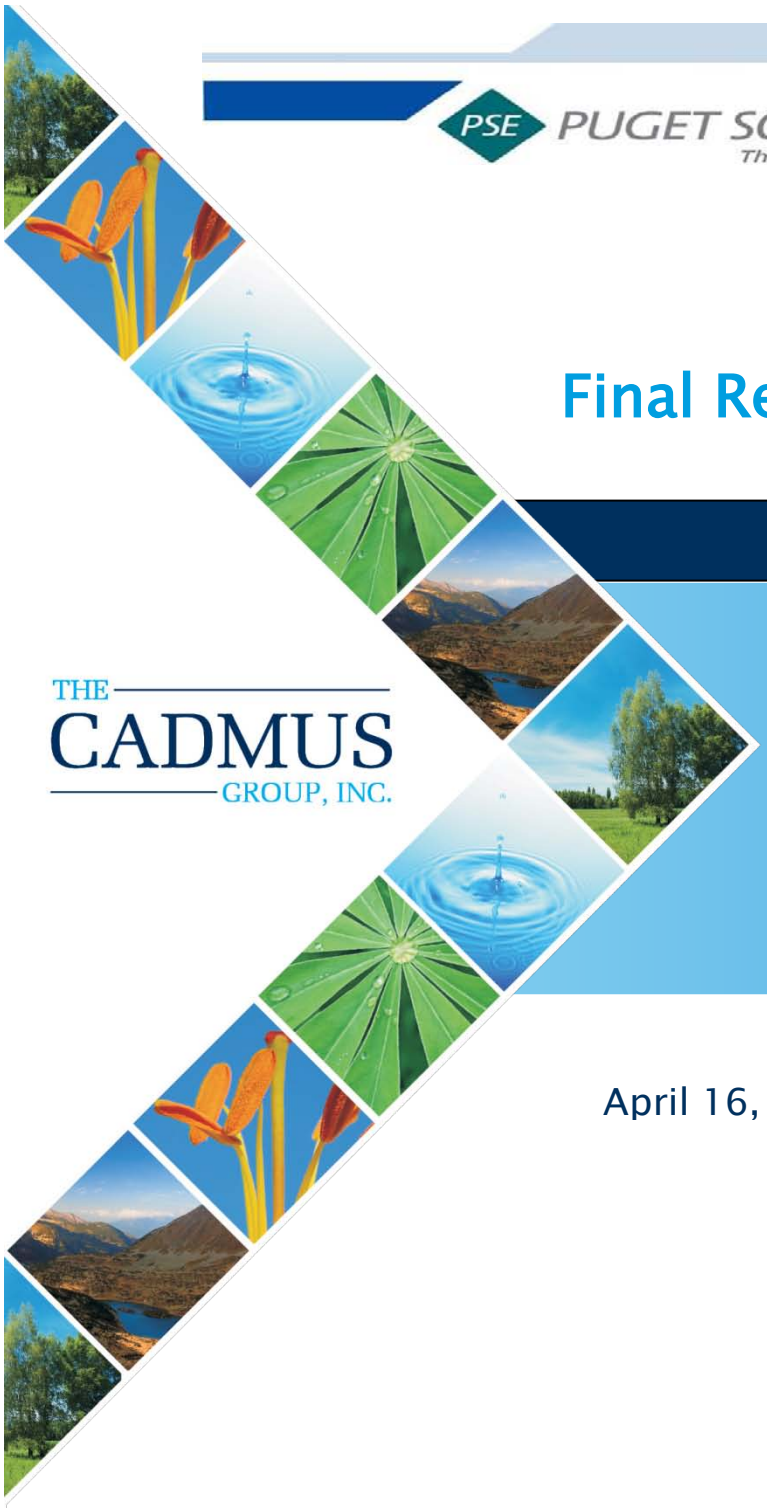
PUGET SOUND ENERGY
The Energy To Do Great Things

Clothes Washer Evaluation

Contents:

- Clothes Washer Evaluation Report
- Evaluation Report Response

This document contains both the final **Clothes Washer Evaluation Report** and the Puget Sound Energy **Evaluation Report Response** (ERR). PSE program managers prepare an ERR upon completion of an evaluation of their program. The ERR addresses and documents pertinent adjustments in program metrics or processes subsequent to the evaluation.



PUGET SOUND ENERGY
The Energy To Do Great Things

Final Report

Regional Technical Forum Savings Review

April 16, 2012

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1. EXECUTIVE SUMMARY

Puget Sound Energy (PSE) asked The Cadmus Group, Inc. (Cadmus) to review energy savings estimates for its clothes washer and single-family home weatherization programs. PSE savings estimates have been based on unit savings and calculations developed by the Regional Technical Forum (RTF).[1] The Cadmus review included the specific tasks shown in Table E-1.

Table E-1. Project Tasks

Clothes Washer Program Savings Review
Task 1: Develop Savings Estimates For Alternative Tier Structure Using RTF Approach
Task 2: Review RTF Approach Assumptions and Update Savings Estimates
Task 3: Develop Alternative Savings Estimate Based on Cadmus 2009 Metering Study
Weatherization Program Savings Review
Task 1: Compile and Review Data
Task 2: Develop Alternative Gas Savings Estimate Based Upon Billing Analysis
Task 3: Develop Alternative Electric Savings Estimate Based Upon Billing Analysis

Clothes Washer Program Savings Review

For clothes washers, Cadmus first calculated the potential savings of an alternative clothes washer rebate structure PSE is considering. The alternative structure would align PSE Tiers 1 and 2 with the Consortium for Energy Efficiency (CEE) Tiers 2 and 3, respectively. To date, this new structure has yet to be implemented by PSE.

Cadmus then examined data sources and methodology used in development of RTF savings estimates for PSE's current two-tier clothes washer program rebate structure. Cadmus updated the model by:

- Using the latest clothes washer data set;
- Limiting the analysis to clothes washers meeting federal standards taking effect in 2011;
- Grouping clothes washer models by modified energy factor (MEF) and water factor (WF), and not just MEF; and
- Using a recent PSE residential survey to determine the portion of customers with electric heaters and dryers.

These adjustments resulted in clothes washer program annual per machine savings lower than their original values in nine out of 10 configurations.[2] The final adjustment to RTF electricity savings range from -69% to +13%, depending on the efficiency tier and configuration.

[1] In 1996, Congress directed the Bonneville Power Administration and the Northwest Power Planning Council to convene a RTF to develop standardized protocols for verifying and evaluating conservation savings.

[2] Configuration refers to two different tiers with 5 different mixes of dryer and water heater type for a total of 10 different configurations.

Cadmus then compared this updated model with an alternative savings estimate, based on a 2009 Cadmus metering study.[3] Cadmus binned data collected in the metering study into the current PSE 2012 tiers, derived per-cycle energy savings estimates for each clothes washer measure; and compared these savings estimates to those from the updated RTF approach, previously described. Metering study-based savings are within +/-10 kWh/year of the updated RTF value for Tier 1. For Tier 2, metering study-based savings range from 17 kWh/year below the updated RTF value to 45 kWh/year above it.

Weatherization Program Savings Review

For homes with gas and electric heat, Cadmus compared two different estimates of energy savings per home resulting from the weatherization program: one using the latest RTF-based weatherization measure unit savings values[4]; and the other using a billing analysis (i.e., a conditional savings analysis [CSA] model). Estimates used weatherization program tracking data and participant gas and electric billing records from 2006 to 2010.

With a large sample of over 8,000 participants, Table E-2 shows overall gas savings per home are slightly higher than the PSE *ex ante* deemed savings, with a realization rate of 110%. The estimate has a relative precision plus or minus 0.85%, with 90% confidence. The 90% confidence interval ranges from 132 therms to 135 therms.

Table E-2. Weatherization Program Gas Savings Summary

Model	N	Average Pre Period Therms	Model Savings (Therms)	PSE Ex Ante Savings (Therms)	Realization Rate	Relative Precision 90% level
Overall CSA	8,184	893	133	121	110%	0.85%

With a large sample of over 1,100 participants, Table E-3 shows overall electric savings per home lower than the RTF *ex ante* deemed savings, with a realization rate of 78%. The estimate has a relative precision plus or minus 3.94%, with 90% confidence. The 90% confidence interval ranges from 1,559 kWh to 1, 687 kWh.

Table E-3. Weatherization Program Electric Savings Summary

Model	N	Average Pre Period kWh	Model Savings (kWh)	RTF Ex Ante Savings (kWh)	Realization Rate	Relative Precision 90% level
Overall CSA	1,193	17,870	1,623	2,079	78%	3.94%

[3] The Cadmus Group, Inc. "Do the Savings Come Out in the Wash? A Large Scale Study of In-Situ Residential Laundry Systems." 2010. http://www.cadmusgroup.com/pdfs/Do_the_Savings_Come_Out_in_the_Wash.pdf

[4] These RTF-based unit saving values were for specific shell measures (attic insulation, floor insulation, wall insulation, duct insulation and duct sealing) applied to homes with different types of heating systems (electric zonal, electric forced air furnace, electric heat pump, electric "average" and gas forced air furnace).

The results of the electric savings analysis, realization rate of 78%, were different than those of the gas savings analysis – realization rate of 110%. These differences may be explained by:

- **Supplemental Heat**. Unable to capture supplemental heat (e.g., wood stoves or propane heaters) use in electric bills, billing analysis can lead to lower realized electric energy savings estimates and lower realization rates.
- **Heating System Type.** For sites from the 2006 to 2008 program years, the database did not indicate heating system type and an "average" electric heating system was assumed. The savings estimates could be inaccurate if the "average" system did not represent actual heating system types at these homes.
- **Zonal Heat Actual Usage**. The electricity use of zonal systems (where entire rooms can remain unheated) may have been overestimated in the RTF-based unit savings estimates and could contribute to the lower realization rate.

In order to more accurately estimate savings in the future, we suggest that PSE collect more specific information about both the **primary** and **supplemental** heating systems in each home. (Please see the *Task 3* section of the report for a detailed list of information to gather.)

2. CLOTHES WASHER PROGRAM SAVINGS REVIEW

In this section, Cadmus describes the analysis methodology and results for the PSE clothes washer program. Rebate levels have been based on efficiency tiers, defined by the following clothes washer efficiency ratings:

- The MEF equals the cubic feet of laundry that can be washed and dried per kilowatt hour of electricity.
- The WF equals the number of gallons of water needed to wash each cubic foot of laundry.

Cadmus first compiled information on the current PSE tier levels and the RTF-based savings analysis, which PSE provided in the file *RTF.Clothes.Washers.Decision8.2010.xls*. Reviewing this information helped Cadmus understand the current approach and savings values.

Task 1: Develop Savings Estimates for an Alternative Tier Structure Using an RTF Approach[5]

PSE evaluated an alternative clothes washer rebate structure for 2012. As shown in Table 1, this alternative tier structure would align 2012 PSE Tiers 1 and 2 with CEE Tiers 2 and 3, respectively. While Table 1 and internal PSE documents show three tiers, PSE currently presents the clothes washer program to customers in two tiers, as Tiers 2 and 3 receive the same $100 rebate level.

If implemented, the new tier structure would produce the following changes to PSE MEF requirements, while leaving WF requirements unchanged:

- Tier 1: the same minimum MEF of 2.2, but a new maximum MEF of 2.39.
- Tier 2: a new minimum MEF of 2.4, and the same maximum MEF of 2.69.
- Tier 3: no change.

PSE asked Cadmus to determine new electricity savings values for the alternative tier structure. To estimate these savings, Cadmus employed the same RTF data and methodology used by PSE to calculate 2011 savings.

[5] Cadmus originally provided this analysis to PSE in a memo, submitted on October 31, 2011.

Table 1. PSE Clothes Washer Rebate Structure

CEE Tier	PSE 2011 Tier	PSE 2012 Tier	Min. MEF	Max. WF	PSE Incentive
1	N/A	N/A	2.00	6.0	NA
2	1	1	2.20	4.5	$50
3	N/A	2 – Alternative	2.40	4.0	$100
Qualify Under Tier 3	2	2 – Original	2.46	4.0	$100
Qualify Under Tier 3	3	3	2.70	4.0	$100

Methodology

Cadmus calculated savings for the alternative PSE tiers using the same RTF data and methodology used to determine current PSE savings for clothes washers. We took the following steps:

- Using the California Energy Commission (CEC) appliance database to determine the following average values for models in each 2012 tier:
  - MEF;
  - WF;
  - Remaining percent moisture;
  - Annual electricity consumption normalized to the average capacity; and
  - Annual water consumption normalized to the average capacity.
- Calculating the average breakdown of energy consumption (machine, hot water, dryer energy) in each tier using the RTF methodology and the specifications listed above. These calculations used the following key RTF assumptions:
  - Formula based on Department of Energy data for dryer energy:

    Dryer energy per load = 2.525 x remaining moisture content - 0.0856
  - 352 loads/year; and
  - 10.5% of water used for laundry is hot water.
- Using the breakdown of machine energy, hot water energy, and dryer energy in each tier to calculate annual electricity consumption for all 15 measures, based on the fuel type used for the water heater and dryer. The *any fuel* measures were based on the RTF assumption of 64% electric water heaters and 82% electric dryers.
- Subtracting calculated energy consumption for each measure from the corresponding CEC baseline consumption.
- Adding 15 kWh/year wastewater energy savings to each measure (the RTF assumption for all ENERGY STAR-qualified models).

Results

Table 2 shows measure savings for current and alternative PSE tiers, including measure savings for each tier and configuration (water heater and dryer type).

Table 2. Electricity Savings for Current & Alternative PSE Clothes Washer Tier Structures

PSE Tier	Configuration		WF	Alternative Tiers		Current Tiers	
	Water Heat Type	Dryer Type		MEF	Annual Measure Savings (kWh)	MEF	Annual Measure Savings (kWh)
1	Any	Any	4.5 or above	2.2-2.39	106	2.2-2.45	112
2	Any	Any	4.0 or above	2.4-2.69	143	2.46-2.69	167
3	Any	Any	4.0 or above	2.7 and above	183	2.7 and above	183
1	Elec	Elec	4.5 or above	2.2-2.39	140	2.2-2.45	149
2	Elec	Elec	4.0 or above	2.4-2.69	188	2.46-2.69	219
3	Elec	Elec	4.0 or above	2.7 and above	240	2.7 and above	240
1	Elec	Gas	4.5 or above	2.2-2.39	80	2.2-2.45	84
2	Elec	Gas	4.0 or above	2.4-2.69	99	2.46-2.69	108
3	Elec	Gas	4.0 or above	2.7 and above	114	2.7 and above	114
1	Gas	Elec	4.5 or above	2.2-2.39	75	2.2-2.45	81
2	Gas	Elec	4.0 or above	2.4-2.69	108	2.46-2.69	130
3	Gas	Elec	4.0 or above	2.7 and above	145	2.7 and above	145
1	Gas	Gas	4.5 or above	2.2-2.39	15	2.2-2.45	16
2	Gas	Gas	4.0 or above	2.4-2.69	19	2.46-2.69	20
3	Gas	Gas	4.0 or above	2.7 and above	20	2.7 and above	20

As expected, by reducing the maximum MEF of Tier 1, average annual savings decreased for that tier. For example, for homes with an electric dryer and electric water heater, estimated savings for a Tier 1 clothes washer in the alternative tier structure (MEF range of 2.2 to 2.39) were 140 kWh/year, less than the 149 kWh/year for the current tier (MEF range of 2.2 to 2.45).

Similarly, by reducing the minimum MEF of Tier 2, average annual savings decreased for that tier. For example, for homes with an electric dryer and electric water heater, estimated savings for a Tier 2 clothes washer in the alternative tier structure (MEF range of 2.4 to 2.69) were 188 kWh per year, less than the 219 kWh/year for the current tier (MEF range of 2.46 to 2.69).

Tier 3 results remained the same as the Tier 3 MEF range does not change in the alternative tier structure. To date, PSE has not adapted this alternative tier structure.

Task 2: Review RTF Approach Assumptions and Update Savings Estimates[6]

Developing clothes washer savings estimates requires a complex process, which can include combining field data, usage assumptions, and engineering analysis. As part of evaluating the RTF-based clothes washer savings estimates, Cadmus examined the data sources and methodology they used in developing estimated savings for the current 2012 rebate structure shown in Table 3, below.

[6] Cadmus originally provided this analysis to PSE in a memo, submitted on January 5, 2012.

Table 3. PSE 2012 Clothes Washer Rebate Structure

PSE Tier	Rebate	MEF	WF
1	$50	2.2 – 2.45	4.5 or below
2	$100	2.46 or above	4.0 or below

Overall, RTF's analysis used a sound methodology in evaluating clothes washer electricity savings. Electricity consumption and savings were attributed to the following four sources, all of which depend on the clothes washer's efficiency:

- Clothes washer
- Water heater
- Dryer
- Wastewater treatment

In detail, this section describes the review of assumptions going into the RTF analysis; presents recommended changes to these assumptions; and provides updated savings estimates, based on those changes.

Model Data and Baseline Assumptions

The RTF analysis is based on a CEC database of available clothes washer models,[7] which was used to determine the following average values for models in each efficiency tier:

- MEF;
- WF;
- Remaining percent moisture;
- Annual electricity consumption, normalized to the average capacity; and
- Annual water consumption, normalized to the average capacity.

The RTF approach used all residential models meeting federal standards for the baseline, including high-efficiency models qualifying for incentives. Some utilities use an alternate approach to include only lower-efficiency models in the baseline and then conducting a separate net-to-gross (NTG) adjustment. The RTF approach proved sound, provided another NTG adjustment was not made.

Further, Cadmus reviewed the CEC database, finding it a good source for information on available clothes washers, but opportunities existed to improve and update application of this data for the analysis, as described below.

Employ Latest Clothes Washer Models

PSE's current RTF analysis was completed in 2010, and the latest models used in the database were added in June 2010. In order to update the models used in the analysis, Cadmus accessed

[7] http://www.appliances.energy.ca.gov

the CEC appliance database online, and updated the analysis with more current data (including models added through October 2011) to determine updated savings values for PSE's use going forward.

In using a database of available products for analysis, one should consider the degree that the available product mix represents actual sales. If sales data could be procured, weighted averages could be used to determine metrics used in the analysis, but such data prove very difficult for nonparticipants to obtain; so the RTF approach, taking a simple average of available models, provides a reasonable baseline estimate.

Use Only Clothes Washer Models Meeting the Latest Federal Standard

The RTF analysis is based upon clothes washer models in the database entering the market on or after January 1, 2007, when a new federal standard for clothes washers took effect. On January 1, 2011, the federal standard was modified again to include WF requirements, but the MEF level did not change. Current federal standards requires following efficiency levels:

- MEF $\geq$ 1.26
- WF $\leq$ 9.5.[8]

Of models used in the RTF analysis, 35% have WF ratings exceeding current federal standards for maximum WF, and the current baseline calculation includes specifications for these models. Models not meeting the federal standard should not be considered at all; so, for 2011 and beyond, analysis should be modified to only use models meeting the new WF requirement.

Cadmus modified the analysis using the updated database, described above, and including in the baseline only models meeting current federal standards. The difference between annual electricity savings values in the RTF analysis and savings calculated using these updated data ranged from -68% to +14%, depending on the efficiency tier and configuration (water heater fuel and dryer type). Substantial changes primarily resulted from the baseline's increased efficiency; the RTF analysis showed a baseline of 1.9 MEF and 7.0 WF, while the updated version showed a baseline of 2.3 MEF and 4.8 WF (note that for WF, lower is better).[9] While baseline efficiency increased overall by more than 100 kWh, the machine energy component of the baseline increased slightly; so savings increased in some cases and decreased in others.

Apply Both MEF and WF Criteria

PSE's tier definitions have been based on MEF and WF.[10] The RTF analysis, however, grouped models in the database based solely on MEF (see the RTF file ResClothesWashersSF_FY10v2_0 .xls, CEC clothes washers - unique tab, columns AQ & AR). If factoring in WF, average metrics would slightly differ for each tier, resulting in changing savings for clothes washer measures by up to +/-3%.

[8] http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers
[9] http://www.appliances.energy.ca.gov
[10] http://www.washwiserebate.com/rebates/qualifications.html

Fuel and Usage Assumptions

Data from several sources allowed the accuracy of the following key assumptions used in the RTF analysis to be evaluated:

- 352 loads of laundry per year;
- 10.5% of water used for laundry is hot water; and
- For *any fuel* measures with an unspecified configuration: 64% of water heaters are electric, and 82% of dryers are electric.

This year, Cadmus surveyed customers throughout the Northwest regarding clothes washer use, and, according to customer reports, use averaged about 360 loads per year. Cadmus' 2009 metering study of clothes washers in California found an average of five loads per week in the summer, or annual use of 260 loads per year, based on summer use.[11] Therefore, Cadmus considered the 352 loads per year RTF assumption reasonable, and continued to use this value in the updated analysis.

The 2009 California study found about 13% of water use was heated, a value close to RTF's 10.5% assumption. Therefore, Cadmus considered the 10.5% RTF assumption reasonable, and continued to use this value in the updated analysis.

To determine weighting for the *any fuel* measures, Cadmus considered a 2010 PSE residential survey[12] as a more suitable information source for the portion of PSE customers with electric heaters and dryers. On average, the survey indicated 44% of PSE customers had electric water heaters, compared to the 64% assumption used in the RTF analysis. For dryers, survey data showed 88% of customers had electric dryers, compared to the 82% RTF assumption. Cadmus updated the *any fuel* measures, weighting them based on these PSE-specific values, which resulted in lower electricity savings for those measures.

Wastewater Energy Assumptions

As a final step in the RTF analysis, 15 kWh/year wastewater energy savings were added to savings for each clothes washer measure, due to reductions in water use by ENERGY STAR machines (see the RTF file ResClothesWashersSF_FY10v2_0.xls, Measure Development tab, columns AX & AY). Actual wastewater energy savings vary, based on washer efficiency, but this provides a reasonable estimate for average savings.

Such energy savings would occur at the water and sewer utility levels, rather than in the residential sector. Therefore, they should be included in total savings achieved, but not in any savings estimate realized by individual residential customers. PSE can reasonably continue to claim this savings using the current approach, provided the savings cannot be counted elsewhere, such as a separate accounting of water savings (which could result in double-counting). In the

[11] The Cadmus Group, Inc. "Do the Savings Come Out in the Wash? A Large Scale Study of In-Situ Residential Laundry Systems." 2010. http://www.cadmusgroup.com/pdfs/Do_the_Savings_Come_Out_in_the_Wash.pdf

[12] Puget Sound Energy. 2010 Residential Household Characteristics Research. February 2011. slides 42 and 56.

updated analysis, Cadmus continued to include RTF's assumption of 15 kWh/year wastewater energy savings.

Results

After making the adjustments described above, Cadmus recalculated savings for 2011 and future years, as shown in Table 4. Updated annual electricity savings per clothes washer are lower than their original values in nine out of 10 configurations. The final adjustment from RTF electricity savings to savings calculated with this updated data range from -69% to +13%, depending on the efficiency tier and configuration. These values are based on current PSE tier definitions, rather than the alternative tier structure, considered previously in this report.

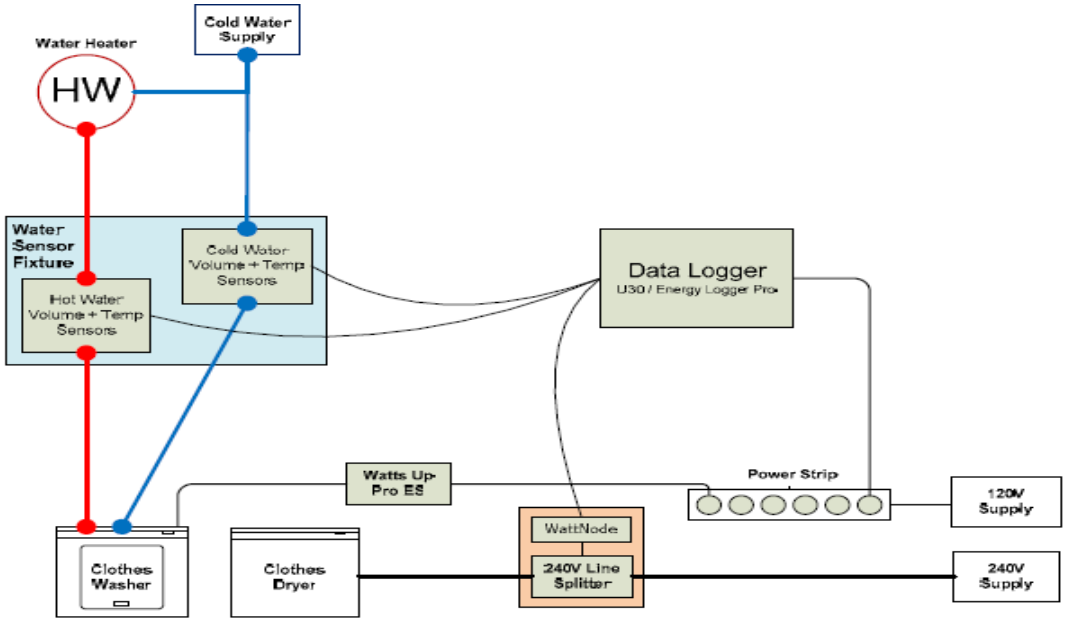
Table 4. Comparison of Updated and Current RTF Electricity Savings for PSE 2012 Clothes Washer Rebate Structure

PSE Tier	MEF	WF	Water Heat Type	Dryer Type	Annual Electricity Consumption (kWh)				Measure Savings (kWh)	
					Baseline		Measure			
					Current RTF	Updated	Current RTF	Updated	Current RTF	Updated
1	2.2– 2.45	4.5 or below	Electric	Electric	636	532	488	484	149	48
1	2.2– 2.45	4.5 or below	Electric	Gas	210	165	127	126	84	39
1	2.2– 2.45	4.5 or below	Gas	Electric	472	416	392	389	81	27
1	2.2– 2.45	4.5 or below	Gas	Gas	46	48	31	31	16	18
1	2.2– 2.45	4.5 or below	Any	Any	500	423	388	388	112	35
2	2.46 or above	4.0 or below	Electric	Electric	636	532	418	417	219	116
2	2.46 or above	4.0 or below	Electric	Gas	210	165	102	128	108	37
2	2.46 or above	4.0 or below	Gas	Electric	472	416	343	325	130	91
2	2.46 or above	4.0 or below	Gas	Gas	46	48	27	37	20	12
2	2.46 or above	4.0 or below	Any	Any	500	423	334	331	167	92

Task 3: Develop Alternative Savings Estimate Based on Metering Study[13]

Based on a 2009 Cadmus metering study, Cadmus developed an alternative savings estimate.[14] In this study of more than 100 clothes washers in California homes, three clothes washing components were measured: the machine; hot water heater; and the dryer, as shown in Figure 1. (Due to the difficulty of measuring clothes dryer gas use, only systems with electric dryers were included in the study.)

Figure 1. California Home Metering Study



This study, the largest *in situ* metering study on residential clothes washers and dryers conducted in the last decade, indicated higher consumption and savings values than those often estimated. The majority of energy consumption and savings were associated with dryers, as high-efficiency washing machines removed more moisture from clothes, allowing shorter drying times.

Cadmus binned data collected in the California study into the PSE 2012 tiers, derived per-cycle energy savings estimates for each clothes washer measure, and compared these savings estimates to those shown in Table 5's updated measure savings. Technical methodology and analysis results follow in detail.

[13] Cadmus originally provided these values to PSE in a memo, submitted on January 12, 2012.

[14] The Cadmus Group, Inc. "Do the Savings Come Out in the Wash? A Large Scale Study of In-Situ Residential Laundry Systems." 2010. http://www.cadmusgroup.com/pdfs/Do_the_Savings_Come_Out_in_the_Wash.pdf

Table 5. Comparison of Updated RTF Electricity Savings and Metering Study Savings for PSE 2012 Clothes Washer Rebate Structure

PSE Tier	MEF	WF	Water Heat Type	Dryer Type	Annual Electricity Consumption (kWh)				Annual Measure Savings (kWh)	
					Baseline		Measure			
					Updated RTF	Meter Data	Updated RTF	Meter Data	Updated RTF	Meter Data
1	2.2– 2.45	4.5 or below	Electric	Electric	532	1,057	484	1,006	48	52
1	2.2– 2.45	4.5 or below	Electric	Gas	165	188	126	158	39	30
1	2.2– 2.45	4.5 or below	Gas	Electric	416	916	389	879	27	37
1	2.2– 2.45	4.5 or below	Gas	Gas	48	46	31	31	18	15
1	2.2– 2.45	4.5 or below	Any	Any	423	874	388	833	35	41
2	2.46 or above	4.0 or below	Electric	Electric	532	1,057	417	902	116	155
2	2.46 or above 2.45	4.0 or below	Electric	Gas	165	188	128	168	37	21
2	2.46 or above	4.0 or below	Gas	Electric	416	916	325	780	91	136
2	2.46 or above	4.0 or below	Gas	Gas	48	46	37	45	12	2
2	2.46 or above	4.0 or below	Any	Any	423	874	331	745	92	128

Methodology

In the following manner, Cadmus used 2009 California meter data to calculate savings for the two PSE tiers:

- Calculating electricity consumed per cycle using meter data by each laundry system component listed above, for each of the 115 homes.
- Grouping the 115 systems according to current PSE tiers:[15]
  - Non-eligible: Not meeting Tier 1 requirements, but meeting the current federal standard.
  - Tier 1: MEF at least 2.2; WF no more than 4.5.
  - Tier 2: MEF at least 2.46; WF no more than 4.0.
- Calculating average electricity consumed per cycle by each component for the following groups:
  - Baseline: including all 115 systems (following RTF's approach of including all models in the baseline, as described previously in this report).[16]
  - Tier 1: 46 systems.
  - Tier 2: 11 systems.

[15] http://www.washwiserebate.com/rebates/qualifications.html
[16] Cadmus memo to PSE, January 5, 2012

- Calculating electricity consumed annually by each component using RTF's assumption of 352 loads per year, which the previous task of this evaluation found to be a reasonable assumption.
- Calculating total annual electricity consumption for each tier and configuration (water heater fuel and dryer type) by totaling each of the three components.

- Assuming 44% of water heaters were electric, and 88% of dryers were electric, based on PSE's survey data, for the *any fuel* measures with unspecified configuration
- Calculating annual electricity savings for each tier and configuration, by subtracting measure consumption from the baseline.
- Adding 15 kWh/year wastewater energy savings to savings for each clothes washer measure, due to reduction in water use by ENERGY STAR machines, as described in the previous task.

Results

Table 5 above shows electricity consumption and savings calculated using the data and methodology previously described as well as a comparison of these values to those calculated with the updated RTF approach in the previous task. The following observations emerged regarding the data:

- Metering study-based savings are within +/-10 kWh/year of the updated RTF value for Tier 1. For Tier 2, metering study-based savings range from 17 kWh/year below the updated RTF value to 45 kWh/year above it.
- The electricity consumption values from meter data were substantially higher than those calculated with the RTF approach. Differences primarily occurred due to dryers. The metering study found dryer electricity consumption, using baseline or efficient washers, to be twice as efficient as consumption calculated using the RTF approach.
- The Tier 2 sample was relatively small due to meter data being collected in 2009, and available clothes washers' efficiency having increased rapidly since then. A model currently qualifying for a PSE Tier 1 rebate would have been one of the most efficient units available at the time of the metering study, qualifying for CEE Tier 3 before CEE requirements raised last year.[17] The federal standard and ENERGY STAR specification also increased in 2011, reflecting recent market changes.[18,19] Additional metering conducted on laundry systems sold recently could supplement data available from the 2009 study and increase the sample size, especially for the higher tier.

[17] The Cadmus Group, Inc. *Do the Savings Come Out in the Wash? A Large Scale Study of In-Situ Residential Laundry Systems.* 2010. http://cadmusgroup.com/pdfs/Do_the_Savings_Come_Out_in_the_Wash.pdf

[18] Federal standard: http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=61b33caa9460da7b2e875b478972dfdc&rgn=div6&view=text&node=10:3.0.1.4.18.3&idno=10

[19] ENERGY STAR specification: http://www.energystar.gov/index.cfm?c=clotheswash.pr_crit_clothes_washers

3. WEATHERIZATION SAVINGS REVIEW

In this section, Cadmus describes the methodology and results of analyzing PSE's single-family weatherization program, using program and billing data from 2006 to 2010. The program includes incentives for the following measures:

- Attic insulation;
- Duct insulation;
- Duct sealing;
- Floor insulation; and
- Wall insulation.

For the weatherization savings review, Cadmus completed the following:

- Reviewing and compiling PSE weatherization tracking databases and supporting documentation for savings estimates.
- Estimating energy savings for PSE gas and electric weatherization programs using billing analysis and comparing those results to savings based on RTF-based unit-savings values and program tracking data.

Task 1: Compile and Review Data

For the weatherization effort, Cadmus reviewed the following information sources received from PSE:

- Data on the basis of 2012 proposed RTF weatherization unit savings (e.g., 1.54 annual kWh savings per square foot for attic insulation R0 to R19).
- Detailed tracking system of the 2010 weatherization program, with specific information about measure quantities (e.g., square footage of insulation) and measure type (e.g., R0 to R19 attic insulation).
- Detailed tracking system of the 2006 to 2009 weatherization program, with specific information about measure quantities (e.g., square footage of insulation) and measure type (e.g., R0 to R19 attic insulation).
- Square footage of each residence installing weatherization measures through the program in 2010.
- A calculator converting kWh to therms.
- Gas and electric billing data, from 2003 to November 2011.
- SEEM files[20]: SEEM Calibration files (in Excel); RLW Analytics, *Residential New Construction Characteristics and Practices Study*, 2007; *Super Good Cents Metered*

[20] Cadmus staff completed training on SEEM calculations on October 31, 2011.)

Data Report; and *Final Report Analysis of Heat Pump Installation Practices and Performance*, David Baylon et al., prepared for the RTF Heat Pump Working Group, December 2005.

For the billing analysis, Cadmus also gathered the appropriate weather data for the territory covered by participants:

- Daily temperature data for all weather stations associated with the participants' ZIP codes, from January 2003 to present.
- Annual normal heating and cooling degree days for participant ZIP codes: TMY3 series (1991–2005) from the National Climatic Data Center.

Task 2: Develop Gas Savings Estimate Based on Billing Analysis

This section describes a billing analysis used to evaluate RTF-based savings for the 2006 to 2010 PSE weatherization program for homes with gas heat. Detailed methodology and savings results follow from an overall model, which estimated average savings per home across all program weatherization measures.

Methodology

Billing analysis is an appropriate methodology for estimating savings from weatherization programs, as the programs typically experience savings significant enough (at least 5% of home gas usage) to be isolated when accounting for weather. For PSE's Gas Weatherization program, Cadmus conducted analysis on more than 10,000 homes served by the program from 2006 to 2010. Cadmus executed a CSA cross-sectional, pooled, time series regression modeling approach to estimate overall average gas savings per home realized through program participation.

RTF-Based Weatherization Program Savings

Cadmus calculated RTF-based weatherization program savings for homes heated with gas using a two-stage process:

- Cadmus first multiplied RTF-based weatherization unit savings for a home with an electric forced air furnace[21] (e.g., a 1.77 annual kWh savings per square foot for attic insulation increase from R0 to R19) by the specific measure quantity (e.g., square foot of insulation) for each measure type installed at each gas program participant home in the 2006 to 2010 databases.[22]
- Cadmus converted these electric RTF-based savings (kWh/year) for weatherization measures in a home with an electric forced air furnace to one with a gas furnace by converting kWh to therms by dividing by 29.3 kWh/therms. We then adjusted for the differences in electric and gas furnace efficiency by dividing 0.8 (since a gas furnace has an efficiency of 80% versus 100% for an electric furnace.)[23]

[21] If using the "average" electric home heating system set of RTF-based unit savings, the saving results are 12 percent lower.

[22] *ECOS2010revV2.xls* and *NEW2006-2009ParticipantData_11.08.11xlsx*

[23] These are the same assumptions as used in the kWh-to-therm calculator provided by PSE.

Table 6 summarizes average PSE gas tracking savings per participant for the population of weatherization measures (the table also summarizes population sizes and percentage of participants installing each measure). Attic and floor insulation measures were most commonly installed. The population of 2006 to 2010 participants had average expected gas therm savings per participant of **123 therms**.

Table 6. Gas PSE Average Measure Savings and Measure Distribution

	Attic Insulation	Duct Insulation	Duct Sealing	Floor Insulation	Wall Insulation	Windows	Gas Total
Savings (therms)	88	41	58	63	72	37	123
Participant Homes	5,899	3,480	2,413	4,788	2,636	8	10,551
Percentage	56%	33%	23%	45%	25%	0.075%	100%

Data Screening

A data-intensive process, billing analysis requires knowledge of all energy-efficient measures implemented in a home, and sufficient energy bill data before and after measure installation. In preparing data for analysis, Cadmus began with 10,551 homes[24] participating in the program from 2006–2010. After data preparation and screening, 8,184 participating homes provided sufficient data to support the analysis. The following screens were applied:

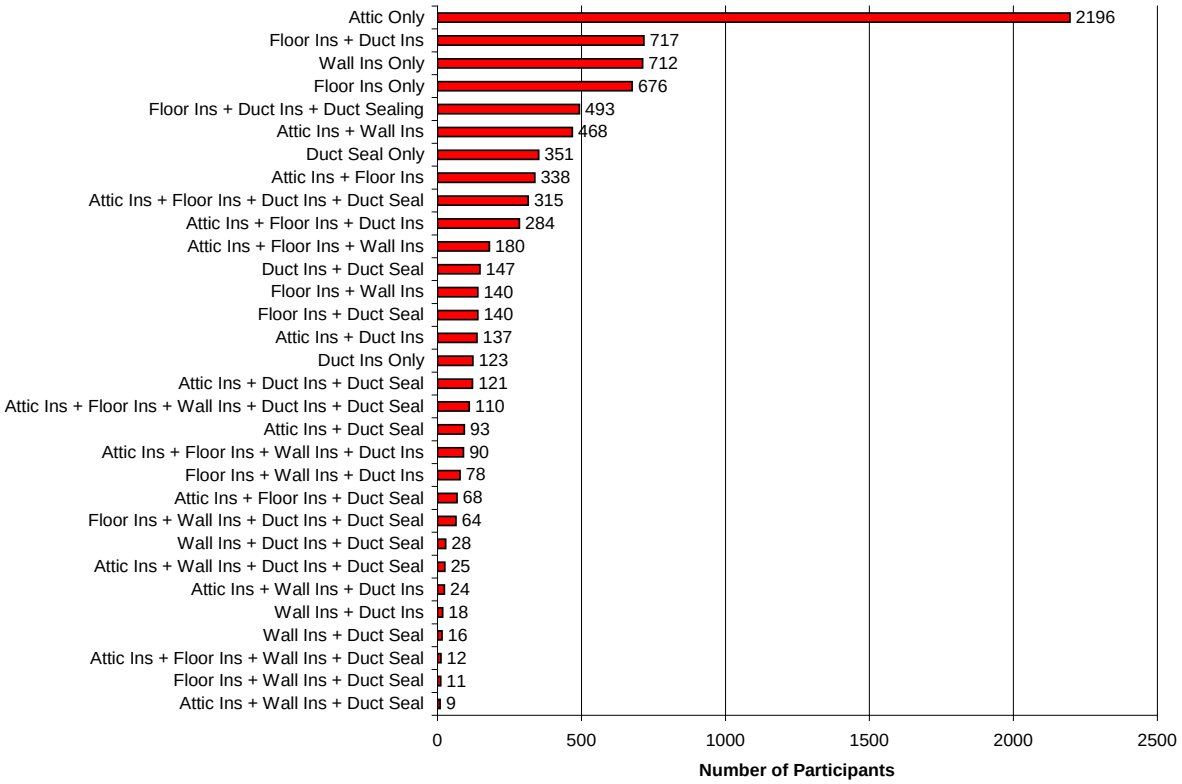
- Any participant with less than 300 pre- or post-installation total billing days. **n=991 dropped.**
- Accounts that were not single-family homes. **n=1,075 dropped.**
- Any participants with total expected savings more than 70% of average pre-installation period usage. These typically related to vacancies in the pre-installation period. **n=14 dropped.**
- The top and bottom 1% of average pre-installation period usages. This screen excluded customer sites with total annual usage less than 200 therms or more than 2100 therms. This eliminated some vacant sites, which likely did not have heating, and some very large participants. **n=216 dropped.**
- Accounts with a percentage change over 70%[25] from pre- to post-installation periods. **n=71 dropped.**

Figure 2 illustrates the measure combinations for the final group of 8,184 sites used in the analysis. The most common measure combinations installed are attic insulation only, floor insulation and duct insulation, wall insulation only, and floor insulation only. These four measure combinations represent over half of all the gas weatherization installations.

[24] Though the program had 11,896 participant homes, 1,345 gas Duct Ninja participants were entirely removed from the billing analysis, as their savings had already been obtained through a separate, comprehensive study.

[25] More than 70% change most likely reflects fuel switching or use of secondary fuel sources and thus was removed from the sample.

Figure 2. Number of Participating Homes Receiving Each Measure Combination



Pre- and Post-Installation Period Definitions for 2006-2010 Participants

The pre-installation period was defined for each participant as 2005 to the earliest measure installation date for the participant and the post-installation period was defined for each participant as the latest measure installation date[26] for the participant to November 2011. With this definition the future year participants serve as a control group for the previous year participants. The billing data for the entire period from 2005-2011 is used for all participants. Then, for example, pre-install data for 2007, 2008, 2009 and 2010 participants serve as a control group for 2006 participants.

[26] For the gas measures, the latest installation date used in the billing analysis occurred in December 2010.

Conditional Savings Analysis Model

The billing analysis used a CSA modeling approach to determine the overall gas savings estimates. CSA models include an indicator in the post-installation period to isolate the savings while accounting for weather differences. The CSA model specification is shown below[27]:

$$ADC_{it} = \alpha_i + \beta_1 * AVGHDD_{it} + \beta_2 * POSTHDD_{it} + \varepsilon_{it}$$

Where for home i and month t;

ADC_{it} = average daily usage during the pre- or post-installation period for home i

α_i = unique intercept for each home i

$AVGHDD_{it}$ = average daily heating degree days, base 65º F

$POSTHDD_{it}$ = the average daily heating degree days after the latest measure installation date for customer i, and 0 before the earliest measure installation date for customer i.

β_1 = average daily usage per heating degree day

β_2 = average daily overall savings per heating degree day across all measures

ε_{it} = the model estimation error

The overall CSA model estimated average program daily savings (β_2) for the analysis period. The β_2 coefficient was multiplied by the TMY3 normal heating degrees estimate of 4,710 heating degree days to obtain the average annual normal weather savings across all the measures. Dividing the annual savings estimates by the average expected *ex ante* savings estimate yielded the program realization rate.

Results

Table 7 summarizes the results of the overall gas savings model. The model parameters are all highly significant with very high t-tests and very low p-values. Multiplying the 0.02834 therm savings per heating degree day from the model by the TMY3 normal heating degree days (4,710), Cadmus calculated the weather normal gas program savings estimate of 133 therms.

Table 7. Gas Model Parameter Estimates

Variable	Parameter Estimate	Standard Error	t Value	P-Value
Average Heating Degree Days	0.17952	0.00012848	1397.19	<.0001
POST * Average Heating Degree Days	-0.02834	0.00013359	-212.12	<.0001

[27] Alternate model specifications including POST + POST*HDD, and POST + POST*HDD + POST*HDD_SQFT were attempted. These models had very high multi-collinearity between the variables interacted with POST and the variance inflation factors (VIFs) were very high, over 5, that made the interpretation of the model parameters very difficult.

Table 8 presents the overall gas model savings results.[28] Following are some observations based on the data in the table.

- The gas model indicates that the billing analysis savings overall are slightly higher than the PSE deemed *ex ante* savings estimates. The PSE deemed *ex ante* gas savings estimate appears to be accurate.
- Overall the savings estimate is slightly higher than the PSE *ex ante* deemed savings, with a realization rate of 110%.
- With the large sample size of 8,184 participants, the savings were relatively precise with a t-value of 212 and a p-value of less than 0.0001.
- The relative precision of the estimate is plus or minus 0.78%, with 90% confidence. The 90% confidence interval is from 132 therms to 135 therms.
- The overall savings estimate is 133 therms. Compared to the average weather normalized baseline usage of 893 therms, this translates to 15% savings compared to the pre-period usage.

Table 8. Gas Savings Results

Model	N	Average Therms	Model Savings (Therms)	PSE Ex Ante Savings (Therms)	Realization Rate	Relative Precision 90% level	T-test	P-Value	Savings as % of Pre Therms
Overall CSA	8,184	893	133	121	110%	0.78%	212.12	<0.0001	15%

Task 3: Develop Electric Savings Estimate Based on Billing Analysis

This section describes a billing analysis used to evaluate RTF-based savings for the 2006 to 2010 PSE weatherization program for homes with electric heat. The detailed methodology and savings results follow from an overall model, estimating average savings per home across all program weatherization measures.

Methodology

For PSE'S Electric Weatherization program, Cadmus conducted an analysis on more than 1,800 homes served by the program from 2006 to 2010. Similar to the gas savings analysis, Cadmus executed a CSA cross-sectional, pooled, time series regression modeling approach to estimate overall average electric savings per home realized through program participation.

[28] The detailed CSA model output is found in the appendix. Furthermore, a statistically adjusted engineering (SAE) modeling approach was also estimated to check the accuracy of the CSA based savings. The specification is presented in an appendix. The SAE model yields slightly lower estimates compared to the CSA approach above.

RTF-Based Weatherization Program Savings

Cadmus estimated RTF-based weatherization program savings for homes heated with electricity. Similar to the gas program analysis, Cadmus multiplied proposed RTF-based weatherization unit savings for a home with a particular heating system (e.g., 1.80 annual kWh savings per square foot for attic insulation increases from R0 to R11 in a home with an electric forced air furnace) by the specific measure quantity (e.g., square footage of insulation) for each measure type installed at each electric program participant home in the 2006 to 2010 databases.[29] If the database did not include information about the specific type of electric heating system used in the home (i.e., forced air furnace, heat pump, or zonal), than the "average" heating system unit savings were applied to that home.

Table 9 summarizes average PSE electric tracking savings per participant for the population of weatherization measures. These are RTF-based electric deemed savings estimates for weatherization measures. The table also summarizes population sizes and percentages of participants installing each measure. Attic and floor insulation were measures most commonly installed. For the population of 2006 to 2010 participants, average expected electric kWh savings per participant were **1,990 kWh**.

Table 9. Electric PSE Average Measure Savings and Measure Distribution

	Attic Insulation	Duct Insulation	Duct Sealing	Floor Insulation	Wall Insulation	Electric Total
Savings (kWh)	1,697	1,079	1,277	1,222	1,293	1,990
Participant Homes	834	241	359	994	189	1,806
Percentage	46%	13%	20%	55%	10%	100%

Data Screening

In preparing data for analysis Cadmus started with 1,806 homes,[30] participating in the program from 2006–2010. After data preparation and screening, 1,193 participating homes remained with sufficient data to support the analysis. The following screens were applied:

- Any participant with less than 300 pre- or post-installation total billing days. **n=232 dropped.**
- Accounts that were not single-family homes. **n=299 dropped.**
- Any participants with total expected savings more than 70% of the average pre-installation period usage. Typically, these are related to vacancies in the pre-installation period. **n=8 dropped.**
- The top and bottom 1% of average pre-installation period usage. This screen excluded customer sites with total annual electric usage below 300 kWh or above 44,000 kWh. This eliminated some vacant sites, which likely did not have heating, and some very large participants. **n=32 dropped.**

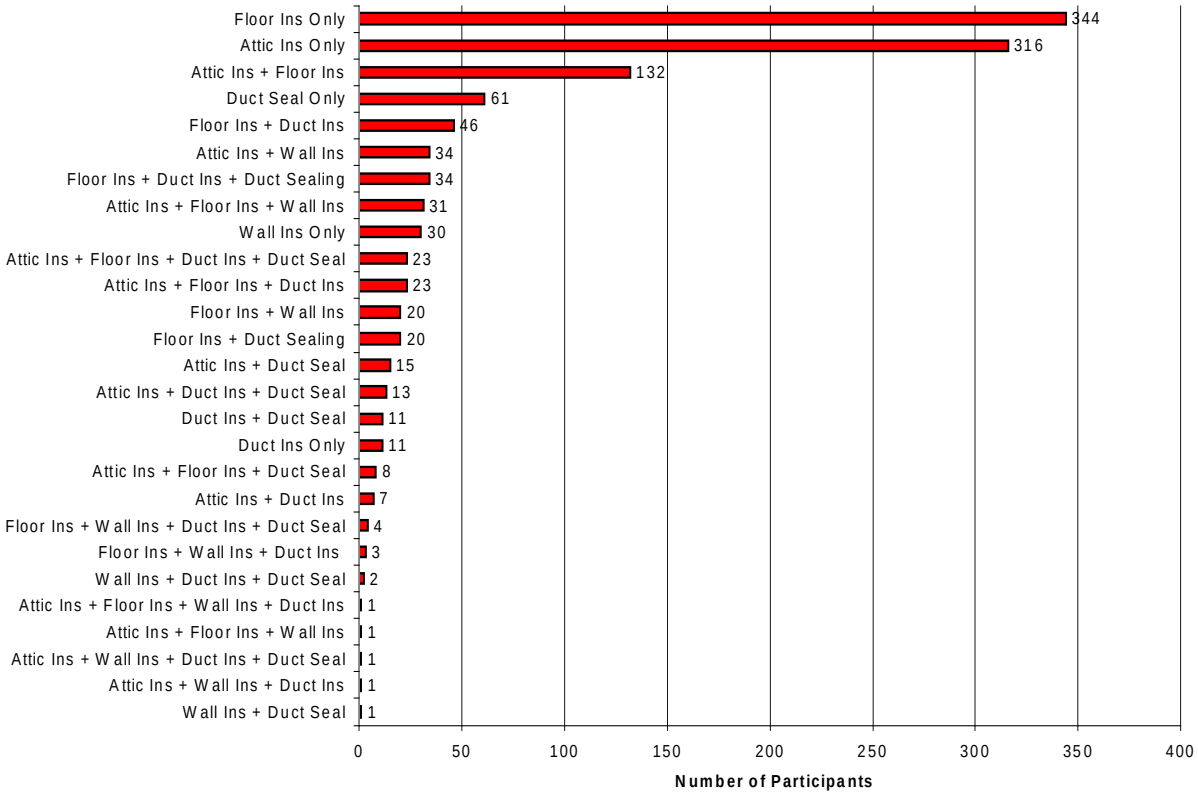
[29] *ECOS2010revV2.xls* and *NEW2006-2009ParticipantData_11.08.11xlsx*

[30] Though the program had 1,875 participant homes, 69 electric Duct Ninja participants were entirely removed from the billing analysis as their savings had already been obtained through a separate comprehensive study.

- Accounts with a 70% percentage[31] change from pre- to post-installation periods. **n=42 dropped.**

Figure 3 illustrates measure combinations for the final group of 1,193 sites used in the analysis. Most commonly installed measure combinations included: floor insulation only, attic insulation only, attic insulation and floor insulation, and duct sealing only. These four measure combinations represented nearly three-quarters of all electric weatherization installations.

Figure 3. Number of Participating Homes Receiving Each Measure Combination



Pre- and Post-Installation Period Definitions for 2006–2010 Participants

Like the gas analysis, the pre-installation period was defined for each participant as 2005 to the earliest measure installation date for the participant and the post-installation period was defined for each participant as the latest measure installation date[32] for the participant to November 2011. With this definition the future year participants serve as a control group for the previous year participants. The billing data for the entire period from 2005-2011 is used for all

[31] More than 70% change most likely reflects fuel switching or use of secondary fuel sources and thus was removed from the sample.

[32] For the electric measures, the latest installation date used in the billing analysis occurred in December 2010.

participants. Then, for example, pre-install data for 2007, 2008, 2009 and 2010 participants serve as a control group for 2006 participants.

Conditional Savings Analysis Model

The billing analysis used a CSA modeling approach to determine overall electric savings estimates. The CSA model, which included an indicator in the post-installation period to isolate savings while accounting for weather differences, took the following form:

$$ADC_{it} = \alpha_i + \beta_1 * AVGHDD_{it} + \beta_2 * AVGCDD_{it} + \beta_3 * POSTHDD_{it} + \varepsilon_{it}$$

Where for home i and month t;

ADC_{it} = average daily usage during the pre- or post-installation period for home i

α_i = unique intercept for each home i

$AVGHDD_{it}$ = average daily heating degree days, base 65º F

$AVGCDD_{it}$ = average daily cooling degree days, base 65º F

$POSTHDD_{it}$ = the average daily heating degree days, base 65º F, after the latest measure installation date for customer i, and 0 before the earliest measure installation date for customer i.

β_1 = average daily usage per heating degree day

β_2 = average daily usage per cooling degree day

β_3 = average daily savings per heating degree day across all measures

ε_{it} = the model estimation error

The overall CSA model estimated average program daily savings (β_2) for the analysis period. The β_3 coefficient was multiplied by the TMY3 normal heating degrees estimate of 5,191 heating degree days to obtain the average annual normal weather savings across all the measures. Dividing the annual savings estimates by the average expected *ex ante* savings estimate yielded the program realization rate.

Results

Table 10 summarizes the results of the overall electric model savings model. The model parameters are all highly significant with very high t-tests and very low p-values. Multiplying the 0.312162 kWh savings per heating degree day from the model by TMY3 normal heating degree days (5,191), Cadmus calculated the weather normal electric program savings estimate of 1,623 kWh.

Table 10. Electric Model Parameter Estimates

Variable	Parameter Estimate	Standard Error	t Value	P-Value
Average Heating Degree Days	2.21126	0.00823	268.62	<.0001
Average Cooling Degree Days	2.02325	0.07758	26.08	<.0001
POST * Average Heating Degree Days	-0.31262	0.0075	-41.70	<.0001

Table 11 presents overall electric model savings results.[33] The following observations have been drawn from data presented in the table:

- The overall electric model indicates billing analysis savings are lower than RTF deemed *ex ante* savings estimates. RTF deemed *ex ante* savings appears to overstate savings.
- Overall the savings estimate is lower than the RTF *ex ante* deemed savings, with a 78% realization rate.
- With a large, 1,193 participant sample size, the savings were relatively precise, with a t-value of 42 and a p-value less than 0.0001.
- The estimate's relative precision is plus or minus 3.94%, with 90% confidence. The 90% confidence interval fell between 1,559 kWh to 1,678 kWh.
- The overall savings estimate is 1,623 kWh. Compared to the average pre-period usage of 17,870 kWh, this translates to 9% savings, compared to the pre-period usage.

Table 7. Electric Savings Results

Model	N	Average Pre Period kWh	Model Savings (kWh)	RTF Ex Ante Savings (kWh)	Realization Rate	Relative Precision 90% level	T-test	P-Value	Savings as % of Pre kWh
Overall CSA	1,193	17,870	1,623	2,079	78%	3.94%	41.70	<0.0001	9%

The results of the electric savings analysis, realization rate of 78%, were different than those of the gas savings analysis – realization rate of 110%. Both the gas and electric savings analysis were performed using the same methodologies. However, some differences in the gas and electric data sets and the nature of using electric versus gas heat may have led to the differences in realization rates.

- **Supplemental Heat**. Homes heated with electric heat sometimes use supplemental heat (e.g., wood stoves) to help them defray the high costs of electric heat. Unable to capture supplemental heat use, billing analysis can lead to lower electric energy savings estimates and lower realization rates.

[33] The appendices present detailed CSA model outputs. Further, a statistically adjusted engineering (SAE) modeling approach was estimated to check the accuracy of CSA-based savings, also presented in the appendices. The SAE model yielded very similar savings estimates to the above CSA approach.

- **Heating System Type.** Only homes from the 2009 to 2010 program years included the specific type of electric heating system in the database. In those homes, the specific RTF-based unit savings for a forced air furnace, heat pump, or zonal heating could be applied. For sites from the 2006 to 2008 program years, the database did not indicate heating system type and an "average" heating system was assumed. The savings estimates could be inaccurate if the "average" system did not represent actual heating system types at these homes.
- **Zonal Heat Actual Usage**. Zonal baseboard heating was the predominate heating system type in electric heated homes. Electric baseboard heaters are typically controlled by thermostats located within each room. The electricity use by these systems (where entire rooms can remain unheated) may have been overestimated in the RTF-based unit savings estimates and could contribute to the lower realization rate.

In order to more accurately estimate savings in the future, we suggest that PSE collect more specific information about both the **primary** and **supplemental** heating systems in each home, including:

- Fuel type (e.g., gas, electric, oil, propane, wood, etc.)
- System (e.g., boiler, furnace, condensing furnace, stove, baseboard, air source heat pump, ground source heat pump)
- Heating and Cooling Capacity (for heat pumps)
- Brand and model number
- Age
- If electric baseboard, during the heating season, what percentage of floor area are never heated, heated half the time, or heated all the time.
- If supplemental heat, during the heating season, what percentage of time is the supplemental heating system used and for what percentage of the floor area.

APPENDIX A. PSE GAS MODEL OUTPUTS

CSA Model Overall

The REG Procedure	
Dependent Variable: adc3	
Number of Observations Read	672260
Number of Observations Used	672260
Note: No intercept in model. R-Square is redefined.	

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1414013	707007	1066991	<.0001
Error	672258	445450	0.66262		
Uncorrected Total	672260	1859463			

Root MSE	0.81401	R-Square	0.7604
Dependent Mean	1.55E-18	Adj R-Sq	0.7604
Coeff Var	5.26E+19		

Parameter Estimates						
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
avghdd3	1	0.17952	0.00012848	1397.19	<.0001	1.223817
posthdd3	1	-0.02834	0.00013359	-212.12	<.0001	1.223817

Statistically Adjusted Engineering (SAE) Model Alternate Savings Modeling Approach

To obtain a comparative savings estimate, an SAE billing model specification, shown below, was used to estimate savings. The SAE modeling method and the CSA modeling approach primarily differed in that the SAE approach using the PSE *ex ante* savings estimate rather than solely using a post-installation indicator:

$$ADC_{it} = \alpha_i + \beta_1 * AVGHDD_{it} + \beta_2 * EE_{it} + \varepsilon_{it}$$

Where for home i and month t;

ADC_{it}	= average daily usage during the pre- or post-installation period for home i
α_i	= unique intercept for each home i
$AVGHDD_{it}$	= average daily heating degree days, base 65º F
EE_{it}	= average daily total expected PSE *ex ante* savings in the post installation period, *0* otherwise
β_1	= average daily usage per heating degree day
β_2	= realization rate across all program measures

In the model, β_3 directly estimated the program realization rate. Annual SAE model savings were derived by multiplying the overall realization rate with average total annual PSE *ex ante* expected savings. [34]

A realization rate of approximately 101% and model savings of 122 therms (101% * 121) result. As shown in Table A-1, the SAE approach produced a lower savings estimate than the CSA modeling method (Table 8), Both the CSA and SAE modeling approaches provided very accurate savings estimates, very close to PSE *ex ante* savings estimates. The primary CSA approach has lower errors on the savings estimates than the SAE modeling approach.

Table A-1. Gas Savings Results (SAE Alternate Model)

Model	N	Average Pre Period Therms	Model Savings (Therms)	PSE Ex Ante Savings (Therms)	Realization Rate	Relative Precision 90% level	T-test	P-Value	Savings as % of Pre Therms
Overall SAE	8,184	893	122	121	101%	0.93%	177.82	<0.0001	14%

SAE Model Overall

The REG Procedure	
Dependent Variable: adc3	
Number of Observations Read	672260
Number of Observations Used	672260
Note: No intercept in model. R-Square is redefined.	

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1405550	702775	1040828	<.0001
Error	672258	453914	0.67521		
Uncorrected Total	672260	1859463			

Root MSE	0.82171	**R-Square**	0.7559
Dependent Mean	1.55E-18	**Adj R-Sq**	0.7559
Coeff Var	5.31E+19		

Parameter Estimates						
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
avghdd3	1	0.16761	0.0001173	1429.56	<.0001	1.00014
total_save3	1	-1.00661	0.00566	-177.82	<.0001	1.00014

[34] Since it is possible that the billing analysis period weather may be different than the normal TMY3 weather, we examined the differences in heating degree days between the billing analysis period and the TMY3 normals. The TMY3 normal HDDs were 4,710 and the regression model HDDs were 4,832, a 2.5% difference, The model controls for pre and post weather differences already, and no additional normal weather adjustment was made to the savings estimates produced by the models.

APPENDIX B. PSE ELECTRIC MODEL OUTPUTS

CSA Model Overall

The REG Procedure	
Dependent Variable: adc3	
Number of Observations Read	93459
Number of Observations Used	93459
Note: No intercept in model. R-Square is redefined.	

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	28386692	9462231	32030.8	<.0001
Error	93456	27607860	295.41025		
Uncorrected Total	93459	55994553			

Root MSE	17.1875	**R-Square**	0.5070
Dependent Mean	2.29E-16	**Adj R-Sq**	0.5069
Coeff Var	7.50E+18		

Parameter Estimates						
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
avghdd3	1	2.21126	0.00823	268.62	<.0001	1.58372
avgcdd3	1	2.02325	0.07758	26.08	<.0001	1.48667
posthdd3	1	-0.31262	0.0075	-41.70	<.0001	1.11211

Statistically Adjusted Engineering (SAE) Model Alternate Savings Modeling Approach

To obtain a comparative savings estimate, an SAE billing model specification, shown below, was also used to estimate savings. The SAE modeling method and CSA modeling approach primarily differed in the SAE model using PSE *ex ante* savings estimate rather than just a post-installation indicator:

$$ADC_{it} = \alpha_i + \beta_1 * AVGHDD_{it} + \beta_2 * AVGCDD_{it} + \beta_3 * EE_{it} + \varepsilon_{it}$$

Where for home i and month t;

ADC_{it} = average daily usage during the pre- or post-installation period for home i

α_i = unique intercept for each home i

$AVGHDD_{it}$ = average daily heating degree days, base 65º F

$AVGCDD_{it}$ = average daily cooling degree days, base 65º F

EE_{it} = average daily total expected PSE *ex ante* savings in the post installation period, *0* otherwise

β_1 = average daily usage per heating degree day

β_2 = average daily usage per cooling degree day

β_3 = realization rate across all program measures

ε_{it} = the model estimation error

In the model, β_3 directly estimated the program realization rate. Annual SAE model savings were derived by multiplying the overall realization rate with average total annual PSE *ex ante* expected savings. [35]

This produced approximately a 65% realization rate and model savings of 1,349 kWh (64.9% * 2079). As shown in Table B-1, the SAE approach produced a savings estimate considerably lower than the CSA modeling method (Table 11). Both the CSA and SAE modeling approaches provided very accurate savings estimates, however they are both lower than the RTF *ex ante* savings estimates. The primary CSA approach has lower errors on the savings estimates than the SAE modeling approach.

Table B-1. Electric Savings Results (SAE Alternate Model)

Model	N	Average Pre Period kWh	Model Savings (kWh)	RTF Ex Ante Savings (kWh)	Realization Rate	Relative Precision 90% level	T-test	P-Value	Savings as % of Pre kWh
Overall SAE	1,193	17,870	1,349	2,079	65%	4.68%	35.15	<0.0001	8%

[35] Since it is possible that the billing analysis period weather may be different than the normal TMY3 weather, we examined the differences in heating degree days between the billing analysis period and the TMY3 normals. The TMY3 normal HDDs were 5,172 and the regression model HDDs were 5,107, a 1% difference, The model controls for pre and post weather differences already, and no additional normal weather adjustment was made to the savings estimates produced by the models. The cooling load was approximately 220 kWh and normal cooling degree days were very low at 110, and we only examined differences in space heating load where the savings were predominantly occurring.

SAE Model Overall

The REG Procedure	
Dependent Variable: adc3	
Number of Observations Read	93459
Number of Observations Used	93459
Note: No intercept in model. R-Square is redefined.	

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	28239831	9413277	31696.5	<.0001
Error	93456	27754721	296.9817		
Uncorrected Total	93459	55994553			

Root MSE	17.23316	**R-Square**	0.5043
Dependent Mean	2.29E-16	**Adj R-Sq**	0.5043
Coeff Var	7.52E+18		

Parameter Estimates						
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Variance Inflation
avghdd3	1	2.11131	0.008	263.78	<.0001	1.48935
avgcdd3	1	1.99776	0.07783	25.67	<.0001	1.48824
total_save3	1	-0.64932	0.01847	-35.15	<.0001	1.00293

Evaluation Report Response

Program: Clothes Washer

Program Manager: Dennis Rominger

Study Report Name: Regional Technical Forum Savings Review

Report Date: 4/16/2012

Evaluation Analyst: Bobette Wilhelm

Date ERR Provided to Program Manager: 4/16/2012

Date of Program Manger Response: 5/14/2012

Key Impact Evaluation Report Recommendations:

The Cadmus Regional Technical Forum Savings Review suggests that the market baseline for energy efficiency clothes washers has increased and that PSE's Program should consider adjusting the clothes washer annual measure savings.

Report Overview:

Cadmus first calculated the potential savings of an alternative clothes washer rebate structure that PSE is considering. This is Task 1 results below. The alternative structure would align PSE Tiers 1 and 2 with the Consortium for Energy Efficiency (CEE) Tiers 2 and 3, respectively.

Cadmus then examined data sources and methodology used in development of RTF savings estimates for PSE's current two-tier clothes washer program rebate structure. This is Task 2 results below. Cadmus updated the model by:

- Using the latest clothes washer data set;
- Limiting the analysis to clothes washers meeting federal standards taking effect in 2011;
- Grouping clothes washer models by modified energy factor (MEF) and water factor (WF), and not just MEF; and
- Using a recent PSE residential survey to determine the portion of customers with electric heaters and dryers.

These adjustments resulted in clothes washer program annual per machine savings lower than their original values in nine out of 10 configurations.[36] The final adjustment to RTF electricity savings range from -69% to +13%, depending on the efficiency tier and configuration.

Cadmus then compared this updated model with an alternative savings estimate, based on a 2009 Cadmus metering study.[37] Cadmus binned data collected in the metering study into the current PSE 2012 tiers, derived per-cycle energy savings estimates for each clothes washer measure; and compared these savings estimates to those from the updated RTF approach, previously described. Metering study-based savings are within +/-10 kWh/year of the updated RTF value for Tier 1. For Tier 2, metering study-based savings range from 17 kWh/year below the updated RTF value to 45 kWh/year above it.

Cadmus Results Task 1:

Table 1 shows measure savings for current and alternative PSE tiers, including measure savings for each tier and configuration (water heater and dryer type).

Table 8. Electricity Savings for Current & Alternative PSE Clothes Washer Tier Structures

	Configuration			Alternative Tiers		Current Tiers	
PSE Tier	Water Heat Type	Dryer Type	WF	MEF	Annual Measure Savings (kWh)	MEF	Annual Measure Savings (kWh)
1	Any	Any	4.5 or above	2.2-2.39	106	2.2-2.45	112
2	Any	Any	4.0 or above	2.4-2.69	143	2.46-2.69	167
3	Any	Any	4.0 or above	2.7 and above	183	2.7 and above	183
1	Elec	Elec	4.5 or above	2.2-2.39	140	2.2-2.45	149
2	Elec	Elec	4.0 or above	2.4-2.69	188	2.46-2.69	219
3	Elec	Elec	4.0 or above	2.7 and above	240	2.7 and above	240
1	Elec	Gas	4.5 or above	2.2-2.39	80	2.2-2.45	84
2	Elec	Gas	4.0 or above	2.4-2.69	99	2.46-2.69	108
3	Elec	Gas	4.0 or above	2.7 and above	114	2.7 and above	114
1	Gas	Elec	4.5 or above	2.2-2.39	75	2.2-2.45	81

[36] Configuration refers to two different tiers with 5 different mixes of dryer and water heater type for a total of 10 different configurations.

[37] The Cadmus Group, Inc. "Do the Savings Come Out in the Wash? A Large Scale Study of In-Situ Residential Laundry Systems." 2010. http://www.cadmusgroup.com/pdfs/Do_the_Savings_Come_Out_in_the_Wash.pdf

2	Gas	Elec	4.0 or above	2.4-2.69	108	2.46-2.69	130
3	Gas	Elec	4.0 or above	2.7 and above	145	2.7 and above	145
1	Gas	Gas	4.5 or above	2.2-2.39	15	2.2-2.45	16
2	Gas	Gas	4.0 or above	2.4-2.69	19	2.46-2.69	20
3	Gas	Gas	4.0 or above	2.7 and above	20	2.7 and above	20

Cadmus Results Task 2:

Cadmus recalculated savings for 2011 and future years, as shown in Table 2, below. Updated annual electricity savings per clothes washer are lower than their original values in nine out of 10 configurations. The final adjustment from RTF electricity savings to savings calculated with this updated data range from -69% to +13%, depending on the efficiency tier and configuration. These values are based on current PSE tier definitions.

Table 9. Comparison of Updated and Current RTF Electricity Savings for PSE 2012 Clothes Washer Rebate Structure

PSE Tier	MEF	WF	Water Heat Type	Dryer Type	Annual Electricity Consumption (kWh)				Measure Savings (kWh)	
					Baseline		Measure			
					Current RTF	Updated	Current RTF	Updated	Current RTF	Updated
1	2.2– 2.45	4.5 or below	Electric	Electric	636	532	488	484	149	48
1	2.2– 2.45	4.5 or below	Electric	Gas	210	165	127	126	84	39
1	2.2– 2.45	4.5 or below	Gas	Electric	472	416	392	389	81	27
1	2.2– 2.45	4.5 or below	Gas	Gas	46	48	31	31	16	18
1	2.2– 2.45	4.5 or below	Any	Any	500	423	388	388	112	35
2	2.46 or above	4.0 or below	Electric	Electric	636	532	418	417	219	116
2	2.46 or above	4.0 or below	Electric	Gas	210	165	102	128	108	37
2	2.46 or above	4.0 or below	Gas	Electric	472	416	343	325	130	91
2	2.46 or above	4.0 or below	Gas	Gas	46	48	27	37	20	12
2	2.46 or above	4.0 or below	Any	Any	500	423	334	331	167	92

Discussion of Key Findings/Analysis:

For Cadmus task 1 & 2 results, the program team makes the following observations. Page 7 & 8 outlines the model data assumptions used by Cadmus in establishing the baseline. This approach uses all residential models meeting federal standards. Cadmus suggests that a more accurate analysis could be performed by looking at the actual sales of the available product mix. The program team would agree that with a measure like clothes washer, with narrow energy savings, that a closer look at actual sales could provide more perspective into the energy savings associated with PSE's measure.

For Cadmus task 2 only, Cadmus uses a comparison, as outlined on pages 11-13, of metering study results that were done in California. There are some distinctive factors about California that may not allow for a proper savings comparison. This includes behavioral factors, climate, energy prices, and incoming water temperatures. None of these factors were discussed within the Cadmus report on how it may affect savings. At a minimum, the program team would request a comparative analysis between Washington State and California as all of these factors on how they negatively affect savings. A Washington State meter study should be conducted.

Since this is a review of the RTF's approach on clothes washer savings, the program team would like to request a response from the RTF on whether or not they agree with the Cadmus report and methodology used. If the RTF does adopt these updated savings, the RTF and/or PSE will be required to update the incremental measure costs. With the Cadmus task 2 savings estimates, updated measure costs are required in order to determine the cost effectiveness of the clothes washer measure. This is not addressed by Cadmus.

Program Action Plan:

For January 2013, the program team will update to the latest RTF savings, regardless of this Cadmus Clothes Washer savings review. The PSE program team will augment the RTF savings numbers for all "any" clothes washer measures as PSE will reflect our known water heat fuel mix known by the 2011PSE Residential Characteristic Study.

PSE understands that the RTF is in the process of reviewing Federal Standards released on May 16, 2012, and the RTF intends to update savings. If the RTF does update savings between now and the end of 2012, PSE will adopt the most currently published RTF numbers to remain in compliance.

The currently published RTF savings are the electric numbers in use by the PSE program team. For natural gas savings, PSE has deemed savings based upon the accepted RTF kWh to therm conversion spreadsheet.

Action Plan for RTF:

Formally provide the Cadmus savings review and PSE ERR to the RTF and request a response on whether or not they agree with Cadmus report and methodology. If the RTF plans to adopt any part of the Cadmus savings, request timeline for updated measure tables, which would include updated measure costs.