Do the Savings Come Out in the Wash?
A Large Scale Study of In-Situ Residential Laundry Systems

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ABSTRACT

This report explores the energy use of laundry systems at residences across southern California and the Bay area. Efficient laundry systems, and in particular clothes washers, are an unusual retail efficiency product in that the energy savings potential occurs primarily outside of the clothes washer, namely in the hot water heater and the clothes dryer. The study metered the actual energy use of 115 laundry systems – clothes washer, hot water heater, and clothes dryer – comprised of 24 non-ENERGY STAR qualified clothes washers, and 91 clothes washers that qualified under current or previous ENERGY STAR specifications, and under Tier 1, 2, or 3 criteria published by the Consortium for Energy Efficiency (CEE). Contrary to previous assumptions, the analysis determined that only 13 percent of the water used in the laundry system was heated, and that the majority of the energy consumed and potential savings arise in reduced operation of the clothes dryer.

Introduction to Energy Savings in Laundry Systems

Energy Use by Laundry Systems

Laundry systems consume energy to operate the clothes washer, to heat water used for hot and warm cycles, and to operate the clothes dryer. Each of these categories of energy use is discussed below.

Clothes washer electricity use. Clothes washers use electricity while in active mode to drive motors that spin the clothes tumbler and that operate a water pump to drain the clothes tumbler. Many advanced machines use universal and 3-phase AC motors capable of spinning in both directions to operate advanced cycles (Bianchi, 2003).

Many advanced clothes washers consume standby energy to keep various controls active. While standby power consumption is typically low, on an order of 2 watts, over a week this equates to about 340-watt hours. In contrast a washer load might consume about 200 watt-hours.

Hot water energy use. Clothes washers have a variety of temperature settings, including cold, warm and hot. Even hot cycles however are typically coupled with a cold or warm rinse cycle. Warm cycles combine hot and cold water. Therefore, even households that wash primarily using hot or warm cycles only use hot water for a fraction of their total laundry water volume. Hot water heaters can either use gas or electricity, and the fuel shares vary by region. Nationally 58% of residential domestic hot waters use gas and 42% use electricity (EIA, 2005).

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Dryer energy use. Moisture remaining in clothing after the wash and spin cycles is removed in the clothes dryer. Electrical resistance heaters or a gas-fired heat exchanger is used to heat air that is blown through tumbled clothing. The higher moisture carrying capacity of the warmer air carries the moisture from the clothes to the drier vent. Nationally, 22% of residential dryers use gas and 78% use electricity. Based on national data, millions of households have access to gas, as evidenced by the hot water heater fuel type, but purchase an electric dryer.

How Are Laundry Systems Rated?

Modified Energy Factor (MEF). MEF is the quotient of the cubic foot capacity of the clothes container divided by the total clothes washer energy consumption per cycle, with such energy consumption expressed as the sum of the machine electrical energy consumption, the hot water energy consumption, and the energy required for removal of the remaining moisture in the wash load. The units are cubic feet per kWh per cycle (ft^3/kWh/cycle): the higher the value, the more efficient the clothes washer. MEF is determined by the J1 test procedure.[2]

Water Factor (WF). The term is expressed as gallons per cycle per cubic foot. WF is the quotient of the total weighted per-cycle water consumption divided by the capacity of the clothes washer. The lower the value, the more efficient the clothes washer. WF has not been incorporated into the Federal standard but is included in the 2007 ENERGY STAR criteria. Both ENERGY STAR, a voluntary standards and product labeling program administered by the U.S. EPA, and the Consortium for Energy Efficiency (CEE), a membership group of utilities, set voluntary energy efficiency standards for clothes washers. Typically the CEE Tier 1 rating matches ENERGY STAR requirements, and Tiers 2 and 3 offer more stringent standards. The voluntary standards are displayed with minimum Federal standards in Table 1, and the expected savings for each efficiency level are presented in Table 2.

How Do Laundry Systems Save Energy?

Unlike other energy efficient appliances, the difference in the actual energy use of standard vs. efficient clothes washers is negligible. Instead, efficient clothes washers save energy in two ways: by reducing the amount of water used to wash clothes and therefore hot water used in warm and hot cycles, and by removing more water and thereby shortening dryer cycles.

Reduce water usage. Efficient clothes washers are designed to draw in less water to wash and rinse clothes. This is accomplished in most machines by tumbling clothes through water in a horizontal axis tumbler as opposed to soaking them under water in a vertical axis machine. There do remain, however, several ENERGY STAR-qualified, vertical axis machines.

[2] The J1 test procedure is a clothes washer test procedure published in 10 CFR Part 430 Energy Conservation Program for Consumer Products: Test Procedure for Clothes Washers; Direct Final Rule and Proposed Rule (DOE, 2003)

Table 1: Clothes Washer Efficiency Standards

Standard	Before January 1, 2007		On or after January 1, 2007		July 1, 2009 (MEF; WF)	July 1, 2011 (MEF; WF)
	Minimum MEF	Maximum Water Factor (WF)	Minimum MEF	Maximum Water Factor		
Federal Standard	1.04	NA	1.26	NA	*no change*	TBD
EPA ENERGY STAR	1.42	NA	1.72	8.00	1.80; 7.50	2.00; 6.00
CEE Tier 1	1.42	9.50	1.80	7.50	*no change*	TBD[3]
CEE Tier 2	1.60	8.50	2.00	6.00	*no change*	TBD
CEE Tier 3	NA	NA	2.20	4.50	*no change*	TBD
CEE Tier 3A	1.80	7.50	NA	NA	NA	NA
CEE Tier 3B	1.80	5.50	NA	NA	NA	NA

Table 2: Expected Savings[4] with Clothes Washer Efficiency Standards

Standard	On or after January 1, 2007		Expected Energy Savings vs. Federal Minimum	Expected Water Savings Over Next Lower Tier
	Minimum MEF	Maximum Water Factor		
Federal Standard	1.26	NA		
EPA ENERGY STAR	1.72	8.00	26.7%	
CEE Tier 1	1.80	7.50	30.0%	6.3%
CEE Tier 2	2.00	6.00	37.0%	20.0%
CEE Tier 3	2.20	4.50	42.7%	25.0%
CEE Tier 3A	NA	NA	30.0%	0
CEE Tier 3B	NA	NA	30.0%	(vs. Tier 2) 9%

Better water removal. Efficient clothes washers spin at faster rates than previous generations imparting high g-forces[5] to the clothes and removing more water. Modern machines can exert 100 to 500 g's on the clothes. Higher water removal should equate with proportionally shorter drying cycles. This is dependent on the clothes dryer, however, and on user behavior. To achieve savings the dryer must be equipped with a functioning moisture sensor and an automatic shut off. The user must employ this automatic drying cycle or if a timed cycle is used, set the cycle to a shorter time than they would have with wetter clothing.

In theory moisture sensors would combine with the user's behavior to eliminate excessive drying. In reality, dryers may dry clothing more than necessary. For a dryer operated using a timed cycle it is likely that some over drying will occur. For example, consider a load of laundry that is dried for 15 minutes after the clothes are sufficiently dry. A typically sized 4,800W dryer would then waste 1.2 kWh for no benefit. Because the average dryer in the study used 2.64 kWh per cycle, this level of waste could be significant.

[3] Typically CEE Tier 1 is designed to align with the ENERGY STAR Standard

[4] Because the MEF specifies the total energy used by the washer, hot water use, and the clothes dryer, a ratio of the MEF should indicate the overall energy savings.

[5] G-force is a way of describing acceleration where 1 g-force is equal to gravity's pull or 32 ft/s^2

Prior Research

Early studies of efficient clothes washers include a study of 103 clothes washers in Bern, Kansas (Tomlinson and Ritzy, 1998), and a study in Boston of 50 clothes washers and 50 dryers (Tomlinson and Durfee, 2001). In the Bern study, households with horizontal access machines used 18% hot water and 82% cold water, and households with conventional machines used about 28% hot water. A more recent study of laundry machines at Fort Hood, had some findings similar to this study including the electricity use of efficient clothes washers and the relative proportion of hot and cold-water use (DOE, 2000). The authors found that the efficient machines used about 18% hot water and 82% cold water. Another study done on coin operated washing machines found hot water percentages at less than 20% (Water Management, 2006).

Research Methodology

Study Sample

Residences were recruited from the territories of Pacific Gas and Electric (PG&E) and San Diego Gas and Electric (SDGE) during spring and early summer 2009. The sample included both those that had received a utility incentive for purchasing an efficient clothes washer (participants) and homes that had not received an incentive, yet may have also purchased a high efficiency washer (non-participants). Homes with 240V electric dryers were accepted, and homes with gas dryers were excluded because of the difficulty of directly metering clothes dryer gas use. Two hundred and fifty homes were recruited, of which 136 were studied, and 115 produced complete data. The remaining 114 were not studied for a variety of reasons, but the majority were excluded because the laundry layout would not accept metering equipment. The 115 studied laundry systems studied are summarized in Table 3. In all 24 non-ENERGY STAR clothes washers and 91 ENERGY STAR-qualified clothes washers were studied, split among program participants and non-participants. Most machines were ENERGY STAR Tier 3 qualified, and no machines below CEE Tier 1 but meeting the ENERGY STAR specification were recruited.

Table 3. Metering Clothes Washers by Efficiency Tier

Participant/ non-participant	Tier Label	Total
Non-participant	CEE Tier 1 (2007-2008)	5
	CEE Tier 2 (2007-2008)	4
	CEE Tier 3A (2006)	1
	CEE Tier 3B (2006)	2
	CEE Tier3 (2007-2008)	5
	Non-ENERGY STAR	24
Non-participant Total		41
Participant	CEE Tier 1 (2007-2008)	3
	CEE Tier 2 (2007-2008)	10
	CEE Tier 3A (2006)	1
	CEE Tier 3B (2006)	9
	CEE Tier3 (2007-2008)	51
Participant Total		74
Study Total		115

Metering Approach

The following aspects of laundry systems were metered in situ to characterize their use and to directly measure the energy their operation consumed. At each site a variety of information was collected and logged for three weeks:

- Volumetric flow through hot water hose serving the clothes washer
- The temperature of the hot water entering the clothes washer
- The electricity consumed by the clothes washer (kW, kWh)
- The electricity consumed by the 240 V electric dryer (kW, kWh)

In addition, to understand how the laundry system was operated and in particular to understand the use of cold water in various wash cycles, the following was also logged:

- Volumetric flow through cold water hose serving the clothes washer
- The temperature of the cold water entering the clothes washer

The electricity use of the clothes washer and dryer was metered directly. However, the heat energy of hot water used was calculated based on the following equation:

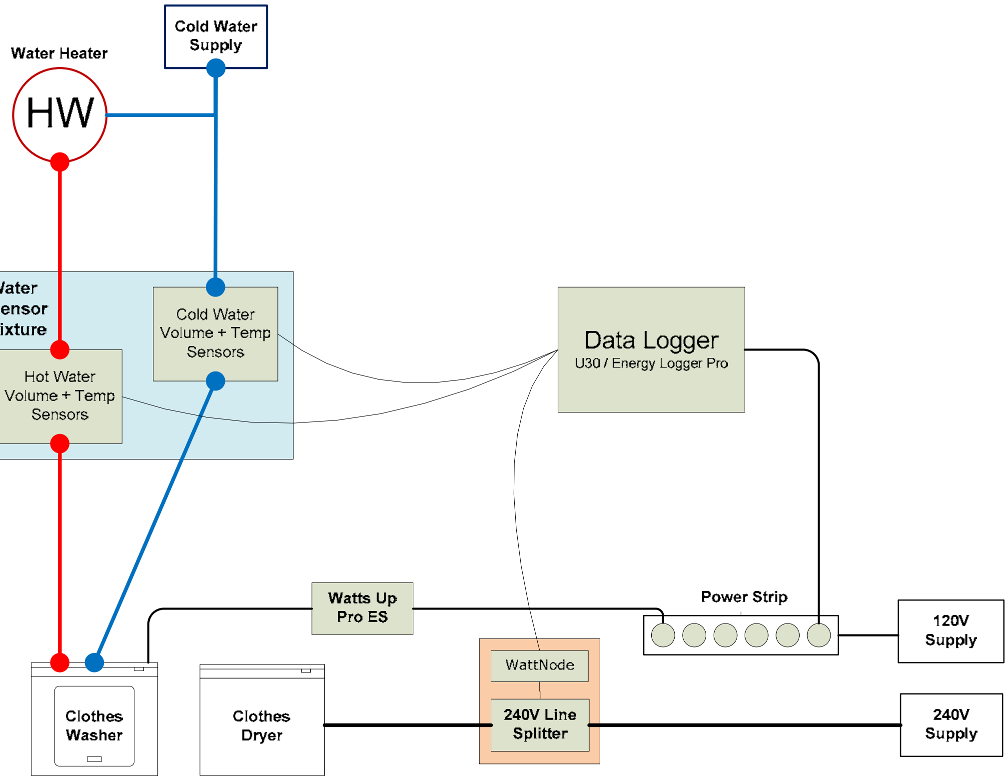
$$\textit{Heat energy (BTU)} = \textit{Flow (gallons)} * (\textit{hot temperature} - \textit{entering cold temperature}) * 8.3\ (\textit{lb/gallon}) * 1\ \textit{BTU/°F*lb}$$

The meter setup is shown in Figure 1 and specific components are listed in Table 4.

Table 4: Clothes Washer Metering Equipment

Function / Data to Measure	Brand / Model	Full Scale Accuracy	Expected Measurement	Metering Interval
Water Flow / Water Temp	Omega FTB-8007B-PT (20 pulses / gallon)	1.5% reading	pulse	30s log
	Onset Pulse Input Adapter S-UCD-M006	NA		NA
	Copper Mounting Setup	NA		NA
	Onset Water Temp Sensor S-TMB-M006	±0.2°C, ±0.36°F	50F; 130F	2s measure/ 30s log
Dryer Power	WattNode T-WNB-3D-240	0.3% reading	pulse	30s log
	Onset Pulse Input Adapter S-UCC-M006	1% of reading	Pulse; 5000 W-hour per load	30s log
	MAGNELAB 50A CT T-MAG-SCT-050	NA		NA
	Dryer Cord / Line Splitting Apparatus	NA	pulse	30s log
Washer Power	Watts Up? PRO ES	±1.5%	100Wh per load	5 min
	Power Strip	NA	NA	NA
Data Logger	Onset HOBO H22-001 Energy Logger Pro	NA	NA	NA
	HOBO U30-GSM-VIA-10-S100-105	NA	NA	NA
Power Supply	Onset AC-U30	NA	NA	NA
	Onset P-AC-1	NA	NA	NA

Figure 1: Clothes Washer Metering Equipment Setup



Research Findings

Laundry System Use

Table 5 shows the number of wash loads per week and Table 6 shows the number of dryer loads per week for the 115 clothes washers, split by participant category and by clothes washer efficiency tier. Non-participant households did about five washer and dryer loads per week on average, with some variability. For the 74 participants, the number of dryer loads per week lagged the number of washer loads by 0.5 loads. This could have been caused by re-washing loads, or by air drying some loads. Because all energy and water results are normalized per load, the impact of this difference is small.

Table 5: Wash Loads by Participant Category and Machine Type

Wash Loads			
Participant Category	**Efficiency**	**Average**	**Precision (at 90% Confidence)**
41 Non-participants	*24 Non-ENERGY STAR*	4.77	*23%*
	17 ENERGY STAR, Tiers 1-3	6.23	*21%*
	All non-participants	5.38	*16%*
74 Participants	*ENERGY STAR*, Tiers 1-3	4.80	*11%*

Table 6: Dryer Cycles by Participant Category and Machine Type

Dryer Loads			
Participant Category	**Efficiency**	**Average**	**Precision (at 90% Confidence)**
41 Non-participants	*24 Non-ENERGY STAR*	*4.71*	*28%*
	17 ENERGY STAR, Tiers 1-3	*5.94*	*19%*
	All non-participants	5.22	*17%*
74 Participants	*ENERGY STAR*, Tiers 1-3	4.30	*12%*

Clothes Washer Electricity Use

The average electricity use of the 24 baseline machines was 0.21 kWh per cycle and the energy use of all 115 machines averaged 0.20 kWh per cycle. This small difference is not statistically significant and could easily arise from differing usage patterns.

Many advanced clothes washers consume standby energy to keep various controls active. While standby power consumed is typically low, on an order of 2 watts, over a week this equates to 0.340 kWh, greater than the 0.20 kWh consumed during a typical washer load. This means that for highly used machines the standby losses are small but for lightly used machines, standby electricity use could be a substantial portion of the electricity directly consumed by the clothes washer.

Hot Water Use

Table 7 shows actual average water use per load for 115 clothes washers monitored for three weeks. Most of the water used is cold water, with only about 13 percent of water use heated. CEE Tier 1, 2, and 3 machines use substantially less water than non-ENERGY STAR machines. ENERGY STAR-qualified machines are not listed as a separate category because all efficient machines in the study already met Tier 1. This is probably because manufacturers had been anticipating the alignment of ENERGY STAR and Tier 1 in July 2009.

Table 7: Metered Water Use in 115 Clothes Washers

Categories in Order of WF	Average Hot Water Gallons/cycle	Average Cold Water Gallons/cycle	Average Total Gallons/cycle	Water Savings	Hot Water Savings
Non-ENERGY STAR	3.8	37.4	41.2		
CEE Tier 1 (2007-2008)	4.2	18.7	22.9	44.4%	-10.5%
CEE Tier 2 (2007-2008)	2.5	13.6	16.1	29.7%	40.5%
CEE Tier 3B (2006)*	3.2	11.6	14.9	7.5%	-28.0%
CEE Tier 3 (2007-2008)*	2.2	14.5	16.8	-4.3%	12.0%
Average	2.9	19.3	22.2		

*versus Tier 2

Tier 1 machines use about 44% less water than non-ENERGY STAR clothes washers and Tier 2 machines use about 30 percent less than Tier 1. Curiously, Tier 3 machines actually use more than Tier 2. We suspect that this is because of the small sample size of Tier 1 and 2 machines and because Tier 3 machines are generally larger. Tier 3 machines were found to be, on average, 6% larger than the other ENERGY STAR-qualified machines. However, the effect of size on washer usage and savings was not studied as part of this evaluation.

The hot water usage varies and does not appear to correspond with the efficiency of the machines. This is because the choice of wash cycles is variable and user driven. In addition, the sample sizes for Tier 1, 3A, and 3B are small.

Figure 2 shows the actual water savings versus those expected from improvements in WF. Savings are expressed in percent savings by CEE Tier category. Since there is no Federal energy standard for water use by clothes washers Tier 2 is compared to Tier 1 and Tier 3 is compared to Tier 2 for expected savings. The actual water savings compares the listed tier with the lower adjacent standard (e.g. Tier 1 with the federal maximum, Tier 2 vs. Tier 1)

Table 8 shows that hot water is heated about 50° F above ambient cold water, with non-ENERGY STAR systems heating water slightly less. Small differences in hot water temperature had little impact on the analysis because, as previously shown, hot water accounts for about 13% of the energy used in laundry systems.

Figure 2: Anticipated vs. Actual Water Savings

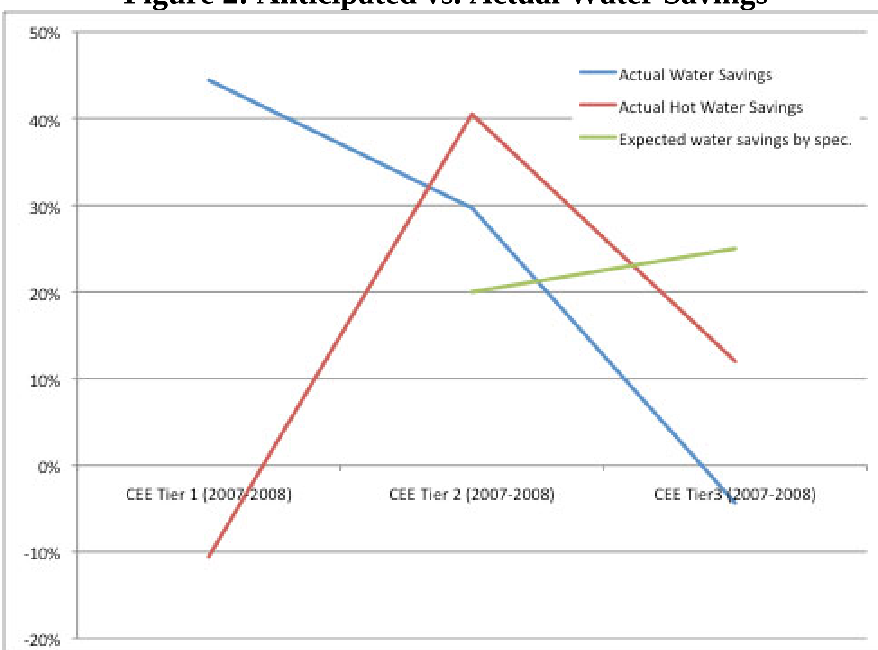


Table 8: Temperature Delta by Participant Category and Machine Type

Temperature Change			
Participant Category	**Efficiency**	**Average**	**Relative Precision at 90% C.I.**
41 Non-participants	*24 Non-ENERGY STAR*	*48.67*	*16%*
	17 ENERGY STAR, Tiers 1-3	*56.10*	*8%*
	All non-participants	52.25	*9%*
74 Participants	*ENERGY STAR*, Tiers 1-3	54.40	*5%*

Piping Losses

Typically, there is a run of piping from the hot water heater to the clothes washer valve that is usually between 12 feet, for pipes run across the ceiling, to 20 feet long and longer where the hot water tank and clothes washer are in different rooms. This water sits between washes and equalizes with the ambient temperature. Table 9 shows that this can create a "dead leg" of 1 gallon or more.

Table 9: Pipe Volume in Gallons/Minute

Run length	Pipe Diameter	
	1/2"	3/4"
10'	0.4 gallons	0.9 gallons
15'	0.6 gallons	1.4 gallons
20'	0.8 gallons	1.8 gallons

Based on our metering, the temperature of initial hot water flow is ambient temperature in the range of 70° to 75°F, then rises to near the hot water set point minus a small steady state loss between the hot water heater and the clothes washer, due to the dead leg of water. To account for this we assigned a representative hot water temperature to the initial cold water flow from the dead leg flow. Table 10 is arranged to reflect decreasing WF rather than increasing MEF to better indicate water use. The energy used to heat water for non-ENERGY STAR machines is low due to the small amount of hot water used in our sample of non-ENERGY STAR machines. Tier 2 and 3 clothes washers save about 900 BTU or a little more than 0.25 kWh per cycle.

Table 10: Average Water heating BTU's per Cycle

	Average BTU's per Cycle
Non-ENERGY STAR	1,975
CEE Tier 1 (2007-2008), 3A	2,171
CEE Tier 2 (2007-2008)	1,084
CEE Tier 3B (2006)	1,787
CEE Tier3 (2007-2008)	1,050
Average	1,410

Dryer Electricity Use

Dryer electricity use was directly metered using a custom assembled 240V meter that plugged into the dryer. The meter consisted of a 240V Watt Node, 2 50A CTs with wires wrapped twice around them, and a pulse converter. The electricity use was continuously measured and logged or recorded every 30 seconds. Similar to the other energy inputs, dryer energy was normalized to the average energy used per load for each site. Table 11 is arranged in order of increasing MEF. The average electricity use per drying cycle dropped sharply from a dryer associated with a base machine to a Tier 1 machine, and dropped again for Tier 3B and Tier 2 machines. Curiously, the average use rose for Tier 3 machines, by roughly 20 % over Tier 2. These washers were on average 6% larger, which may have contributed to users washing and drying larger loads. This does not appear to entirely explain the higher energy use for Tier 3. Another factor is that Tier 3 washers achieve savings through higher spin rates. Advanced machines may have 3 or 4 spin settings. If users choose less than the maximum spin rate for vibration or noise reasons, they may inadvertently defeat the efficiency of the Tier 3 machines. Figure 3 shows the results of operating a Tier 3 clothes washer at various spin settings. The moisture remaining after running medium, high, and very high spin settings and the impact of running very high twice is shown. Based on an MEF of 2.4 (Tier 3) at the very high setting, the effective MEF at each setting was calculated. By operating the machine on medium, the MEF drops from 2.4 to 1.76 – below the current ENERGY STAR and Tier 1 specifications.

Table 11: Average Dryer Energy Use per Cycle

Clothes Washer Efficiency	Average Dryer kWh/Cycle	Average Dryer Therms/Cycle @ 90% efficiency
Non-ENERGY STAR	3.66	0.139
CEE Tier 1, 3A (2007-2008)	2.63	0.100
CEE Tier 2 (2007-2008)	2.17	0.082
CEE Tier 3B (2006)	2.31	0.088
CEE Tier3 (2007-2008)	2.38	0.090
Total Average	**2.64**	**0.100**

Overall Energy Use

As shown in Figure 4, roughly 82 percent of the energy used by the studied systems was in the clothes dryer, with water heating (13%), and the clothes washer (6%) relatively minor contributors to laundry system energy use. An oft-repeated statistic is "*About 90% of the energy used for washing clothes in a conventional top-load washer is for heating the water.*"[6] This is high if the clothes dryer is omitted, with a true proportion of about 72%, however if total energy is used it makes up only 13%. Clearly, how dryers are used is a critical component of the savings delivered by an efficient clothes washer.

[6] http://www1.eere.energy.gov/consumer/tips/laundry.html

Figure 3: Effect of Spin Setting on Remaining Moisture and Effective MEF

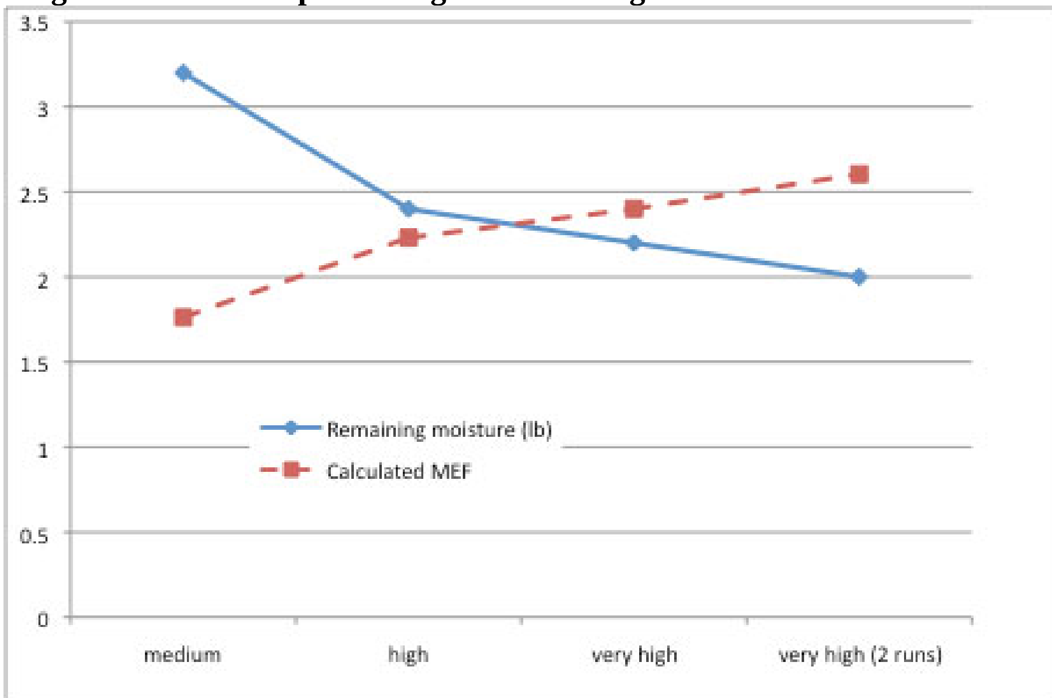
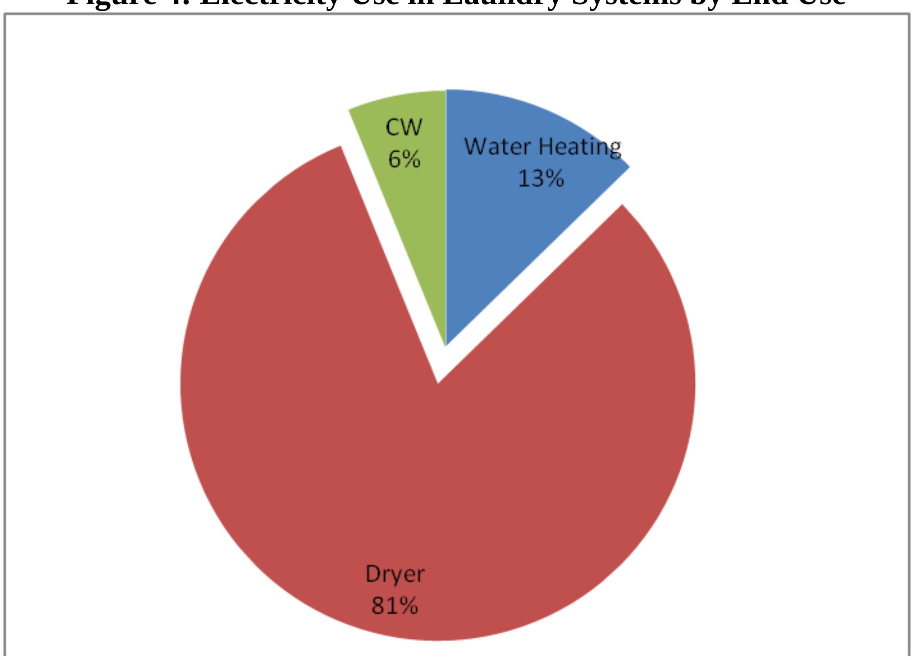


Figure 4: Electricity Use in Laundry Systems by End Use



Total Electricity Use by Efficiency Level

The total electricity use is shown by type for the 115 clothes washer studied (Table 12). Total electricity used drops from the base machine through Tier 2, but rises for Tier 3 machines, because of the rise in dryer energy previously discussed. Tier 3B is a relatively small sample size. As described in this report most of the energy used in a laundry system is for drying clothes, in part because hot water makes up a small proportion of the water used in the 115 systems studied.

Table 12: Average Per Cycle Energy Use by End Use

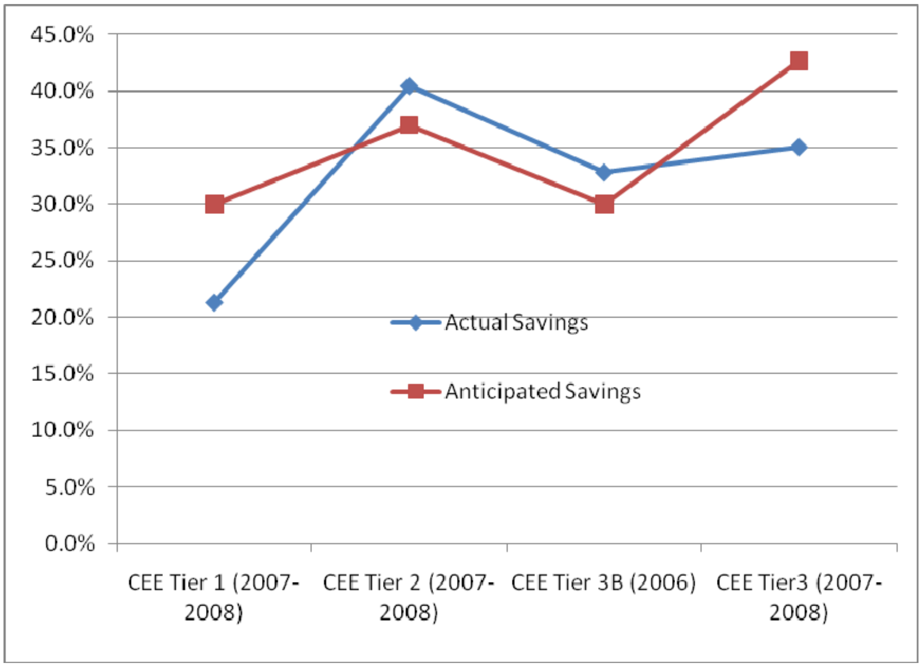
Efficiency	Water Heating Use	Dryer Use	Clothes Washer Use	Total Electricity
	kWh/ cycle	kWh/ cycle	kWh/ cycle	kWh/ cycle
Non-ENERGY STAR	0.58	3.66	0.21	4.45
CEE Tier 1 (2007-2008)	0.64	2.63	0.23	3.50
CEE Tier 2 (2007-2008)	0.32	2.17	0.16	2.66
CEE Tier 3B (2006)	0.52	2.31	0.15	2.99
CEE Tier3 (2007-2008)	0.31	2.38	0.21	2.89
Average	0.41	2.64	0.20	3.26

To calculate per cycle savings (Table 13) we took the difference of the various Tiers of efficient units from the non-ENERGY STAR clothes washer usage. Savings are dominated by dryer usage, and are greatest for Tier 2. The actual savings by percent are shown along with the anticipated savings from the differences in MEF shown previously in the standards table. Figure 5 shows that the actual savings and anticipated savings match fairly well with Tier 3 savings lagging, probably for the reasons previously discussed.

Table 13: Average per Cycle Energy Savings by End Use

Efficiency	Water Heating Savings	Dryer Savings	Clothes Washer Savings	Total Electricity Saved	Actual Savings	Anticipated Savings
	kWh/ cycle	kWh/ cycle	kWh/ cycle	kWh/ cycle	%	%
CEE Tier 1 (2007-2008)	-0.06	1.02	-0.02	0.95	21.3%	30.0%
CEE Tier 2 (2007-2008)	0.26	1.48	0.05	1.8	40.4%	37.0%
CEE Tier 3B (2006)	0.06	1.35	0.06	1.46	32.8%	30.0%
CEE Tier 3 (2007-2008)	0.27	1.28	0.01	1.56	35.1%	42.7%

Figure 5: Savings Anticipated from MEF vs. Actual Savings for Tier 1, 2, and 3 Clothes Washers



Summary and Conclusion

Efficient clothes washers have the unique attribute of achieving nearly all of their energy savings in other devices, namely water heaters and clothes dryers. This study of 115 laundry systems showed that most of the energy consumed and most of the potential savings arise in reduced operation of the clothes dryer.

- Residences studied ran about 5 loads of laundry per week. Little hot water was used in the system, in part because of cold washing and cold water rinsing. Only 13 percent of the water used in the laundry system was heated. Of the hot water used, a portion of the heat is lost in the standing water in the piping between the washer and dryer.
- Tier 1 and 2 machines appear to save substantial amounts of water, but Tier 3 machines do not save as much water as anticipated. This may be because Tier 3 machines are used for larger loads or may be a result of automatic water sensing, we recommend that it be investigated.
- Efficient clothes washers use as little as 12 gallons per load. Hot water would only be a portion of this, even for hot cycles, meaning that hot water use could be only several gallons per load. In some installations, dead leg standing water could be 2 gallons or more. In these cases, very little hot water would actually reach the clothes washer, meaning that choosing hot water cycles would waste energy but give no cleaning benefit.
- Tier 1 and 2 machines appear to be saving substantial drying energy and therefore total energy. Tier 3 machines are using more energy than Tier 2 machines in the study. This may be in part due to the small sample size of Tier 2 machines, but may also arise from factors including laundry load size and how the spin cycle is operated.

- Slower spin settings remove less water than the highest spin rate. So much less that a laundry system with a Tier 1 machine could use less energy than one with a Tier 3 machine if a medium spin setting were used on the Tier 3 machine. Users should be educated in the use of spin cycles.
- Given that most of the savings delivered by clothes washers are from shorter drying cycles it is important that dryers be equipped with functioning moisture sensors and that users understand that energy savings are dependent on the use of automated drying cycles.

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