Estimating Commercial Clothes Washer Use in California Coin Laundry Stores

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ABSTRACT

The LightWash program, in collaboration with California water utilities, provided rebates for over 8,000 high efficiency "family-sized" commercial clothes washers throughout the state of California from 2002 through 2005. Aside from a small number of studies on a limited number of washers (Tomlinson 1998; Sullivan 2000; Durfree 2001; FEMP 2002; Sullivan 2004), there is a dearth of publicly available information on the actual frequency of use (i.e., "turns per day") for commercial washers. However, energy impact estimates are directly proportional to how often the washers are used. Since this vital piece of information had the highest degree of uncertainty in the LightWash savings estimate, evaluation resources were focused on metering commercial washers to estimate the average number of turns per day per washer.

In this study, a total of 77 washers across thirteen coin laundry stores in the Pacific Gas and Electric Company service territory were randomly chosen from the 2004/2005 LightWash program participant database. The washers were metered for a two-week period in 2005 using the watts up? Pro data logger. The average number of turns per day was found to be 2.97 ± 0.70 at the 90% confidence level, roughly half of the number presumed by the program for washers in commercial laundromats.

LightWash Program

In 2002, Energy Solutions' LightWash program was awarded funding by the California Public Utilities Commission (CPUC) for implementation in the Pacific Gas and Electric Company (PG&E), Southern California Gas Company, and San Diego Gas and Electric Company territories. During 2002/2003, LightWash provided prescriptive rebates for the installation of high efficiency commercial clothes washers in coin laundry stores (e.g., Laundromats), multi-family and institutional common area laundry facilities, and businesses with on-premise laundry.

Based on the success of the first two program years, Energy Solutions proposed and was granted a modified version of the LightWash program for 2004/2005. While the 2002/2003 program was offered throughout the state, the 2004/2005 program was only offered in the PG&E service territory. In addition, Energy Solutions added incentives for high efficiency commercial water heaters to their existing commercial clothes washer and lighting measures.

At the heart of the LightWash program's success promoting efficient commercial clothes washers was Energy Solutions' initial collaboration with the California Urban Water Conservation Council and the program's ongoing partnerships with 25 California water agencies. Through these partnerships, the LightWash program provided combined energy and water rebates, which were funded by participating water utilities in amounts determined by each water utility. The program also provided targeted outreach and marketing to encourage the adoption of high efficiency clothes washer technology by eligible customers in qualifying energy and water utility territories. In addition to incentive funding, many water agencies contributed to marketing efforts and education through their standard channels, including bill inserts, newsletters, etc. By consolidating resource-intensive activities, such as incentive processing and targeted outreach, the LightWash program attempted to remove substantial cost and staff resource barriers, thereby facilitating the active involvement of additional water agencies.

The LightWash program developed a qualifying product list based on the national Consortium for Energy Efficiency's (CEE) Commercial, Family-Sized Washer Initiative product list (www.cee1.org), which includes Water Factor (WF)[1] and Modified Energy Factor (MEF)[2] requirements. During its four years of operation, LightWash sometimes offered multiple energy rebate levels for multiple qualifying efficiency levels. Table 1 lists the specifications and energy rebates for qualifying washers during the LightWash program. The water utility rebate component (not shown in Table 1) varied from $50 to $350, and was provided in addition to the energy rebate shown.

Table 1. LightWash Program Washer Specifications and Energy Rebates

Program/Year	LightWash Specifications	Modified Energy Factor (cubic feet/kWh)	Water Factor (gallons/cubic foot)	Rebate (not including water utility rebates)
LW I- 2002/03	All qualifying washers	≥ 1.26	≤ 9.5	$100-150 (depending on customer type)
LW I- Jan-Feb 2004	All qualifying washers	≥ 1.42	≤ 9.5	$150
LW II- Mar-Dec 2004	Washer Level 1	≥ 1.42	≤ 9.5	$50
LW II- Mar-Dec 2004	Washer Level 2	≥ 1.8	≤ 7.5	$150
LW II- Jan 2005-Mar 2006	Washer Level 2	≥ 1.8	≤ 7.5	$100

Evaluation

Equipoise Consulting Inc. had performed a comprehensive evaluation of the 2002/2003 program and had identified the number of washer turns per day as an area of significant uncertainty. (Equipoise 2004) Because primary data collection of turns per day is expensive[3], efforts during the 2002/2003 evaluation concentrated on assessing program theory and program operation. Having assessed those issues within the last twelve months, the CPUC, program staff, and evaluators concluded the best use of 2004/2005 evaluation funds would be to collect primary metered data on laundromat washer turns per day with the objective of creating a higher level of certainty in the energy impact values. Washing machines within commercial laundromats were estimated to experience six turns per day while multi-family washers were estimated to

[1] The Water Factor is the standardized metric for water use, expressed as the number of gallons per cycle per cubic foot of tub capacity. The lower the water factor, the more efficient the washer.
[2] Modified Energy Factor (MEF) is the standardized metric for energy consumption of the average total laundry cycle (washing and drying). It is expressed as cubic feet of tub capacity divided by energy use (kWh) for the average total laundry cycle. The higher the number, the greater the efficiency.
[3] The data collection effort used approximately 27 percent of the evaluation budget.

experience between three and four turns per day. Because metering is expensive, the effort was limited to the commercial laundromat sector. Additionally, the sample was pulled using the participants of the 2004/2005 program, who were all PG&E customers.

While several metering options were investigated, the watts up? Pro data logger was chosen based on price and ease of use. At less than $200 per logger, this choice allowed the purchase of enough loggers to run two sites of six meters simultaneously, letting the evaluation collect the required data within a shorter time frame. The washer plugs directly into the logger, which then plugs into the outlet. Not only did this allow for washer specific monitoring, the ease of installation meant that an electrician was not required, minimizing costs. However, the kWh data is logged across time with longer metering interval periods as the logger is left in place longer, creating analysis issues that required some judgment on the part of the evaluators. During the course of this evaluation, the company manufacturing the watts up? meter came out with a newer product with vastly improved data storage capabilities. This improved data storage capability would have shortened the metering interval average time and made identification of the on/off break points significantly easier. The availability of these newer meters could make analysis of the data from future studies more straightforward.

Sampling

Because the number of clothes washers across all the laundromats was unknown, but the number of all participating laundromats was known, the two-stage cluster sample design was chosen. A two-stage cluster is obtained by first selecting a probability sample of clusters and then selecting a probability sample of elements from each sampled cluster (Scheaffer, Mendenhall & Lyman 1996). Each laundromat was considered to be a cluster and each washing machine was considered to be an element within each cluster.

The notation that is used for this discussion of the two-stage cluster design is presented below.

$N=$	the number of clusters in the population
$n=$	the number of clusters selected in a simple random sample
$M_i=$	the number of elements in cluster i
$m_i=$	the number of elements selected in a simple random sample from cluster i
$M = \sum_{i=1}^{N} M_i =$	the number of elements in the population
$\overline{M} = \frac{M}{N} =$	the average cluster size for the population
$y_{ij} =$	the jth observation of turns per day in the sample for the ith cluster
$\bar{y}_i = \frac{1}{m_i}\sum_{j=1}^{m_i} y_{ij} =$	the sample mean turns per day for the ith cluster

Using this sample design, the unbiased estimator of the population mean μ is:

$$\hat{\mu} = \left(\frac{N}{M}\right)\frac{\sum_{i=1}^{n} M_i \bar{y}_i}{n} = \frac{1}{\overline{M}}\frac{\sum_{i=1}^{n} M_i \bar{y}_i}{n} \qquad \text{Eq. 1}$$

The estimated variance of $\hat{\mu}$ is:

$$\hat{V}(\hat{\mu}) = \left(\frac{N-n}{N}\right)\left(\frac{1}{n\overline{M}^2}\right)s_b^2 + \frac{1}{nN\overline{M}^2}\sum_{i=1}^{n} M_i^2\left(\frac{M_i - m_i}{M_i}\right)\left(\frac{s_i^2}{m_i}\right) \qquad \text{Eq. 2}$$

where

$$s_b^2 = \frac{\sum_{i=1}^{n}(M_i\bar{y}_i - \overline{M}\hat{\mu})^2}{n-1}$$

and

$$s_i^2 = \frac{\sum_{j=1}^{m_i}(\bar{y}_{ij} - \bar{y}_i)^2}{m_i - 1} \qquad \mathrm{i} = 1, 2, \ldots, \mathrm{n}$$

As indicated above, the two-stage cluster sample was composed of (1) the laundromat sites selection, and (2) which washers at each site would be metered. The participant population from which to sample was derived from the LightWash II participants from January 1, 2004 through March 30, 2005 (the start of data collection). This population of 305 sites was first filtered based on the total number of washers at the site. Because the analysis was interested in laundromats, not multi-family sites, a filter was applied to all 305 sites to only keep those with greater than 20 machines (i.e., laundromats). The choice of 20 machines was based on filtering out the larger multi-family sites that had an average of 18.5 washers/site and conversations with the program staff. This filter reduced the potential metering population to 52 sites. Next these 52 sites were reviewed to determine if there were any non-laundromat or duplicate sites. Six sites were found to be duplicates and seven were assumed to be non-laundromat sites based on the site name (e.g., Park Apartments). Additional analysis of the remaining 39 sites caused two more sites to be removed from the potential metering sample because of the extraordinarily large number of washing machines at the site (76 and 100 machines), which we believed to be outliers and not representative of the general population[4]. The remaining metering sample of 37 sites was randomly ordered and recruited to participate in the metering effort, rigorously following the random order. Seventeen sites refused the metering. Sites that agreed to allow metering were required to sign a release form authorizing installation of monitoring equipment.

At each site that agreed to participate, a systematic random sample of six machines was selected from all washers at the site that had a washer load capacity of less than 25 pounds. (This machine size matched the machine sizes being rebated by the LightWash program.) The approach of metering *all* 25 pound or smaller washers at each site, whether rebated through the LightWash program or not, was chosen to eliminate any bias that customers may have toward newer machines. Since the evaluation was trying to collect the number of turns per day for the

[4] This number of washers per site was at least two standard deviations above the mean.

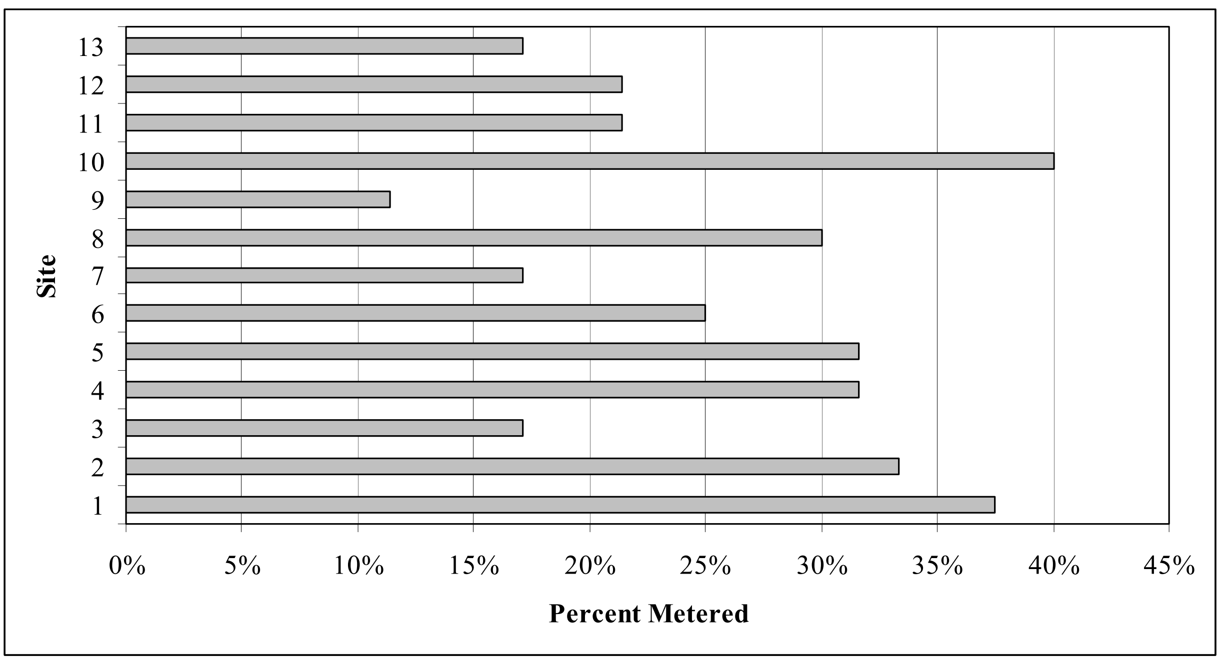
typical machine, and was not trying to determine the kWh per load, the age of the washer was irrelevant to the effort. Once the six random washing machines were chosen, plug-in watts up? brand data loggers were installed between the outlet and the power cord behind each selected machine and left in place for approximately two weeks per site.[5] The loggers were installed on one set of randomly selected machines for the entire two weeks, thus requiring only two visits per site, one visit to install and initialize the loggers and one visit to remove the loggers and download the data. At some of the early sites, data was also downloaded after one week to assess the data and check data quality.

The convenience of the small plug-in style loggers, and the ability to place them out of sight between or behind the machines, made the meter installation quick and virtually eliminated any temptation for staff or customers to tamper with the meters.

The research planned for a total sample size of 72 individual machines. This sample size, assuming a coefficient of variation of 0.50, would have exceeded a 90 percent plus or minus 10 percent level of precision for turns per day from the average laundromat washer. One meter failure resulted in fewer machines being metered than planned, so a 13th site was recruited from the randomized list of sites. The six machines metered at the 13th site resulted in a total of 77 metered machines.

The 77 metered machines covered an average of 23 percent of the possible washers available for metering at the 13 metered sites. (336 total machines possible for metering). Figure 1 shows the range across all metered sites.

Figure 1. Percent of Eligible Machines Metered at Each Site



All the laundromats had machines that fell outside the metering criteria. Across the 13 metered sites, there were 131 machines with capacities over 25 pounds. Some sites had only 2 larger machines while others had 10 to 15 larger machines. One laundromat had 33 large

[5] Three sites were left in place for 16 days due to other commitments that precluded picking up the meters at 14 days.

machines. Therefore, the total of 467 total machines at these 13 sites had 131 machines excluded from metering for the reasons stated above. This left a total of 336 machines that were eligible for metering. However, the total number of eligible machines at all 37 sites was unknown since the only way to determine how many of the machines at the non-metered sites were actually eligible was to conduct on-site inspections, which was too expensive. Thus, the total, M (used in equation 1), was calculated using the following formula:

$$Total\ Number\ of\ Eligible\ Machines = N * \frac{\sum_{i=1}^{n} m_i}{n} \qquad \text{Eq. 3}$$

That is, the total number of sites, 37, is multiplied by the mean number of eligible machines at the 13 sites in the sample, 25.85. This yielded an estimated total of 956 eligible machines at the population of 37 laundromats for use in equation 1.

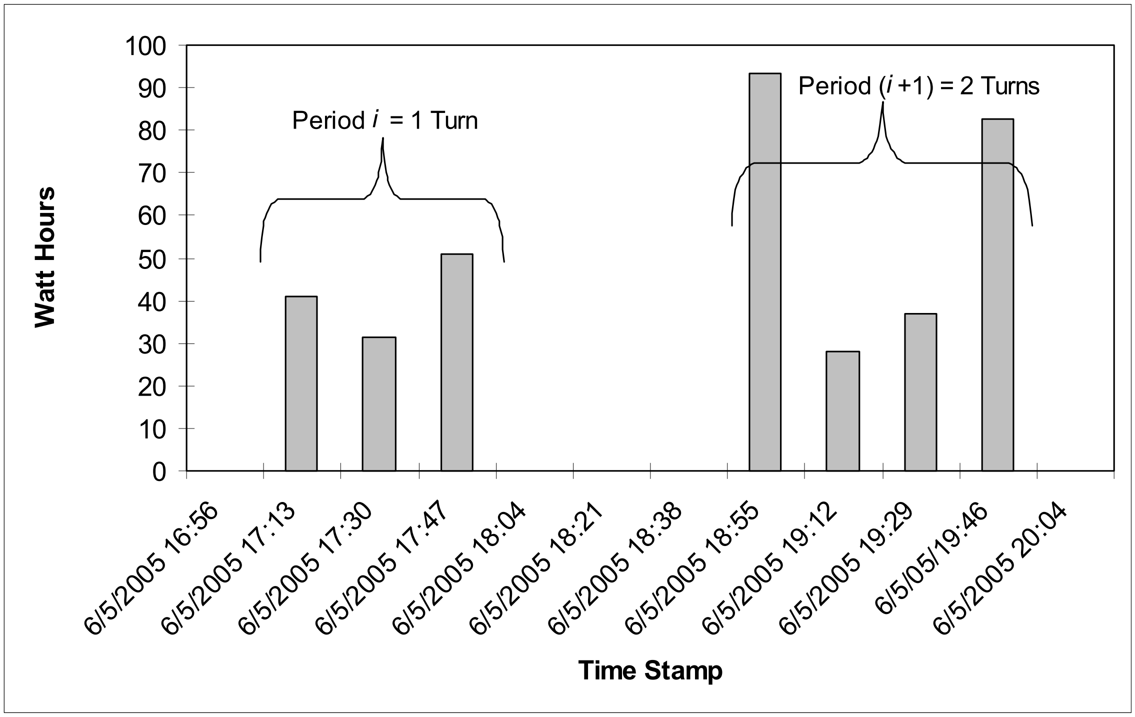
Analysis

The metered washers provided data for two analyses: 1) average turns per day across all washers, and 2) an hourly operating factor profile. These are presented next.

Turns per day. The watts up? meters used in this evaluation recorded a series of watt-hour (Whr) values collected at uniform intervals. The interval for each meter varied depending on the period of time between the downloading of the data, with the interval becoming longer as the time between data downloads increased. For the two week period that the meters were installed during this evaluation, the interval was typically either 17 or 34 minutes, with an average interval period of 31.6 minutes. In total, there were 59,628 intervals recorded across all 77 washers. Because of the way the meters collected the data, a washer cycle could start in the middle of the metering interval, be on during the entire metering interval or stop sometime during the metering interval. Also, it was possible that a person could have completed one washer cycle and immediately begun another load of laundry in the middle of a metering interval.

To help explain this part of the analysis, Figure 2 shows an example of the raw data taken from one of the meters. The analysis set an "assigned period" (*i*) based on the watt-hour values. Because electronic controls have a constant base load, the watt hour value was given a zero value if the use during that interval was less than or equal to ten watts-hours and labeled "Updated Watt Hours". A new period (*i*+1) was begun whenever a metering interval of zero updated watt-hours was followed by a metering interval greater than zero watt-hours. The sum of updated watt-hour use for assigned periods *i* and *i*+1, shown in Figure 2, are 123.2 and 240.5, respectively. The evaluation team analyzed the updated watt-hour use per assigned period and designated a specific number of turns that occurred in that assigned period. For this particular site, assigned period *i* was determined to be equal to one turn while assigned period *i*+1 was considered to be two turns.

Figure 2. Example of Raw Metering Data and Periods



Thus, the raw data was a series of updated watt-hour usage values over varying time intervals and the first task in analyzing the number of turns per day per machine was to determine how many turns had occurred during a single assigned period that encompassed multiple metering intervals. The first attempt at setting the number of turns per assigned period tried to apply statistical analysis techniques to remove all human bias from the interpretation. Because of the variations in washer model numbers (recall that the sample included both new and existing machines) and the grouped format of the raw data, this method proved unsuccessful.

The final approach to analyzing the data used two separate people to visually review the data from each meter at each site, and have each person decide the differentiation between the number of cycles represented in the data. In most cases, the differentiation was obvious, with gaps of 50 to 100 watt-hours between bunched data. Some cases required much closer scrutiny, sometimes involving plotting all machines of the same model from a given site to achieve clarity. Once both analysts had established break points, the two analysts reviewed any disputed values and agreed on the final break points. In no cases did the analysts disagree as to the final chosen value.

A factor confounding the analysis, was the sporadic appearance of watt-hour blips much smaller than the value expected for a single cycle. This was clarified by one laundromat operator, who said that they were most likely caused by owner/operators emptying machines that had not completed a cycle. Apparently operators have the ability to short-cycle the machine to empty it of water and reset it ready for use if it has not completed a wash cycle.

After the number of turns was designated to each assigned period, the average turns per day for each metered washer were calculated as shown in equation 4.

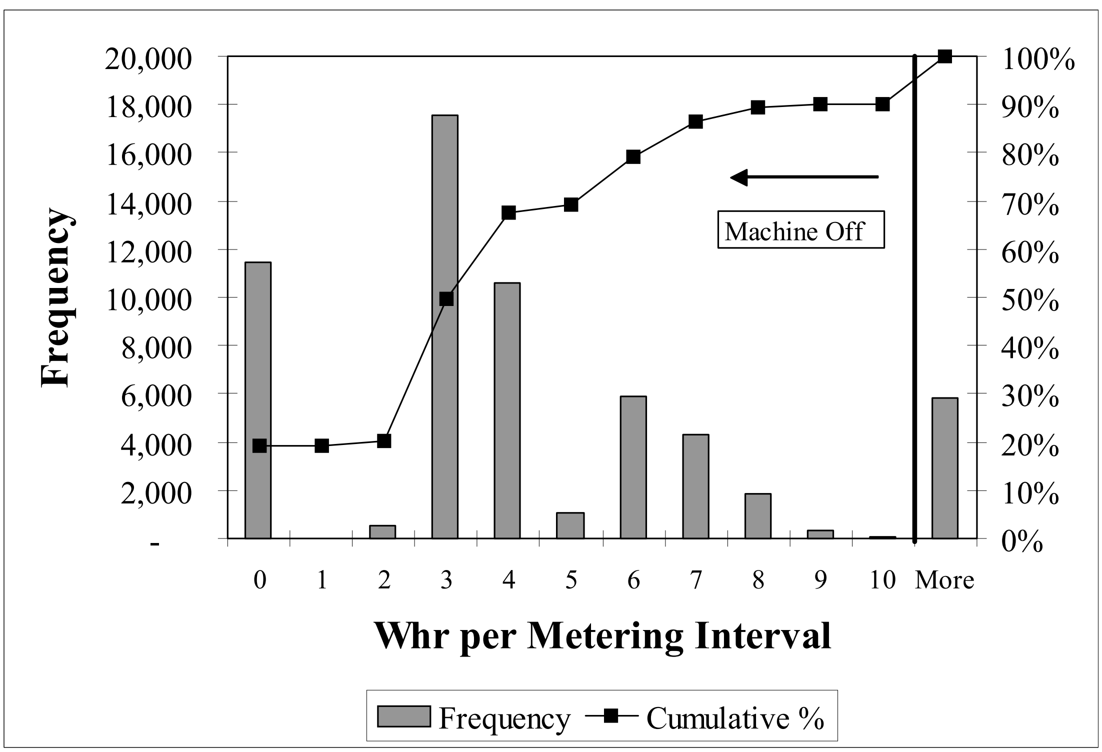
$$\text{Average Turns/Day} = \frac{\sum \text{turns for meter}}{\text{metered days}} \qquad \text{Eq. 4}$$

Once each washer had an average turns per day value, equation 1 was used to calculate a population estimate of turns per day for commercial laundromats. Application of equation 2 provided the estimated 90% upper and lower confidence intervals of the turns per day value.

Operating factor. In addition to calculating the turns per day, the time-stamped metered data allowed an estimation of the operating factor across days and hours. The sites were metered sequentially, so an actual daily use metered across the same days could not be created (except for those 6 meters at the same site). However, the watt-hour use for a time stamp period was summed across each hour and the day of the week was based on the actual day metered.

A binary operating factor of one for "on" and zero for "off" was assigned to each metering interval based on the watt-hour usage. However, because electronic controls built into some washers use a small amount of energy all the time, a method was used to differentiate between actual machine use and control use (the stand-by loss when the machine is not in use). All 59,628 records of metered data were used to set the threshold value at which a machine was determined to be "off" (and hence the operating factor = 0). Ninety percent of the records were at or below ten watt-hours. This value was chosen as the threshold at or below which a washer was considered "off". Figure 3 plots the frequency with which metering interval energy use values corresponded to the watt-hour bins on the X axis of Figure 3.

Figure 3. Watt-hours per Metering Interval



After setting the binary operating factor for the intervals, the operating factor for the day of the week and hour of the day was calculated by averaging the binary operating factors within that day of the week and hour. The metered sample average operating factor was calculated using the algorithm shown in equation 5. The hour and day of the week was set using the time stamp variable from the metered data.

$$\text{Average Hourly Operating Factor}_{i,d} = \frac{\sum \text{Operating Factor per hour}_{i,d}}{\text{N Hours with metered data}_{i,d}} \qquad \text{Eq. 5}$$

Where: i = 0 to 23 (hour zero is from midnight to 1 AM)
d = day of the week

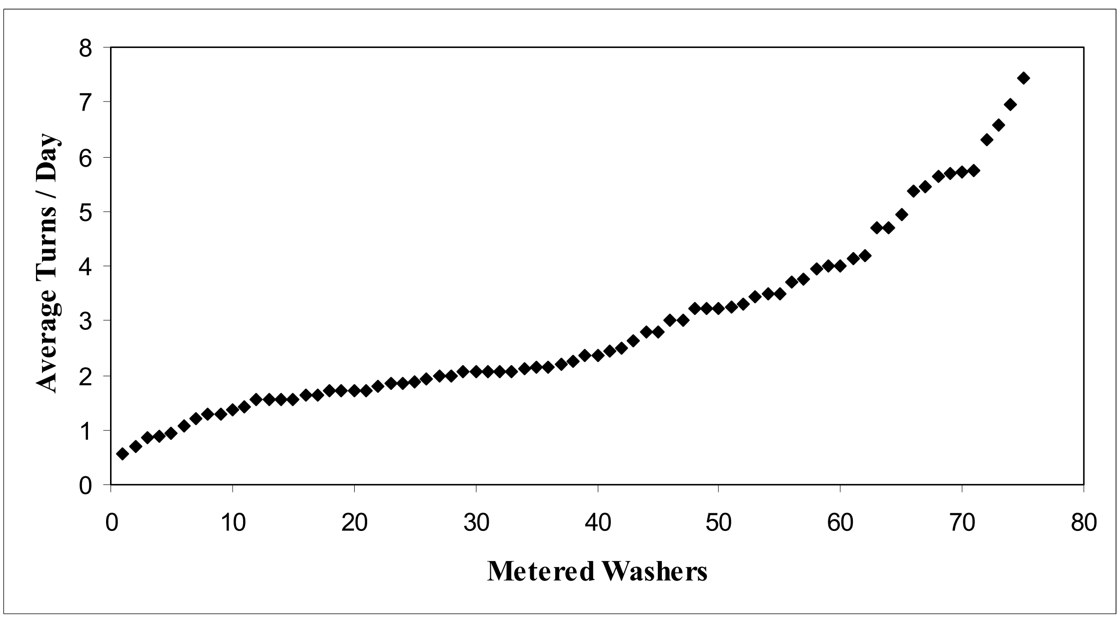
While operating factors for all days are available, the operating factors for Saturday and Sunday, typically the busiest coin operated laundry days, were averaged to obtain a weekend profile while the rest of the days were averaged for a weekday profile in order to clearly see differences in use between weekends and weekdays.

Findings

The metered data showed one washer with an estimated thirteen turns in a single assigned period. However, 83 percent of the time, the washer was used only a single time before a break in usage. Twelve percent of the time, the washers were used twice before a data break.

The number of turns per day was calculated for each of the 77 metered machines and graphed to show the range of values found (shown below in Figure 4).

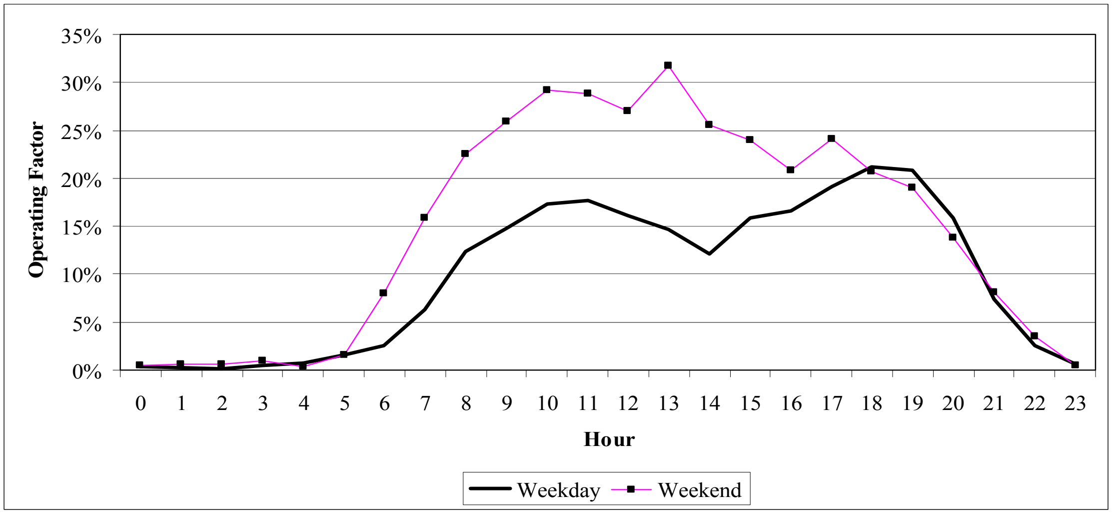
Figure 4. Average Turns per Day for each Metered Machine



Applying the equations based on the sample design, the average turns per day for commercial laundromat machines with a load capacity under 25 pounds was 2.97 ± 0.70 (at the 90% confidence level).

Using the analysis method outlined above, the hourly operating factor across all metered machines was calculated and is shown in Figure 5, separately for weekdays and weekends.

Figure 5. Hourly Operating Factor, Weekday and Weekend Day Types



Conclusions

The metered analysis performed in this evaluation shows that for coin-operated laundromats in the PG&E service territory, the following conclusions can be made:

- The average turns per day across all machines was 2.97 ± 0.70 at the 90% confidence level.
- The peak operating factor for typical weekday operation is 21% and occurs at approximately 6 to 7 PM.
- The peak operating factor for typical weekend operation is 32% and occurs at approximately 1 PM.

The data show that while there are machines that do have high use (Figure 4), for a commercial laundromat, the average use is approximately three turns per day. If these findings are representative of both California and the nation, generally, they have significant implications for commercial clothes washer program planners and policy makers with respect to cost-effectiveness and resource savings assumptions as it is generally assumed that typical laundromat washer use rates are considerably higher. Additionally, the operating factor data would be useful in further characterizing load profiles and coincident peak demand factors for commercial washers, dryers and laundromat water heaters. Such analyses were, however, outside the scope of this study.

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