PUGET SOUND ENERGY

Program(s):

- Conservation Voltage Reduction

Program Year(s):

- 2016

Contents:

- PSE Evaluation Report Response
- Evaluation Report

This document contains Puget Sound Energy's (PSE) Conservation Voltage Reduction Program Evaluation Report and Evaluation Report Response (ERR). In accordance with WUTC conditions, all PSE energy efficiency programs are evaluated by an independent, third party evaluator.[1] Evaluations are planned, conducted and reported in a transparent manner, affording opportunities for Commission and stakeholder review through the Conservation Resource Advisory Group (CRAG) and reported to the UTC.[2] Evaluations are conducted using best-practice approaches and techniques.[3]

PSE program managers and evaluation staff 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.

Please note that this is an evaluation of the program as it operated during the 2016-2017 program years, and does not necessarily reflect the program as currently implemented, or measures currently deployed by the program.

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[1] (6)(c.) Approved Strategies for Selecting and Evaluating Energy Conservation Savings, Proposed Conditions for 2016-2017 PSE Electric Conservation.

[2] PSE 2016-2017 Biennial Plan, Exhibit 8: Evaluation, Measurement & Verification (EM&V) Framework, revised August 6, 2015.

[3] Ibid.

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Evaluation Report Response

Program:	Conservation Voltage Reduction
Program Manager(s):	Lionel Metchop
Study Report Name:	Evaluation of the Energy Savings Impacts of PSE's Conservation Voltage Reduction Program
Primary Author(s):	Michael Noreika (Puget Sound Energy)
Report Date:	December 2017
Evaluation Analyst(s):	Michael Noreika
Date of ERR:	January 2018

Evaluation Overview, Key Findings, Recommendations and Program Responses:

I. Context

Puget Sound Energy's (PSE) Conservation Voltage Reduction (CVR) program demonstrates pro-active compliance with I-937 obligations. I-937 is an initiative requiring utilities in Washington to achieve an energy portfolio of 15% renewable energy and to "undertake cost-effective energy conservation." Although CVR energy savings are reported in PSE's Biennial Conservation Plans, PSE does not allocate a Conservation Rider budget for the program.

CVR is a program where the distribution line voltage at a substation is set at a more efficient level while staying within the required customer voltage limit defined by the ANSI Standard range of 114V to 126V. Historically, the practice has been to set the voltage on the higher end of the range in order to safeguard the end-of-line (EOL) voltage. However, advancements in voltage optimization allows utilities to lower the voltage and remain securely within the range.

This report includes an evaluation of the 2016 energy savings reported by the CVR program.

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II. Conclusions, Recommendations, and PSE Responses

A. Overall Performance

For the 2016 program period, the PSE CVR program achieved 93.5% of the reported energy savings as shown in Table 1. PSE used the best available data at the time of the reported energy savings calculation. However, since the time the savings were reported, more recent data concerning residential customer load characteristics became available. The updated load characteristics led to a change in one of the energy savings parameters, which ultimately reduced the evaluated energy savings compared to the reported.

Table 1. Reported vs. evaluated savings for 2016 CVR projects.

Project (Substation Name)	Reported Energy Savings (MWh)	Evaluated Energy Savings (MWh)	Realization Rate†
Hazelwood	1,352.1	1,259.4	93.1%
Panther Lake	804.3	750.7	93.3%
Pine Lakes	1,163.2	1,095.4	94.2%
Total	3,319.6	3,105.5	93.5%

† Realization rate is the evaluated energy savings divided by the reported energy savings.

B. Recommendations and PSE Responses

- **Recommendation:** PSE should continue to use the RTF protocol, but PSE should update the energy savings calculation methodology for future CVR projects to incorporate the most recent residential load characteristics data completed in 2017. Specifically, PSE should change:
    - Percentage of existing residential class consumers that have electric heat from 28.0% to 35.7%
    - Percentage of existing residential class consumers that have any type of electric air conditioning from 25.0% to 27.3%

  PSE Response: PSE will update the analysis calculation methodology to incorporate the new data.

Evaluation of the Energy Savings Impacts of PSE's Conservation Voltage Reduction Program

December 15, 2017

Analysis and Report by:

Michael Noreika

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I. Executive Summary

A. Evaluation Context

Puget Sound Energy's (PSE) Conservation Voltage Reduction (CVR) program demonstrates pro-active compliance with I-937 obligations. I-937 is an initiative requiring utilities in Washington to achieve an energy portfolio of 15% renewable energy and to "undertake cost-effective energy conservation." Although CVR energy savings are reported in PSE's Biennial Conservation Plans, PSE does not allocate a Conservation Rider budget for the program.

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This report includes an evaluation of the 2016 energy savings reported by the CVR program.

B. Conclusions and Recommendations

For the 2016 program period, the PSE CVR program achieved 93.5% of the reported energy savings as shown in Table 1. PSE used the best available data at the time of the reported energy savings calculation. However, since the time the savings were reported, more recent data concerning residential customer load characteristics became available. The updated load characteristics led to a change in one of the energy savings parameters, which ultimately reduced the evaluated energy savings compared to the reported.

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Recommendation: PSE should continue to use the RTF protocol, but PSE should update the energy savings calculation methodology for future CVR projects to incorporate the most recent residential load characteristics data completed in 2017. Specifically, PSE should change:

- Percentage of existing residential class consumers that have electric heat from 28.0% to 35.7%
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II. Introduction

A. Program Description

PSE first researched the relationship between CVR also known as Voltage Optimization (VO), and energy savings in 1983. In 2006, PSE and 13 other Pacific Northwest utilities participated in the Distribution Efficiency Initiative (DEI) managed by Northwest Energy Efficiency Alliance (NEEA). The DEI study was intended to quantify the effects of power consumption in relation to the applied voltage or CVR. The results of the 2007 NEEA study conclusively showed that operating a utility distribution system within the lower half of the acceptable voltage range (120-114 volts) saves energy, reduces demand, and reduces reactive power requirements without negatively impacting the customer. The results of energy savings are within expected values of one to three percent total energy reduction, two to four percent reduction in kW demand, and four to ten percent reduction in kilovolt amperes-reactive (kvar) demand. Computer model simulations showed that by performing selected system improvements, between 10 and 40 percent of the total energy savings occurs on the utility side of the meter.

PSE CVR projects are implemented at selected electric substations. These projects are completed without the assistance of conservation funding, and thus the projects are completed on the timeline of the transmission and distribution (T&D) department of PSE. The energy management engineers are engaged in a reactive manner and determine energy savings for completed projects.

a) Reported Program Achievements (2016)

As shown in Table 2, PSE reported energy savings for three CVR projects in 2016. The projects were implemented in the summer of 2015

Table 2. Summary of CVR program achievements as reported, 2016.

Project (Substation Name)	Reported Energy Savings (MWh)	Project Cost	Implementation Period
Hazelwood	1,352.1	$14,241	Aug-2015
Panther Lake	804.3	$15,573	Aug-2015
Pine Lakes	1,163.2	$9,397	Sept-2015
Total	3,319.5	$39,211	

Source: Analysis of completed CVR projects provided by program staff.

III. Impact Evaluation Findings

A. Reported Savings Methodology

The program relies on the Simplified VO M&V Protocol published by the Regional Technical Forum (RTF).[1] The protocol was approved for use in 2010 and deactivated in 2015. The measure was deactivated as a result of the RTF subcommittee decision that the value of the protocol did not sufficiently justify the necessary resources for proving and maintaining the protocol. However, the RTF agrees that the protocol as published remains a practical method for determining energy savings associated with CVR. Through its review of the calculations, PSE evaluation staff confirmed the correct use of the RTF protocol.

Equation 1 shows the algorithm used in the RTF protocol for each feeder.

Equation 1. Energy savings algorithm used for reported savings calculation.

$$Energy\ Savings_{substation} = \sum_{feeder} \left\{ E_{annual} \times VOf \times \frac{V_{oc} - V_{cvr}}{V_{oc}} \right\}$$

E_{annual} = Annual energy load
VOf = Voltage optimization factor provided in protocol tables
Voc = Average substation voltage before CVR implementation
Vcvr = Average substation voltage after CVR implementation

a) Substation and Feeder Annual Energy Load

Energy consumption data were obtained for the feeders associated with each substation. The data were aggregated by rate category and categorized as Residential, Small Commercial, Large Commercial, and Mix (Residential and Agriculture). Table 3 shows the feeders associated with each substation. The RTF protocol is valid only for feeders that have a majority of residential and small commercial loads. Therefore, PIN-17 was excluded from the reported savings and evaluated savings.

[1] https://rtf.nwcouncil.org/subcommittee/automated-conservation-voltage-regulation-cvr-and-voltage-optimization

Table 3. Substation and feeder energy consumption data and load class (July 2014-June 2015).

Substation	Feeder	Energy Consumption (MWh)	% Residential Load	WECC Load Class†	Included in Energy Savings?
Hazelwood	HAZ-12	30,993	54.9%	MIX	TRUE
Hazelwood	HAZ-13	12,658	86.7%	RES	TRUE
Hazelwood	HAZ-15	21,637	64.4%	MIX	TRUE
Hazelwood	HAZ-16	28,301	89.5%	RES	TRUE
Panther Lake	PAN-12	6,021	90.9%	RES	TRUE
Panther Lake	PAN-13	10,927	87.2%	RES	TRUE
Panther Lake	PAN-14	13,721	85.0%	RES	TRUE
Panther Lake	PAN-15	19,591	85.4%	RES	TRUE
Panther Lake	PAN-16	13,208	82.9%	RES	TRUE
Pine Lakes	PIN-17	7,019	35.9%	MIX	FALSE
Pine Lakes	PIN-23	20,746	75.2%	RES	TRUE
Pine Lakes	PIN-25	20,664	83.7%	RES	TRUE
Pine Lakes	PIN-26	22,654	91.9%	RES	TRUE
Pine Lakes	PIN-27	18,734	65.9%	RES	TRUE

† Load class is defined in the Western Electricity Coordinating Council (WECC) "Composite Load Model for Dynamic Simulations" report dated June 12, 2012.

b) Voltage Reduction Determination

The reduction in substation voltage was observed upon implementation of the projects using 15-minute interval energy usage data at each substation. Average voltage readings were analyzed for one month prior to implementation and one month after implementation. Table 4 shows the voltage readings and percent average voltage reduction for each substation included in the evaluation.

Table 4. Substation voltage reduction after CVR implementation.

Project (Substation Name)	Avg. Pre-Implementation Voltage	Avg. Post-Implementation Voltage	Avg. Voltage Change	% Avg Voltage Reduction
Hazelwood	122.44	118.97	3.47	2.83%
Panther Lake	122.48	119.43	3.05	2.49%
Pine Lakes	122.08	118.68	3.40	2.79%

c) Voltage Optimization Factor Determination

The RTF protocol relies on data obtained through the DEI project and estimates VO factors based on the following parameters:

- "Heating and cooling climate zone classification for each substation area
- Percentage of existing residential class consumers that have electric heat
- Percentage of existing residential class consumers that have any type of electric air conditioning"[2]

The PSE 2010 Residential Characteristics Study (RCS) reported the percentage of residential customers with electric heat as 28.0% and the percentage of residential customers with electric air conditioning as 25.0%. By applying those values to the RTF protocol, the applicable VO factor is 0.510.

See Appendix A for the full matrix of VO factors.

B. Evaluated Savings

The evaluation methodology followed the RTF protocol. Energy consumption data for the three substations were accessed for the same period used in the reported savings (July 2014-June 2015) and July 2015-May 2016. The July 2015-May 2016 period was analyzed to ensure that no significant changes to the customer class had occurred since the implementation of the CVR projects. No significant changes to feeder load characteristics were identified.

Since the implementation of these CVR projects, PSE completed an updated residential characteristics study. As such, the evaluated savings calculation replaced the 2010 RCS data with the 2017 RCS data for a more accurate representation of load characteristics at the time of the CVR implementation. Table 5 shows both the 2010 and 2017 data relevant to the RTF protocol. Since 2010, both the percentage of residential consumers with electric heat as well as the percentage of residential consumers that have electric air conditioning have increased. By applying the new values to the RTF protocol, the applicable VO factor is 0.475. As such, this evaluation recommends PSE continue to report savings using the RTF protocol, but PSE should incorporate the updated RCS data and change the VO factor used in the energy savings calculation.

[2] Regional Technical Forum. "Simplified voltage optimization (VO) measurement and verification protocol." (Portland, OR: 2010). Accessed December 2017. https://rtf.nwcouncil.org/subcommittee/automated-conservation-voltage-regulation-cvr-and-voltage-optimization

Table 5. Load characteristics data available from PSE Residential Characteristics Studies (RCS).

Parameter	2010 RCS	2017 RCS
Percentage of existing residential class consumers that have electric heat	28.0%	35.7%
Percentage of existing residential class consumers that have any type of electric air conditioning	25.0%	27.3%

Source: Energy savings analysis files; 2017 RCS

IV. Appendix A: Savings Review Details

Figure 1. Measured voltage data for each substation

Hazelwood

AVERAGE VOLTAGE AT SUBSTATION BEFORE	122.44
AVERAGE VOLTAGE DROP AT EOL BEFORE	121.24
AVERAGE VOLTAGE AT SUBSTATION AFTER	118.97
AVERAGE VOLTAGE DROP AT EOL AFTER	117.95
Delta Voltage	3.47
% V reduction	0.0283

Panther Lake

AVERAGE VOLTAGE AT SUBSTATION BEFORE	122.48
AVERAGE VOLTAGE DROP AT EOL BEFORE	121.53
AVERAGE VOLTAGE AT SUBSTATION AFTER	119.43
AVERAGE VOLTAGE DROP AT EOL AFTER	117.35
Delta Voltage	3.05
% V reduction	0.0249

Pine Lakes

AVERAGE VOLTAGE AT SUBSTATION BEFORE	122.08
AVERAGE VOLTAGE DROP AT EOL BEFORE	121.86
AVERAGE VOLTAGE AT SUBSTATION AFTER	118.68
AVERAGE VOLTAGE DROP AT EOL AFTER	118.32
Delta Voltage	3.40
% V reduction	0.0279

Table 6. End-use voltage optimization factors from RTF protocol for Climate Zone 1 and Heating Zone 1.

	% of Customers with Non Electric heat and Heat Pumps (e.g. gas, oil, or wood heat)										
%AC	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
20%	0.270	0.300	0.330	0.360	0.390	0.430	0.470	0.510	0.570	0.630	0.700
25%	0.280	0.305	0.335	0.365	0.395	0.435	0.475	0.515	0.570	0.630	0.695
30%	0.290	0.310	0.340	0.370	0.400	0.440	0.480	0.520	0.570	0.630	0.690
35%	0.290	0.315	0.345	0.375	0.405	0.445	0.485	0.525	0.575	0.630	0.690
40%	0.290	0.320	0.350	0.380	0.410	0.450	0.490	0.530	0.580	0.630	0.690
45%	0.295	0.325	0.355	0.385	0.415	0.450	0.490	0.535	0.580	0.630	0.690
50%	0.300	0.330	0.360	0.390	0.420	0.450	0.490	0.540	0.580	0.630	0.690

Note: The gray shaded rows are linearly interpolated.

Table 7. Western Electricity Coordinating Council (WECC) classification of load types.

Load Type	Load Mix	Res	Com	Ind	Agr	Data	Service
Residential	RES	75%	23%	0%	0%	0%	2%
Commercial	COM	20%	73%	0%	0%	5%	2%
Mixed	MIX	45%	48%	0%	0%	5%	2%
Rural/Agricultural	RAG	40%	20%	15%	25%	0%	0%

Table 8. Evaluated savings analysis table.

Feeder	Usage (kWh) 07/2014 thru 06/2015	Summary of Percent Customer Type					Load Class	RTF protocol applicable?	% Electric Heat:	VO Factor	%V reduction (Voc-Vcvr)/Voc	ΔE (kWh)	Period of Implementation
		Residential	Small Com.	Large. Com	Mix (Res + Ag)	Total % (CHECK)							
HAZ-12	30,992,712	54.9%	12.5%	30.2%	2.5%	100.0%	MIX	Yes	35.7%	0.475	2.83%	417,067	From: 8/24/2015 @ 11:30:00 AM
HAZ-13	12,657,970	86.7%	4.5%	8.2%	0.6%	100.0%	RES	Yes	35.7%	0.475	2.83%	170,337	
HAZ-15	21,636,572	64.4%	10.0%	24.1%	1.5%	100.0%	MIX	Yes	35.7%	0.475	2.83%	291,162	To: 8/27/2015 @ 11:30 AM
HAZ-16	28,301,224	89.5%	3.9%	3.4%	3.3%	100.0%	RES	Yes	35.7%	0.475	2.83%	380,848	
PAN-12	6,020,575	90.9%	0.7%	8.4%	0.1%	100.0%	RES	Yes	35.7%	0.475	2.49%	71,214	From: 8/24/2015 @ 10:15:00 AM
PAN-13	10,927,475	87.2%	0.3%	12.4%	0.2%	100.0%	RES	Yes	35.7%	0.475	2.49%	129,255	
PAN-14	13,721,456	85.0%	1.2%	13.6%	0.2%	100.0%	RES	Yes	35.7%	0.475	2.49%	162,304	
PAN-15	19,590,758	85.4%	9.4%	4.4%	0.8%	100.0%	RES	Yes	35.7%	0.475	2.49%	231,729	To: 8/30/2015 @ 10:15:00 AM
PAN-16	13,207,775	82.9%	8.1%	6.1%	2.9%	100.0%	RES	Yes	35.7%	0.475	2.49%	156,228	
PIN-17	7,019,475	35.9%	9.8%	54.0%	0.3%	100.0%	MIX	No	35.7%	0.475	2.79%	0	From: 09/14/2015 @ 11:00 AM
PIN-23	20,746,032	75.2%	6.0%	10.0%	8.9%	100.0%	RES	Yes	35.7%	0.475	2.79%	274,450	
PIN-25	20,663,814	83.7%	5.5%	9.2%	1.5%	100.0%	RES	Yes	35.7%	0.475	2.79%	273,362	To: 09/20/2015 @ 11:00 AM
PIN-26	22,654,406	91.9%	3.7%	3.6%	0.8%	100.0%	RES	Yes	35.7%	0.475	2.79%	299,696	
PIN-27	18,734,721	65.9%	11.3%	22.3%	0.5%	100.0%	RES	Yes	35.7%	0.475	2.79%	247,842	
											Total	3,105,493	