July 17, 2026

REPORT#E26-355

Evaluation of the U.S. Test Procedure for Residential Clothes Dryers

Prepared For NEEA:
Blake Ringeisen, Sr. Engineer, Codes & Standards

Prepared By:
Suzanne Foster Porter, Principal,
Kannah Consulting
PO Box 4672, Grand Junction CO 81502

and

David Denkenberger, Engineering Consultant
Denkenberger Inventing and Consulting
2068 Bridgewater Dr., Fairbanks, AK 99709

Northwest Energy Efficiency Alliance
PHONE
503-688-5400
EMAIL
info@neea.org

Table of Contents

Table of Contents (cont'd)

Glossary of Terms and Abbreviations

Term/Abbreviation	Definition
AHAM	Association of Home Appliance Manufacturers
All-in-one	A washer/dryer combination unit
Automatic Termination	A dryer program that uses sensors and programming to adjust the cycle length to the textile load's dryness
Bone-dry Load Weight	The bone-dry weight of the load, as defined by the DOE-developed test procedure for dryers in Appendix D2 (CFR 2025a)
CEF	Combined energy factor, i.e., the energy performance metric for clothes dryers. It compares the energy efficiency of gas and electric dryers in pounds per kWh. The higher the CEF, the more efficient the dryer is.
CFR	Code of Federal Regulations
Compact dryer	A smaller, space-saving version of a traditional clothes dryer, designed for apartments, small homes, or areas with limited laundry space. They have a reduced footprint compared to standard models and have a drum capacity of less than 4.4 cubic feet.
Conventional dryer	Conventional dryers that use either electricity or gas to heat up air and pass it into the drum to dry clothes and then vent it out of the drum. Also: compare to heat pump dryer.
cu ft	cubic foot or cubic feet
Cycle	For this report, a cycle refers to the entire program to dry a load of textiles.
DOE	U.S. Department of Energy
Dual-stage burners	A dryer technology that enables lower power heating at different points of the cycle to improve efficiency
Eco mode cycle modifiers	The Eco mode on dryers is designed to reduce energy consumption while maintaining the effectiveness of the drying process.
Electric resistance dryer	A conventional dryer that uses electric resistance to heat the air that passes through the drum to dry clothes.
ENERGY STAR®	The government-backed symbol for energy efficiency for laundry and other equipment. At the date of this publication, the EPA administers the ENERGY STAR program.
EPA	U.S. Environmental Protection Agency
ESRPP	ENERGY STAR Retail Products Program, which partners with utilities and national retailers to increase the availability and sales of energy-efficient consumer products. See https://neea.org/program/retail-product-portfolio-rpp/.

Term/Abbreviation	Definition
Field use factor	Established in 1981 by DOE, the field use factor provided a beneficial energy credit for the presence of automatic termination in the Appendix D2 test procedure.
FMC	Final moisture content of a load of textiles coming out of the dryer
Front load	A clothes washer with a horizontal axis
Gas dryer	A conventional dryer that uses natural gas or propane to heat the air that passes through the drum to dry clothes.
Half-load	A dryer load for a test procedure that is half the size of a standard full load, i.e., 4.23 lb compared to 8.45 lb.
Heat pump dryer	An energy-efficient dryer that uses heat pump technology to dry clothes by moving heat, making it more economical to operate compared to conventional dryers.
Hybrid heat pump dryer	A type of dryer that combines traditional electric resistance and heat pump technologies.
IMC	Initial moisture content of a dryer load, expressed as a percentage, calculated by dividing the total water in a load (in lb) by the total bone-dry weight of the textiles.
Inverter heat pump dryer	A variable-speed heat pump system that can adjust its heat output and energy use.
IRA	Inflation Reduction Act (IRA): Provides rebates as financial incentives for homeowners to improve energy efficiency in their homes
lb	pound or pounds
Load	For this report, a load refers to the textiles in a drying cycle.
Load size	Weight of dryer load
NEEA	Northwest Energy Efficiency Alliance
Non-qualified (NQ)	A dryer that does not have the ENERGY STAR label.
Power profile	Time-series power data showing power over time of a dryer cycle
Program	The name of a washer or dryer cycle setting; each is capitalized in this report for clarity (e.g., Normal, Heavy Duty).
QPL	Qualified Product List
RMC	Remaining moisture content (in washer textiles at cycle completion).
Single-stage heating system	This type of heating system has only one heat output. The heating is either on, or it is off; there are no levels.
Standard dryer	Full-sized dryer (greater than or equal to 4.4 cu ft)
Test cloths	Cloths used for measuring the energy use of washer and dryer

Term/Abbreviation	Definition
Timed Dry	A clothes dryer program that allows a consumer to set a specific drying length for a load (in minutes).
Top load	A clothes washer with a vertical axis (agitator or impeller).
Vented dryers	A type of clothes dryer that expels moist air and lint directly outside through a dedicated exhaust vent.
Ventless dryers	These use a heat exchanger to collect moisture and then often reject it down the drain, rather than venting outside like vented dryers. Nearly all heat pump dryers and all condenser dryers are ventless dryers.
Weighted average	An average value that is weighted by another population parameter to better represent the population.

Notes: For clarity, common nouns with specific definitions in this report are intentionally capitalized (e.g., Clean Dry-Load Weight, Normal Program Setting, Metered Data).

Executive Summary

Stakeholders rely on appliance test results to set standards, develop ENERGY STAR® levels and other specifications, and implement utility market intervention programs such as the ENERGY STAR Retail Products Program (ESRPP). The US test procedure for clothes dryers (10 CFR part 430, Appendix D2) is currently used to qualify ENERGY STAR dryers, and it will be required for testing all dryers starting in 2028. *But does Appendix D2 accurately reflect real-world dryer energy use?*

This study investigated this question, testing 12 top-selling electric dryers across four common use cases identified in its 2023 laundry field study (NEEA 2026). The dryers—which represented three efficiency groups: non-qualified, ENERGY STAR qualified, and heat pump—were tested per Appendix D2 with the specified 8.45 lb load, and then again with a half load (4.23 lb) of the test textile. Each load size was tested with the Eco mode modifier both on and off, for a total of four tests per dryer.

NEEA's research and testing revealed the following key findings:

- Dryer technology is more diverse than ever before. Heating technology and automatic termination controls differ widely, and both impact efficiency.
- Currently, a dryer's efficiency at full load usually predicts the half-load efficiency.
- A dryer's Eco mode modifier produces an operational mode distinct from the Normal program and generally increases dryer efficiency (CEF). For conventional ENERGY STAR models, Eco mode also extends cycle time.
- The Eco mode control is the primary means by which conventional dryers meet the ENERGY STAR level (3.93 CEF) under Appendix D2; without Eco mode, these products exhibit lower efficiency than the current standard level of 3.73 CEF.
- Heat pump dryers with a CEF of 6 or higher are more efficient than conventional ENERGY STAR and non-qualifying dryers in all tested conditions.

The implication of these findings is that inexpensive control strategies are likely the primary means by which conventional dryers will meet the 2028 standard (3.93 CEF). NEEA's latest field research shows consumers regularly disable Eco mode in real-world use, and this study confirms that without Eco mode enabled, ENERGY STAR dryers have efficiency similar to non-qualified dryers (3.72 CEF or lower). Given the control schemes observed in the latest dryers, the project team concludes that not all of the expected energy savings will be realized in the mandatory standard update. While the sample included electric dryers only, the project team expects similar findings for conventional gas dryers as well.

The test results also suggest the following possible Appendix D2 updates in the next cycle of revisions:

1. Account for changes to dryers' electronic controls, ensuring lab testing is performed with the most common setting(s).
2. Add a second half-load test to the test procedure to create opportunities for manufacturers to save energy on this common load size by implementing more effective automatic termination controls and/or variable-speed fans.
3. Lower the initial moisture content (IMC) of textiles at the start of the dryer test. Research revealed that a lower starting water moisture of the load may be warranted.

Finally, results indicate heat pump dryers provide more consistent energy savings than conventional ENERGY STAR dryers, suggesting that utility program focus on heat pump dryers could prove valuable. Future research could include a national field study of residential dryers to track possible changes in program settings and the development of a test procedure for commercial clothes dryers.

Introduction and Rationale

This project evaluates whether the existing Appendix D2 test procedure developed by the U.S. Department of Energy effectively predicts dryer performance under common usage conditions and makes recommendations to improve the correlation between laboratory test results and real-world performance. NEEA's prior research indicates that Appendix D2 (CFR 2026b), which measures dryer energy use, may not accurately reflect real-world performance, particularly given the rapid technological changes over the past 15 years. This issue concerns stakeholders because the test results are used to set standards, develop ENERGY STAR® levels, and implement utility market intervention programs such as the ENERGY STAR Retail Products Program (ESRPP). This study focuses on electric conventional and heat pump dryers, but because electric and gas conventional dryers are similar in design and operation, the project team assumes most of the project findings for conventional electric dryers also apply to conventional gas dryers. NEEA commissioned Kannah Consulting to conduct the lab testing and analyze results.

Relevant Background

History of US Dryer Technology

The first dryers were sold in the US in 1938, with sales increasing after World War II (Liegey 2003). 82% of US households now have clothes dryers, and most of those (80%) are electric (EIA 2023). Early technological advancements included outside venting in the 1950s, condensing drying in the late 1950s (Figure 1), and automatic termination in the 1980s. From 1950 to 2010, dryer technology remained relatively stable. However, in the past decade, additional consumer convenience and energy-saving features have entered the market, such as:

- Smart features introduced in 2012 to support maintenance requirements of more efficient (such as filter cleaning) (Samsung 2012)
- Dual-stage burners for gas and electric resistance dryers—prototypes in 2005 (Pescatore 2005) and becoming more common by 2015
- Heat pump systems starting in 2014, offering greater efficiency (Bush et al. 2015)
- Eco mode cycle modifiers first appeared in 2008 (Bosch 2009) and became more prevalent around 2015.

Figure 1. 1959 advertisement for a condensing dryer

Today, technology is more diverse, with most innovations directly improving efficiency or enabling consumers to adopt more efficient solutions. Some of this technology—including heat pump dryers, dual-stage burners, and energy-saving Eco modes—has been adopted in response to the ENERGY STAR dryer program (launched in 2014) (ENERGY STAR 2014) and associated utility incentives for ENERGY STAR dryers. This program and the history of U.S. Department of Energy's (DOE's) mandatory standard levels for dryers are discussed next.

Dryer Mandatory Standard and ENERGY STAR Specification Levels

The current DOE dryer standards and ENERGY STAR specifications, along with future mandatory levels for both compact and standard-sized dryers, are summarized in Table 1. Recognizing technological diversity as an opportunity, ENERGY STAR launched its dryer program in 2014 to guide consumers, though updates to the specification have been paused since 2025. Notably, the 2028 standard is nearly equivalent to the ENERGY STAR level for the most common category of standard-sized vented and ventless electric dryers.

Table 1. Summary of current residential clothes dryer mandatory standards and ENERGY STAR specification levels

Size	Product Type	2015 Mandatory Standard (DOE 2015)	2028 Mandatory Standard (DOE 2024b)	ENERGY STAR (ENERGY STAR 2024a) [a]	2025 ENERGY STAR Most Efficient [Max Dryness] (ENERGY STAR 2024b)
Standard (4.4 cu ft or greater capacity)	Ventless or Vented Electric	3.73 [b]	3.93	3.93	5.2 [3.93]
	Vented Gas	3.3	3.48	3.48	Excluded
Compact (less than 4.4 cu ft capacity)	Ventless or Vented Electric, (120V)	3.61 [b]	4.33	3.80	6.3 [3.80]
	Vented Electric, (240V)	3.27	3.57	3.45	5.2 [3.93]
	Ventless Electric, (240 V)	2.55	2.68	2.68	5.5 [2.68]
	Vented Gas,	N/A	2.02	N/A	Excluded
All sizes	Ventless Electric, Washer/Dryer Combinations	2.08	2.33	3.93 [c]	Excluded [d]

[a] Note that connected dryers are given a 5% credit on their CEF. Specifically, they are allowed to report 1.05 times their measured CEF. [b] DOE's 2015 standards did not define a ventless electric dryer for this size, but ENERGY STAR and later mandatory standards did include ventless in this group. [c] Although the ENERGY STAR specification excludes washer/dryer combination appliances, ENERGY STAR has allowed certification of certain washer/dryer combos. As of publication, 11 combos are listed on ENERGY STAR's QPL that are 3.93 CEF or above. [d] As of publication, one combination washer/dryer is listed as ENERGY STAR Most Efficient in the clothes washer QPL (but not in the clothes dryer QPL).

Dryer Test Procedure

Test Procedure History

The Appendix D dryer test procedure was developed in 1977—leveraging clothes washer test cloths and available data on dryer usage—but was not required for mandatory standards until 1994 (DOE 1977, DOE 2011). The Energy Policy and Conservation Act (EPCA) established a prescriptive standard banning pilot lights in gas dryers in 1987, and in 1981, a flat credit was given for automatic load termination (DOE 2011). The energy impact of automatic termination was not measured, but the credit encouraged dryer manufacturers to incorporate this feature. None of these mandatory requirements required the use of the test procedure, and specific energy performance requirements were not established until 1991 and did not take effect until 1994 (DOE 2010 and DOE 1982). This first test procedure (Appendix D) required the technician to open the dryer door to stop the test when textiles reached a set level of dryness (2.5% to 5.0% final moisture content, or FMC).

In 2011, DOE updated the test procedure to Appendix D1, lowering the IMC from 70% to 57.5% and adding standby power measurement to meet legal requirements for standby consideration. This updated the test procedure to account for improvements to clothes washer spin cycles that removed more water from loads before they were put in the dryer.

Table 2. History of dryer test procedure development

<table>
<tr><th>Year Adopted</th><th>Years required for mandatory standard?</th><th>Test Procedure (10 CFR [a] Part 430)</th><th>Initial Moisture Content (IMC)[b]</th><th>Std. Load Size (lb) [c]</th><th>Automatic or Timed Test?</th><th>Energy Metric</th></tr>
<tr><td>1977</td><td>NA
(DOE 2011)</td><td>Appendix D
(CFR 1977)</td><td>70%</td><td>7.00</td><td>Timed</td><td rowspan="2">Energy Factor (EF); lb bone-dry load per kWh used)</td></tr>
<tr><td>1981</td><td>1994–2014
(DOE 2011)</td><td>Appendix D
(CFR 1981)</td><td>70%</td><td>7.00</td><td rowspan="2">Timed, credit for auto termination [d]</td></tr>
<tr><td>2011</td><td>2015–2028
(DOE 2013)</td><td>Appendix D1
(CFR 2026a)</td><td rowspan="3">57.5%</td><td rowspan="3">8.45</td><td rowspan="3">Combined Energy Factor (CEF); includes standby</td></tr>
<tr><td>2013</td><td>Optional [e]
2015–2028</td><td>Appendix D2
(CFR 2026b)</td><td rowspan="2">Automatic Termination and Timed [f]</td></tr>
<tr><td>2021</td><td>2028+
(CFR 2026c)</td><td>Appendix D2
(CFR 2026b)</td></tr>
</table>

[a] CFR—Code of Federal Regulations

[b] IMC is expressed as a percentage, calculated by dividing the total water in a load (in lb) by the total bone-dry weight of the textiles. Tolerance in the test procedure increased over time to improve repeatability and reproducibility. The tolerance on this value was ±3.5% until Appendix D2 when it was tightened to ±0.33% (DOE 2013).

[c] This table focuses on the load size for standard-sized dryers. The compact dryer load size has always been 3.0 lb.

[d] This is the field use (FU) factor, which multiplied the energy use by 1.18 for timed (no automatic termination available) and by 1.04 when automatic termination options were present. It was originally established in the May 1981 test procedure Final Rule based on analysis of data from a field use survey conducted by AHAM involving 72 homes as well as an analysis conducted by NIST of field test data on automatic termination control dryers (DOE 2013).

[e] Manufacturers are optionally allowed to certify products with Appendix D2 (DOE 2013), and the EPA ENERGY STAR Program requires it for qualified products (ENERGY STAR 2024a). From 2015 to 2028, non-qualified dryers were generally tested with Appendix D1, and ENERGY STAR dryers were tested with Appendix D2.

[f] The field use factor for the timed test is 1.18.

2013 marked the first substantial change in testing approach (DOE 2013). A secondary optional test procedure was introduced, Appendix D2. Appendix D2 enabled measurement of automatic termination performance and was required for participation in the ENERGY STAR program. Non-qualified dryers continued to test with the older version of the test procedure, now called Appendix D1, and continued to receive a flat credit for the presence of automatic termination (CFR 2026a). The latest test (Appendix D2), adopted in August 2013 (DOE 2013) and effective with the standard currently planned for March 2028 (CFR 2026b), requires testing with automatic termination, if available, while still allowing a timed test if automatic termination is not available. Appendix D2 requires specific settings intended to represent the most common automatic termination settings. These include the Normal program, the highest heat level, the medium dryness level, and other default settings (excluding networking or wi-fi capability). The current metric is the combined energy factor (CEF), expressed in lb of bone-dry textile per kWh. Key attributes of each test procedure and revision are shown in

Table 2. Note that neither the load type nor the cycle settings have changed over time.

Clothes Washer RMC Is Dryer IMC in Real-World Use

Clothes washer remaining moisture content (RMC)—the amount of water left in a load of textiles—impacts dryer efficiency (CEF). RMC is expressed as a percentage, calculated by dividing the total water in a load (in pounds) by the total bone-dry weight of the textiles (in pounds). RMC has changed over time as clothes washers have become more effective at spinning out water at the end of the wash cycle. The moisture content at the end of the wash cycle becomes the initial moisture content (IMC) at the beginning of a dryer cycle.

As noted in

Table 2, DOE lowered the IMC from 70% to 57.5% in a 2011 revision. Some evidence suggests that further reductions may be warranted. While NEEA's 2013 field study found the average washer RMC was 62% (NEEA 2014a), the US market-weighted average washer RMC based on results from its 2023 field study was lower, 52.4% (See Appendix B based on NEEA 2026). This field-measured IMC does not directly correspond to a lab-measured value because the textile loads in the field are not bone-dry when IMC is calculated; they retain some moisture at the end of the cycle. When this value is mathematically adjusted to account for bone-dry weights that can be consistently replicated in a laboratory, 52.4% in the field corresponds to 56.8% in the lab (See Appendix A: Calculating Laboratory Dryer IMC from Field Washer RMC). Lower IMC values are not used in the testing methodology in this study but are discussed as a possible update in the Test Procedure Recommendations section of this report.

Relative Test Procedure Burden

Table 3 below documents that a clothes dryer uses significantly more energy than a clothes washer, dishwasher, or refrigerator. Yet clothes dryers have the lowest test burden among these appliances. The project explores whether a higher test burden is warranted to better reflect real-world energy use, thereby enabling further efficiency gains for clothes dryers.

Table 3. Relative Appliance Test Procedure Burden

Appliance	Current Test Procedure for Standards Compliance	Number of Conditions/ Cycles Evaluated	Test Length	Cost at Independent lab relative to dryer test	Estimated Annual Energy Use (kWh)[a]
Clothes Dryer	Appendix D1 and D2 (CFR 2026a, 2026b)	1 [b]	1 to 2 days	NA	725
Refrigerator	Appendix A (2026d)	2	3 to 14 days	1.4x dryer	604
Dishwasher	Appendix C1 (2026e)	5	4 to 5 days	1.4x dryer	239 [c]
Clothes Washer	Appendix J2 (2026f) [d]	13 to 21	5 to 8 days	1.6x dryer	55 [e]

[a] Source: NEEA 2014b, Table ES3

[b] If the RMC is not low enough for the first test under Appendix D2, then the test must be run a second time, using the highest dryness setting. However, only one test is recorded for efficiency evaluation.

[c] Excluding water heating

[d] Appendix J is expected to have a shorter length and lower cost due to changes relative to Appendix J2 (CFR 2026g)

[e] Excluding water heating and drying energy

Consumer Use Patterns of Dryers

NEEA's 2023 field research that examined laundry use patterns in homes across the Northwest revealed the following information relevant to the Appendix D2 testing of automatic termination dryers (NEEA 2026):

- The most common automatic termination program is the Normal program.

A small load size (0 to 6.29 lb) is nearly as commonly used as the medium load size (6.3 to 11.59 lb, averaging 8.45 lb) currently employed in the DOE test procedure (see

- Table 2Figure 2).
- For ENERGY STAR dryers with Eco mode, it was engaged only part of the time.

While other dryer-use studies (e.g., the Florida Solar Energy Center study (Martin et al. 2016)) have been conducted, NEEA is not aware of any other recent studies that document dryer use with the level of detail in NEEA's 2023 study.

Many stakeholders observe that consumers value shorter dryer cycle times. One strategy to improve dryer efficiency is to lower the heat level and lengthen the cycle time, but stakeholders worry that consumers may not be comfortable with excessively long cycle times. To address this, the ENERGY STAR qualification criteria, as of publication, have a requirement for cycles to be no longer than 80 minutes (ENERGY STAR 2024).

Methodology

Objectives

The objectives of this project were twofold:

1) to examine whether the current DOE test procedure effectively predicts dryer performance in other common use cases; and

2) to identify what additional testing may be helpful to accurately differentiate among the latest dryer technologies while keeping the test procedure manageable.

The project team examined available information (as summarized in the background section of this report) and spoke with energy-efficiency organizations and manufacturers to inform the methodology. NEEA reached out to these organizations three times:

1. at the beginning of the project's formation to get input on the testing approach;
2. before NEEA went into the lab, sharing the testing plan with stakeholders; and
3. after the lab results were complete.

This outreach enabled NEEA to consider the perspectives of other important players in the energy-efficiency field and the marketplace as it formulated its study design and recommendations.

Sampling Plan

NEEA leveraged ESRPP 2023 sales data for the Northwest to select 12 standard-sized (larger than 4.4 cu ft) dryers for testing. The sample was designed to represent the market after the 2028 standard, such that the study could be applicable to future dryer test procedure efforts. The sample incorporated five ENERGY STAR-qualified dryers, five standard-sized heat pump dryers (including one combination washer/dryer),[1] and two non-qualified dryers (for the purposes of comparison). The project team focused on selecting top-selling models, and the sample includes six manufacturers and seven brands: Beko, Electrolux, GE, LG, Maytag, Samsung, and Whirlpool. These 12 dryers represent 21.4% of the sales in the Northwest from

[1] Four of the five heat pump dryers included in the sample were qualified to the 2025 ENERGY STAR Most Efficient (ESME) level. The combination washer/dryer was not qualified as ESME, but efficiency of the dryer cycle does meet the ESME requirement of 5.2 CEF under Appendix D2.

January to December 2023. All of the dryers selected were electric. Yet, given the similar designs of conventional gas and electric models, the project team assumes that findings from conventional electric dryers can be applied to conventional gas dryers.

Table 4. Dryer Sample Summary

Dryer Efficiency Level	Dryer #	2023 Dryer Market Share (%)	Design Characteristics	Drum Size Range (Avg) in cu ft	Reported Cycle Time Range (Avg) in min	2024 MSRP Range and (Average)
Non-Qualified CEF=3.73 *(n=2)*	Dryers 01–02	8.2%	Conventional single-stage burner [a]	7.0 to 7.5 (7.25)	NA	$799 to $899 ($849)
ENERGY STAR CEF=3.93 *(n=5)*	Dryers 03–07	10.2%	Conventional with single-stage and dual-stage burner [b]	7.4 to 8.0 (7.6)	57 to 73 (68)	$899 to $1,249 ($1,077)
Heat Pump CEF=5.2 to 11 Avg CEF=7.9 *(n=5)*	Dryers 08–12	3.0%	All-in-one 120 V washer-dryer, heat pump, hybrid heat pump, modulating heat pump [b]	4.8 to 7.8 (6.5)	67 to 70 (69) [c]	$1,399 to $2,299 [d] ($1,848)

[a] One NQ dryer has an electro-mechanical control without Eco mode, and one has electronic control with Eco mode.

[b] All with electronic controls and Eco mode.

[c] Note that one washer-dryer combination all-in-one unit included in the sample does not report a cycle time to ENERGY STAR and is excluded here.

[d] Note that the washer-dryer combination unit in the sample increases the average for this set.

Test Plan

To represent a significant portion of the consumer use cases observed in the 2023 field study, NEEA performed four tests: Appendix D2 (8.45 lb), half load (4.23 lb), each with the Eco mode modifier turned on and off:

- DOE Appendix D2—8.45 lb load and Eco on
- DOE Appendix D2—8.45 lb load and Eco off
- DOE Appendix D2—4.23 lb load and Eco on
- DOE Appendix D2—4.23 lb load and Eco off

These tests were performed according to the Appendix D2 test procedure, including the use of the DOE-specified test cloth. They were selected to represent the green areas of field use NEEA observed in its 2023 study, which examined the prevalence of the automatic termination program selected (Normal and other), the load size (small: < 6.29 lb, medium: 6.3 to 10.59 lb, and large: ≥ 10.6 lb), and the use of Eco mode in the field (NEEA 2026). Figure 2 shows the field prevalence of each, and the green areas are represented by the four lab tests in this study.

The methodology is intended to build on DOE's examination of half-load results during the last test procedure revision (DOE 2021). Other auto termination programs (e.g., Heavy-duty, Delicate, Mixed-load), timed settings, large loads, and other more difficult-to-dry textiles are not represented in the four tests. Key data collected for each cycle included efficiency (CEF), cycle time, power profiles (time-series power data), and final moisture content (FMC).

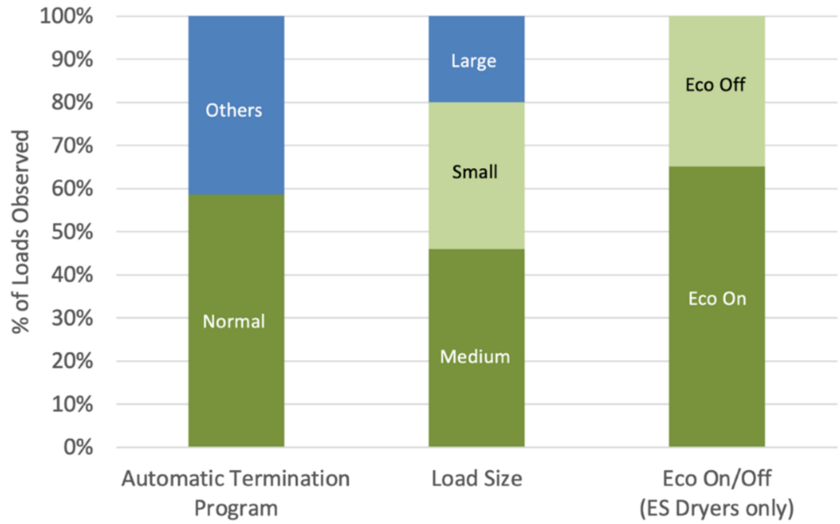


Figure 2. Clothes dryer settings and load size distribution from NEEA's 2023 field study (NEEA 2026). Green areas are those consumer use conditions represented for the four lab tests in this study.

Test Results

This section presents key results from the lab testing described in the prior section, including technology results, half-load results, Eco mode results, and results relative to the Appendix D2 test procedure.

Technology Results

Key finding: Electric dryer technology is more diverse than ever before. Heating technology and automatic termination controls differ widely, and both impact efficiency.

By observing the time-series power data, the project team observed a variety of electric heating technologies, including:

- **Single-stage electric resistive element.** This is the traditional dryer heating system with one electric resistance element. The team observed this technology in non-qualified and in some ENERGY STAR-qualified dryers.
- **Dual-stage electric resistance element.** Three of the five ENERGY STAR dryers employed a dual-stage heating system that enabled lower-power heating at different points in the cycle to improve efficiency.
- **Heat pump and inverter heat pump.** Three of the five heat pump dryers were heat pump only, and two of those three were controlled by an inverter, enabling variable heat output.
- **Hybrid heat pump and electric resistance.** Two of the five heat pump dryers had a heat pump combined with a lower-power electric resistance element.

Figure 3 provides time-series power data for these heating systems. Time-series power data for all dryers across all four tests in the study are in Appendix B.

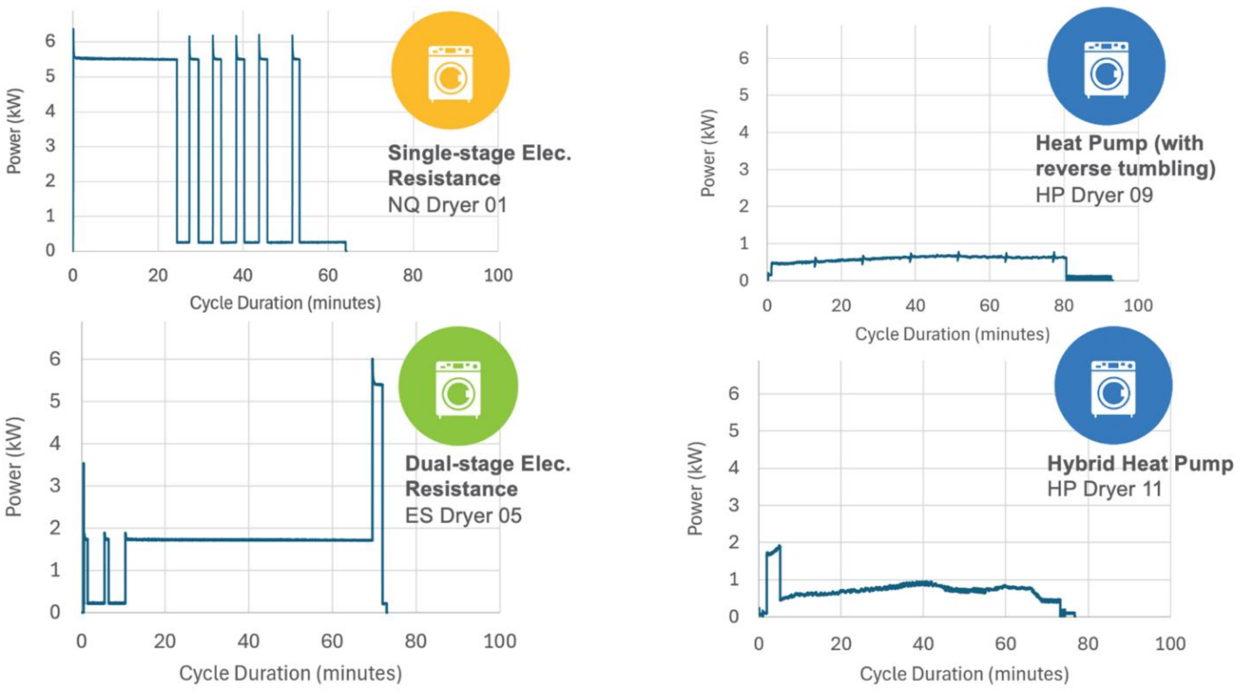


Figure 3. Time-series power data for the four key types of heating systems observed in the sample

The testing revealed significant differences in automatic termination accuracy. Automatic termination should lower the energy use (and cycle time) when a smaller load is placed in a dryer. Ideally, a load half the size should use half the energy of a full load.[2] While the study team did not observe any dryers that achieved this result, it did observe variability in a dryer's ability to scale energy with load size (Table 5).

Table 5. Averages and ranges of power scaling for different dryer efficiency groups

Dryer Efficiency Level	Range of percent change in cycle time (Average)	Range of percent change in energy use (Average)	Range of percent change in CEF (Average)
Non-Qualified *(n=2)* **Dryers 01–02**	-13% to 13% (0%)	-25% to -13 % (-20%)	-33% to -43% (-38%)
ENERGY STAR *(n=5)* **Dryers 03–07**	-21% to 0% (-10%)	-23% to -14 % (-20%)	-35% to -42 % (-37%)
Heat Pump *(n=5)* **Dryers 08–12**	-34% to 9% (-19%)	-38% to 0% (-25%)	-19% to -50% (-33%)

The accuracy of automatic termination appears to be independent of the heating system type. Heat pump dryers can have both effective and ineffective automatic termination systems, as can non-qualified dryers. One heat pump used the same amount of energy to dry an 8.45 lb load as the 4.23 lb load. Non-qualified dryers reduced their energy use with half load by the same average as ENERGY STAR Dryers. Given that automatic termination results vary across electric heating types and efficiency levels, the project team assumes these results are also applicable to conventional gas dryers.

[2] To achieve this result, dryers would need to slow the dryer's fan speed so the air moving in the drum has more time to pick up moisture from the smaller area of wet surface with a half size load. The study team's understanding is that fan speed is generally fixed in dryers. This limits these dryers' ability to scale the air speed to the wet surface area of the load. Without the ability to adjust the fan/air speed, the energy use is roughly proportional to the square root of the load size. This means that if the load is half the size, it should use about 30% less energy. This is within the range of data shown for heat pumps in Table 5. Some reductions may be more than 30% because the dryer may not have effectively terminated with the full load and so had a larger reduction in energy use when tested with the half load. Another possibility is that a few of the heat pumps (which is the only group with greater reductions in energy use with a half load) may have variable speed fans. Our research could not characterize the type of fan in each dryer.

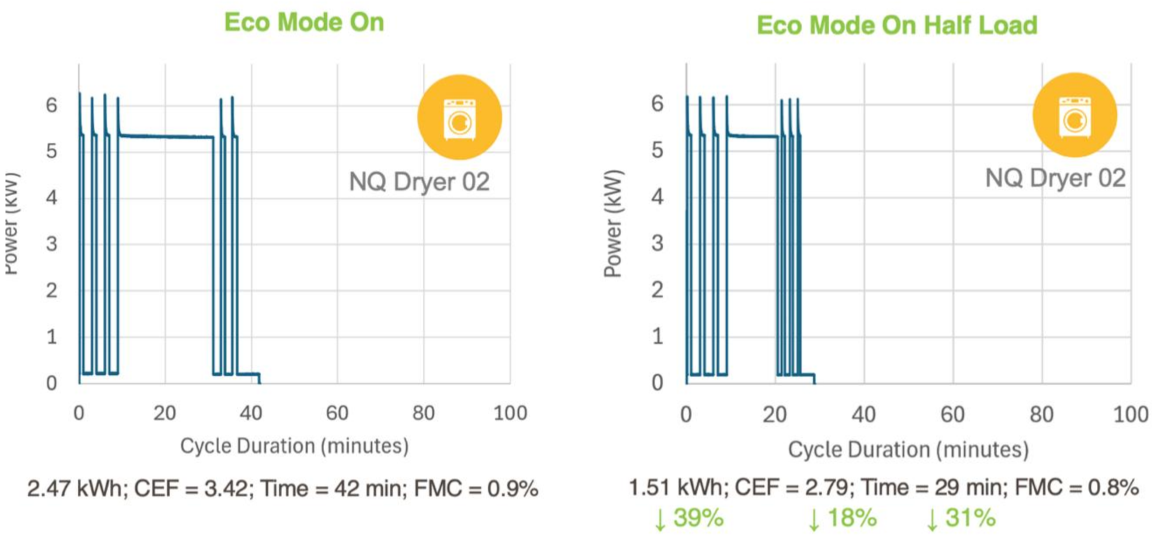


Figure 4 below illustrates one non-qualified dryer that terminated the half load quite effectively in Eco mode, reducing its energy use by 39% compared to full load. Given that automatic termination results vary across electric heating types and efficiency levels, the project team assumes these results are also applicable to conventional gas dryers.

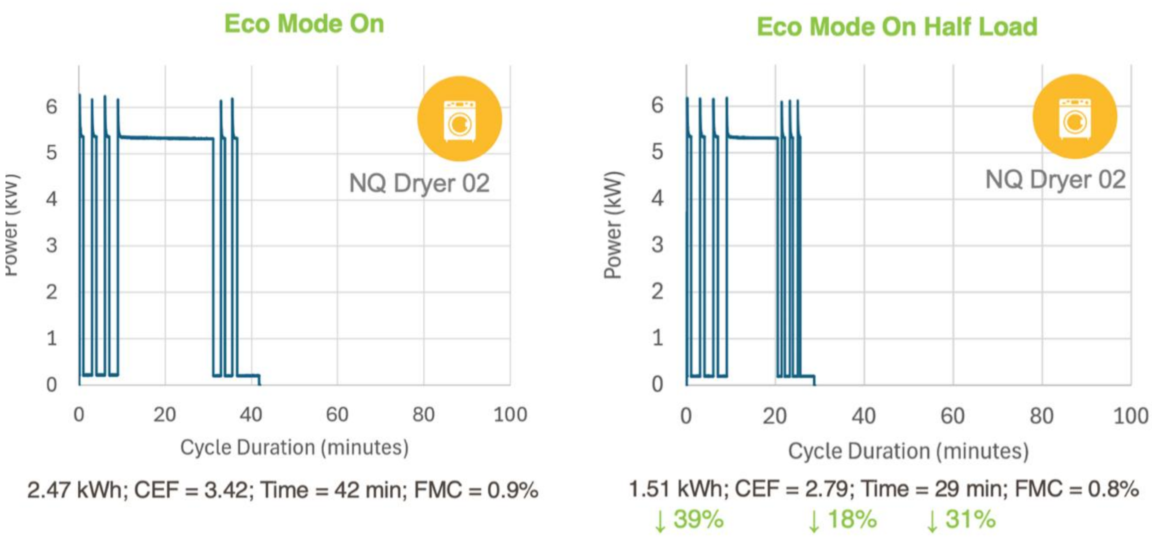


Figure 4. Time-series power data on non-qualified Dryer 02 with effective automatic termination

Half-Load Results

Key finding: A dryer's efficiency at full load usually predicts the efficiency at half load.

The team tested the dryers strictly according to Appendix D2 and then changed the load size to half load and tested it again with exactly the same test parameters and dryer settings. As shown in Figure 5Figure 5, the heat pump (HP) dryers (blue) have the highest CEF (higher is better) of the dryers tested, ranking at the top for both the 8.45 lb and 4.23 lb loads, followed by the ENERGY STAR (ES) dryers (green) and then the non-qualified (NQ) dryers (yellow and brown). Some interesting observations of these data include:

- Three heat pump dryers (Dryers 08, 11, and 12) demonstrate a wide range of efficiency with the 8.45 lb load (CEFs of less than 7 to nearly 11). Yet, they have a similar drying efficiency with the 4.23 lb load (around 6 CEF).
- One heat pump dryer (Dryer 10) and one top-selling ENERGY STAR dryer (Dryer 04) have different efficiencies when tested with the 8.45 lb load (5.4 and 4.3 CEFs). Yet, they have similar efficiencies when tested with the 4.23 lb load.

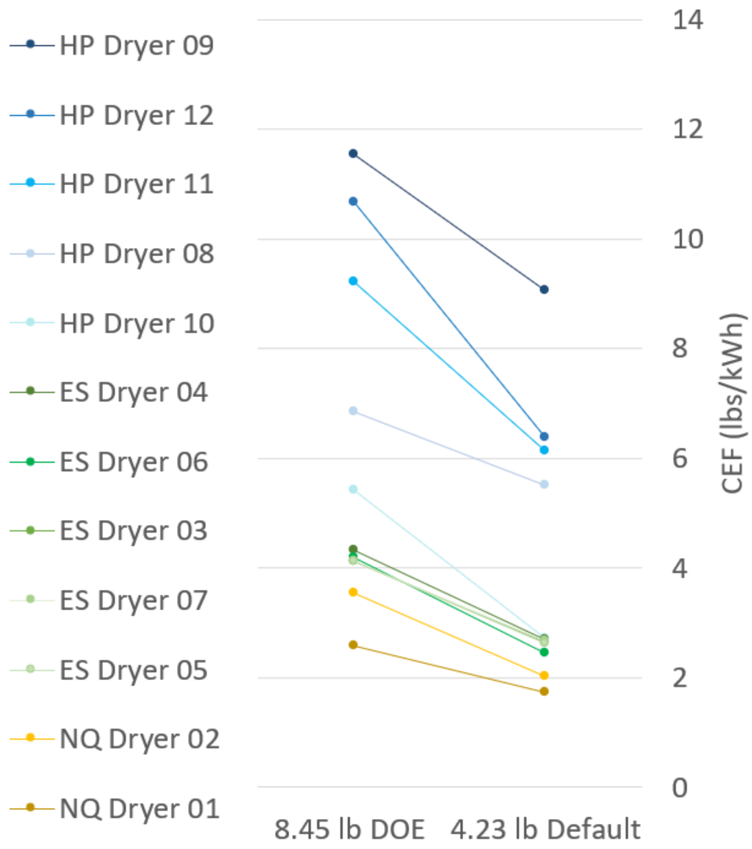


Figure 5. A dryer's efficiency at full load (8.45 lb) usually predicts the efficiency at half load (4.23 lb)

CEF consistently decreased under half-load conditions, with reductions ranging from 18 to 50% (Figure 6). The dryer that showed a 50% decrease in CEF used the same amount of energy (and even more time) to dry a half-sized load as a full-sized load. This is an example of poor automatic termination as discussed in the prior section. In contrast, dryers with a 20% CEF decrease yielded not only better energy efficiency, but also a shorter drying time, providing multiple benefits to consumers. The ENERGY STAR dryers' CEF reductions had a much smaller range than heat pump dryers. The variation in both dryer groups is attributable to key technologies that enable a dryer's ability to scale its energy use to the load size discussed in the Technology Results section: 1) effectiveness of the automatic termination algorithm and 2) ability to adjust heat output (dual-stage electric elements and inverter heat pumps). We expect these results to be applicable to gas dryers as well, given they have similar automatic termination technologies and future opportunities to use dual-stage gas burners (Pescatore and Carbone 2005).

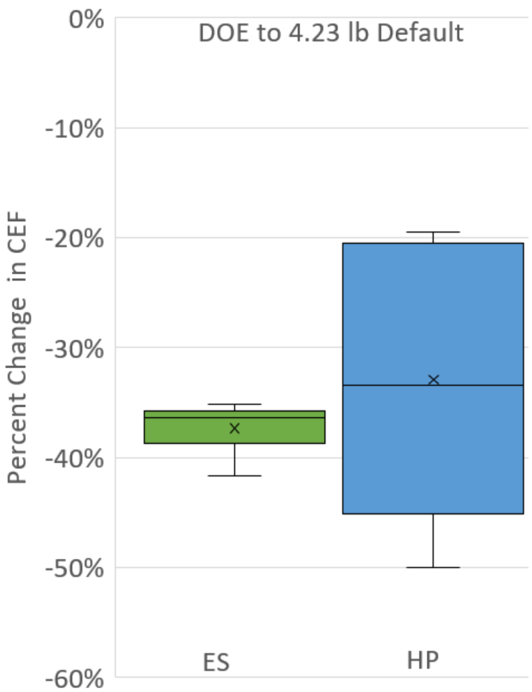


Figure 6. CEF decrease and variation from full load to half load condition

Eco Mode Results

Key finding: The Eco mode modifier produces an operational mode distinct from the Normal program and generally increases dryer efficiency (CEF). For conventional ENERGY STAR models, Eco mode also extends cycle time.

The impact of Eco mode on dryer efficiency for ENERGY STAR and heat pump dryers is summarized in Table 6, Figure 7, and Figure 98. We expect these results to be indicative of both electric and gas dryers, given that many ENERGY STAR gas dryers also have Eco mode.

Table 6. Summary of Eco mode impacts to dryer energy use, efficiency, and cycle time

Question	8.45 lb load	4.23 lb load
Does Eco mode lower energy use?	• On average, Eco mode saves energy and increases efficiency (CEF) relative to having it turned off (10 of 11 dryers [a]).	Eco mode saves energy and increases efficiency (CEF) for most dryers (nine of 11 dryers).
When Eco mode is turned off, how is the efficiency impacted? (Figure 7)	• CEF of ENERGY STAR Dryers decreases 20% to 30%. • CEF of heat pump dryers decreases 10% to 40%.	Efficiency (CEF) sometimes increases and sometimes decreases • 20% decrease to 10% increase for ENERGY STAR dryers • 20% decrease to nearly 30% increase for heat pump dryers
How does Eco mode impact cycle time? (Figure 8)	• For ENERGY STAR qualified dryers, cycle time is lengthened when Eco mode is engaged. • For heat pump dryers, cycle time may be lengthened or shortened.	

[a] The exception dryer was a non-qualifying dryer certified with testing under Appendix D1, so not designed for the Appendix D2 test. One non-qualifying dryer did not have Eco mode and so is excluded from this analysis.

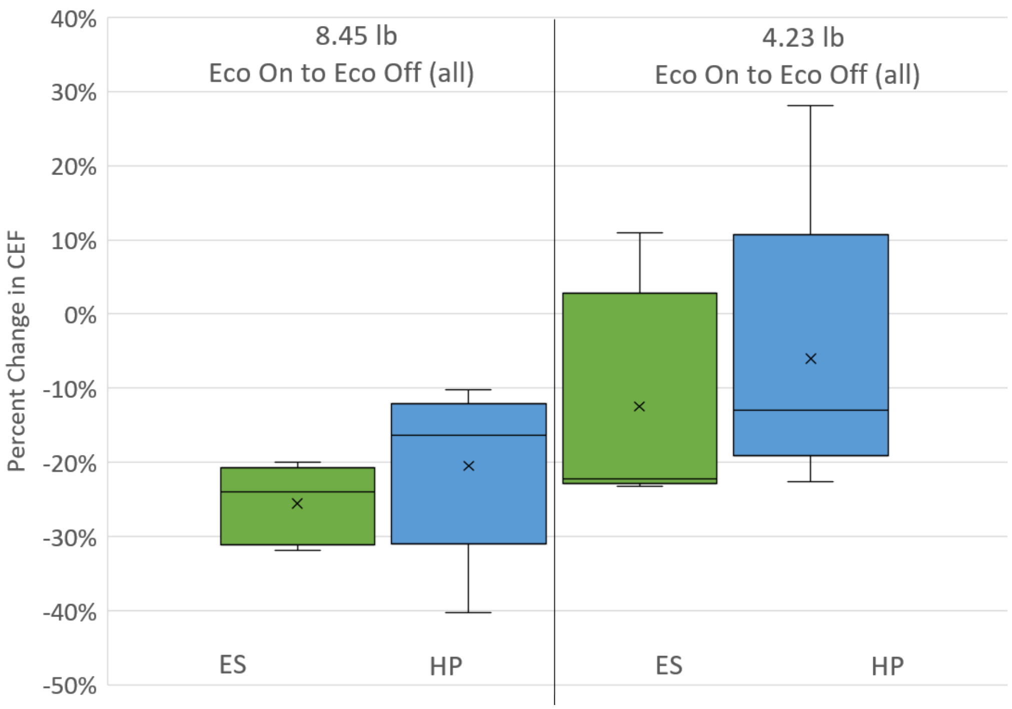


Figure 7. Eco on vs. Eco off—Percent changes in CEF for 8.45 lb load and 4.23 lb load

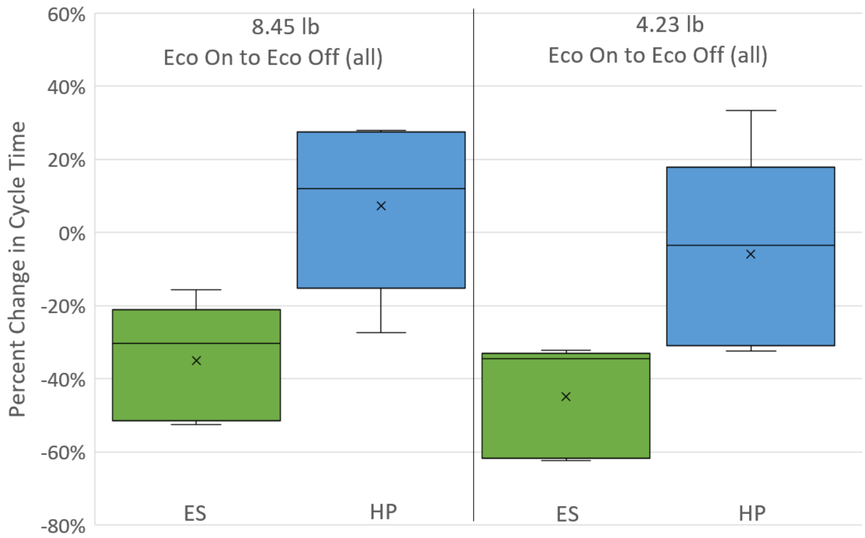


Figure 8. Percent change in cycle time when Eco mode is turned off

Results Relative to the Current Appendix D2 Test

Key findings:

1) ***Enabling Eco mode by default is the primary means by which conventional dryers meet the ENERGY STAR level (3.93 CEF); with Eco mode turned off, these products exhibit lower efficiency than the 2013 standard level (3.73 CEF).***
2) ***Heat pump dryers with a CEF of 6 or higher, as per Appendix D2, are more efficient than conventional ENERGY STAR and non-qualifying dryers in all tested conditions (including Eco mode turned off and half load).***

The team compared the test results to the Appendix D2 test that is now used for ENERGY STAR dryers and will be used for all dryers starting in 2028. Under Appendix D2, dryers are tested at specific settings intended to represent the consumer's typical automatic termination settings. Section 3.3.2 of the test procedure requires:

> *…[A] "normal" program shall be selected for the test cycle. For dryers that do not have a "normal" program, the cycle recommended by the manufacturer for drying cotton or linen clothes shall be selected. Where the drying temperature setting can be chosen independently of the program, it shall be set to the maximum. Where the dryness level setting can be chosen independently of the program, it shall be set to the "normal" or "medium" dryness level setting….* ***Any other optional cycle settings that do not affect the program, temperature or dryness settings shall be tested in the as-shipped position****….* (CFR 2026a, emphasis added)

Manufacturers seem to have interpreted this to enable use of an Eco mode during the evaluation of the efficiency if Eco mode is engaged by default in the as-shipped position. Two of the five heat pump dryers and all five of the conventional ENERGY STAR dryers had Eco mode engaged by default for the DOE (Appendix D2) test. Figure 9 shows NEEA's tests in the following order (left to right):

- DOE Appendix D2 8.45 lb load and Eco off
- DOE Appendix D2 8.45 lb load *per the test procedure with as-shipped default settings*
- DOE Appendix D2 with a 4.23 lb load *and as-shipped default settings*
- DOE Appendix D2 with a 4.23 lb load and Eco off

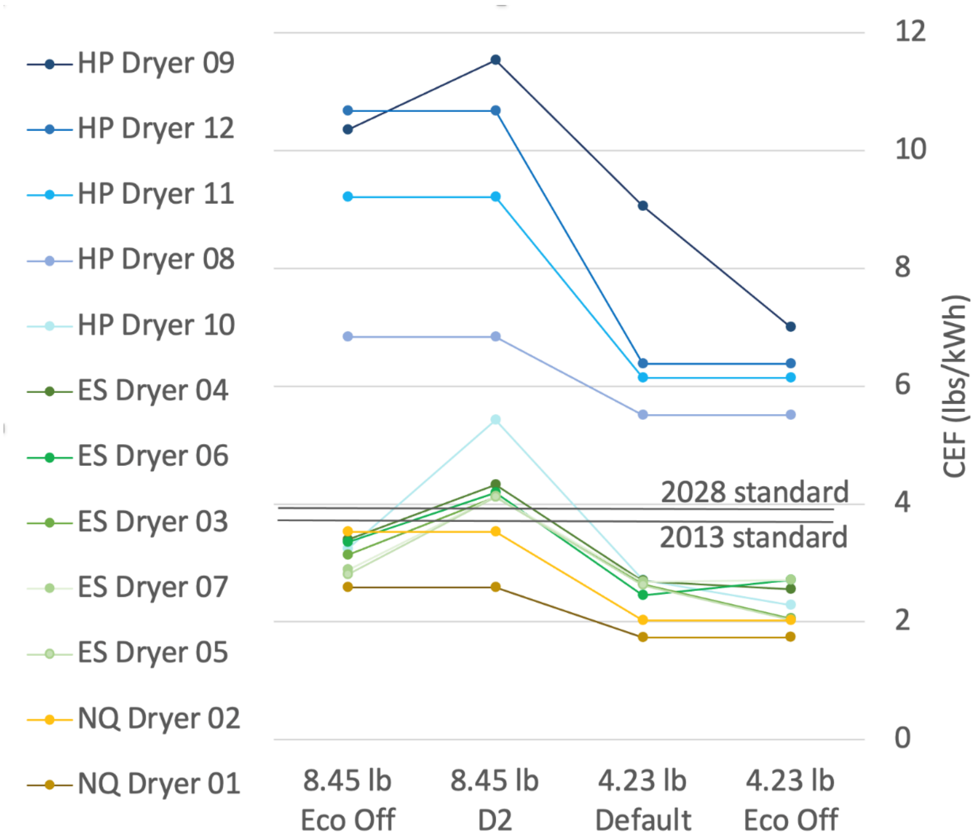


Figure 9. Test results relative to the current Appendix D2 Test

Notes: The 8.45 lb D2 test is the current method used to evaluate dryers. For the 8.45 lb Eco Off and 4.23 lb Default, only one parameter differs from the current method. In the former, Eco is turned off (if it is not already off by default), and in the latter, the load size is reduced while the settings specified by Appendix D2 remain the same. The 4.23 lb Eco Off has two changes from the current method: the load size is reduced, and Eco is turned off (for those dryers that have Eco on by default). It is most unlike the current method (8.45 lb D2) and is thus shown farthest from it.

Eco Mode and the 8.45 lb Load in the Context of Appendix D2 Testing

Turning off Eco lowers the efficiency for all dryers when it is engaged by default for the Appendix D2 test. Some specific observations of Figure 9 include:

- When Eco mode is turned off with an 8.45 lb load, none of the ENERGY dryers meet the 2013 standard (3.73 CEF); one heat pump dryer likewise does not meet the standard.
- When Eco mode is turned off with the 8.45 lb load, the efficiency of one non-qualified dryer (Dryer 02) is better than all the ENERGY STAR dryers and one heat pump dryer, changing the rank order.
- With Eco mode off, the efficiency of one heat pump dryer (Dryer 10) is like that of non-qualified and ENERGY STAR dryers.

Half Load (4.23 lb) in the Context of Appendix D2 Testing

Some specific observations of half load results (Figure 9) relative to Appendix D2 include:

- Heat pump dryers with wide-ranging efficiencies under Appendix D2 appear more similar when tested with a 4.23 lb load (Dryers 08, 11, and 12). The Appendix D2 measures CEF from under 7 to nearly 11 for these heat pump dryers, but they are all about 6 CEF with a half load. This is due to the differing abilities of heat pump dryers to scale energy use and cycle time with load size.
- With a half load and default as-shipped settings, the efficiencies of ENERGY STAR dryers are somewhat better than those of top-selling non-qualified dryers.
- Rank order performance changes for one heat pump dryer (Dryer 10) and most ENERGY STAR dryers when tested with Eco off and a 4.23 lb load.

Although results relative to the current Appendix D2 are based on electric dryers, the project team expects non-qualified and ENERGY STAR conventional gas dryers to perform similarly to non-qualified and ENERGY STAR conventional electric dryers.

Findings, Implications, and Recommendations

Findings

NEEA's research and testing revealed the following key findings:

- Dryer technology is more diverse than ever before. Electric heating technology and automatic termination controls for all dryers differ widely, and both impact efficiency (Technology Results Section).

A dryer is more efficient with larger load sizes. A dryer's efficiency at full load usually predicts its efficiency at half load (

- Half-Load Results Section).

- Dryer Eco mode modifier produces an operational mode distinct from the Normal program and generally increases dryer efficiency (CEF). For conventional ENERGY STAR models, Eco mode also extends cycle time (Eco Mode Results Section).
- The Eco mode control is the primary means by which conventional dryers meet the ENERGY STAR level (3.93 CEF) under Appendix D2; without Eco mode, these products exhibit lower efficiency than the current standard level of 3.73 CEF (Figure 9).
- Heat pump dryers with a CEF of 6 or higher, as per Appendix D2, are more efficient than conventional ENERGY STAR and non-qualifying dryers in all tested conditions (including Eco mode turned off and half load) (Figure 9).

Implications

Key Implication: Manufacturers are likely to rely on inexpensive control strategies as the primary means of achieving conventional dryer compliance with the 2028 standard (3.93 CEF), which may reduce expected energy savings from the standard update.

One of the key questions the research team asked at the conclusion of this testing was: What does this reveal about how dryers may be adapted and redesigned for the upcoming 2028 standard, which will require Appendix D2 testing and an efficiency level equivalent to 3.93 (the ENERGY STAR level at the time this study was conducted)? Data and market observations on the latest dryer control designs suggest that controls will likely be implemented in conventional dryers to meet the 2028 standard. Key evidence supporting controls as a key strategy for 2028 compliance includes:

- Conventional ENERGY STAR dryers already use controls, specifically Eco mode, as a key strategy to meet the standard. All top-selling conventional ENERGY STAR dryers in the sample for this study employ Eco mode by default. NEEA's prior analysis of the ENERGY STAR qualified product list for dryers revealed that the majority of conventional dryers are qualified using Eco mode (NEEA 2021, p. 4).
- The research data from this study shows that single-stage electric resistance dryers can exceed 3.93 CEF with Eco mode. (Dual-stage electric resistance is not required.)
- Using a controls-only compliance strategy is less expensive than other redesign options (like dual-stage electric resistance elements) and can be implemented while adhering to the requirements of Appendix D2. While some ENERGY STAR dryers utilize dual-stage resistive elements, this project confirms that technology is not required to meet a CEF of 3.93, as two of the three ENERGY STAR dryers had single-stage electric resistance elements.
- Evidence in the marketplace suggests that some manufacturers may be using Eco mode and other program/setting/control strategies in anticipation of the 2028 standard (Figure 10).

Green circles = program with preferential treatment on the control panel
Orange circles = program specified in Appendix D2

Figure 10. Marketplace evidence of control strategies in the newest products from top-selling manufacturers

However, if consumers select controls other than those tested, energy savings are likely to be lower than expected. NEEA's lab data in this study show that settings other than the default, such as Eco off, reduce dryer efficiency below the 2013 standard (3.73 CEF). In NEEA's 2026 market survey of the newest dryer models, some manufacturers are giving priority placement to dryer programs that are not currently evaluated under Appendix D2. This priority placement increases the likelihood that consumers will select them. For example, the "Mixed Loads" and "Regular" programs in the top and middle dryers in Figure 10 are likely to be selected more often by the consumer than the "Cottons" or "Normal" programs specified for testing in Appendix D2, as these are farther from the top of the dial.

While NEEA's 2023 Field Research study found that the most common automatic termination program is the Normal program, changes to preferential program placements on the control panel could lead to greater diversity in consumer program selection as new models come to market. In addition, even consumers who specifically purchased ENERGY STAR dryers disengage Eco mode on a significant portion of the cycles. The average consumer is less likely to engage Eco mode or use other programs that significantly extend cycle time to achieve more efficient drying.

Recommendations

Test Procedure Recommendations

Three possible recommended test updates emerged from this research:

1) Update the test procedure to account for changes to dryers' electronic controls, ensuring the test's intended goal of measuring energy use under the most common setting or settings is met.
2) Add a second half-load test to the test procedure to create opportunities for manufacturers to save energy on this common load by implementing more effective automatic termination controls and/or variable-speed fans.
3) Consider lowering the initial moisture content of textiles at the start of the test. IMC research revealed that a lower IMC for dryer tests may be warranted.

These three recommendations are discussed in the sections below.

1) Changes to dryers' electronic controls

Key Recommendation: Updating the test procedure to account for changes to dryers' electronic controls will help ensure the test meets its intended goal of measuring energy use under the most common setting(s).

The intent of the Appendix D2 test procedure is to measure the most used program, which has historically been the normal program with high heat. However, when Eco mode is enabled in the "as-shipped" condition, the commonly used settings are bypassed in favor of a more energy-efficient, longer-running program. While the use of Eco mode generally saves energy, it is not the most common operating condition for dryers today, and these types of programs will be less common in the future for many reasons (see Implications section).

One way to address this is to clarify that the settings for testing the 8.45 lb load in Appendix D2 should exclude (turn off) any cycle modifier (such as Eco) that changes the dryer's efficiency. Furthermore, care shall be taken to specify that the program tested is the program most likely to be used by the consumer. For example, including phrasing such as "the program recommended for common use that is placed in a priority location on the control panel" may help ensure the dryer is being tested in a commonly used condition and is readily accessible to the user via the dryer controls, regardless of the program name. For digital controls that are not physically printed on the exterior dryer panel but instead appear on a screen, the program's priority location may need to be defined as “the first program that appears on the screen when the dryer is powered on.”

2) A half-load test in the test procedure

Key Recommendation: Including a half-load test in the test procedure would create an opportunity for manufacturers to demonstrate energy savings for this common load size, perhaps through better automatic termination control or variable-speed fans.

While the rank order of dryer CEF does not change substantially when dryers are tested with a 4.23 lb (half) and 8.45 lb load, NEEA’s testing revealed that dryers differ in how effectively they scale their energy use to the size of the load. One dryer used the same amount of energy to dry a half load as it did to dry an 8.45 lb load. Another dryer lowered its 8.45 lb cycle energy use by nearly 40% when it dried the half load (see section on Technology Results). Furthermore, NEEA’s field research indicates that small loads are common, representing 35% of all loads dried, second only to medium loads (46% of all loads dried) (NEEA 2026). Adding a half-load test to the test procedure would increase the testing burden by about 25%,[3] but could help distinguish dryers that effectively scale energy use and cycle time with load size, significantly benefiting consumers through utility bill savings and reduced cycle times. Furthermore, Appendix D2 has the lowest test burden among similar white-good appliances, yet it has the highest energy use (see section on Relative Test Procedure Burden). Providing more opportunities for manufacturers to demonstrate and receive credit for energy-saving technologies, such as automatic termination controls and variable-speed fans, can help deliver cost-effective energy savings to consumers.

[3] NEEA’s experience with dryer testing confirms that a set amount of effort is required for dryer setup, instrumentation, and standby testing. Once that is complete, adding more test runs results in only a fractional increase in the current testing effort.

3) Adjusting the initial moisture content (IMC) of the textile load

Key Recommendation: A lower IMC may be warranted in a future revision of Appendix D2.

The project team's IMC research and calculations revealed that a lower IMC may be warranted for dryer testing. This recommendation considers the most recent data on washer RMC in the field (NEEA 2026) and is a sales-weighted average of top- and front-load washers in the US (See Clothes Washer RMC Is Dryer IMC in Real-World Use and Appendix A: Calculating Laboratory Dryer IMC from Field Washer RMC for details on this calculation). NEEA's 2020 clothes washer lab study suggests new models may achieve lower RMCs than the 2023 field average as the new clothes washer test procedure—Appendix J—is implemented in 2028 (CFR 2026g). So, washer RMC may drop further in the coming years.

Utility Program Recommendations

Key Recommendation: Based on its testing research, the NEEA project team recommends a greater focus on promoting heat pump dryers, which offer higher, more certain energy savings.

This research indicates that increased promotion and support for heat pump dryers—which offer higher, more certain energy savings than conventional ENERGY STAR dryers—could increase the quantity and reliability of energy savings for laundry equipment. Conventional ENERGY STAR dryers save energy with Eco mode, but the real-world savings depend on user settings. In contrast, the energy savings are more secure with heat pump dryers 6.0 CEF and above.

At the time of publication, many more standard-size heat pump dryers are available on the market than ever before, so consumers can purchase a heat pump dryer in a size they are familiar with. Furthermore, the Inflation Reduction Act (IRA) rebates have allowed consumers in some states (e.g., California and New York) to receive a government rebate for heat pump dryers. Utilities and NEEA can supplement this market momentum by supporting consumers and retailers. Market intervention opportunities include:

- Developing consumer education programs that promote heat pump dryers and familiarize consumers with their benefits and differences from conventional dryers.
- Allocating higher incentive dollars to mid-stream retail partners in programs such as the ENERGY STAR Retail Products Program (ESRPP) to encourage retailers to place full-size heat pump dryers and laundry combos on the floor, supporting consumer adoption.
- Implementing an award for high-efficiency dryers (≥ 6.0 CEF) with a short drying time could incentivize the development of more efficient dryers that meet consumer cycle-time expectations (60 minutes or less).

In conclusion, capitalizing on this market momentum toward heat pump dryers can help utilities and utility-like agencies (such as NEEA) confidently secure energy savings for ratepayers.

Conclusions

Analysis of Objectives

The project fulfilled the objectives identified at the outset. The study team examined whether the Appendix D2 test procedure effectively predicts dryer performance in other commonly found use cases. The team concluded that while the current test procedure does seem to effectively predict the performance of a small load size for most dryers, cycle modifiers used in the default position (Eco mode) have a significant impact on efficiency. Today's dryer settings are more complicated than those in prior models, and the Appendix D2 testing language for selecting programs and settings may no longer capture the original intent: to measure the most-used settings. The team recommended revisions to the test procedure to better address the latest dryer controls and technology. These included:

- Update the test procedure to account for changes to dryers' electronic controls, ensuring the test's intended goal of measuring energy use under the most common setting or settings is met.
- Add a second half-load test to the test procedure to incentivize manufacturers to save energy in this common load size, perhaps by implementing more effective automatic termination controls.
- Consider lowering the initial moisture content of textiles at the start of the test. IMC research revealed that a lower IMC for dryer tests may be warranted.

Suggested Areas of Additional Research

Potential additional areas of research include:

- A nationally representative field study. NEEA leveraged its 2023 field study to identify common use conditions, but given the changing dryer technology, it may be helpful to conduct a national study to document dryer use patterns, including settings and load sizes. This type of study may be most useful after the implementation of the 2028 mandatory standard, to capture the latest control strategies and technologies.
- Development of a commercial dryer test procedure. This study addressed residential dryers, but opportunities for energy savings in commercial dryers remain largely untapped due to a lack of standardized testing to measure efficiency. Developing a commercial dryer test procedure would be the first step to supporting utility and government programs that could reward and encourage improved efficiency of commercial dryers.

References

American Society for Testing and Materials (ASTM). 1975. *Standard Test Methods for Quantitative Analysis of Textiles.* West Conshohocken, PA: American Society for Testing and Materials. Retrieved from https://file.yizimg.com/175706/2011090909585167.pdf.

Bosch. 2009. *Appliances that do everything. Except compromise.* 2009 Home Appliances Full Product Line. Farmington Hills, MI: Bosch U.S. Headquarters. Retrieved from https://www.scribd.com/document/90441268/2009-Bosch-Full-Line-Catalog-LR.

Bush, Eric, Anette Michel, Francisco R. Zuloaga, Chris Granda, and Christopher Wold. 2015. *Heat Pump Tumble Driers: Market Development in Europe and MEPS in Switzerland.* Presented in Lucerne, Switzerland at the 8th International Conference on Energy Efficiency in Domestic Appliances and Lighting, 2015. Retrieved from https://storage.topten.eu/source/files/EEDAL15_Eric_Bush_Heat_Pump_Tumble_Driers.pdf.

Code of Federal Regulations (CFR). 1977. Appendix D to Subpart B of Part 430—*Uniform Test Method for Measuring the Energy Consumption of Clothes Dryers.* Washington, DC: Code of Federal Regulations. Retrieved from https://www.govinfo.gov/content/pkg/FR-1977-09-14/pdf/FR-1977-09-14.pdf pp. 461450-46151

Code of Federal Regulations (CFR). 1981. Appendix D to Subpart B of Part 430—*Uniform Test Method for Measuring the Energy Consumption of Clothes Dryers.* Washington, DC: Code of Federal Regulations. Retrieved from https://archives.federalregister.gov/issue_slice/1981/5/19/27323-27328.pdf pp. 27326-27328.

Code of Federal Regulations (CFR). 2026a. Title 10—Chapter II—Subchapter D—Part 430—Subpart B—Appendix D1 to Subpart B of Part 430. Appendix D1 to Subpart B of Part 430—*Uniform Test Method for Measuring the Energy Consumption of Clothes Dryers.* Washington, DC: Code of Federal Regulations. Accessed 3/17/2026 from https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20D1%20to%20Subpart%20B%20of%20Part%20430.

Code of Federal Regulations (CFR). 2026b. Title 10—Chapter II—Subchapter D—Part 430—Subpart B—Appendix D2 to Subpart B of Part 430. Appendix D2 to Subpart B of Part 430—*Uniform Test Method for Measuring the Energy Consumption of Clothes Dryers.* Washington, DC: Code of Federal Regulations. Accessed 4/11/2026 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.

Code of Federal Regulations (CFR). 2026c. Title 10—Chapter II—Subchapter D—Part 430—Subpart C—§ 430.32. *Energy and water conservation standards and their compliance dates.* Washington, DC: Code of Federal Regulations. Accessed 3/17/2026 from https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-C/section-430.32.

Code of Federal Regulations (CFR). 2026d. Title 10—Chapter II—Subchapter D—Part 430—Subpart B—Appendix A to Subpart B of Part 430—*Uniform Test Method for Measuring the Energy Consumption of Refrigerators, Refrigerator-Freezers, and Miscellaneous Refrigeration Products.* Washington, DC: Code of Federal Regulations. Accessed 4/15/2026 from https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20A%20to%20Subpart%20B%20of%20Part%20430

Code of Federal Regulations (CFR). 2026e. Washington, DC: Code of Federal Regulations. Title 10—Chapter II—Subchapter D—Part 430—Subpart B—Appendix C1 to Subpart B of Part 430—*Uniform Test Method for Measuring the Energy Consumption of Dishwashers.* Washington, DC: Code of Federal Regulations. Accessed 4/15/2026 from https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20C1%20to%20Subpart%20B%20of%20Part%20430

Code of Federal Regulations (CFR). 2026f. Title 10—Chapter II—Subchapter D—Part 430—Subpart B—Appendix J2 to Subpart B of Part 430—*Uniform Test Method for Measuring the Energy Consumption of Automatic and Semi-automatic Clothes Washers.* Washington, DC: Code of Federal Regulations. Accessed 4/15/2026 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). 2026g. Title 10—Chapter II—Subchapter D—Part 430—Subpart B—Appendix J to Subpart B of Part 430—*Uniform Test Method for Measuring the Energy Consumption of Automatic and Semi-Automatic Clothes Washers.* Washington, DC: Code of Federal Regulations. Accessed 4/15/2026 from https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-430/subpart-B/appendix-Appendix%20J%20to%20Subpart%20B%20of%20Part%20430

ENERGY STAR. 2024. *ENERGY STAR® Program Requirements: Product Specification for Clothes Dryers—Partner Commitments.* Washington, DC: ENERGY STAR, U.S. Environmental Protection Agency. Retrieved from https://www.energystar.gov/sites/default/files/2024-10/ENERGY%20STAR%20Version%201.1%20Clothes%20Dryers%20Specification%20-%20Rev.%20October-2024.pdf.

ENERGY STAR. 2024. *Most Efficient 2025: Recognition Criteria for Clothes Dryers.* Washington, DC: ENERGY STAR, U.S. Environmental Protection Agency. Retrieved from https://www.energystar.gov/sites/default/files/2024-09/Clothes%20Dryer%20ENERGY%20STAR%20Most%20Efficient%202025%20Criteria.pdf.

ENERGY STAR. 2014. *Clothes Dryers Specification Version 1.* Washington, DC: ENERGY STAR, U.S. Environmental Protection Agency. Retrieved from https://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Final%20Version%201%200%20Clothes%20Dryers%20Program%20Requirements.pdf.

Liegey, Paul R. 2003. *Hedonic Quality Adjustment Methods For Clothes Dryers In the U.S.* CPI. Washington, DC: U.S. Bureau of Labor Statistics. Accessed 3/17/2026 from https://www.bls.gov/cpi/quality-adjustment/clothes-dryers.htm.

Martin, Eric, Karen Sutherland, and Danny Parker, Florida Solar Energy Center. 2016. *Measured Performance of Heat Pump Clothes Dryers.* Presented at 2016 ACEEE Summer Study on Energy Efficiency in Buildings. Retrieved from https://www.fsec.ucf.edu/en/publications/pdf/fsec-rr-645-16.pdf.

National Archives and Records Service (NARS). 1982. *Federal Register, Wednesday December 22, 1982, Selected Subjects.* Vol 47, No. 246. Washington, DC: National Archives and Records Service, General Services Administration. Retrieved from https://www.govinfo.gov/content/pkg/FR-1982-12-22/pdf/FR-1982-12-22.pdf

Northwest Energy Efficiency Alliance (NEEA). 2026. *2023 Residential Laundry Field Study.* Portland, OR: Northwest Energy Efficiency Alliance. Retrieved from https://neea.org/resource/2023-residential-laundry-field-study/.

Northwest Energy Efficiency Alliance (NEEA). 2023. [Comment letter to ENERGY STAR] *NEEA Comments on the EPA's ENERGY STAR Most Efficient 2024 Proposed Criteria.* Portland, OR: Northwest Energy Efficiency Alliance. Retrieved from https://www.energystar.gov/sites/default/files/asset/document/NEEA_0.pdf.

Northwest Energy Efficiency Alliance (NEEA). 2021. *2021-07-06 Comment response to the published Notification of a webinar and availability of preliminary technical support document.* Portland, OR: Northwest Energy Efficiency Alliance. Retrieved from https://www.regulations.gov/comment/EERE-2014-BT-STD-0058-0030.

Northwest Energy Efficiency Alliance (NEEA). 2020. *Coming Clean: Revealing the Real-World Efficiency of Clothes Washers.* Portland, OR: Northwest Energy Efficiency Alliance. Retrieved from https://neea.org/wp-content/uploads/2025/03/Coming-Clean-Revealing-Real-World-Efficiency-of-Clothes-Washers.pdf.

Northwest Energy Efficiency Alliance (NEEA). 2014a. *NEEA Clothes Dryer Field Study.* Portland, OR: Northwest Energy Efficiency Alliance. Retrieved from https://neea.org/resource/rbsa-laundry-study/.

Northwest Energy Efficiency Alliance (NEEA). 2014b. *Residential Building Stock Assessment: Metering Study.* Table ES3. Major Appliance Yearly Usage (Averages). Portland, OR: Northwest Energy Efficiency Alliance. Retrieved from https://neea.org/wp-content/uploads/2025/03/residential-building-stock-assessment-metering-study.pdf.

Pescatore, Peter, and Phil Carbone. 2005. *High Efficiency, High Performance Clothes Dryer.* Final Report to U.S. Department of Energy (DOE). Cambridge, MA: TIAX LLC. Retrieved from https://www.osti.gov/servlets/purl/888669.

Samsung. 2012. [CES 2012] *Anything but Routine, Samsung Launches a Laundry Appliance Game-Changer.* Suwon, Gyeonggi, Republic of South Korea: Samsung Newsroom. Retrieved from https://news.samsung.com/global/anything-but-routine-samsung-launches-a-laundry-appliance-game-changer.

U.S. Department of Energy (DOE). 2024a. *Energy Conservation Program: Energy Conservation Standards for Residential Clothes Dryers; Direct Final Rule* [10 CFR Part 430, Docket Number EERE-2017-BT-STD-0014-0515]. Washington, DC: U.S. Department of Energy. Retrieved from https://www.regulations.gov/document/EERE-2017-BT-STD-0014-0515.

U.S. Department of Energy (DOE). 2024b. *Energy Conservation Program: Energy Conservation Standards for Residential Clothes Dryers* [10 CFR Part 430, Docket Number EERE–2014-BT-STD-0058]. Washington, DC: U.S. Department of Energy. Retrieved from https://www.energy.gov/sites/default/files/2024-02/clothes-dryers-ecs-dfr.pdf.

U.S. Department of Energy (DOE). 2021. *Energy Conservation Program: Test Procedure for Clothes Dryers; Final rule.* Washington, DC: U.S. Department of Energy. Retrieved from https://www.regulations.gov/document/EERE-2014-BT-TP-0034-0039.

U.S. Department of Energy (DOE). 2015. *Energy Conservation Program: Energy Conservation Standards for Residential Clothes Dryers* [10 CFR Part 431, Docket Number EERE–2014-BT-STD-0058]. Washington, DC: U.S. Department of Energy. Retrieved from https://www.energy.gov/eere/buildings/articles/2015-03-23-issuance-energy-conservation-standards-residential-clothes.

U.S. Department of Energy (DOE). 2013. *Energy Conservation Program: Test Procedures for Residential Clothes Dryers* [10 CFR Parts 429 and 430, Docket No. EERE–2011–BT–TP–0054]. Washington, DC: U.S. Department of Energy. Retrieved from https://www.federalregister.gov/documents/2013/08/14/2013-18931/energy-conservation-program-test-procedures-for-residential-clothes-dryers.

U.S. Department of Energy (DOE). 2011. *Energy Conservation Program for Consumer Products: Test Procedures for Clothes Dryers and Room Air Conditioners.* Washington, DC: U.S. Department of Energy. Retrieved from https://www.federalregister.gov/documents/2011/01/06/2010-32118/energy-conservation-program-for-consumer-products-test-procedures-for-clothes-dryers-and-room-air.

U.S. Department of Energy (DOE). 2010. *Energy Conservation Standards for Residential Clothes Dryers and Room Air Conditioners: Public Meeting and Availability of the Preliminary Technical Support Document.* Washington, DC: U.S. Department of Energy. Retrieved from https://www.federalregister.gov/documents/2010/02/23/2010-3479/energy-conservation-standards-for-residential-clothes-dryers-and-room-air-conditioners-public.

U.S. Department of Energy (DOE). 1982. *Energy Conservation Program for Consumer Products; Final Rule for Clothes Dryers and Kitchen Ranges and Ovens.* Washington, DC: U.S. Department of Energy. Retrieved from https://www.govinfo.gov/content/pkg/FR-1982-12-22/pdf/FR-1982-12-22.pdf. [applies to former footnote 15]

U.S. Department of Energy (DOE). 1977. *Energy Conservation Program for Consumer Products: Test Procedures for Clothes Dryers and Room Air Conditioners.* Washington, DC: U.S. Department of Energy. Retrieved from https://www.federalregister.gov/documents/2011/01/06/2010-32118/energy-conservation-program-for-consumer-products-test-procedures-for-clothes-dryers-and-room-air. See also original source at https://archives.federalregister.gov/issue_slice/1977/9/14/46111-46191.pdf#page=35.

U.S. Energy Information Administration (EIA). 2023. *2020 Residential Energy Consumption Survey.* Tables: “Table HC3.9—Appliances in U.S. homes, by home size, 2020” and “Relative standard errors (RSEs) for Table HC3.9 Appliances in U.S. homes, by home size, 2020” Data release date: March 2023. Washington, DC: U.S. Energy Information Administration, Office of Energy Demand and Integrated Statistics. Retrieved from https://www.eia.gov/consumption/residential/data/2020/hc/pdf/HC%203.9.pdf.

Appendix A: Calculating Laboratory Dryer IMC from Field Washer RMC

While NEEA's 2013 field study found the average washer RMC was 62% (NEEA 2014a), market average washer RMC derived from NEEA's 2023 field study was significantly lower (NEEA 2026). The team used existing market data on the share of top and front load washers to estimate that the average field RMC for the US is 56.8%, and for the Northwest, it is 56.3% (source data in Table 7).

Table 7. Data and sources used for IMC calculations

	Washer RMC 2023 NEEA field study	US Market Share Fraction	NW Market Share Fraction
Top-load Washer	54%	74%	64%
Front-Load Washer	48%	26%	36%
Source	NEEA 2026	DOE 2024a	NEEA 2023

These field values do not directly correspond to lab-measured values because the textile load weights used to calculate them are not bone-dry; they contain some moisture, as they are loads actually dried in homes. This Appendix A provides the NEEA project team's methodology for mathematically adjusting the field RMC average of a washer to bone-dry values that can be consistently replicated in a laboratory setting.

The NEEA project team estimated the weight of water remaining in home laundry loads in the Northwest, assuming a 65% relative humidity. At 65% relative humidity, cotton is 7.4% moisture, and polyester is 0.3% moisture (ASTM 1975). Averaging these because DOE test cloths are 50% cotton and 50% synthetic yields a 3.9% moisture content. The Appendix D2 threshold for the final moisture content (FMC) of a test load is 2%. The team estimated that the actual FMC would be the average of these two values, or 2.9%. It is not as simple as adding 2.9% moisture to the field RMC because the dried weight appears both in the numerator and denominator:

IMC_field = (wet - (bone_dry + 2.9%))/(bone_dry + 2.9%)

Where IMC_field is the percentage point value obtained in the field research, wet is the wet weight and bone_dry is the bone-dry weight. After algebraically arranging the equation, it becomes

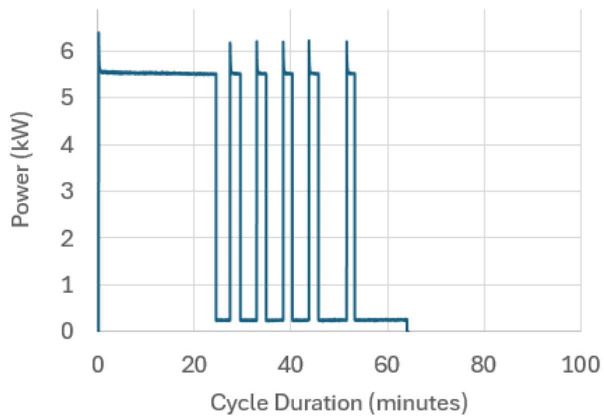
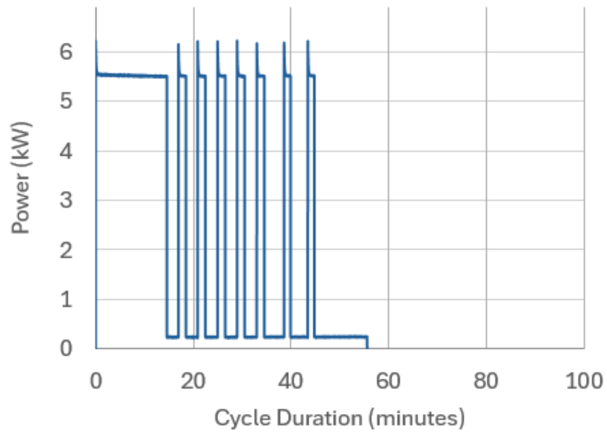
IMC_lab = IMC_field*(1 + 2.9%) + 2.9%

Thus, the initial moisture content used in the lab (IMC_lab) is 58.5% for top load and 52.3% for front load. When considering the market share of these two washer types, the study team estimates the US washer IMC is 56.8% and the Northwest region IMC is 56.3%.

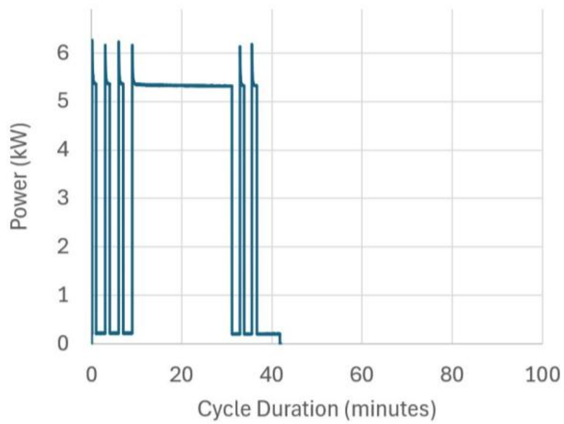
Appendix B: Time-Series Dryer Data

Non-qualified Dryers

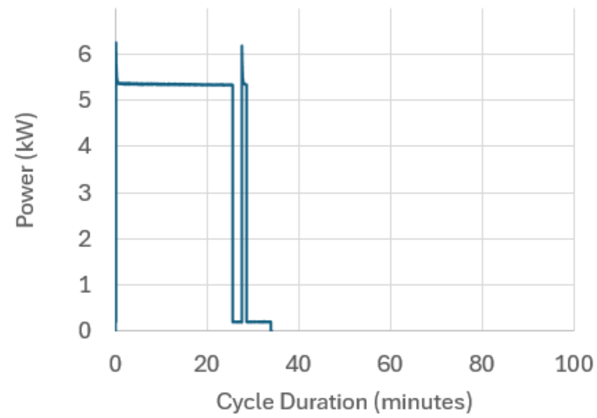
NQ Dryer 01

No image (Dryer 01 does not have an Eco mode)	
DOE Appendix D2—8.45 lb load & Eco on	**DOE Appendix D2—8.45 lb load & Eco off**
No image (Dryer 01 does not have an Eco mode)	
DOE Appendix D2—4.23 lb load & Eco on	**DOE Appendix D2—4.23 lb load & Eco off**

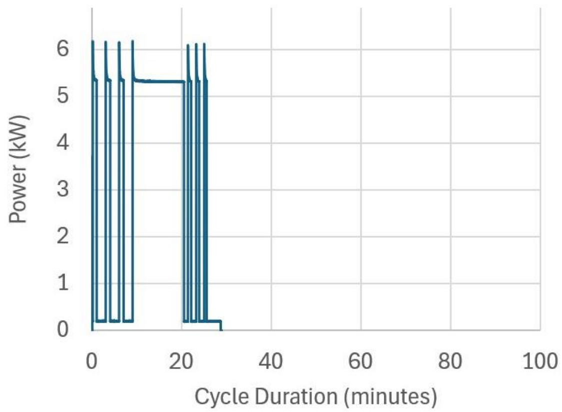
NQ Dryer 02



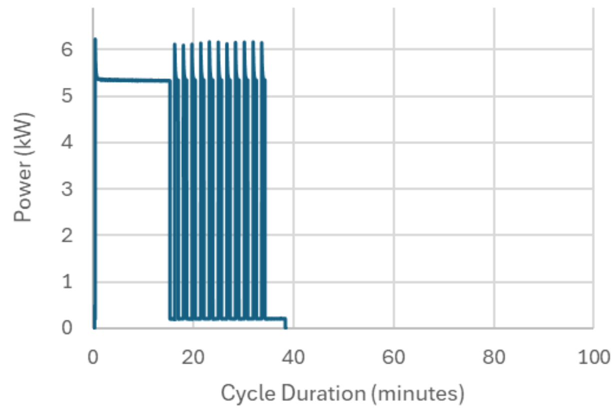
DOE Appendix D2—8.45 lb load & Eco on



DOE Appendix D2—8.45 lb load & Eco off



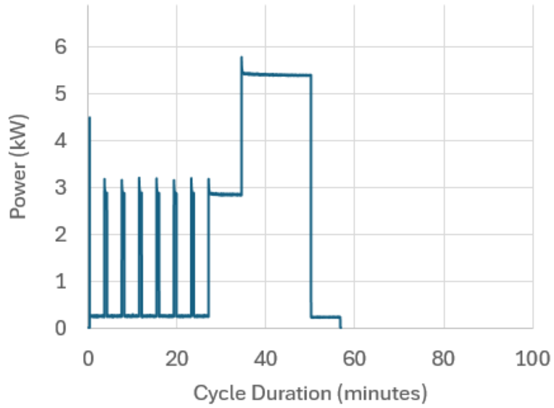
DOE Appendix D2—4.23 lb load & Eco on



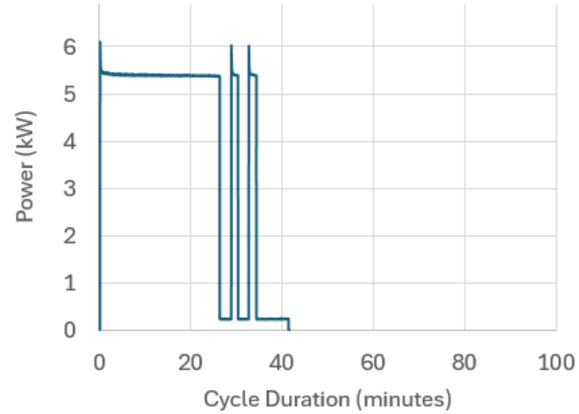
DOE Appendix D2—4.23 lb load & Eco off

ENERGY STAR Dryers

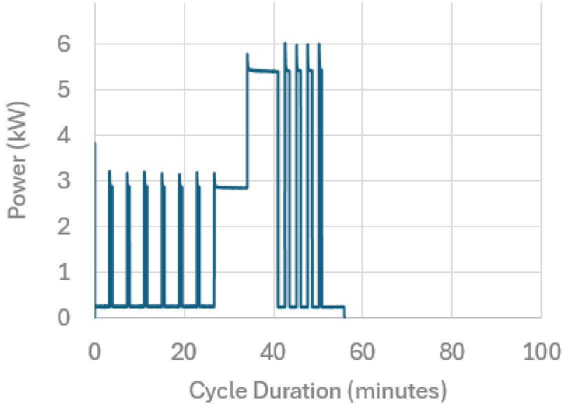
ES Dryer 03



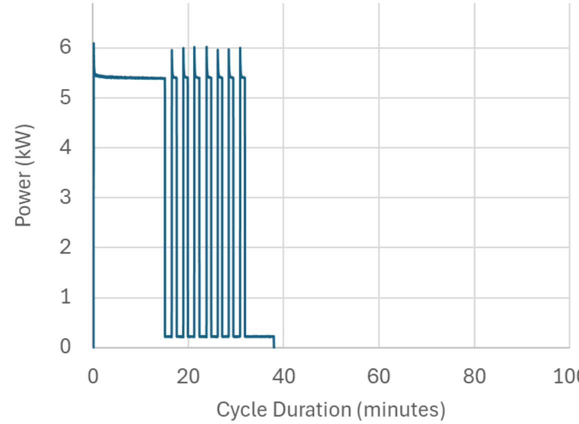
DOE Appendix D2—8.45 lb load & Eco on



DOE Appendix D2—8.45 lb load & Eco off

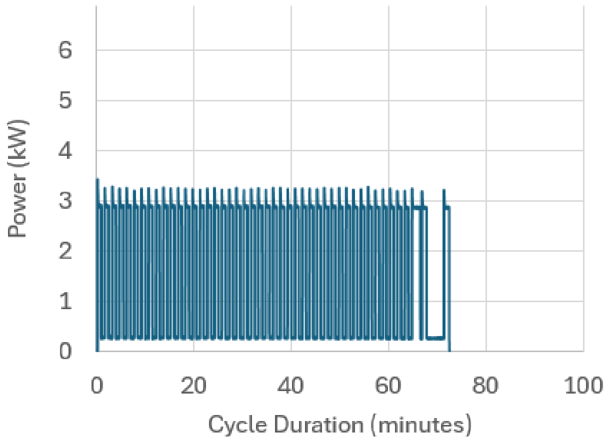


DOE Appendix D2—4.23 lb load & Eco on

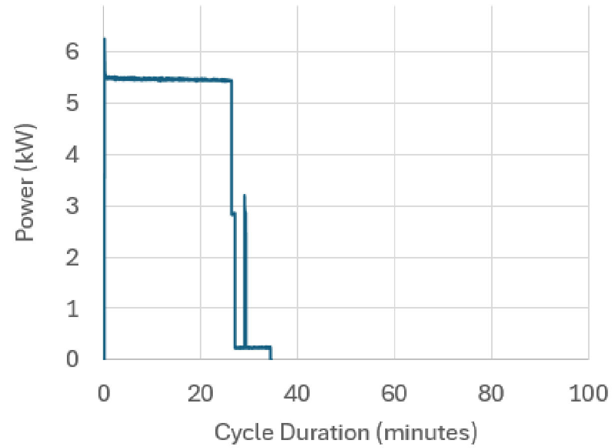


DOE Appendix D2—4.23 lb load & Eco off

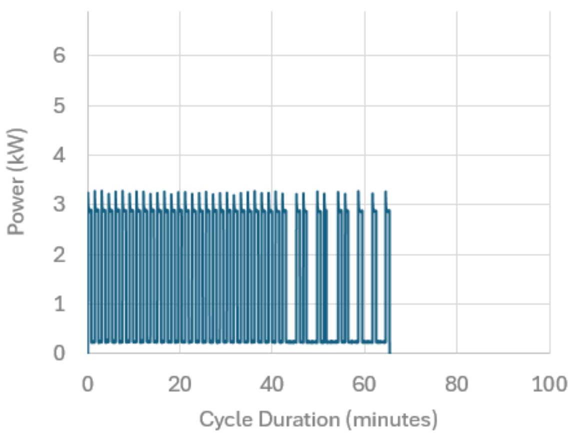
ES Dryer 04



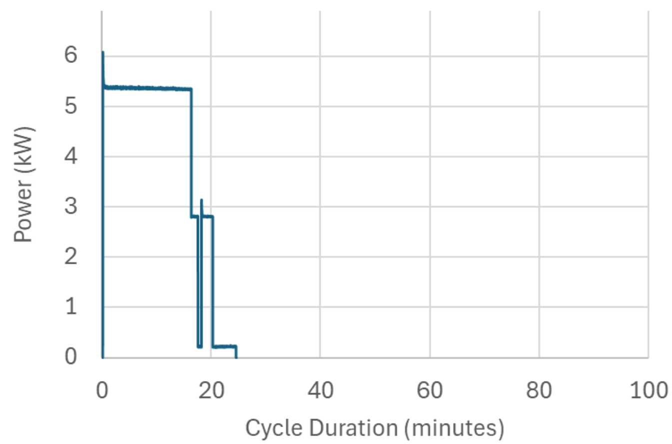
DOE Appendix D2—8.45 lb load & Eco on



DOE Appendix D2—8.45 lb load & Eco off

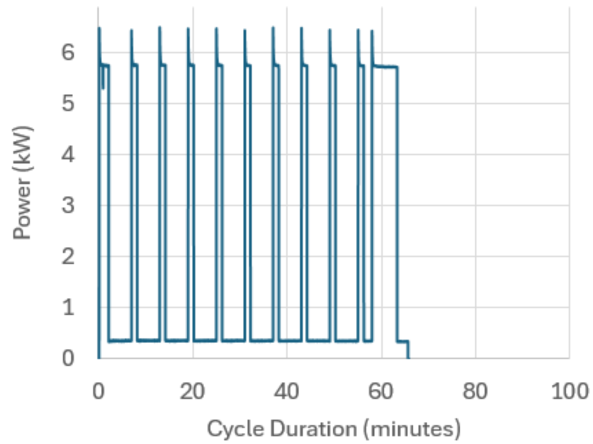


DOE Appendix D2—4.23 lb load & Eco on

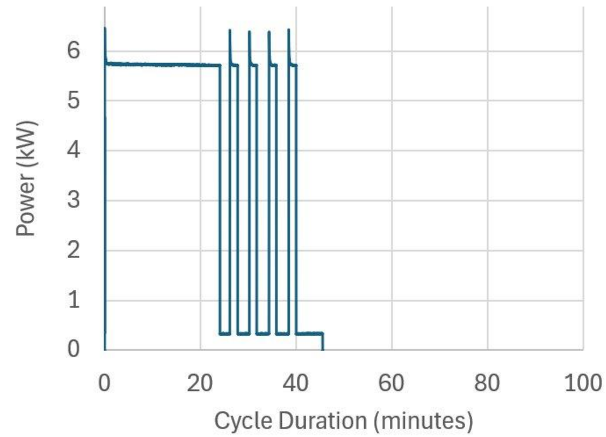


DOE Appendix D2—4.23 lb load & Eco off

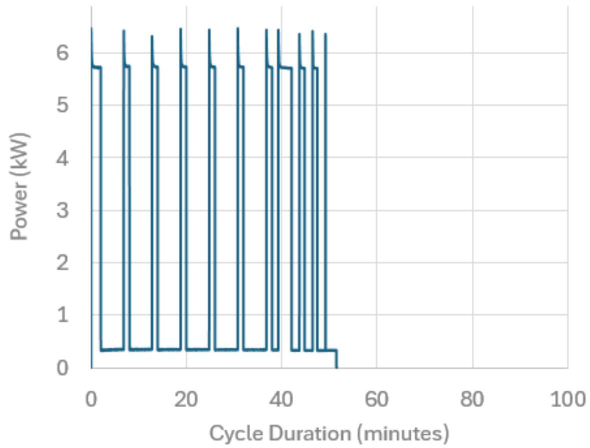
ES Dryer 05



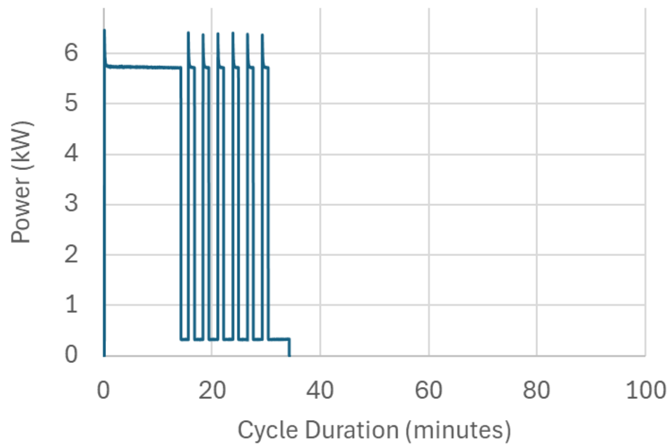
DOE Appendix D2—8.45 lb load & Eco on



DOE Appendix D2—8.45 lb load & Eco off

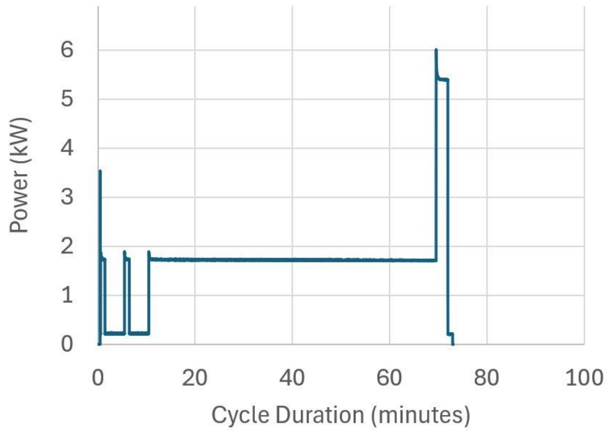


DOE Appendix D2—4.23 lb load & Eco on

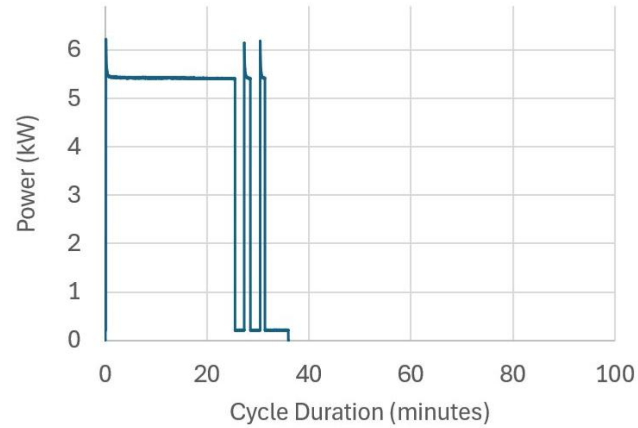


DOE Appendix D2—4.23 lb load & Eco off

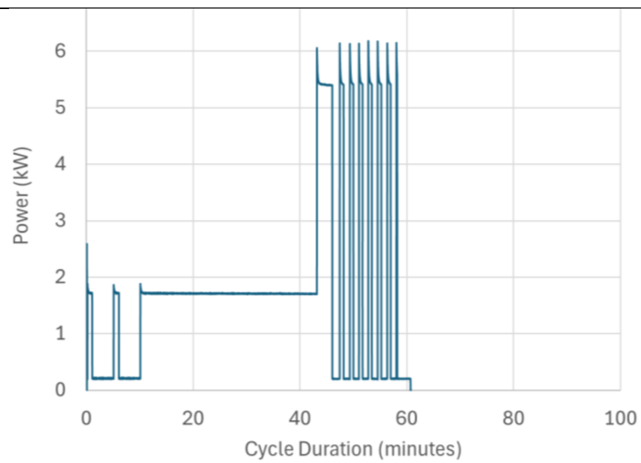
ES Dryer 06



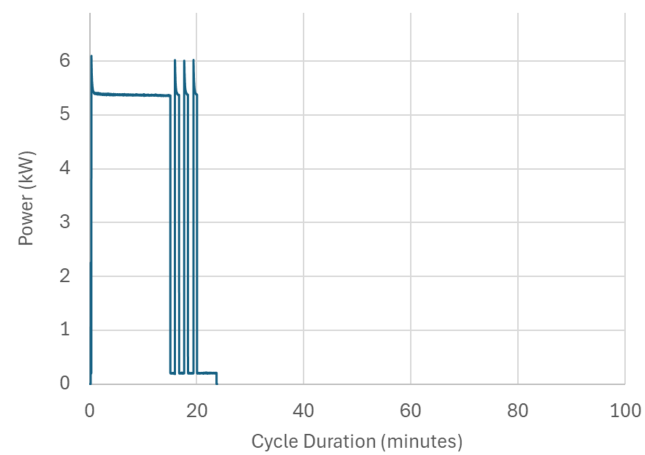
DOE Appendix D2—8.45 lb load & Eco on



DOE Appendix D2—8.45 lb load & Eco off

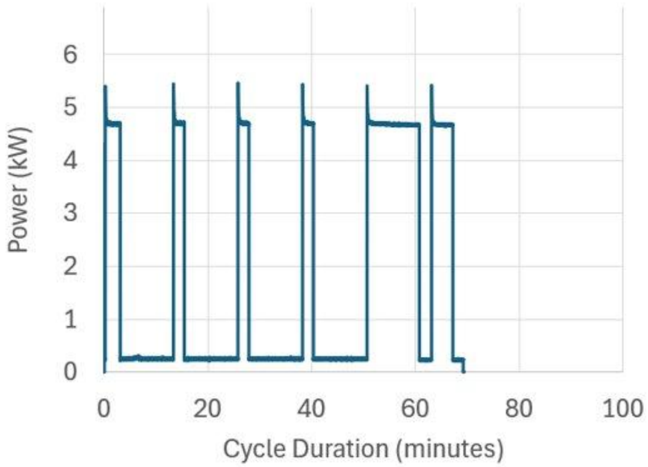


DOE Appendix D2—4.23 lb load & Eco on

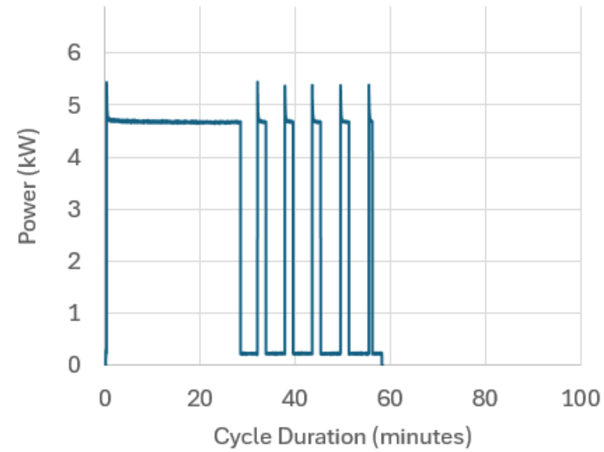


DOE Appendix D2—4.23 lb load & Eco off

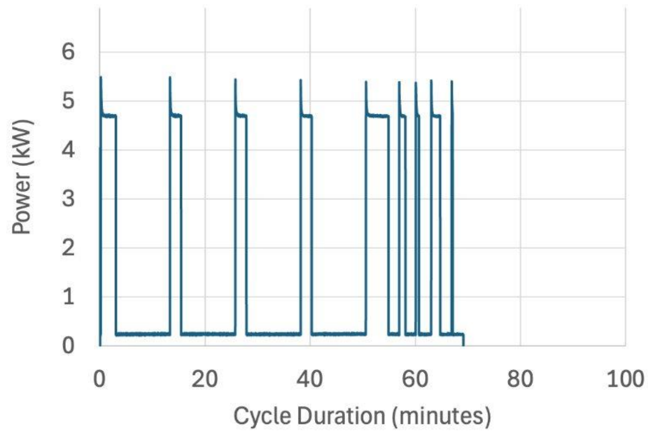
ES Dryer 07



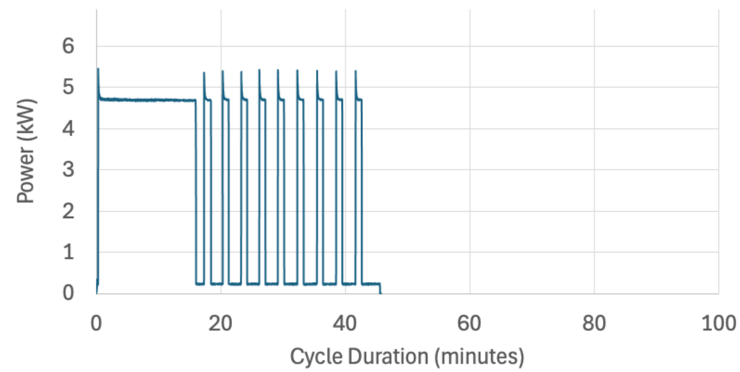
DOE Appendix D2—8.45 lb load & Eco on



DOE Appendix D2—8.45 lb load & Eco off



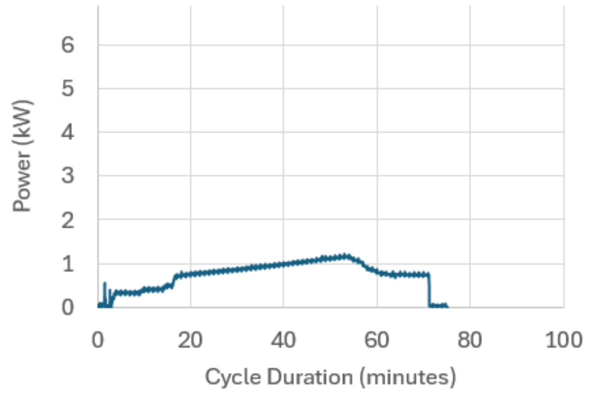
DOE Appendix D2—4.23 lb load & Eco on



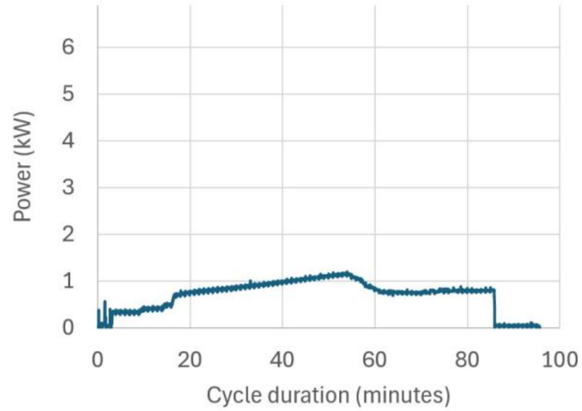
DOE Appendix D2—4.23 lb load & Eco off

Heat Pump Dryers

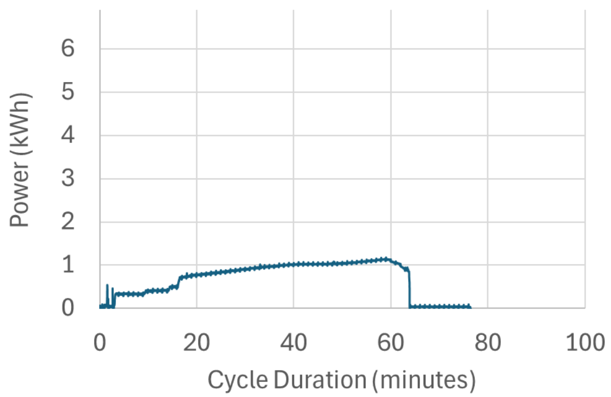
HP Dryer 08



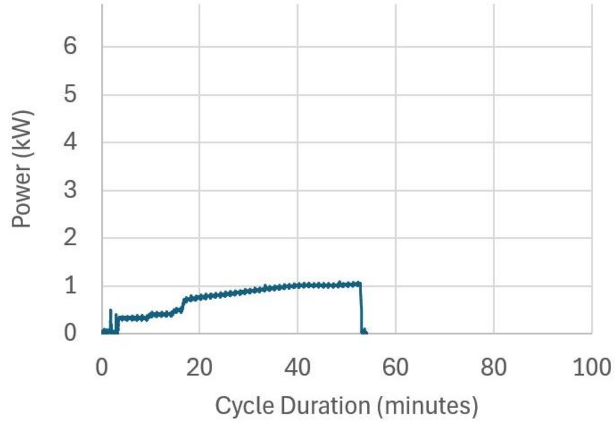
DOE Appendix D2—8.45 lb load & Eco on



DOE Appendix D2—8.45 lb load & Eco off

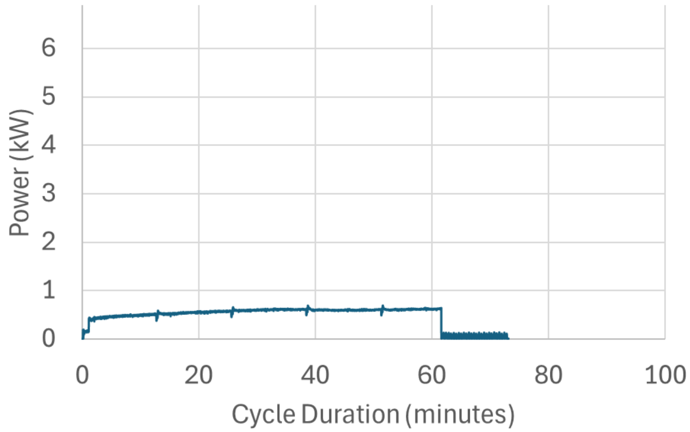


DOE Appendix D2—4.23 lb load & Eco on

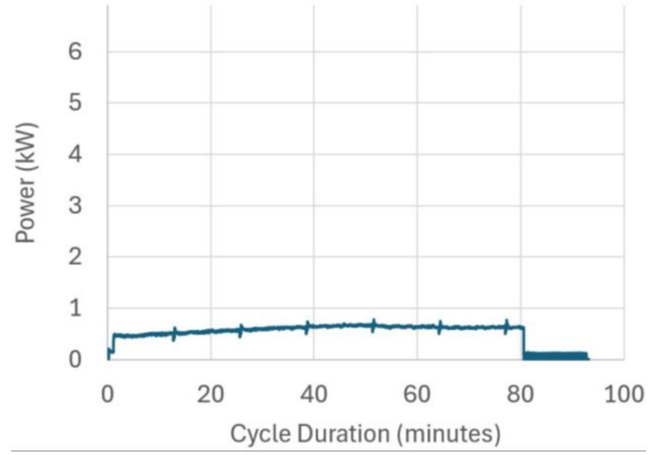


DOE Appendix D2—4.23 lb load & Eco off

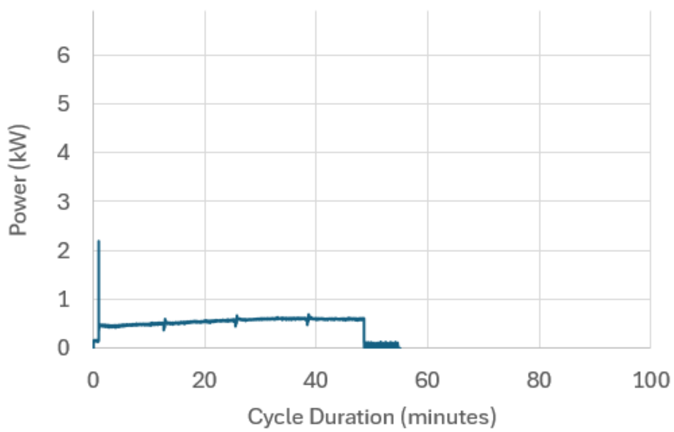
HP Dryer 09



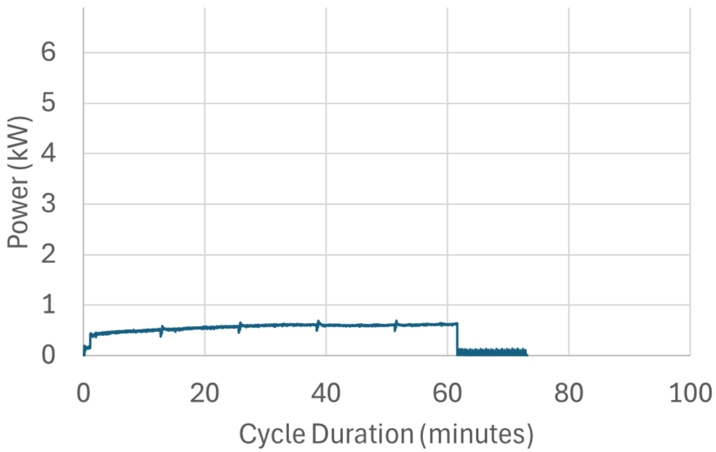
DOE Appendix D2—8.45 lb load & Eco on



DOE Appendix D2—8.45 lb load & Eco off

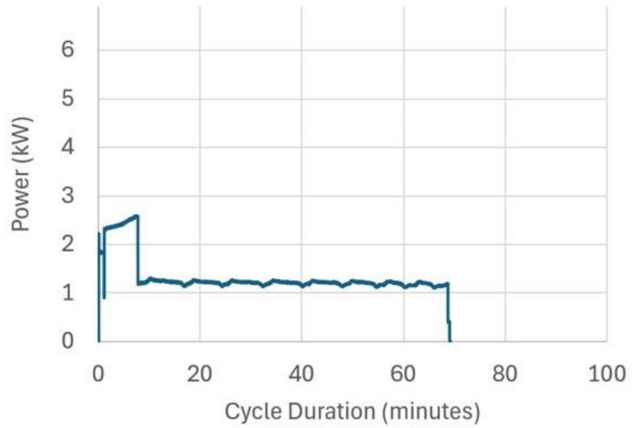


DOE Appendix D2—4.23 lb load & Eco on

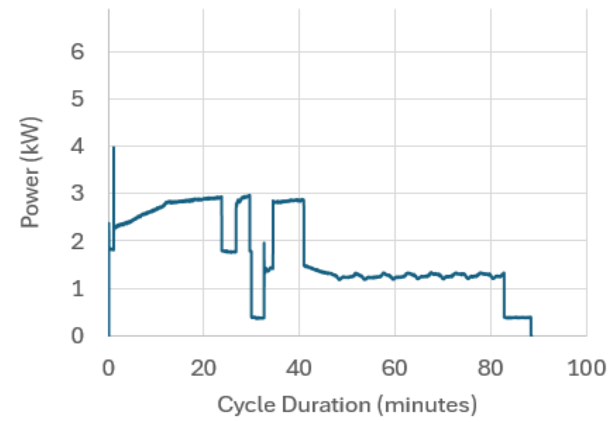


DOE Appendix D2—4.23 lb load & Eco off

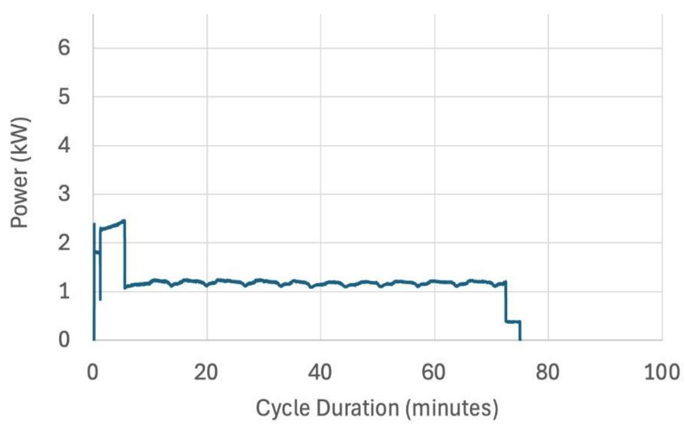
HP Dryer 10



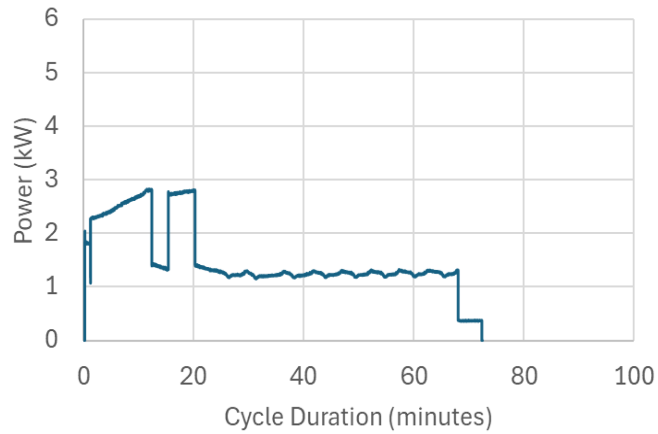
DOE Appendix D2—8.45 lb load & Eco on



DOE Appendix D2—8.45 lb load & Eco off

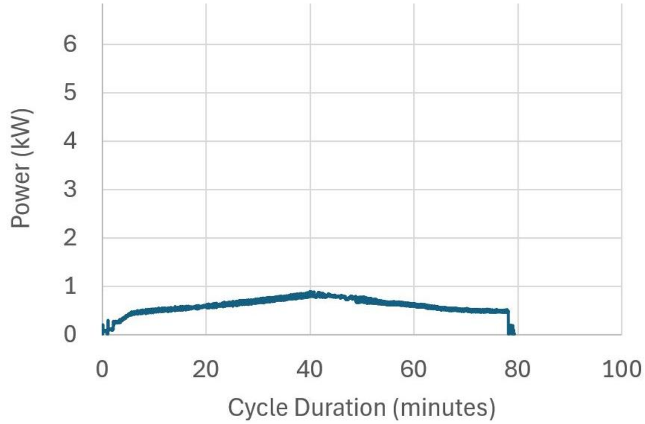


DOE Appendix D2—4.23 lb load & Eco on

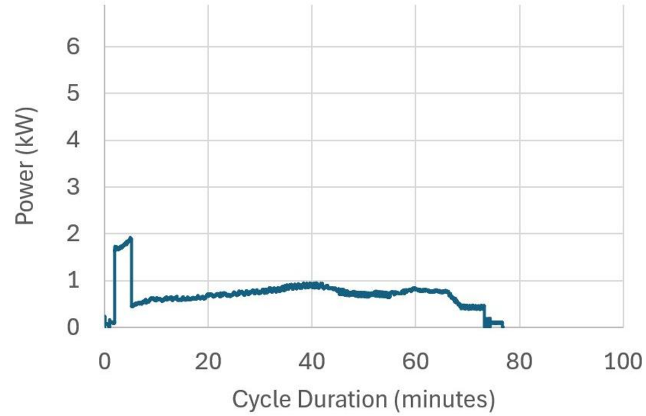


DOE Appendix D2—4.23 lb load & Eco off

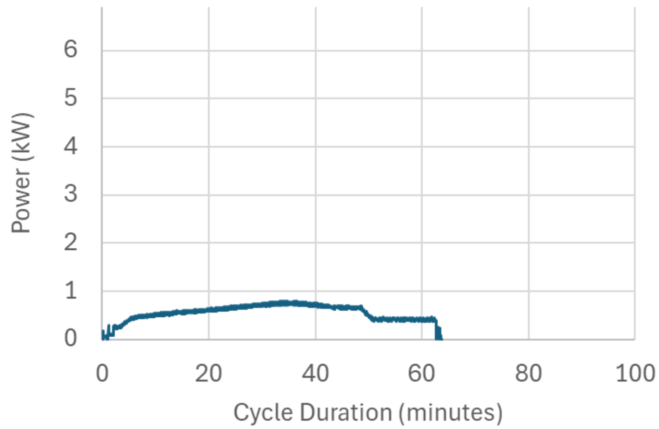
HP Dryer 11



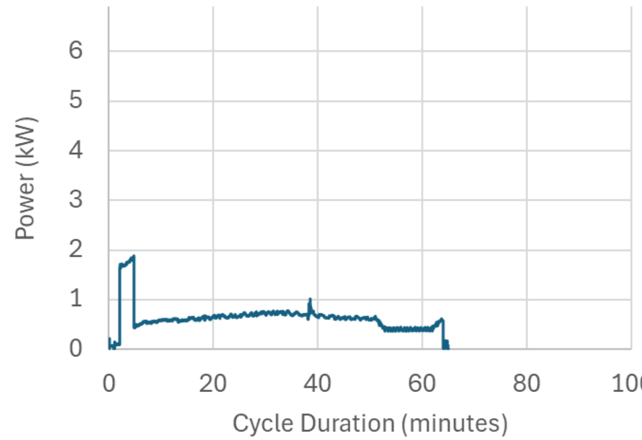
DOE Appendix D2—8.45 lb load & Eco on



DOE Appendix D2—8.45 lb load & Eco off

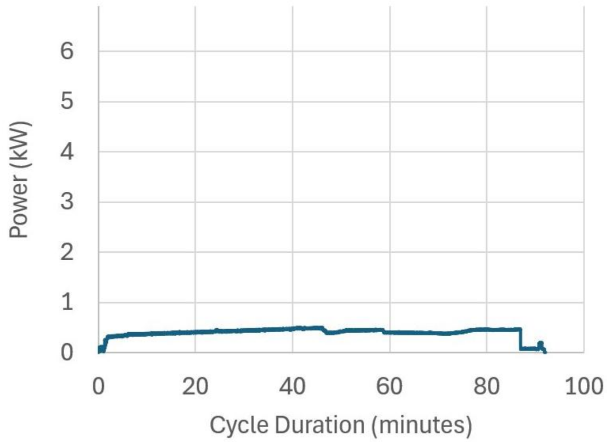


DOE Appendix D2—4.23 lb load & Eco on

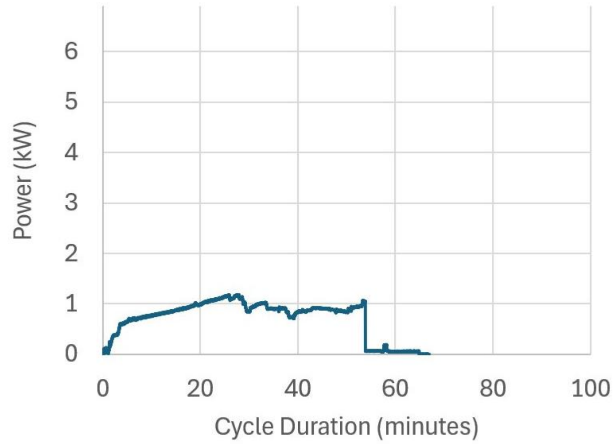


DOE Appendix D2—4.23 lb load & Eco off

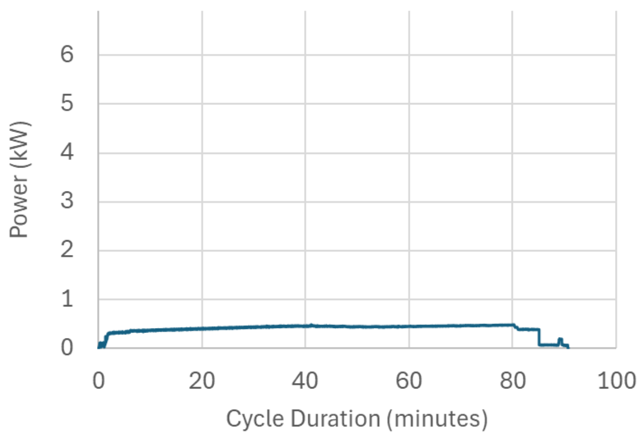
HP Dryer 12



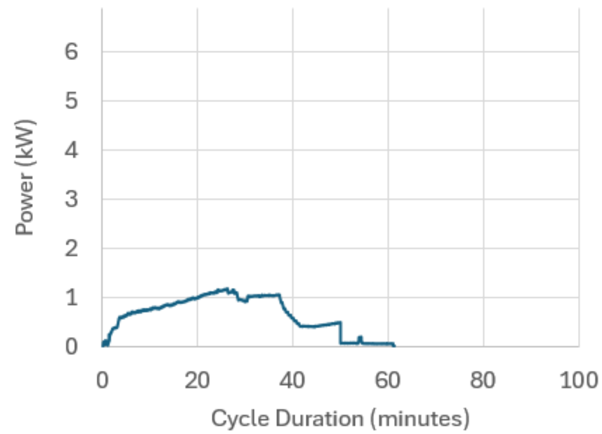
DOE Appendix D2—8.45 lb load & Eco on



DOE Appendix D2—8.45 lb load & Eco off



DOE Appendix D2—4.23 lb load & Eco on



DOE Appendix D2—4.23 lb load & Eco off