DOCKETED

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Comment Received From: Christopher Dymond
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Partial Load to large

Data from NEEA lab test revealed that load size (relative to drum volume), cycle setting and fabric type in that order are the most significant factors on dryer energy use (for a given IMC). Many loads are much smaller than the 1.25xVdrum proposed. Dryer efficiency drops off significantly below 1.25xVdrum. I strongly recommend the small load size be reduced to .5xVdrum to properly capture the performance of the machine at low load conditions. See attached

I like the approach to getting a consistent target moisture by conducting two tests on either size of the target RMC (4%). I worry about the test burden, but this is a better approach than simple one run and extrapolate approach.

Test clothing is rather limited in complexity and variety. Some kind of field adjustment factor will be needed.

It wasn't clear to me if these are timer based dryers or dryers that have auto termination or how each of the different cycles are used to develop an overall dryer performance metric.

Additional submitted attachment is included below.

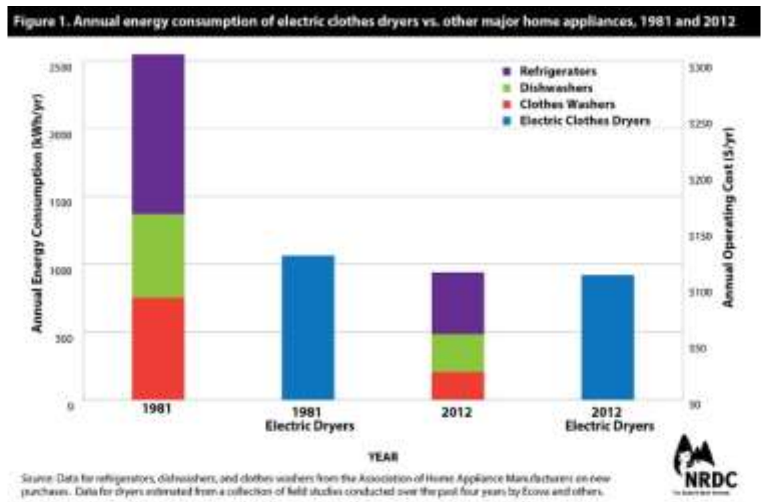
NEEA Super-Efficient Dryer Technology Update

Northwest Efficiency Exchange – April 2016

This document provides an overview of the product testing, standards and emerging technology investigation NEEA has conducted on clothes dryers (and to a lesser extent, clothes washers). NEEA's goal is to increase adoption of more efficient dryer technologies, including ENERGY STAR, throughout the Northwest. NEEA partners with manufacturers to support the launch of products.

Why Clothes Dryers

Dryer technology & efficiency has not improved since 1981. The small drop in dryer energy use noted by NRDC in 2012 is actually due to more efficient washers, which extract more water, so that the dryer does not have to work as hard. Northwest consumers own six million electric clothes dryers, more than 80% of which use electric resistance heating to remove moisture. If the Northwest were to convert all the existing dryers to "Super-Efficient Dryers" (SEDs), the "technical potential" savings to the region would be 180 aMW.



Initial Field Testing

Fifty homes from NEEA's 2011 Residential Building Stock Assessment were selected to provide a representative household sample for a field study of laundry energy use. The laundry equipment in the sample homes was less than five years old with 30% of the washers being front loaders. Researchers installed data loggers capable of monitoring the energy use of both the washer and dryer in the homes, and the homeowners were paid to record the setting, load weight, and completion time for each wash and dry cycle. The resulting data set provided evidence of how much energy is actually used in the typical home for washing and drying laundry. The results provide the following significant insights:

1. Average annual clothing weight dried in the Pacific Northwest is 2,342 lbs in 303 loads.
2. Cycle settings and load sizes have significant impacts on dryer performance.
3. Annual average dryer energy use is **915 kWh/yr**, which translates to 2.6 lbs dried per kWh, 43% more energy per pound than is determined using the DOE D1 test procedure.
4. About 40% of all loads are small. These loads use nearly twice the energy per pound than large loads.
5. About 30% of the loads were set on high heat, which shortened cycle time, but increased energy use.
6. The average initial moisture content from the washing machines was 62%. Many cycles begin much wetter than the average – the result of an incomplete or unbalanced spin cycle.
7. The average drying cycle duration is 57 minutes.

Lab Testing

From 2010 to late 2014, NEEA contracted Ecova to investigate and test the performance of conventional dryers and heat pump dryers sold in Europe, but not available in the USA. The results provide the following significant insights:

1. Heat pump dryers are capable of drying clothes with half the energy of conventional dryers.
2. Reducing heat and extending drying time improves efficiency. One test revealed that turning off the heating altogether doubles efficiency, but at the expense of vast increases in drying time (as much as several hours).
3. Auto termination (better moisture sensors) can reduce energy consumption by approximately 20%.
4. Real clothing performance is significantly different than the test cloths used in the DOE test protocols (D1 or D2).

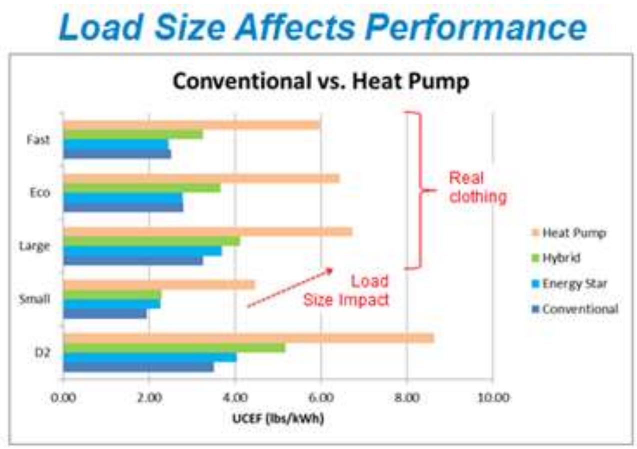
NEEA Super-Efficient Dryers Program
Program Manager: Stephanie Baker – (503) 688-5483 - sbaker@neea.org
Product Manager: Christopher Dymond – (503) 688-5454 - cdymond@neea.org

Northwest Energy Efficiency Alliance
421 SW Sixth Avenue, Suite 600, Portland, OR 97204
503.688.5400 | Fax 503.688.5447
neea.org | info@neea.org

5. DOE test protocols are based on the default (energy efficient) cycle setting of dryers, but these may be different from the settings consumers choose, which compared to the default setting, has negative impacts on performance. Moreover, some machines do not return to the default cycle setting but remain at the last setting chosen. Field data corroborated this observation. Once a consumer finds a setting they like, they may never return to the default setting it was shipped with.
6. DOE's D1 test protocol cannot be simply "cross-walked" to D2 because relative ranking of machine performance is significantly different between the two approaches.

In 2014, NEEA partnered with PG&E to develop a new dryer lab test protocol using real clothing and running the dryer in a variety of load sizes and cycle settings. The resulting supplemental test protocol combined four real clothing tests with the D2 test protocol to produce a "utility CEF" (UCEF) metric that more accurately estimates the performance of clothes dryers. The four additional tests consist of a small 4.2 lb load run on normal settings, a large 16.8 lb load run on normal settings, and two 8.4 lb loads run on a heavy-duty high heat setting and a most efficient "Eco" setting. Testing with this metric highlights the impact of setting differences by technology and the impact of load size. UCEF is the average of all five tests (4 real clothing + 1 D2 test).

In all, the Ecova lab in Durango completed 185 individual tests using the supplemental test protocol. On average, UCEF values are 80% of D2 test protocol CEF values. The UCEF results corroborate NEEA dryer field study results. Additional testing was also done on 11 conventional dryers to establish a baseline performance value for non-efficient machines. This baseline testing revealed that the market weighted average (as of December 2014) had a UCEF value of 2.73 lbs/kWh. Real world energy savings estimates are now calculated using the UCEF metric and established baseline performance.



Field Testing of New SEDs

To understand how people responded to new SEDs, how well they performed, and what cycle settings were actually used, NEEA began testing heat pump dryers as they entered the market. To date, NEEA has conducted two field tests with a third and final planned test to be completed in Q3 2016. The field test procedure developed for this was published and promulgated to other utilities that wish to do field testing.

1. Whirlpool HybridCare™. Field test completed in Q1 2015 in single family dwellings. Consumer responses were very positive.
2. Blomberg/Arcelik. Field test completed in Q3 2015 in apartments. Consumer responses were positive.
3. LG EcoHybrid™. Field test of ten units will begin in Q2 2016.

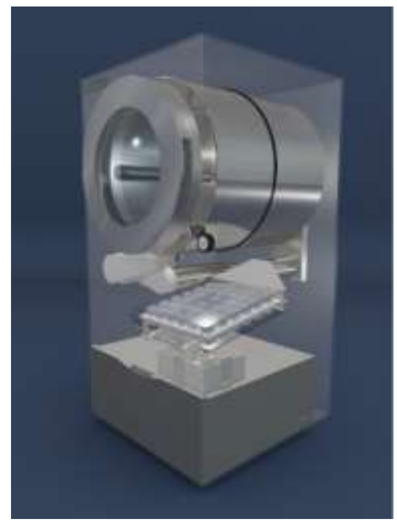
Emerging Technologies

NEEA has identified eight technology innovations with the potential to make clothes dryers more efficient. The two technologies being adapted into the most efficient clothes dryers are:

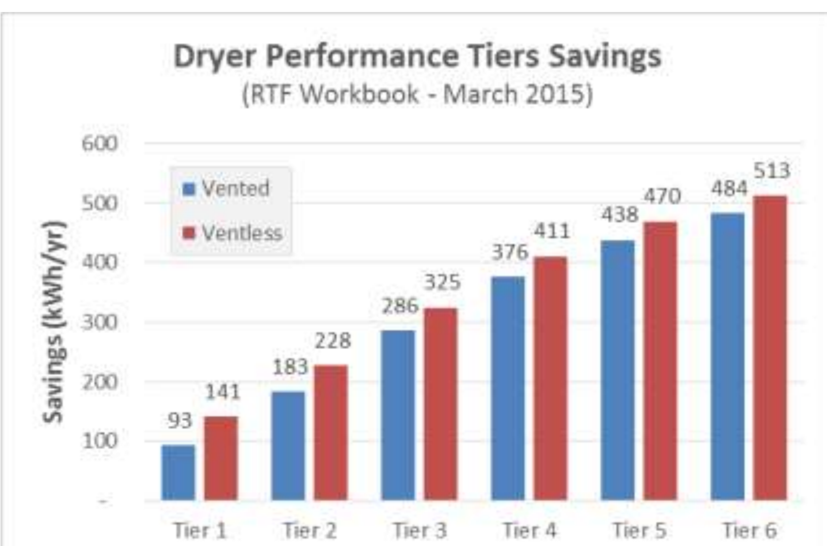
1. Accurate moisture sensors and controls to turn off the drying once the clothing is dry (stop over drying). Better moisture sensors are all that is needed for a conventional dryer to be capable of achieving the approximately 20% savings over federal minimum requirements and to meet EPA ENERGY STAR specifications. The added cost is minimal (<$15) if the machine already has some kind of microprocessor driven interface, and roughly $50 for a dryer that currently only has a simple timer control.
2. Heat pumps to dehumidify and heat the air circulated through the drum. Whirlpool, LG, Kenmore, Blomberg and Asko currently offer products (available in the US) that use heat pumps and better sensors to reduce energy use. Savings range from 25-65% compared to federal minimum requirements. At full scale production, this technology could save 400+ kWh/yr/household with an incremental cost of $250-$350 per dryer.

Other technologies that have not been included in retail products include:

3. Heat recovery heat exchangers on exhaust air. No manufacturer has yet used this, however JR Thermal (a heat exchanger company) has tested a prototype that claims quicker drying with 20-30% less energy use (technical details limited under an NDA). At full scale production this technology could be implemented on conventional dryers for less than $150. Considerable development work is needed for this however, as the savings claimed require additional improvements in controls and lint control.
4. Radio frequency excitation of water. RF heating is like a microwave oven, but without risk of hyper-heating metal on clothing. Drying time is much reduced and clothing is dried with little or no fabric heating (technical and business details limited under an NDA with CoolDryRF). At full scale production, this technology could potentially save 200 kWh/yr/household with an incremental cost estimate of $200 per dryer. Considerable development work is needed for this, however.
5. Enhanced heat recovery with a Heat Pump. PNNL research has verified the technical potential of enhancing the performance of conventional heat pump dryers. (Manufacturer interest details limited under NDA with PNNL).
6. Liquid CO_2 clothes washing. Room temperature liquid CO_2 clothes washing eliminates the need for water and enables superior washing without detergent, but only at very high pressures. The secondary benefit is that no energy is expended to dry the clothing. Once the CO_2 is pumped out of the washer and returned to atmospheric pressure, all the residual CO_2 flashes to vapor leaving the clothing perfectly dry. A company is currently beta testing commercial scale machines. NEEA staff plan to investigate laundry efficiency of commercial systems using liquid CO_2 in 2017.



7. Retrofit module for improving sensors in old machines. The system uses a blue-tooth connected moisture sensor located on the exhaust pipe to turn off the power once the clothing is dry. Savings potential is likely less than 150kWh/yr, and the business working on it has yet to develop and test a prototype.
8. Oakridge National Laboratory has partnered with Sheetak, Inc to develop a prototype of a dryer that uses thermoelectric heat pumps to transfer heat into the drum (evaporating water) and then to cool the outside of the drum (condensing water). While still in the research phase, at full scale production the theoretical potential would produce approximately 300 kWh/year savings with an incremental cost of only $80. The researchers claim this could be accomplished without extending drying time.



Multi-Tiered Specification

NEEA collaborated with the RTF staff to develop a multi-tier specification. This specification has six performance tiers based on the UCEF metric. Machines without venting gain additional performance because of the space heating benefits of keeping the heat inside the home. Consequently, the calculated savings for the six tiers were split into both vented and ventless machines separately (see left). The reason for having this many tiers was to provide a roadmap for manufacturers to achieve future improvements and enable utilities to capture smaller increments. For simplicity, consumer facing marketing would not likely have more than three tiers.

SED Qualified Products List

NEEA is committed to providing UCEF performance test data for the NW utilities on all new SEDs until a revised (more accurate) federal test protocol is developed. NEEA has contracted Underwriters Laboratories (UL) in Newton, Iowa, to perform testing of dryers with the supplemental test protocol. The UL facility was formerly owned by Maytag before it was acquired by Whirlpool and retains considerable technical expertise for testing and evaluating laundry equipment. The qualified products list is posted on Conduit and is updated as needed.

Tier 1 Clothes Dryers

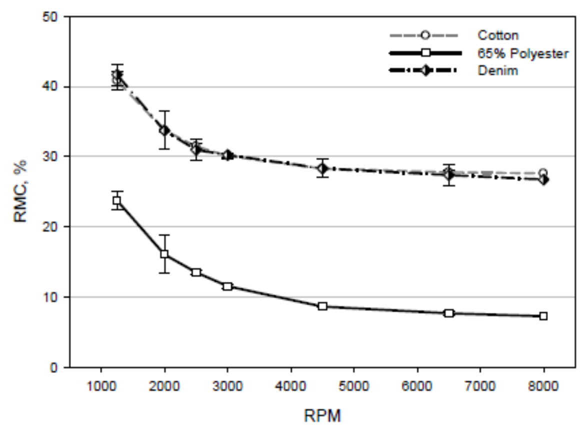
EPA Website https://www.energystar.gov/productfinder/product/certified-clothes-dryers/results

Tier 2 and above Clothes Dryers - LAB TESTED WITH SUPPLEMENTAL (real clothing) TEST PROTOCOL 4/24/2016

Product Brand	Model	Tech	Type	Tier	Savings (kWh/yr)	IMC	UCEF	D2 Cycle Time	Test Lab	Test Date
Blomberg	DHP24400W	HP	Ventless	6	513	$555	8.1	76	UL	Q1 2015
Blomberg	DHP24412W	HP	Ventless	6	513	$555	8.1	76	UL	Q1 2015
Whirlpool	WED99HED##	Hybrid	Ventless	2	228	$555	3.7	62	UL	Q4 2014
LG	DLHX4072##	Hybrid	Vented	2	183	$555	3.5	59	UL	Q4 2014
Kenmore	8159####	Hybrid	Vented	2	183	$555	3.5			
Whirlpool	WED9299HED##	Hybrid	Ventless	2	228	$555	3.5			
Whirlpool	WED9299HED##	Hybrid	Ventless	2	228	$555	3.5			
Beko		HP	Ventless							
Asko	T884XLHP	HP	Ventless							

Washer Dryer Paired Savings

Current washer savings includes savings resulting from moisture extraction of the washer spin cycle. The values reported by the EPA for washer and dryer savings overlap and should not be used for estimation of utility savings. The RTF analysis provides an accurate accounting of energy savings that accounts for the overlap in the savings values. NEEA field testing shows real clothing has 150-200% higher remaining moisture content (RMC) when compared to D2 cloths in the lab. Daniel Carter's 2006 PhD thesis contained a clear illustration (see figure right) that when high polyester content cloths are spun dried they contain nearly 20% less moisture than cotton. In essence, real clothing that is thicker, more three-dimensional and largely cotton will start in the dryer wetter than the DOE test cloths.



Washer Spin Cycle Testing

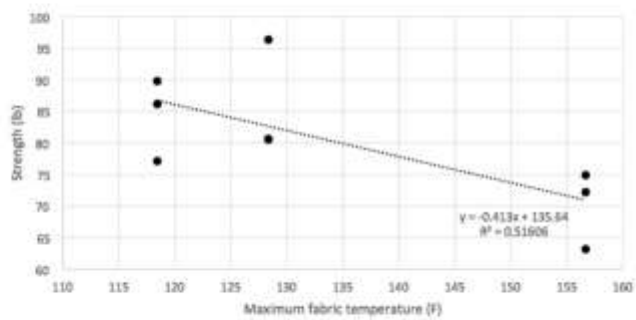
NEEA contracted Underwriters Laboratories to investigate remaining moisture from the spin cycle of washers. The purpose of this was to determine how to improve the federal test procedure, and how to accurately estimate the overlap between washer and dryer energy use metrics. Thirteen washers representing the most common models from the largest manufacturers were tested with multiple runs of real clothing sets used in the supplemental test protocol. The results not only confirmed the added moisture content of real clothing, but the much greater disparity between top load and front load machines when tested with real clothing. Top loading washing machines averaged an RMC of 32% with DOE test cloths (50% polyester) while they averaged 68% RMC when tested with real clothing. Front loading machines averaged an RMC of 31% with DOE test cloths, compared to 53% RMC when tested with real clothing. This implies that top loaders are not as effective at extracting moisture from real clothes as implied by the current DOE test procedure.

Clothing Wear Study

Because heat pump dryers represent a high incremental cost (approximately $550) over the equivalent featured dryers, NEEA sought to quantify possible non-energy benefits resulting from the lower temperature of heat pump dryers. In particular, NEEA wanted to test the assumption that heat pump dryers impose less damage on clothing, due to their lower operating temperature. All manufacturers claim these machines are “gentler to clothing”, however no hard evidence existed to confirm this. NEEA initiated and led a research project to investigate the impact on clothing life from different dryer technologies. This project was co-funded by PG&E with testing performed by Underwriters Laboratory and Ecos Research, with advisory researchers from the University of Texas and University of Tennessee.

The study involved selecting a laundry load that would represent a diversity of fiber types, as well as clothing types that could be used as a proxy for clothing wear. One control load was cycled through a single cycle and set aside. Four other loads were each run through 25 dryer cycles with weight, color photography and spectrophotometry measurements made every 5 cycles. Test load 1 and 2 were run with an ENERGY STAR dryer, with test load 1 starting with a moisture content of 55% and test load 2 starting with a moisture content of 40%. Test load 3 was run with a hybrid heat pump dryer, and Test load 4 was run with a pure heat pump dryer. Both loads had an initial moisture content of 40%. Once the machine cycles were completed the clothing was sent to Ecos Research to perform fiber testing and human response evaluation by both trained textile professionals and a group of five consumers.

The results did not show statistically significant differences between ENERGY STAR dryer induced wear and heat pump dryer induced wear on average. Some materials such as denim jeans did show degraded fiber strength due to higher temperature drying from the ENERGY STAR dryers (see right), but no quantifiable non-energy benefits were identified. A scientific paper was written and submitted to the Journal of Textile Research for publication, and a detailed report is available from NEEA upon request.



Federal Standards Work

Long term market transformation of dryer technology will benefit from both improvements in federal test protocols (J2 = washers, D1 and D2 = dryers) and federal standards. The rule making process follows a 6 or 7 year cycle on test protocols and standards. The data gathered from the work performed is an essential component of NEEA’s strategy to influence federal test protocols and standards. To date, the DOE has not yet initiated a formal rule making process for washers or dryers, but they have begun the initial process through a request for information on clothes dryer standards. NEEA has provided data on our lab and field studies and recommended strongly that the DOE complete a revision of the test protocols for both washers and dryers prior to initiating standard rulemaking as they rely on the accuracy of the test protocols.

NEEA seeks to influence DOE test protocols to include the following changes:

1. Adopt a multi-cycle test that includes more than just the default setting shipped from the factory.
2. Adopt tests that include the use of real clothing, some of them with 100% cotton content fabric.
3. Consider a combined washer/dryer pair test that evaluates the benefits of a matched pair and removes any uncertainty from test procedure overlap.
4. Adopt tests that include small and large loads.
5. Allow European compact dryers to be tested with the same test procedure. The current 3 lb compact load they are tested with is too small, as they are designed to handle 16+ lb loads, so the 3 lb test load severely underestimates their real world performance.

Graphs and Data from Lab and Field Testing

The following pages contain a variety of graphs, pictures and tables gathered from field testing. No descriptive text is provided.

Field Testing – 50 Homes, 2012

Table 1. Summary of Field Study Results Compared to Test Procedures

Dryer Metric	DOE			Field Study – Simple Loads		Field Study – All Loads	
	Amended D Procedure	D1 Test Procedure	D2 Test Procedure	Mean	EB	Mean	EB
Load Composition	DOE Test Cloths			Homeowner Clothes			
Dryer Setting	Normal Duty, High Heat			Homeowner Settings			
Initial RMC of Dryer Load (%)	66.5%-73.5%	54.0%-61.0%	57.5% ± 0.33%	62.9%	1.0%	71.0%	2.7%
Final RMC of Dryer Load (%)	2.5%-5.0%	2.5%-5.0%	Auto: <2.0%	3.3%	0.5%	7.2%	3.2%
Water Removed/Load (lb)	4.62	4.52	4.69	4.73	0.14	4.81	0.13
Bone-Dry Load Weight (lb)	7.00	8.45	8.45	7.87	0.19	7.64	0.17
Duct restriction or exhaust cfm	2 7/8"	2 7/8"	2 7/8"	90.2 cfm ± 11.1 cfm			
Average Drying Time (min)	23 [a]	N/A	N/A	57.0	1.4	56.0	1.1
Raw Energy Use/Load (kWh)	2.24 [a]	2.84 [a,b]	2.84 [a,b]	3.17	0.07	2.96	0.06
Field Use Factor – Auto Cycle	1.04	1.04	1.00	N/A	N/A	N/A	N/A
Adj. Energy Use/Cycle (kWh)	2.33 [a]	2.95 [a]	2.84 [a]	3.17	0.07	2.96	0.06
Dryer Use Factor (J/J1/J2)	84%	84%	91%	100%	0.0%	93.5%	0.0%
Loads per Year	416	283	283	N/A	N/A	311	42
Average EF (lbs/kWh)	3.01 [a]	2.86 [a]	2.98 [a]	2.66	0.12	2.62	0.28
Lbs Dried per Year (lbs/yr)	2,912	2,391	2,391	N/A	N/A	2342	428
Energy Use per Year (kWh/yr)	967 [a]	835 [a]	804 [a]	N/A	N/A	915	132
Washer Vintage 2005-2009	N/A	N/A	N/A	77% [d]			
Washer Vintage 2009+	N/A	N/A	N/A	23% [d]			
Vertical Axis Washer	N/A	N/A	N/A	28% [d]			
Average Household Size	N/A	N/A	N/A	3.0 ± 0.3			
Fraction of Clothing Removed	N/A	N/A	N/A	0.0%	0.0%	Unk	Unk
Fraction of High Heat	100%	100% if avail.	100% if avail.	37.5%	0.1%	43.0%	0.1%
Dryness Setting [c]	N/A	N/A	Normal	61.0% [c]	0.2%	64.8% [c]	0.1%
Simple Loads (see definition)	100%	100%	100%	44.6%			

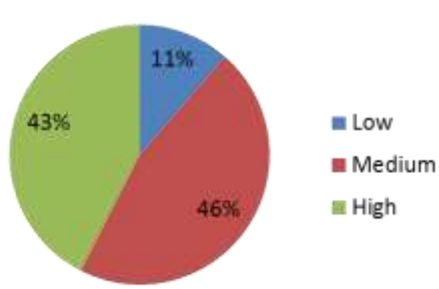
[a] Based on NEEA laboratory testing

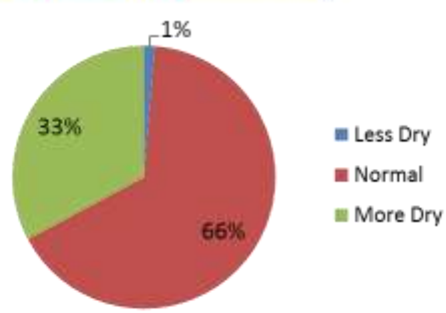
[b] Though automatic termination in the field saves energy relative to timed dry, here we are comparing to technician termination in the test

[c] Test procedures D/D1 do not stipulate a dryness setting (cycle is stopped manually when the clothing reaches the final RMC range). D2 uses Normal dryness as long as final RMC <2.0%. Percents reported for field study are percent of loads using Normal dryness setting.

[d] Based on number of sites

Load Weight	Temperature Setting: Low	Medium	High	Total
0-6.5 lbs	6.6%	small 17.4%	16.5%	40.5%
6.6-10.5 lbs	eco 3.0%	20.8%	fast 13.1%	36.9%
10.6-25 lbs	3.0%	large 12.9%	6.7%	22.6%
Total	12.6%	51.1%	36.3%	100%

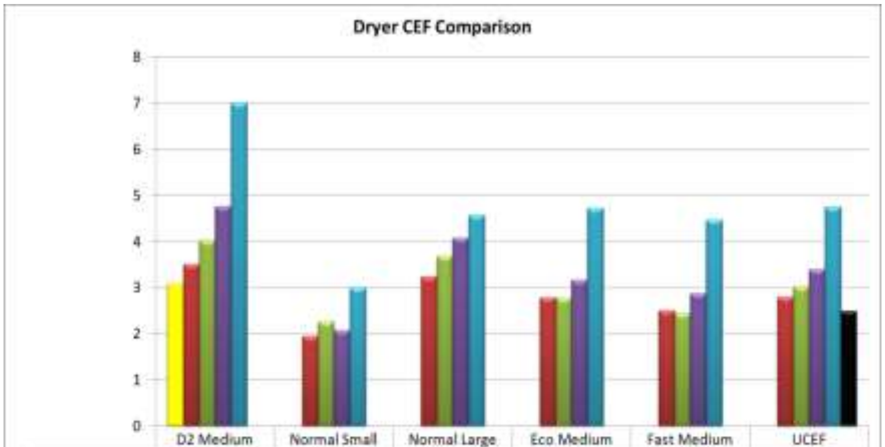




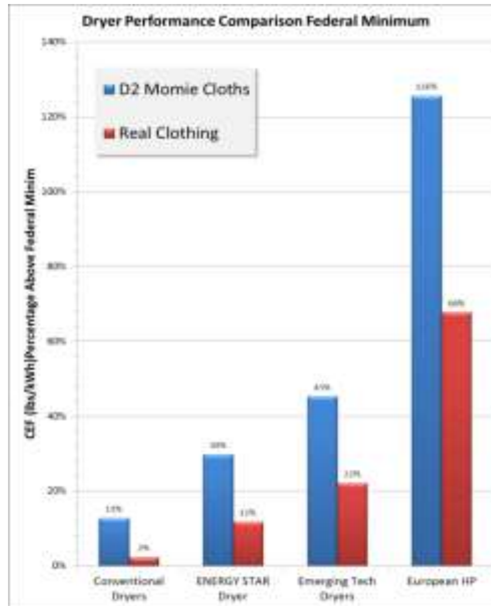
Lab Testing

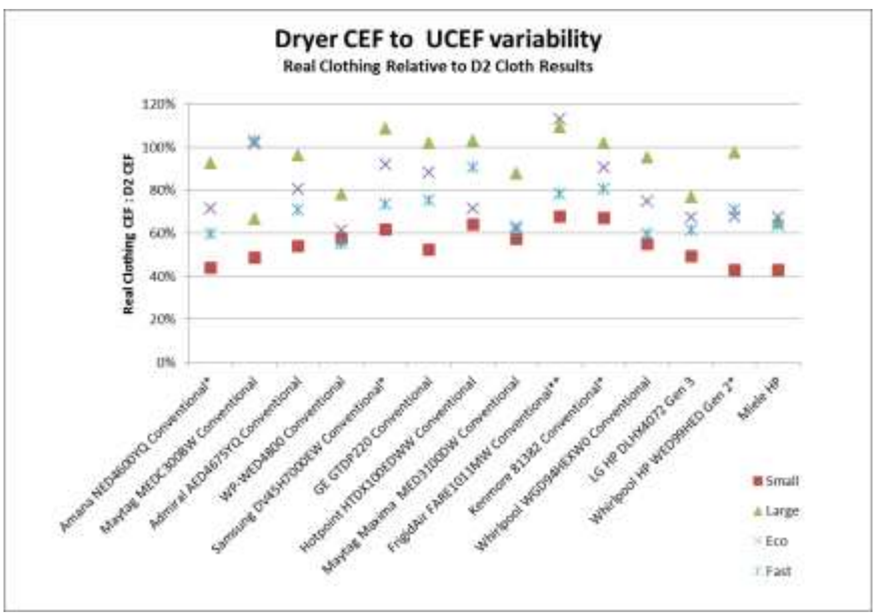
DOE Test Cloth

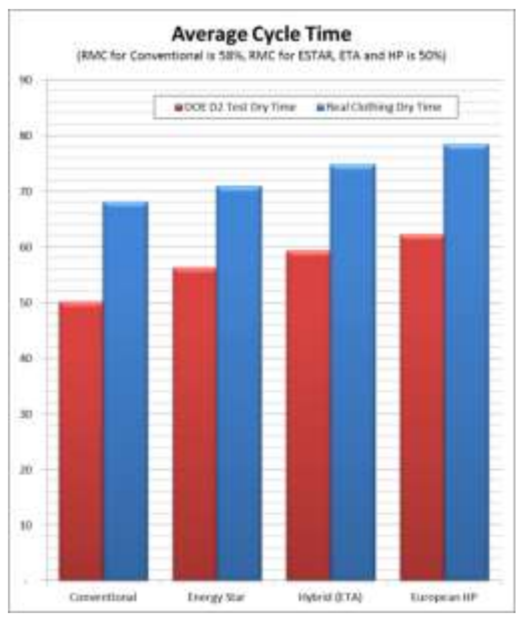
Supplemental Test Load - Land's End catalogue



	D2 Medium	Normal Small	Normal Large	Eco Medium	Fast Medium	UCEF
Federal Min	3.11					
Conventional	3.51	1.95	3.25	2.80	2.51	2.80
Energy Star	4.04	2.26	3.69	2.78	2.44	3.03
Hybrid (ETA)	4.76	2.08	4.08	3.17	2.87	3.39
European HP	7.02	3.00	4.58	4.72	4.47	4.76
NEEA Field Study						2.50







Field Testing of New Machines