MEMO

Date: March 8, 2017
To: Energy Trust Board of Directors
From: Erika Kociolek, Evaluation Project Manager
Mike Bailey, Engineering Manager
Kate Scott, Multifamily Program Manager
Subject: Staff Response to Multifamily Showerhead Study

Energy Trust's Planning and Evaluation group worked with the Existing Multifamily Program Management Contractor (PMC) to implement a field test. This mechanism is an outcome of Energy Trust's redesigned measure development process, and enables PMCs to coordinate with Energy Trust to collect data in a streamlined fashion to feed into measure assumptions. This was the first field test, and it yielded valuable information about two key measures for the Existing Multifamily program: direct-install showerheads and shower wands.

The study collected information about the actual flow rate (in gallons per minute, or GPM) for existing showerheads and shower wands as well as (efficient) replacement showerheads and shower wands. The study results indicated that the actual flow rate for baseline fixtures was much lower than what was assumed, while the actual flow rate for replacement fixtures was only slightly lower than that was assumed. This means that water savings (and therefore, energy savings) are lower than what has been assumed to date, and has reduced measure savings by a significant amount: by 40-50% for showerheads, and by around 70% for shower wands. Measures are still cost-effective.

The study also explored the potential for a new measure: replacing leaky tub spouts. Although a study conducted in New York State suggested sizable energy savings, this study found a relatively lower incidence of leaky tub spouts and lower rate of water leakage, meaning that the measure is not cost-effective for Energy Trust.

As a result of this study, Planning staff have updated multifamily showerhead and shower wand measure assumptions for 2017, which resulted in lower savings numbers for these direct-install measures. This savings reduction significantly impacted overall savings targets for the direct-install track of the multifamily program, as well as the total program savings targets for 2017. Savings targets from the direct-install track in 2017 are 24% lower on the electric side than they would have been prior to this change, and are 41% lower on the gas side. As the direct-install track is a significant portion of overall program savings, total 2017 savings targets are 12% and 27% less on the electric and gas side, respectively, than they would have been prior to this change. Planning staff will be investigating using these findings to adjust claimed savings in 2015 and 2016 as part of the True Up process.

CLEAResult®

Multifamily Showerhead Study Report

To: Kate Scott, Program Manager, Energy Trust of Oregon

Joe Marcotte, Program Manager, Lockheed Martin

From: Lucinda Gilman, Sr. Project Manager, CLEAResult

Stephen King, Sr. Consultant, CLEAResult

Brien Sipe, Sr. Consultant, CLEAResult

Date: March 8, 2017

Introduction

Energy Trust's Multifamily program covers all dwellings with multiple households, from duplexes to high-rise apartment buildings. It offers incentives for a wide range of measures, from lighting to windows to HVAC. Direct install (DI) measures are a significant part of the program. DI measures include in-unit lights, aerators, showerheads and advanced power strips. Property managers are offered DI measures as a free service. The measures are generally installed on a complex-wide basis, although individual residents can opt-out of the install. The DI program reaches a wide socioeconomic range of residents, working with low-income, market rate and assisted living facilities. The program serves approximately 500 complexes a year with typical total annual savings of 10,000,000 kWh and 100,000 therms. The Multifamily program is implemented by Lockheed Martin on behalf of Energy Trust. Lockheed Martin subcontracts the DI portion of the program to CLEAResult. CLEAResult designed and carried out this study with advice and oversight from Lockheed Martin and Energy Trust.

This study was performed to assess the flow rates of baseline and replacement showerheads in multifamily dwelling units. One hundred fifty bathrooms were assessed: 96 with showerheads and 54 with shower wands. Tub spout leakage rates were measured when tub spouts were present.

Background

The primary goal of this study was to assess whether the average flow rate for showerheads estimated by the 2011 Residential Building Stock Assessment (RBSA) is a more accurate baseline than the baseline used in Energy Trust's measure approval document (MAD), or if another baseline entirely is appropriate. Another goal was to compare the actual flow rate of replacement showerheads and shower wands to their rated flow rate. The third goal was to evaluate whether it makes sense to establish a minimum gallons per minute (GPM) rating that would qualify existing showerheads for replacement by the program. The fourth goal was to assess whether or not there is significant energy and water savings potential from replacing leaky tub spouts. More detail about each of these four goals is provided below.

No field testing has been performed on showerheads in Energy Trust service territory since the 2011 RBSA. The current baseline flow rate for showerheads in the Energy Trust MAD for multifamily dwellings is 2.82 GPM compared to the RBSA multifamily-specific estimate of 2.11 GPM. The current baseline flow rate in the Energy Trust MAD for shower wands is 2.75 GPM. To date, shower wand flow rates have not been measured in the field for Energy Trust programs. As noted above, this study gathered information about the average flow rate for existing showerheads and shower wands in multifamily dwellings.

This study also examined the actual flow rate of a pressure-compensating WaterSense certified showerhead and shower wand compared to their 1.5 GPM rating. Currently, there is a derating factor in place in the MAD based on the idea that pressure-compensating showerheads may not flow at the full rated flow rate. At the outset of the study it was not clear whether this was justified or not. Pressure-compensating fixtures theoretically flow at their rated rate at any water pressure above 40 pounds per square inch (psi). Non-pressure-compensating fixture flow rates may vary based on incoming water pressure.

Currently, any existing fixture with a GPM rating of 1.6 or higher qualifies for replacement by the program. There was some question about whether this should be raised to 2.5 GPM to maximize energy savings, which was explored through this study.

Finally, this study also evaluated tub spouts as a potential resource. A study performed by Taitem Engineering in New York found that replacement of leaking tub spouts may be a viable energy efficiency and water conservation resource[1]. In a sample of both single family and multifamily dwellings, the study found that 34% of tub spouts leaked at least 0.1 GPM; those that leaked did so at an average of 0.8 GPM. Tub spouts that leak tend to leak through the diverter valve that directs water to the showerhead. Many tub spouts are screwed on or attached with a simple set screw and would be easy for DI field staff to replace. It would require an exception to plumbing code to allow DI field crewmembers to perform the replacement, similar to the exception that was implemented for showerheads, but if tub spouts were a significant resource it might be worth the effort.

The replacement showerhead studied was the Niagara N2915CH Earth 1.5 GPM pressure-compensating showerhead. The replacement shower wand studied was the Niagara N2945CH Earth 1.5 GPM pressure-compensating shower wand.

Key Findings

The most notable findings from this study are that the field-tested baseline is lower than the current assumed baseline, with shower wands in particular having a much lower than expected baseline flow rate, resulting in greatly reduced water savings for this measure. Table 1 shows the difference between current and field tested flow rates for both showerheads and shower wands.

[1] Taitem Engineering (2011). *Leaking Shower Diverters*. http://www.taitem.com/wp-content/uploads/Diverter-Valve-Tech-Tip-2011.7.20.pdf. Study performed for New York State Homes & Community Renewal.

Table 1. Current Estimated and Field Tested Flow Rates by Fixture Type

	1.5 GPM showerhead		1.5 GPM shower wand	
	Current MAD	Study (n=96)	Current MAD	Study (n=54)
Baseline GPM flow rate	2.82	2.22 †	2.75	1.59 †
Replacement GPM flow rate	1.35	1.32 ‡	1.5	1.21 †
GPM change	-1.47	-0.9 †	-1.25	-0.39 †

Note: The difference between the average flow rates used in the current MAD and the flow rates observed through this study are all statistically significant: † significant at the 0.0001 level. ‡ significant at the 0.05 level.

- **Field measurements of baseline flow rates are significantly lower than those used in current savings estimates.**
- **Multifamily direct install measures are still cost-effective.** Despite the lower baseline flow rates found in the field study, both showerheads and shower wands are still cost-effective direct install measures for both gas and electric water heating systems in multifamily units using Energy Trust-specific utility avoided costs.
- **Baseline flow rates varied significantly depending on the type of fixture previously installed.** Baseline conditions were 2.2 GPM for showerheads and 1.6 GPM for shower wands.
  - Statistically significant differences in post-replacement flow rates were observed between the fixture types despite both being rated at 1.5 GPM and being pressure-compensating.
- **Establishing a floor for fixture rating would not significantly impact savings** but it would impact the reach of the program. At a minimum rated flow of 1.6 GPM, the average measured GPM was 1.99; at a minimum rated flow of 2.5 GPM, the average measured GPM was 2.03. A larger study might find finer-grained differences at lower flow ratings but the data in this study does not support it.
- **Pressure compensating fixtures can flow well below their rated level without dropping below WaterSense specifications.** Minimum flow rates for WaterSense qualified devices are 60% of rated flow at low water pressures (20 psi). Measured flows as a percent of rated flow found in this study were:
  - 1.5 GPM showerhead – 88%
  - 1.5 GPM shower wand – 80%
- **Elevation of showerhead had no statistically significant effect on average flow rates of baseline or replacement fixtures in low rise multifamily.** Multifamily dwellings included in this study were located no higher than the third floor.
- **An analysis of variance indicated an absence of bias due to which field technician took the measurements.**
- **Replacing leaky tub spouts is not a cost-effective resource based on the data found in this sample.** In the 18% of dwellings where leakage from tub spouts was measureable (≥ 0.1 GPM) the average leakage rate was 0.345 GPM, which is not a cost-effective level of energy and water savings if replaced with a new spout based on Energy Trust-specific avoided costs and retail water rates.

Field Protocol

The showerhead sample was designed to be a random sample of an average of 10% of units visited by a measurement team. The sample was selected by the study manager who developed a random list of multifamily units in Excel in advance of the site visit and emailed it to the team. The team tested the units on the list. If a selected unit opted out of DI measures the team would test the following unit. In practice, this worked out fairly well. There were some occasions where the team came under time pressure to complete DI measures in a complex and a small number of units were selected but not measured; however, this was infrequent. Because relatively few shower wands are found in the general population, all shower wands found were sampled with the exception of assisted living facilities which generally are mostly or entirely comprised of shower wands. In those cases, a sampling plan was developed as described above for showerheads. A goal of 100 showerheads and 50 shower wands was set.

Prior to starting the study, the study design team evaluated several methods of measuring water flow and temperature. For water flow, the flow measurement bag, the bucket method, and the EnergyRM microweir were all evaluated. The bag and bucket methods both require the field technician to accurately measure the time it takes to fill the bag or bucket to a specified level. These two methods were rejected because analysis showed that measurement errors as small as a half-second led to significant variation in flow measurement. The microweir, on the other hand, measures flow dynamically and does not have any easy sources of measurement error. The stream of water that one wishes to measure is directed into the weir and flows out through a graduated series of holes in the side of the weir; the water level in the weir indicates the overall GPM flow rate.

For temperature measurement, the study design team evaluated the specifications of multiple thermometers. Claimed thermometer accuracy ranged between ± 2 ºF to ±0.5 ºF. Although the concept of a thermometer with accuracy of ±0.5 ºF was very appealing, these thermometers were not calibrated, so there was no way to guarantee that their measurements were truly accurate. Ultimately a calibrated scientific thermometer with a rated accuracy of ±1 ºF was selected.

The measurement tools were:

- A Thomas Traceable Thermometer, -58 to 572 ºF measurement capacity with an accuracy of ±1 ºF, calibrated at the factory
- A microweir from EnergyRM, capable of measuring water flows from 1.25-7 GPM in 0.25 GPM increments
- A nanoweir from EnergyRM, capable of measuring water flows from 0.1-1.25 GPM in 0.1 GPM increments

Measurements were recorded on paper and then transferred to Excel-based forms.

Field team training consisted of a two-hour in-person session that covered the background of the study, the measurement devices and the protocol, and included a live rehearsal of the protocol. The training PowerPoint was designed to double as a field reference manual.

In the field, the testing protocol was:

1. Ensure the current unit is selected to be measured
2. If the selected unit has a shower wand, sample that unit for the shower wand sample and sample the next unit for the showerhead sample

3. If the selected unit cannot be sampled for some other reason, sample the next unit for the showerhead sample
4. Record building and unit information
5. Record baseline showerhead or shower wand rated GPM
6. Turn water on to full, adjust temperature to 105º-110 ºF (measure at tub spout)
7. Turn on shower
8. Set the microweir so it is capturing the full flow from the showerhead or shower wand, allow to stabilize
9. Record flow
10. Set the nanoweir so it is capturing the full flow from the tub spout, allow to stabilize
11. Record flow
12. Turn off water
13. Change out showerhead or shower wand
14. Turn water on to full, adjust temperature to 105-110 ºF (measure at tub spout)
15. Turn on shower
16. Set the microweir so it is capturing the full flow from the showerhead or shower wand, allow to stabilize
17. Record flow
18. Set the nanoweir so it is capturing the full flow from the tub spout, allow to stabilize
19. Record flow
20. Turn off water

Field Deployment

Fieldwork began on April 11, 2016 and concluded on July 22, 2016. A total of 150 units were measured at 29 different apartment complexes. Ninety-six were showerheads and 54 were shower wands. Of the 150 units, 104 were located in the Portland metro area. Originally, one of the three DI teams was selected to do testing; partway through the field deployment the other two teams were added to the study.

Feedback from the teams indicated that the protocol was straightforward to implement. The most difficult part was setting the temperature of the water. This is a somewhat time-consuming procedure that involves adjusting the temperature control knob to set the temperature, allowing the thermometer time to stabilize its reading, and then repeating to refine the temperature as necessary. The biggest challenge in the field was finding the time to assess the appropriate number of units at a given property. However, the field teams succeeded in this challenge most of the time.

Analytic Methods

Fixture flow rate measurements are presented with a set of basic descriptive statistics and graphics. Average flow rate differences between fixture types were analyzed with *t*-tests. This statistical test determines if there is a reliable difference between the average flow rate of showerheads and the average flow rate of shower wands.

Factors affecting flow rate change (existing fixture vs. replacement fixture flow rate) were investigated using linear regression. The factors investigated for their possible impact on flow rate change include: fixture type, tub spout leakage, location (Portland metro area or not), elevation from ground level (i.e., floor number of the residential unit) and the flow rate of the existing fixture.

The study uses a series of matched pair *t*-tests to examine the magnitudes of the changes in fixture flow rates. These statistical tests determine if there is a reliable overall difference between the flow rate of the existing fixture and the flow rate of the replacement fixture. The matched pair *t*-test accounts for the fact that each pair of observations (the flow rate measurements for the existing and replacement fixtures) is made on the same residential bathroom. Matched pair *t*-tests were conducted for:

- Showerheads (only)
- Shower wands (only)
- Both fixture types (combined)

The possibility of variation in measurement from technician to technician was evaluated using a one-way ANOVA (analysis of variance). This test checks for differences among multiple means defined by a grouping variable. In this case, the grouping variable is the field technician and the means examined are the changes in measured flow rates. A statistically significant finding would suggest the presence of a systematic bias with respect to the technician who made the measurements. Conversely, a non-significant finding supports a conclusion of the absence of technician bias.

The magnitudes of measured tub spout leakage are presented with a set of basic descriptive statistics and graphics. The data gathered on tub spout leakage is potentially informative with regard to whether or not this source of water consumption is a useful conservation target.

For all hypothesis tests in the study, the customarily used alpha level (Type I error rate) of 0.05 was chosen to indicate statistical significance.

Results

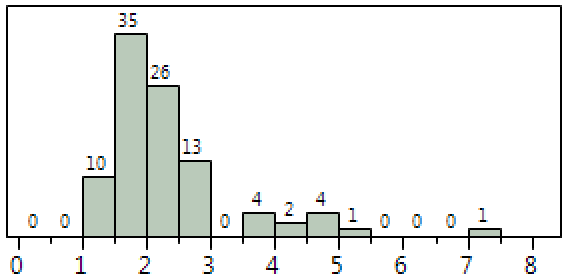
The analysis begins with a presentation of descriptive statistics and graphics to illustrate the flow rates of the existing shower fixtures and the flow rates of the replacement fixtures. Factors influencing flow rate changes are presented which are followed by an analysis of the size of the changes. The results of a check for the presence of measurement bias are shown. This is followed by a summary of tub spout leakage that was measured during the course of data gathering.

DESCRIPTIVE STATISTICS

The existing showerhead fixtures had an average measured flow rate of 2.22 GPM. The existing shower wand fixtures had an average measured flow rate of 1.59 GPM. Combining both types of fixtures, the average measured flow rate was 1.99 GPM. Some fixtures flowed much more than the average. These results are illustrated in the collection of histograms in Chart 1 and the accompanying summary statistics. SD means standard deviation.

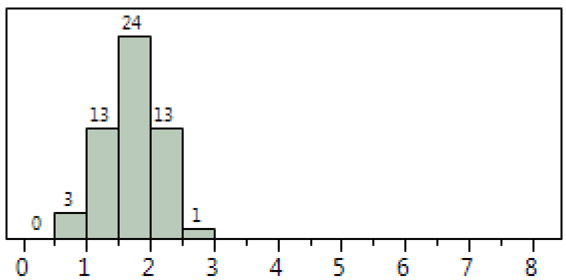
Chart 1. Histograms and Statistics for Measured Flow Rate of Existing Fixtures (all figures in GPM)

Showerheads (only)



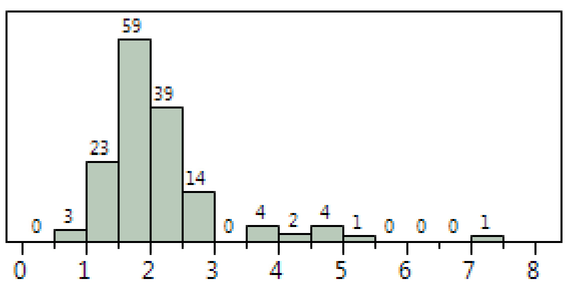
Mean = 2.22
Median = 2.0
SD = 0.98
Lowest = 1.0
Highest = 7.0
N = 96 sites

Shower wands (only)



Mean = 1.59
Median = 1.5
SD = 0.40
Lowest = 0.75
Highest = 2.5
N = 54 sites

Both fixtures (combined)



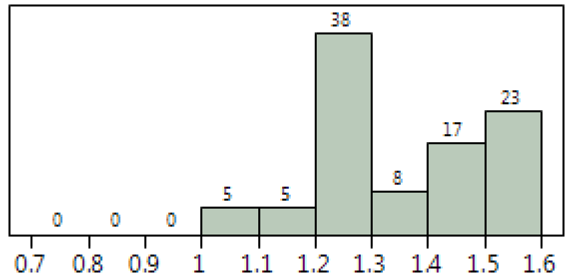
Mean = 1.99
Median = 1.75
SD = 0.87
Lowest = 0.75
Highest = 7.0
N = 150 sites

The replacement showerhead fixtures had an average measured flow rate of 1.32 GPM. The replacement shower wand fixtures had an average measured flow rate of 1.21 GPM. Combining both types of fixtures, the average measured flow rate was 1.28 GPM. Few fixtures had flow rates less than 1.0 GPM. These results are illustrated in the collection of histograms in Chart 2 and the accompanying summary statistics.

Table 2 recaps the flow rates of existing and replacement fixtures for both showerheads and shower wands. A *t*-test of means is included to test the average measured flow rate difference between fixture types. Existing showerheads had a higher flow rate than existing shower wands: an average of 0.63 GPM higher and this difference was statistically significant. Replacement showerheads had a higher flow rate than replacement shower wands: an average of 0.11 GPM higher and this difference was statistically significant.

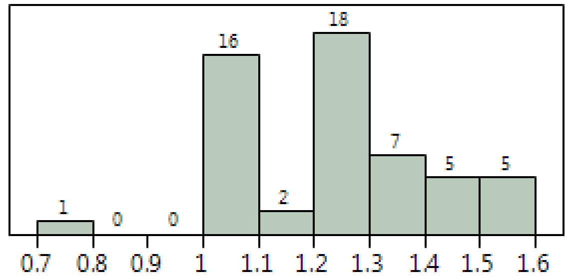
Chart 2. Histograms and Statistics for Measured Flow Rate of Replacement Fixtures (all figures in GPM)

Showerheads (only)



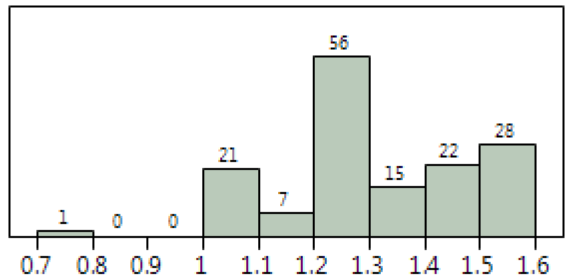
Mean = 1.32
Median = 1.28
SD = 0.14
Lowest = 1.00
Highest = 1.50
N = 96 sites

Shower wands (only)



Mean = 1.21
Median = 1.25
SD = 0.18
Lowest = 0.75
Highest = 1.50
N = 54 sites

Both fixtures (combined)



Mean = 1.28
Median = 1.25
SD = 0.16
Lowest = 0.75
Highest = 1.50
N = 150 sites

Note: **All replacement fixtures rated at 1.5 GPM.**

Table 2. Test of Measured Flow Rate Differences between Fixture Types (Showerheads vs. Shower Wands)

	Showerheads average (GPM)	Shower wands average (GPM)	Difference[1] (GPM)	*t*-ratio	*p*-value	n
Existing fixtures	2.22	1.59	+0.63	4.46	<0.0001	150
Replacement fixtures	1.32	1.21	+0.11	4.38	<0.0001	150

[1]A positive difference indicates the showerhead had a higher flow rate than the shower wand.

FACTORS INFLUENCING FLOW RATE CHANGE

The next analysis explores differences between the flow rates of existing and replacement fixtures attributable to fixture type (showerhead vs. shower wand), elevation from ground level (i.e., floor number), tub spout leakage, location (Portland metro area or not), and the flow rate prior to fixture replacement. Factors influencing flow rate changes were explored via a series of multiple regression models. The response variable in each regression (the dependent variable) is the difference in flow rate between existing and replacement fixtures.

The results of the first regression model are summarized in Table 3. Of the five predictors in the model, only one predictor is statistically significant: existing fixture flow rate. The other predictors' *p*-values are all well above 0.05, indicating that they are not statistically significant at a sample size of 110 units. Predictors that are not statistically significant are evaluated for possible exclusion in subsequent model runs. There are 110 cases in this regression model instead of the full 150 in the study because not all units had tub spouts present. Reducing the sample size reduces statistical power (the ability to detect flow rate change effects).

Table 3. Parameter Estimates of 5-Predictor Regression (n=110)

Term	Estimate	Standard error	*t*-ratio	*p*-value	VIF
Intercept	1.3012	0.0672	19.36	<0.0001	
Existing fixture flow rate (GPM)	-0.9669	0.0161	-60.23	<0.0001	1.05
Unit floor	-0.0066	0.0220	-0.30	0.7664	1.00
Fixture type (shower wand = 1)	-0.0326	0.0423	-0.77	0.4429	1.73
Tub spout leakage (GPM)	-0.0175	0.0691	-0.25	0.8001	1.03
Portland metro area (1 if true)	-0.0365	0.0446	-0.82	0.4150	1.72

The coefficients of the model are reported in the column labeled Estimate. The standard error quantifies the precision of each estimate. The *t*-ratio is the regression coefficient estimate divided by its standard error. *T*-ratios above an absolute value of 2 are evidence supporting predictors' statistical significance. Each *p*-value is the likelihood of observing, under the null hypothesis, a *t*-ratio as large as or larger than the value shown. VIF is variance inflation factor, which is a measure of multicollinearity or covariance among the predictors. VIF statistics below 5 are generally regarded as acceptable.

The results of the next regression model are summarized in Table 4. This model drops the variable tub spout leakage as a predictor (the variable with the highest *p*-value in the prior model). This has the effect of increasing the number of data points available. Two of the predictors in this model remain statistically non-significant: unit floor and Portland metro area. The *p*-values of these two predictors are well above 0.05, indicating that they are not statistically significant predictors of flow rate change. The predictor unit floor in the sample ranged from 1 to 3. These two predictors are dropped in the next model (Table 5).

Table 4. Parameter Estimates of 4-Predictor Regression (n=150)

Term	Estimate	Standard error	*t*-ratio	*p*-value	VIF
Intercept	1.2637	0.0627	20.14	<0.0001	
Existing fixture flow rate (GPM)	-0.9543	0.0150	-63.68	<0.0001	1.14
Unit floor	-0.0088	0.0192	-0.46	0.6472	1.01
Fixture type	-0.1080	0.0372	-2.90	0.0043	2.13
Portland metro area	-0.0322	0.0377	-0.86	0.3937	2.02

The results of the final regression run are summarized in Table 5. This model drops the variables unit floor and Portland metro area as predictors because they were not statistically significant in the prior 4-predictor model. The remaining predictors in this two-predictor model are both statistically significant with *p*-values well below 0.05. One observation was excluded in the final 2-predictor model as a regression outlier to reduce bias in the model. The excluded observation was an unusual combination of fixture flow difference and the existing fixture's flow rate. A scatter plot of fixture flow differences versus measured flow of existing fixtures showed points falling closely along a straight line except for the one unusual observation. Table 6 summarizes the model's fit and Table 7 presents the model's ANOVA details.

Table 5. Parameter Estimates of 2-Predictor Regression (n=149)

Term	Estimate	Standard error	*t*-ratio	*p*-value	VIF
Intercept	1.2243	0.0355	34.45	<.0001	
Existing fixture flow rate (GPM)	-0.9570	0.0146	-65.75	<.0001	1.13
Fixture type	-0.0795	0.0264	-3.01	0.0031	1.13

Table 6. Fit Summary of 2-Predictor Model

Statistic	Value
R-square	0.970
R-square adj.	0.970
Root mean square error	0.145
Mean of response (GPM)	-0.718
Sample size (n)	149

Table 7. ANOVA Summary of 2-Predictor Model

Source	Degrees of freedom	Sum of squares	Mean square	*F* ratio	*p*-value
Model	2	100.1995	50.0998	2,368.966	<0.0001
Error	146	3.0877	0.0211		
Total	148	103.2872			

Using the values in Table 5, the resulting prediction equation for shower fixture flow rate change is:

Flow rate change (GPM) = 1.2243 – (0.9570)(Existing fixture flow rate) – (0.0795)(fixture type)

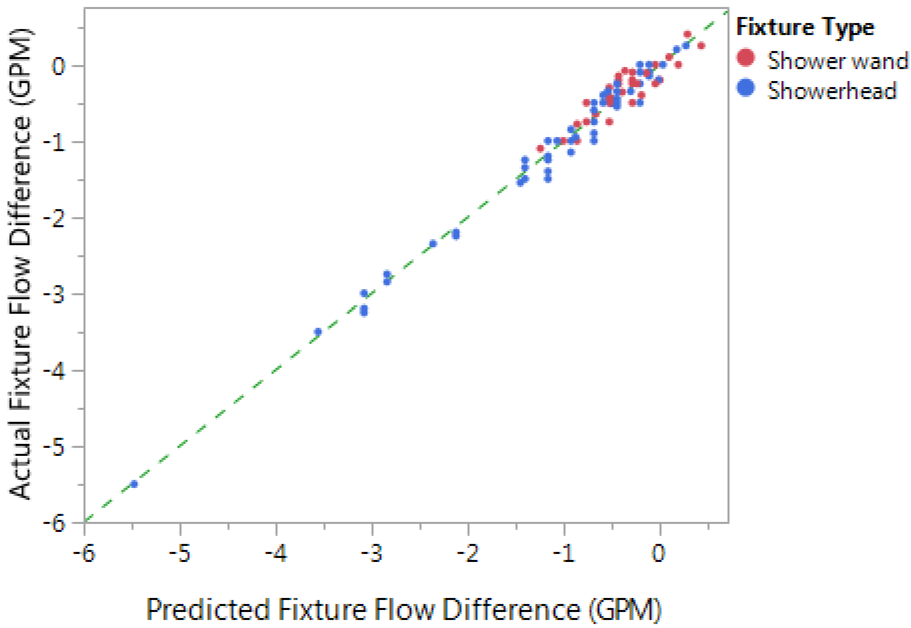
where: fixture type = 0 for showerhead
fixture type = 1 for shower wand

The essential findings from the final model are as follows:

- Flow rate change is primarily predicted by the flow rate of the existing fixture.
- The model is statistically significant; the *p*-value of the *F* test is < 0.0001. This *p*-value indicates that the model offers better predictions of flow rate change than using the average flow rate change for every prediction.
- The model provides excellent fit, explaining 97% of the variance in flow rate changes. This is seen in the R-square statistics in Table 6.
- The model does not suffer from multicollinearity (shared variance among predictors) as shown by the VIF (variance inflation factors) in Table 5 which are all close to 1.0.

The accuracy of the model's predictions is graphically illustrated in Chart 3. The more closely the points fall on the 45-degree line of fit, the better the prediction. The model exhibits good linearity all along the line. In brief, change in fixture flow rate can be readily predicted by knowing the flow rate of the existing fixture and the fixture type. Although the replacement fixtures are all rated at the same GPM irrespective of type, flow rate change prediction is reduced by 0.0795 GPM for shower wands. While this is a small reduction, it is statistically significant.

Chart 3. Regression Model Fit – 2-Predictor Model



FLOW RATE CHANGE MAGNITUDE (EFFECT SIZE)

Table 8 summarizes the magnitude of the flow rate changes (the differences between the flow rates of existing and replacement fixtures). All flow rates are in GPM. A negative sign for flow rate change indicates a reduction in flow rate (i.e., water savings). Showerhead fixtures had the largest average flow rate change (a 0.90 GPM reduction). Shower wands showed a mean reduction of 0.39 GPM. The median changes for showerheads and shower wands (0.58 and 0.33 GPM respectively) are smaller than the average changes due to the susceptibility of the average to be influenced by a few high or low values. The average overall flow rate reduction for both fixture types combined was 0.72 GPM; the median overall reduction was 0.50 GPM.

Table 8. Flow Rate Change Statistics

	Showerhead	Shower wand	Combined
Mean change (GPM)	-0.90	-0.39	-0.72
Median change (GPM)	-0.58	-0.33	-0.50
Standard deviation (GPM)	0.96	0.35	0.83
Lowest change (GPM)	+0.25	+0.40	+0.40
Highest change (GPM)	-5.50	-1.10	-5.50
No change (# of units)	8	4	12
Total units	96	54	150

A series of matched pair *t*-tests were performed to confirm that these changes were statistically significant. Table 9 summarizes these results. All of the flow rate changes were highly statistically significant ($p < 0.0001$). A *p*-value of < 0.0001 is as low as is commonly reported in research. A low *p*-value suggests the presence of an effect (in this case an actual change in average flow rate).

Chart 4 shows flow rate changes as a scatterplot. The replacement fixture's rated flow of 1.5 GPM is identified on the chart as the green dotted line. Data points below the 1.5 GPM line indicate measured flow rates below the fixture manufacturer's specification.

Chart 4. Scatterplot of Flow Rate Changes

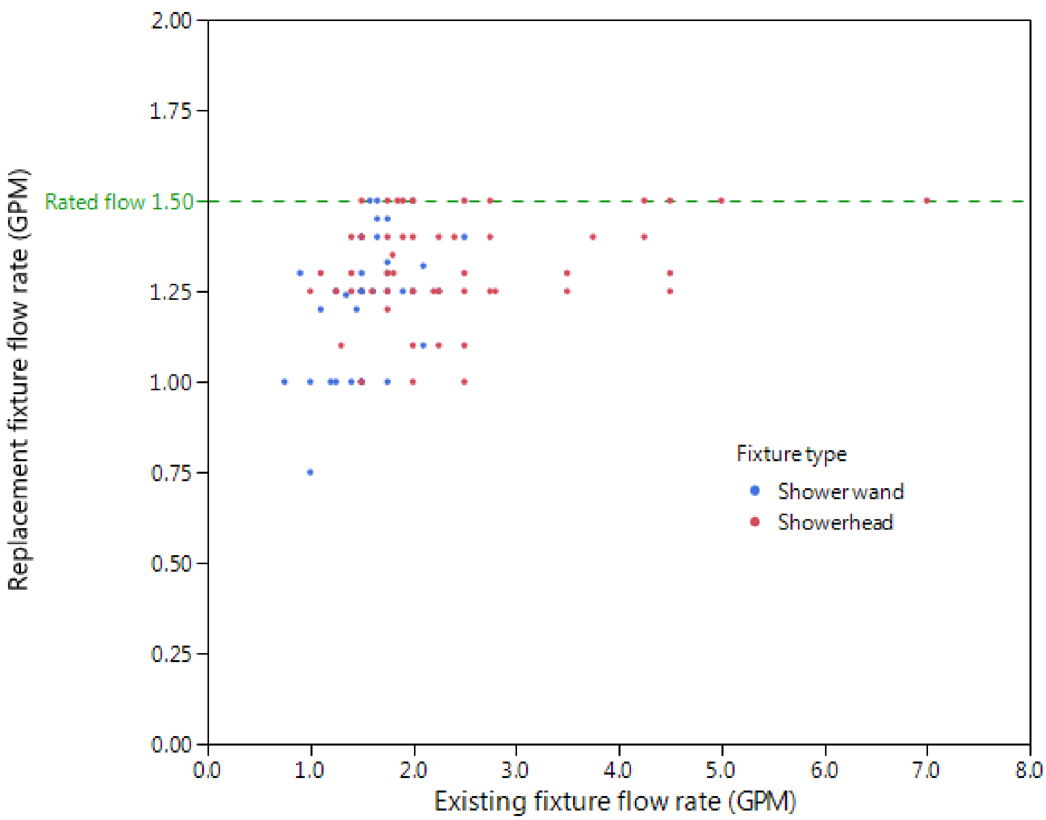


Table 9. Matched Pair *t*-test Results of Flow Rate Changes

Analysis	Mean change[1] (GPM)	*t*-ratio	*p*-value	n
Showerheads (only)	-0.899	9.15	< 0.0001	96
Shower wands (only)	-0.389	8.06	< 0.0001	54
Both fixtures (combined)	-0.715	10.51	< 0.0001	150

[1]A negative change indicates a reduction in flow.

CHECK FOR MEASUREMENT BIAS

Measurement bias from technician to technician was evaluated using a one-way ANOVA (analysis of variance). The results indicate that measured flow rates changes do not appear to be biased as a result of the technician making the measurements (Table 10). The *p*-value shown in the table is above 0.05, leading to the conclusion that the differences across technicians are not statistically significant. A high *p*-value suggests the absence of an effect – in this case, the absence of bias due to the technician making the flow rate measurements.

Table 10. Test for Technician Bias (n=150)

Source	Degrees of freedom	Sum of squares	Mean square	*F* ratio	*p*-value
Technician	4	4.7503	1.1876	1.7437	0.1435
Error	145	98.7547	0.6811		
Total	149	103.5049			

The field technicians also measured the temperature at which the flow rate measurements were made. Temperature data were recorded because it is theoretically possible for temperature to affect flow rates based on uneven corrosion/buildup within the hot or cold water intake. Field testing aimed for a temperature of 105-110 °F, similar to the range of temperatures used in Regional Technical Forum showerhead savings assumptions (108 - 112 °F).

The data showed that the measured temperatures for the existing and replacement fixtures were highly similar. The temperature differences were all within ± 4.7 °F, and the average temperature difference across all cases was 0.0228 °F, which is essentially zero for all practical purposes.

BASELINE FLOW RATE AND RATED GPM

The measured baseline flow rates at a variety of GPM ratings were evaluated for showerheads and shower wands to explore the potential reductions in flow rates based on the existing fixture's rated value. Analysis of existing rated vs. actual flow can be used to estimate the savings potential from requiring a rated flow rate threshold for existing fixtures (e.g., existing rated flow rate must be ≥ 2.5 GPM).

The first step compared the rated flow and measured flow. Table 11 shows the range of GPM ratings found in the field and the average, maximum, and minimum measured flow. Table 12 shows the same data for showerheads only and Table 13 shows the same data for shower wands only.

Table 11. Rated GPM vs. Measured Flow, All Fixtures (N=138)

Fixture's rated GPM	Measured flow (GPM)			N (# fixtures)
	Average	Maximum	Minimum	
1.6	1.60	1.60	1.60	1
1.75	1.50	1.75	1.25	9
2	2.00	7.00	1.35	14
2.2	1.50	1.50	1.50	1
2.5	2.00	5.00	0.75	111
3	2.80	2.80	2.80	1
5	4.50	4.50	4.50	1

Note: Of the 150 fixtures in the sample, 138 had an observable rated GPM.

Table 12. Rated GPM vs. Measured Flow, Showerheads Only (N=87)

Fixture's rated GPM	Measured flow (GPM)			N (# fixtures)
	Average	Maximum	Minimum	
1.6	1.60	1.60	1.60	1
1.75	1.52	1.75	1.25	9
2	2.35	7.00	1.50	8
2.5	2.24	5.00	1.00	67
3	2.80	2.80	2.80	1
5	4.50	4.50	4.50	1

Table 13. Rated GPM vs. Measured Flow, Shower Wands Only (N=51)

Fixture's rated GPM	Measured flow (GPM)			N (# fixtures)
	Average	Maximum	Minimum	
2	1.60	2.10	1.35	6
2.2	1.50	1.50	1.50	1
2.5	1.62	2.50	0.75	44

The second step in this phase of the analysis was to assess how various rated flow rates influenced the average and median measured flow rates of the fixtures. The most common rated flow rate observed in the study sample was 2.5 GPM (Table 14). It is problematic to isolate a flow rating for existing fixtures that would be associated with a specific targeted measured flow because the majority of fixtures share this common flow rating.

Table 14. Rated Flow Rates

Rated flow (GPM)	Proportion of sample	N (# fixtures)
1.6	0.72%	1
1.75	6.52%	9
2.0	10.14%	14
2.2	0.72%	1
2.5	80.43%	111
3.0	0.72%	1
5.0	0.72%	1

Table 15 shows all possible existing fixture rated GPM thresholds and the accompanying average and median tested flow rates at those thresholds. For example, based on the study's sample, targeting fixtures with a flow rating of 2.5 GPM or higher would yield an average measured flow rate of 2.026 GPM. The next increment up (3.0 GPM) would yield an average measured flow rate of 3.65 GPM.

Table 15. Existing Fixture Flow Rates by GPM Rating

Minimum rated flow (GPM)	Average measured GPM	Median measured GPM	N (# fixtures)[1]
1.6	1.987	1.750	138
1.75	1.989	1.750	137
2.0	2.022	1.805	128
2.2	2.021	1.950	114
2.5	2.026	2.000	113
3.0	3.650	3.650	2
5.0	4.500	4.500	1

[1] Sum of the number of fixtures with the rated GPM or higher.

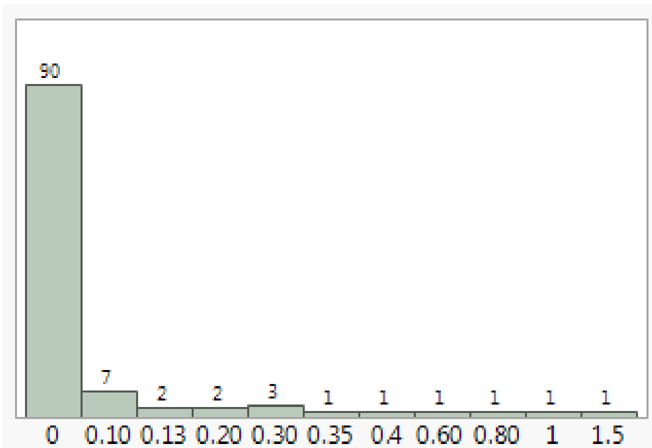
TUB SPOUT LEAKAGE

Tub spout diverter leakage was identified as an overlooked area for potential energy and water savings in a recent study in New York as a part of the Weatherization Assistance Program. The present study measured leakage rates in multifamily units where a shower/tub combination was present.

The data showed that the incidence of measurable tub spout leakage was 18%, or roughly 1 in 6 sites. Of the 20 sites with measurable tub spout leakage, the average leakage rate was 0.345 GPM. There were several sites with relatively high leakage (the highest was 1.5 GPM) which inflates the average.

The median leakage statistic (which is less influenced by a few high values) was 0.2 GPM. Chart 5 shows tub spout leakage graphically.

Chart 5. Tub Spout Leakage Histogram & Statistics before Fixture Change (all figures in GPM)



Tub Spout Leakage (GPM)

Leakage	Instances	Percent
0	90	81.8%
0.100	7	6.4%
0.125	2	1.8%
0.200	2	1.8%
0.300	3	2.7%
0.350	1	0.9%
0.400	1	0.9%
0.600	1	0.9%
0.800	1	0.9%
1.000	1	0.9%
1.500	1	0.9%
Total	110	100.0%

Table 16 shows a comparison of this study's findings to the findings from the New York study. The potential conservation resource identified in the New York study does not appear to translate to this sample of Oregon multifamily units. The New York study included both single and multifamily dwellings, but did not report on the proportion of the sample drawn from each housing type; it is unknown if this had an effect on observed leakage rates.

Table 16. Tub Spout Leakage Rate Comparison Across Studies*

Study	Tub spouts measured	Percent of leaky spouts (leaking ≥ 0.1 GPM)	Average GPM of leaky spout
New York Study (n=120)	120	34%	0.8
Oregon Field Test (n=106)	110	18%	0.345

*Taitem Engineering, Leaking Shower Diverters: http://www.taitem.com/wp-content/uploads/Diverter-Valve-Tech-Tip-2011.7.20.pdf

Limitations

There are several limitations to this study. First, the majority of units in this study sample (69%) were located in the Portland metro area. This potential limitation is mitigated by the finding that unit location (i.e., within the Portland metro area or not) did not have a statistically significant relationship to flow rate changes. A related potential limitation affecting the generalizability of the results to the greater region is that all of the sites were located within Energy Trust territory (all were in Oregon).

Another limitation is that outlet pressure was not measured. Originally, there was a hypothesis that elevation (i.e., the floor a unit was located on) might affect flow due to variations in water pressure. This hypothesis was not supported by the results of this study: regression analysis showed that floor level was not a statistically significant predictor of flow rate. The main concern, however, is not what the water pressure in these buildings is but the *effect* variation in water pressure has, and that effect was captured by the weirs. Nevertheless, it was not possible to directly test and quantify the relationship between water pressure and flow rate because no direct measurement of water pressure was made.

Another potential limitation is that the data regarding replacement showerhead and wand flow rates in this study may only be applicable to the Niagara 1.5 GPM pressure-compensating showerheads and wands used as fixture replacements. However, the data around baseline flow rates is more generally applicable and more significant.

Findings and Implications

Table 17 shows current and estimated savings adjustments and cost-effectiveness metrics using data collected in the field test. Based on the current Energy Trust measure approval document and the results from the field measurements showerhead and shower wand savings would decrease by 38% and 70%, respectively.

Table 17. Current Estimated and Field Tested Flow Rates by Fixture Type

	1.5 GPM showerhead		1.5 GPM shower wand	
	Current MAD	Study (n=96)	Current MAD	Study (n=54)
Baseline GPM flow rate	2.82	2.22	2.75	1.59
Replacement GPM flow rate	1.35	1.32	1.5	1.21
GPM change	-1.47	-0.90	-1.25	-0.39

- **Multifamily direct install measures are still cost-effective.** Despite the lower baseline flow rates found in the field study, both showerheads and shower wands are still cost-effective direct install measures for both gas and electric water heating systems in multifamily units using Energy Trust-specific utility avoided costs.
- **Baseline flow rates varied significantly depending on the type of fixture previously installed.** Baseline conditions were 2.2 GPM for showerheads and 1.6 GPM for shower wands.

    - Statistically significant differences in post-replacement flow rates were observed between the fixture types despite both being rated at 1.5 GPM and being pressure compensating.
- **Establishing a floor for fixture rating would not significantly impact savings** but it would impact the reach of the program. At a minimum rated flow of 1.6 GPM, the average measured GPM was 1.99; at a minimum rated flow of 2.5 GPM, the average measured GPM was 2.02. This is primarily because the bulk of showerheads found in the field in this study were rated at 2.5 GPM. A more extended study might find finer-grained differences at lower flow ratings but the data in this study does not support it.
- **Pressure compensating fixtures can flow well below their rated level without dropping below water sense specifications.** Minimum flow rates for WaterSense qualified devices are 60% of rated flow at low water pressures (20 psi). Measured flows as a percent of rated flow found in this study were:
    - 1.5 GPM showerhead – 88%
    - 1.5 GPM shower wand – 80%
- **Elevation of showerhead had no statistically significant effect on average flow rates of baseline or replacement fixtures in low rise multifamily.** Multifamily dwellings included in this study were located no higher than the third floor.
- **Replacing leaky tub spouts is not a cost-effective resource based on the data found in this sample.** This field study found half the fraction of leaky tub spouts relative to the study of tub spouts in New York (18% in this sample relative to 34% in New York) and less than half the flow rate in those spouts found to be leaking (0.8 GPM in New York relative to 0.345 GPM in this study).