However, both loads would be easier to dry and/or have less article diversity relative to the AHAM 100% cotton load and thus were less desirable choices.

[5] Hydrophilic cotton fiber is more difficult to dry than synthetic fiber.

[6] Energy Conservation Program: Test procedures for Residential Clothes Dryers. Notice of Proposed Rulemaking 10 CFR Parts 429 and 430. Docket EERE-2011-BT-TP-0054. Federal Register Vol 78, No. 1, Wednesday, January 2, 2013, p. 161, Table III.6. and p. 162, Table III.8. Available at https://www.govinfo.gov/content/pkg/FR-2013-01-02/pdf/2012-30677.pdf.

procedure during product design. This could increase NEEA's influence in the product development phase, possibly quickening efficient gas dryer development and bringing efficient dryers to market faster.

- **Textile reproducibility is addressed.** Article design specification, load building approach, and load age requirements (lint loss control) are already described, developed, and controlled in standards IEC 61121, IEC 60456, IEC 60734, ISO 2060, ISO 2061, ISO 7211-2, and EN 12127, among others.

<u>In summary, NEEA selected the AHAM Cotton load for Version 2.0 because it resembles the Version 1.2 test load and has notable advantages, including its reproducibility and its established, routine use by industry stakeholders.</u>

### 2.2. Reduction of Test Runs from Five to Three

Version 2.0 eliminates two of the five required Version 1.2 test runs: DOE Appendix D2 and the *eco* test. First, Version 2.0 no longer requires independent testing of the Appendix D2 test and instead leverages the manufacturer-reported publicly available CEF value for this test (available in the DOE database). This reduces the test burden and aligns exactly with DOE's Appendix D2 approach. [7] Also, it may create an incentive for manufacturers to report the measured CEF values instead of the minimum CEF values needed to verify compliance with the mandatory standard or qualify for the ENERGY STAR program. Secondly, NEEA eliminated the Version 1.2 *eco* test, originally designed to measure the most energy efficient drying cycle available. With the advent of the ENERGY STAR dryer program, the Appendix D2 default settings for ENERGY STAR qualified models usually include an "eco mode," which already maximizes the dryer's efficiency. Consequently, it was no longer necessary to include this supplemental test. Eliminating these two tests is expected to reduce the test burden **by approximately 40%**. All other test runs, *small* and *large* (load size), and *fast* (cycle setting) were retained as they represent important real-world use cases as documented by NEEA's Residential Building Stock Assessment (RBSA) Laundry Study (Hannas and Gilman 2014).

<u>In summary, the revision to include only three supplemental test runs significantly reduces costs while still representing a reasonable range of normal dryer efficiency.</u>

### 2.3. New Definition of Utility Combined Energy Factor (UCEF)

Because the *eco* test was no longer needed to represent the range of dryer efficiency in Version 2.0, NEEA developed revised test weightings to combine the CEF values into UCEF. Version 2.0 UCEF was intentionally developed to represent real-world use, leveraging the most recent RBSA Laundry Study (Hannas and Gilman 2014). Table 3 compares the UCEF test weightings of Versions 1.2 and Version 2.0 to a summary of key attributes of the RBSA Laundry Study (load size and dryer cycle temperature setting). The changes in weighting from Version 1.2 are highlighted in bold.

[7] Note Version 1.2 used a different load size than DOE Appendix D2 for dryers between 4.0 and 4.4 cu ft.

***Table 3. Test Procedure Version 1.2 and Version 2.0 UCEFs Compared to the RBSA Study***

| | | Test Procedure Version 1.2 | Test Procedure Version 2.0 | | RBSA Laundry Study [a] | |
|---|---|---|---|---|---|---|
| UCEF Test Weighting | DOE | 10% | **20%** | | - | |
| | *small* | 30% | 30% | | - | |
| | *large* | 10% | 10% | | - | |
| | *eco* | 20% | - | | - | |
| | *fast* | 30% | **40%** | | - | |
| Dryer Temp Setting Distribution | low | 30% | 20% | | ~10% | |
| | medium | 40% | 40% | | ~50% | |
| | high | 30% | 40% | | ~40% | |
| Load Size[b] Distribution | | Cmpct & Std | Cmpct | Std | Cmpct | Std |
| | small | 30% | **50%** | 30% | NA | ~30% |
| | medium | 60% | **40%** | 60% | NA | ~60% |
| | large | 10% | 10% | 10% | NA | ~10% |

[a] Hannas and Gilman 2014.
[b] For Version 2.0, small and medium load size distribution differs with compact (<4.4 cu ft) and standard-sized (≥ 4.4 cu ft) dryers because the DOE load size differs for these two sizes.
Notes: The changes in UCEF weighting from Test Procedure Version 1.2 are in bold.
Cmpct = compact-sized dryers, Std = standard-sized dryers, Avg = Average

The test burden would be quite high to enable a test procedure to reflect field findings perfectly, but even with the reduction in test burden under Version 2.0, the UCEF matches RBSA Laundry results well. The RBSA study only included standard-sized dryers (not compact), so NEEA focused on matching the UCEF for standard-sized dryers. The load size distribution for Version 2.0 UCEF mirrors the RBSA Laundry Study for standard-sized dryers, and the dryer temperature distribution is also highly similar. The Version 2.0 UCEF is calculated as follows:

$$UCEF_{v.2.0} = 0.2(CEF_{DOE}) + 0.3(CEF_{small\ v.2.0}) + 0.1\left(CEF_{large\ v.2.0}\right) + 0.4(CEF_{fast\ v.2.0})$$

where $CEF_{DOE}$ is CEF as measured by Appendix D2, $CEF_{small\ v.2.0}$ is CEF measured with the *small* test in Version 2.0, $CEF_{large\ v.2.0}$ is the CEF measured with the *large* test in Version 2.0 and $CEF_{fast\ v.2.0}$ is the CEF measured with the *fast* test in Version 2.0.

## 2.4. Other Minor Test Procedure Adjustments

### 2.4.1. Decreased Load Size for Compact Dryers

NEEA testing revealed that the 16.9 lb load size used in the *large* test was not representative for compact-sized dryers (less than 4.4 cu ft), so Version 2.0 uses a 10.3 lb load for the *large* test instead. To determine an appropriate load size for the *large* test of compact dryers, NEEA considered possible maximum load sizes for the six compact-sized heat pump dryers on NEEA's QPL. These included: the manufacturer-reported maximum load size,[8] two load sizes that

[8] Two manufacturers did not provide a maximum load size in their product literature.

scaled with the dryer drum size (2.5 lb per cu ft and 3.5 lb per cu ft), and the Appendix J2-defined washer maximum load for the paired clothes washer. NEEA observed that the scaled load of 2.5 lb per cu ft of the dryer drum volume and Appendix J2 maximum load size for the six matching washers were relatively similar (Figure 1). NEEA averaged the scaled load size (2.5 lb per cu ft) for the six compact heat pump dryers in the QPL to obtain the 10.3 lb. This approach was chosen because this value could be determined by the characteristics of the dryers alone and seemed also to agree relatively well with the washer's capacity.[9]

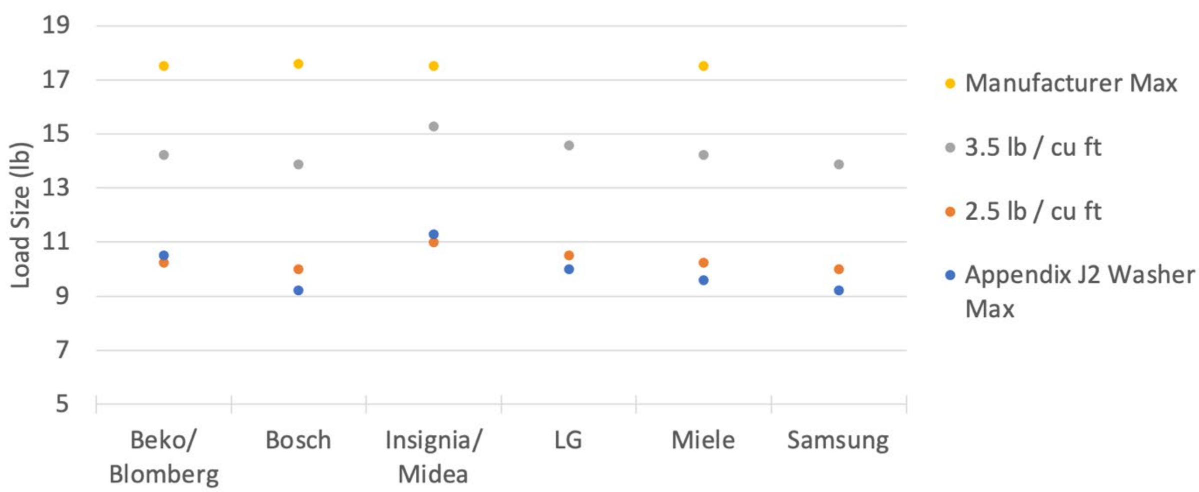


*Figure 1. Possible Large Load Sizes for Six Compact Heat Pump Dryers on NEEA's QPL*

Notes: LG and Samsung did not provide a manufacturer maximum load size in their product literature.

In summary, moving to a 10.3 lb load size for the *large* test of compact dryers reasonably balances the test burden with the representation of real-world use.

### 2.4.2. Alternate Final Moisture Content (FMC) Thresholds at End of Test

To determine an improved approach to the end-of-cycle FMC thresholds, NEEA analyzed data from eight clothes dryer models tested in 2021 with AHAM Cotton textiles: four compact-sized heat pump, two electric conventional, and two gas. Manufacturers in the sample included Amana, Beko, Electrolux, GE, Miele, Bosch, Samsung, and Whirlpool. The analysis examined FMC and dryness level settings for *small*, *large*, and *fast* tests and considered options for adjustments to FMC threshold and dryness settings in the context of results. Key findings include:

- **Moving to the AHAM Cotton load helps reduce duplicate test runs, lowering the test burden.** AHAM Cotton test loads have a lower FMC when tested on the middle dryness setting compared to the Lands' End cloth specified in Version 1.2. This difference will likely help reduce repeat test runs on the highest dryness setting often needed for *small* and *large* tests in Version 1.2.

[9] NEEA considered two other load size options. The first option employed an 8.45 lb load size for the *large* test for compact dryers, but this was rejected because it may not large enough to represent real-world use. The second option considered load scaling with the drum size; this was rejected due to the extra test burden of custom loads for each machine.

- **The *small* tests of all dryers and the *large* tests of standard-sized dryers achieved less than 6% FMC with the specified dryness setting (middle dryness).** All but one dryer in the sample achieved less than 5% FMC with the middle dryness setting.
- **For the *fast* test, all dryers were able to achieve less than 4% FMC with the specified dryness setting (highest dryness).** The dryers analyzed were able to meet the 4% FMC threshold with the high heat, heavy duty cycle, and the highest dryness setting.

Given these findings, NEEA elected to adjust the FMC threshold for the *small* and *large* tests to 6% FMC and retain the 4% FMC threshold for the *fast* test. NEEA retained the specified dryness settings for *small*, *large*, and *fast* tests as well as the approach to re-test with the highest dryness setting for *small* and *large* if the FMC threshold is not met with the middle dryness setting. NEEA removed the mathematical adjustment to CEF for higher-than-threshold FMCs. This adjustment is longer needed in Version 2.0 because:

- the problematic high FMCs were primarily with the compact heat pump dryer *large* test, which (as discussed above) is resized in Version 2.0 to be more representative of real-world use, and
- if the FMC thresholds cannot be attained even on the highest dryness setting, then Version 2.0 specifies that energy will continue to be measured with 10-minute intervals of high-heat drying until the FMC threshold is met.

<u>In summary, changing the FMC threshold to 6% FMC for *small* and *large* tests balances the need for accurate representation of consumer behavior with the goal of reducing testing costs.</u>

### 2.4.3. Various Other Test Procedure Updates

Version 2.0 incorporated several other minor updates that include:

- **Adopting the Appendix D2 water spray technique for IMC adjustment.** This avoids the need to mathematically correct test run energy use to account for differences in IMC at the start of the test.
- **Updating defined terms and language to match the latest version of Appendix D2**. This includes changing RMC (remaining moisture content) to FMC and other changes to ensure Version 2.0 is consistent with the current (2021) Appendix D2.
- **Adjusting the standby test language to reflect network-connected features.** While Appendix D2 requires network mode to be disabled for testing, Version 2.0 tests standby with as-shipped defaults.
- **Changing the data reported for a given test.** Version 2.0 requires photos of dryer settings, the presence of wrinkle prevention mode during a test, and other reporting updates.
- **Eliminating a CEF credit for reverting to efficient settings.** Version 2.0 only requires reporting whether a dryer reverts to more efficient settings when starting a new cycle.
- ***Clarifying other language.*** For example, Version 2.0 states that input voltage must be in tolerance 95 % of the time, which is an unstated industry practice for this parameter.

While some of these updates may increase test burden slightly, others likely decrease it. Therefore, no net changes to test burden are expected with these updates.

### 2.5. Summary of Test Procedure Changes and Associated Benefits

Effective test procedures successfully balance the four "Rs"— repeatability, reproducibility, representativeness, and reasonableness—to optimize benefits and burdens for their users. Table 4 summarizes how these key attributes changed from Version 1.2 to Version 2.0. Some changes focused on a single test procedure attribute, but the change ultimately improved other attributes as well. One example is the adoption of AHAM Cotton, which focused on reproducibility. However, the test load is more uniform in thickness and article shape, which helps improve repeatability. Furthermore, many labs already retain the AHAM Cotton load in stock, which helps reduce the cost of textiles (increasing the reasonableness of performing the test procedure). While test burden increased (and reasonableness decreased) for one change (change to compact dryer large load size), most aspects were improved or remained constant from Version 1.2 to Version 2.0.

***Table 4. Summary of Benefits from NEEA's Dryer Test Procedure Update***

| Change | Change from Version 1.2 to 2.0 | | | |
|---|---|---|---|---|
| | Repeatability | Reproducibility | Representativeness | Reasonableness |
| Adopt AHAM 100% Cotton | 👍 | 👍👍 | No change | 👍 |
| Reduce test runs from three to five | Not applicable | Not applicable | No change | 👍👍 |
| New definition of UCEF | Not applicable | Not applicable | 👍 | No change |
| Other changes: reduce large load size for compact dryers | 👍 | 👍 | 👍👍 | 👎 |
| Other changes: adjust approach to FMC thresholds | 👍 | 👍 | No change | 👍👍 |
| Other changes: various | Not applicable | Not applicable | Not applicable | No change |

## 3. Utility Combined Energy Factor (UCEF) Crosswalk Methodology

NEEA utilized lab data from nearly 70 test runs on a sample of eight dryers to develop a crosswalk from Version 1.2 CEF results to CEF values expected under Version 2.0. The sample included varying efficiency levels and technologies: three heat pump ENERGY STAR Most Efficient dryers, three ENERGY STAR dryers (heat pump, conventional electric, and gas), and two non-qualifying dryers (conventional electric and gas). NEEA tested these eight dryers with Version 1.2 and the beta draft of Version 2.0 and developed a correlation for the CEF of tests for *small, large,* and *fast*.

Note that the key change between these two tests was a swap of the textile type from Lands' End (Version 1.2) to AHAM Cotton (Version 2.0). Because testing was with a beta draft of Version 2.0, the FMC threshold for all supplementary tests was 4%, and the load size for compact dryers was 16.9 lb instead of 10.2 lb. However, NEEA used available data to estimate the CEF impacts of these changes and concluded that they are small relative to the textile type changes.[10] For each test (*small, large,* and *fast*), NEEA plotted Version 2.0 CEF as a function of Version 1.2 CEF and then developed a linear correlation for each. Figure 1 illustrates the results of the linear correlations, which have relatively high R-squared values.

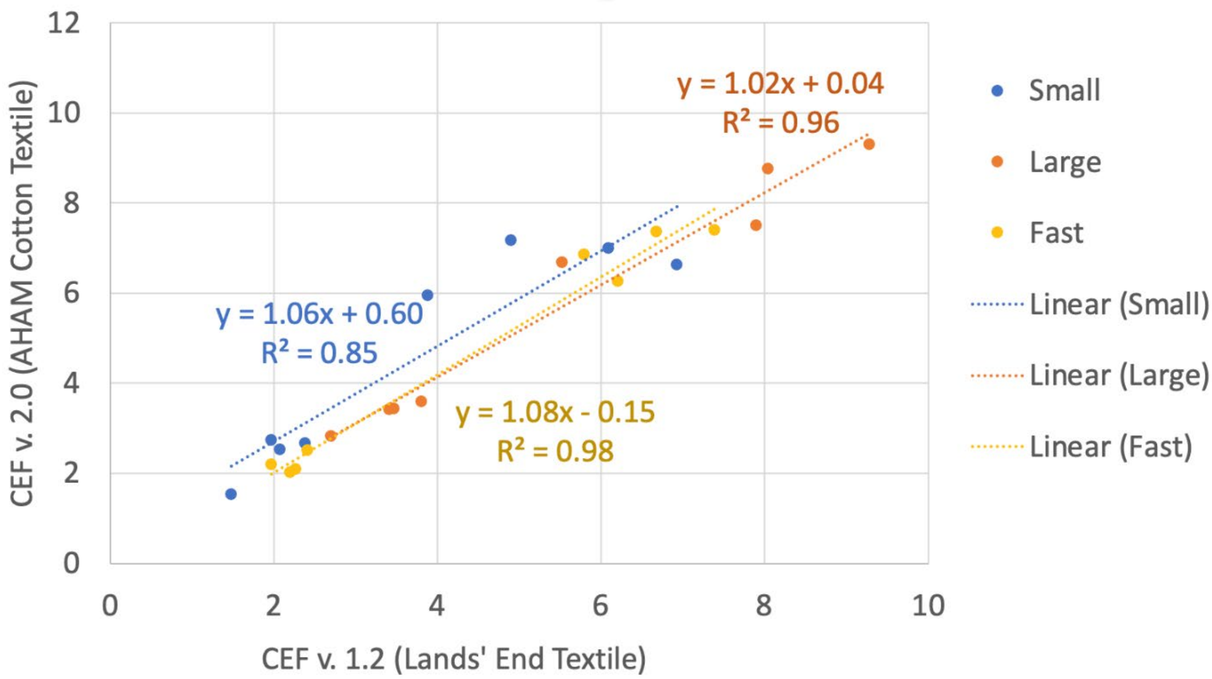


***Figure 2.*** ***Linear Relationship Between Version 1.2 and 2.0 for Small, Large, and Fast Tests***

The CEF of Version 2.0 *small* test is given by the equation below:

$$CEF_{small\ v.2.0} = 1.06(CEF_{small\ \boldsymbol{v.1.2}}) + 0.60.$$

Similarly, the CEF of Version 2.0 *large* test is given by the following equation:

$$CEF_{large\ \boldsymbol{v.2.0}} = 1.02\left(CEF_{large\ \boldsymbol{v.}1.2}\right) + 0.04.$$

[10] Because all standard-sized dryers were able to achieve less than 6% FMC on the middle dryness setting for both the *small* and *large* tests, we assume the CEF for these test runs will be unaffected by the FMC change. The compact-sized dryer 10.3 lb load size for the *large* test will reduce the CEF of that test; however, the 6% FMC is expected to increase the CEF for that test. These two changes approximately cancel one another out. Given this effect and the weighting of the *large* test at 10% of the total UCEF, NEEA expects the impact of these minor test procedure adjustments to be less than 1% of the UCEF calculated with the crosswalk detailed in this section.

Finally, the CEF of Version 2.0 *fast* test is given by the following equation:

$$CEF_{fast\ v.\mathbf{2.0}} = 1.08(CEF_{fast\ v.\mathbf{1.2}}) - 0.15.$$

These equations enable NEEA and its stakeholders to translate the CEF of Version 1.2 *small* and *fast* tests to values expected under Version 2.0. Then, these values can be used to calculate the Version 2.0 CEF.[11]

NEEA's data collection effort also included Version 1.2 *eco* test runs using the specified Lands' End textiles and then a modified version that used the AHAM Cotton load instead. Version 2.0 excludes this test, but NEEA was able to develop correlations for it as well (Figure 2). The relatively high R-squared value for the *eco* tests increases NEEA's confidence in the methodology used to translate the *small, large, and fast* tests.

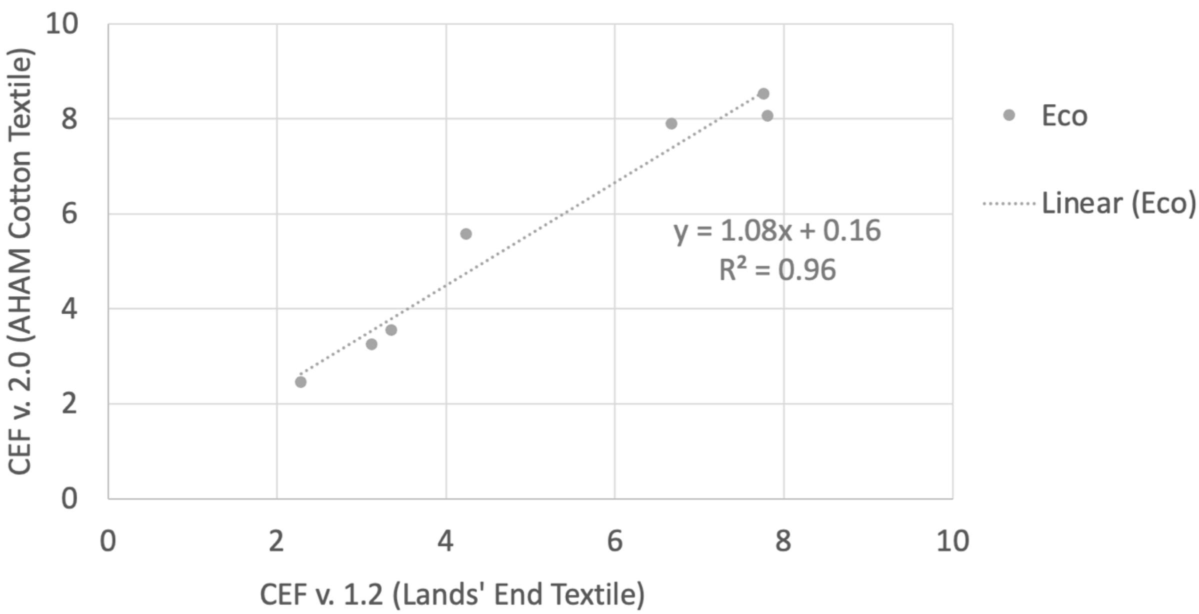


***Figure 3. Linear Relationship Between Lands' End and AHAM Cotton Using Version 1.2 Eco Test***

Once CEF results from Version 2.0 are translated, they can be used to calculate the UCEF detailed in the previous section.

## 4. Regional Savings Implications

To understand the energy savings impact of the test procedure change from Version 1.2 to Version 2.0, we used the crosswalk methodology discussed in the previous section to mathematically adjust the eight unique heat pump dryer models in NEEA's QPL (NEEA 2022b). The average of Version 2.0 UCEF of all models was only 3% higher (more efficient) than the same average using Version 1.2 UCEF. The UCEF of some heat pump models increased (five

[11] NEEA considered other crosswalk methods, including a correlation for UCEF (instead of for individual tests) and a single relationship (and linear equation) for all the tests together. However, these alternative methods were rejected because they had lower R-squared values and were less accurate compared to the individual test crosswalk method selected.

total), while others decreased (three total). For two models, the UCEF changes result in the switching of NEEA's performance tiers (one goes up a tier; one goes down a tier). Figure 3 shows the crosswalk results for the eight unique models in NEEA's heat pump QPL; models with tier changes have dotted lines.

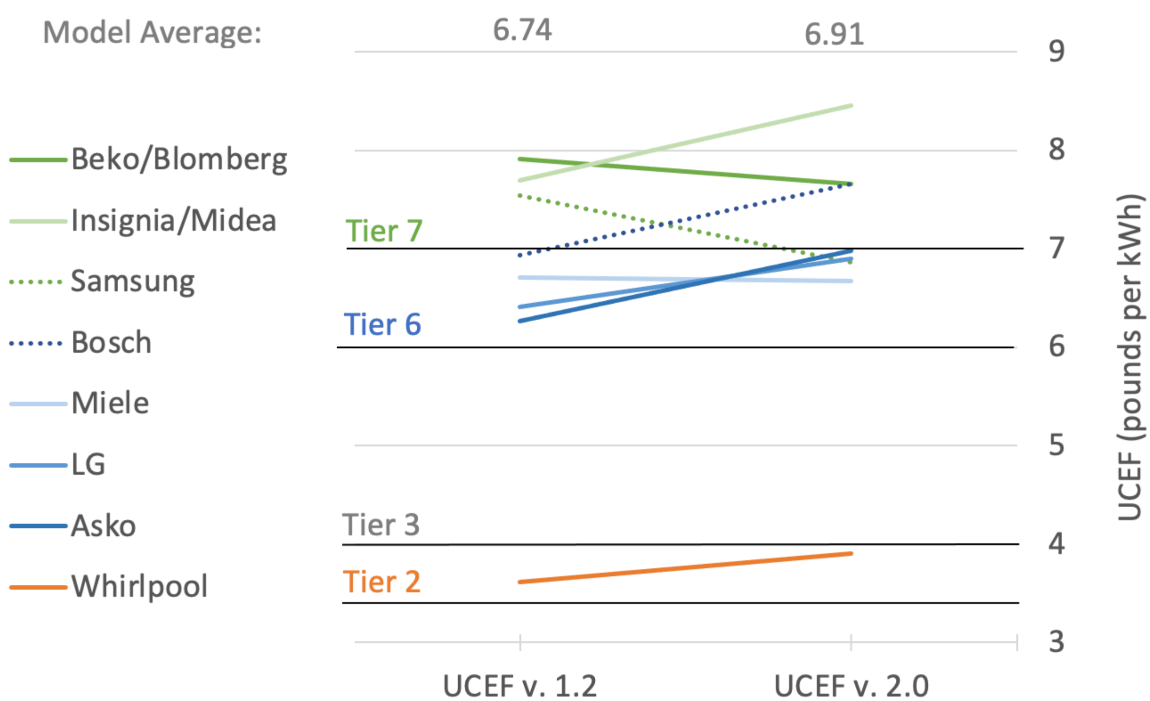


***Figure 4.*** ***Heat Pump Dryer QPL Comparison of Test Procedure Version 1.2 and Version 2.0 UCEF Values***

Notes: The two models annotated with a dotted line switch efficiency tier.

Using its ENERGY STAR Retail Products Platform (ESRPP) sales data for clothes dryers,[12] NEEA also calculated and compared regional energy savings using UCEF in Version 1.2 and Version 2.0 and the Regional Technical Forum (RTF)-adopted energy savings bins (RTF 2022). Sales of five heat pump models drove the regional energy savings. The regional annual energy savings calculated with Version 2.0 were approximately 7% higher than those calculated with Version 1.2.

## 5. Conclusions

NEEA's Dryer Test Procedure Version 2.0 includes the adoption of AHAM Cotton textiles, a reduction in test runs from three to five, a new definition of UCEF, a smaller load for the *large* test for compact dryers, and an adjustment to FMC thresholds at the end of the dryer cycle. These changes improve the repeatability, reproducibility, and representativeness of the test procedure while making it more reasonable through reductions in the overall test burden. NEEA also developed a crosswalk methodology to translate Version 1.2 results to Version 2.0 results.

[12] At the time this calculation was performed, sales data were available for the first three quarters of 2021, and the fourth quarter sales were extrapolated based on sales in the first three quarters.

When utilizing the current RTF-adopted method and translating Version 2.0 UCEF values to calculate regional energy savings of heat pump dryers on NEEA's QPL, the estimated regional energy savings increased only slightly (7%). Given this, the regional energy savings methodology does not need to be updated by the RTF ahead of its normal schedule.

## 6. References

Association of Home Appliance Manufacturers (AHAM). 2020. *Performance Evaluation Procedures for Household Clothes Washers - AHAM HLW-2-2020*. Washington, D.C.: AHAM. Retrieved from: https://www.aham.org/ItemDetail?iProductCode=20002&Category=MADSTD.

Association of Home Appliance Manufacturers (AHAM). 2010. *Performance Evaluation Procedures for Household Tumble Type Clothes Dryers - AHAM HLD-1-2010*. Washington, D.C.: AHAM. Retrieved from: https://www.aham.org/ItemDetail?iProductCode=20001&Category=MADSTD.

Code of Federal Regulations (CFR). 2015. *Title 10 Chapter II Subchapter D Part 430 Subpart B § 430. Appendix J2 to Subpart 430 – Uniform Test Method for Measuring the Energy Consumption of Automatic and Semi-automatic Clothes Washers*. Washington D.C.: CFR. Retrieved from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20J2%20to%20Subpart%20B%20of%20Part%20430.

Code of Federal Regulations (CFR). 2021a. *Title 10 Chapter II Subchapter D Part 430 Subpart B §430. Appendix D2 to Subpart 430 – Uniform Test Method for Measuring the Energy Consumption of Clothes Dryers*. Washington D.C.: CFR. Retrieved from: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20D2%20to%20Subpart%20B%20of%20Part%20430.

Dymond, C. 2017. *Energy Efficiency Test Procedure for Residential Clothes Dryers (Version 1.2), Report* (#E17-303). Originally developed by Northwest Energy Efficiency Alliance (NEEA, Pacific Gas & Electric and Ecova, 2014). Update by NEEA October 9. Portland, OR: NEEA. Retrieved from: https://neea.org/img/uploads/energy-efficiency-test-procedure-for-residential-clothes-dryers.pdf.

Hannas, B. and L. Gilman. 2014. *Dryer Field Study* (Report #E14-287; also frequently referred to as the Residential Building Stock Assessment (RBSA) Laundry Study). Portland, OR: Northwest Energy Efficiency Alliance. Retrieved from: https://neea.org/resources/rbsa-laundry-study.

International Electrotechnical Commission (IEC). 2010. *International Standard for Clothes washing machines for household use – Methods for measuring the performance, #60456* Ed. 5.0. Retrieved from:

https://webstore.ansi.org/Standards/IEC/IEC60456Ed2010?gclid=Cj0KCQiAtOjyBRC0ARIsAIpJyGPRseUkIhRjcB9l1yClx-ni4SE3SaYGoIN-lbZzvkp273ie4m1hHP0aAlsBEALw_wcB.

Northwest Energy Efficiency Alliance (NEEA). 2022a. *Energy Efficiency Test Procedure for Residential Clothes Dryers (Version 2.0)*. Originally developed by Northwest Energy Efficiency Alliance (NEEA, Pacific Gas & Electric and Ecova, 2014). Update by NEEA December 1, 2022. Portland, OR: NEEA. Retrieved from: https://neea.org/img/documents/NEEA-Energy-Efficiency-Test-Procedure-for-Residential-Clothes-Dryers.pdf.

Northwest Energy Efficiency Alliance (NEEA). 2022b. *Clothes Dryer Qualified Products List, Revision 24.* Portland, OR: NEEA. Retrieved from: https://conduitnw.org/pages/file.aspx?rid=2844.

Regional Technical Forum (RTF). 2022. Residential Clothes Dryers v5.0. Technical Advisory Committee to the Northwest Power and Conservation Council (NPCC). Portland, OR: NPCC. Retrieved from: https://rtf.nwcouncil.org/measure/clothes-dryers-sf-mh-and-mf-unit/.

U.S. Department of Energy (DOE). 2022. Compliance Certification Database. Washington, D.C.: DOE. Retrieved from: https://www.regulations.doe.gov/certification-data/#q=Product_Group_s%3A*.

U.S. Environmental Protection Agency (EPA). 2017. *ENERGY STAR Program Requirements Product Specification for Clothes Dryers, Version 1.1.* 5 May. Washington, D.C.: EPA Retrieved from: https://www.energystar.gov/products/clothes_dryers/partners.