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Long-Term Monitoring and Tracking Distribution Efficiency

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Table of Contents

List of Figures and Tables

Figures:

Tables:

Executive Summary

This report documents Navigant Consulting, Inc.'s (Navigant's) research into the current status of distribution efficiency (DE) in the Pacific Northwest (PNW). It provides a market characterization of the breadth and depth of DE activity based on a sample of utilities within the PNW and an assessment of the applicability of tools available to utilities in assessing the cost/benefit of implementing DE measures. Navigant also conducted an impact evaluation of Avista Utilities' conservation voltage regulation (CVR) project.

Market Characterization

Navigant's market characterization effort focused on developing information on the following questions:

- The degree to which regional utilities have already implemented measures, such as CVR, to improve DE
- The degree to which regional utilities understand and are aware of opportunities to improve the efficiency of their distribution systems
- Attitudes toward a variety of potential DE measures among utility personnel who are responsible for planning decisions regarding their utilities' distribution systems
- Barriers that inhibit adoption of DE measures
- Factors that have promoted the adoption of DE measures among utilities that have adopted them
- Utility efforts to evaluate energy and/or demand savings from DE projects they have conducted
- Plans for future DE projects

Methodology

In conjunction with the NEEA project manager and interested parties from BPA, Navigant selected a sample of thirty regional utilities including all of the investor-owned utilities (IOUs) and twenty-four public utilities spanning the spectrum of size and experience with distribution efficiency. Navigant contacted transmission and distribution planners and demand-side management managers at each of the sampled utilities and conducted in-depth interviews exploring the above subject areas with all willing participants. Navigant was able to conduct a total of thirty-four interviews with individuals at twenty-eight utilities.

Findings

Navigant asked those participating in the interview process about whether their utilities had implemented a set of ten measures that can improve the efficiency of distribution systems. Many of the respondents indicated that their utilities had implemented one or more of these measures, but frequently stated that they had done so primarily to improve reliability or to serve a growing load, and that the efficiency benefits were of a secondary nature. The exceptions to this are CVR and de-energizing seasonally unloaded transformers (primarily serving irrigation pumps), which were conducted solely for efficiency purposes. Of the utilities that have implemented or are investigating CVR, the majority (12 of 14) are those utilities that have participated in BPA's Energy Smart Utility Efficiency (ESUE) program, or are IOUs that have received legislative or regulatory directives to implement cost-effective DE.

Most utilities in the region appear to be aware of the concept of DE and are able to articulate a reasonably accurate definition of the term. Respondents indicated similar levels of awareness of CVR, although familiarity with CVR is far lower among small rural utilities. Likewise, IOUs and utilities that have participated in BPA's ESUE program have been more active in educating staff and are much more likely to have conducted research on DE than have their peers from small rural utilities.

The individuals Navigant spoke with overwhelmingly believe that there are opportunities for efficiency improvements on their distribution systems, and that utilities should be investing in those opportunities, though many caution that the cost-effectiveness of such investment is not always clear. The respondents were more cautious when asked specifically about CVR. Few respondents had strongly negative attitudes about CVR, but some expressed reservations about whether CVR would be viable on their systems, mostly for technical reasons.

When Navigant asked generally about barriers to improving efficiency in their distribution system, respondents overwhelmingly reported that capital availability and cost- effectiveness were the two biggest barriers. Other barriers that respondents mentioned frequently include low priority for DE, knowledge about opportunities, personnel constraints, system constraints and regulatory constraints.

Respondents also frequently mentioned cost-effectiveness as a driver for investments in DE. In fact, 25 of the respondents mentioned cost-effectiveness as the primary reason for implementing a DE measure. This apparent contradiction is resolved by noting that many respondents believe that DE should be implemented where it is cost-effective, but that in many cases DE measures are not cost-effective. Over half of the respondents reported incentives and regulations as the primary motivation that has led to CVR implementation. I-937[1], funding from DOE's Smart Grid Investment Grant program, and BPA were mentioned as the explicit drivers for implementation.

In response to Navigant inquiries about evaluation of DE measures, one respondent described an initial study in process, 16 respondents (representing 14 utilities) described some level of study/analysis to determine potential impacts and benefits had been performed at some point in the past, and eight respondents (representing six utilities) described detailed studies—some resulting in positive and some in negative decisions about moving forward.

When Navigant asked about future plans to implement DE measures, the most common measure respondents discussed was CVR. Fourteen respondents indicated future plans for CVR projects. All of the respondents indicating future plans were IOUs or participants in BPA's ESUE

[1] Initiative number 937 (I-937) is a Washington state regulation, mandating that utilities obtain increased portions of their electricity from renewable sources and undertake cost-effective energy conservation measures.

program. Six respondents indicated plans within the next two years, and eight had plans in the two- to five-year range. Other respondents had plans five or more years out or did not know.

Conclusions and Recommendations

Small rural utilities are not subject to PUC regulations, but do face significant informational barriers to implementing DE measures. As a result, they are much less informed about DE opportunities, are much less likely to have knowledgeable employees and much less likely to have conducted research into DE potential on their systems. **If NEEA and/or BPA wish to promote distribution efficiency in the PNW, either or both could develop an Internet-based educational resource, focused primarily on these utilities, detailing the most frequently cost effective opportunities for DE.**

Although there are financial and informational barriers to DE, there do not appear to be attitudinal barriers. However, the respondents Navigant spoke with frequently commented that utilities rarely conduct distribution system improvements solely or even primarily to achieve energy or demand savings. Most often, utilities conduct system improvements to serve a growing load or to improve service reliability, and these improvements often improve efficiency as a side benefit. There are frequently opportunities to capture cost effective efficiency improvements when utilities are replacing distribution system components or expanding service into new areas that would not likely be cost effective at other times. **If NEEA and/or BPA wish to promote DE in the PNW, either or both could develop an informational campaign focusing on these "lost-opportunity" measures, and offer incentives to encourage utilities to adopt such measures when they are making system improvements for other purposes.**

Financial incentives have been effective in motivating utilities to investigate the potential CVR on their systems, and in many cases making implementation financially advantageous to the utility. **If BPA wishes to continue promoting the diffusion of CVR to more of the utilities it serves, it should continue to offer and promote the incentives available through its ESUE program or other mechanisms.**

Many feeders in the PNW have been poor candidates for CVR due to the costs of remediation necessary to enable CVR. There are new technologies that support voltage at the end of the line (and upstream as needed) by sensing feeder load and injecting reactive power on the secondary side of the distribution transformer. There is emerging evidence that, under some conditions at least, these technologies can be very cost-effective, and allow utilities to implement greater voltage reductions, and thus obtain greater savings, without extensive modifications to the feeder. **As small rural utilities appear to be a particularly hard to reach sector within the PNW utility market, Navigant suggests that NEEA and/or BPA follow the results of early deployments of these technologies. If these early results prove promising, Navigant recommends that NEEA and/or BPA consider funding a pilot to investigate the extent to which these technologies can enable CVR on long rural feeders, and to characterize the costs and benefits of doing so.**

Evaluation Tool Assessment

The primary objective of the tool assessment was to identify tools that have been used to evaluate and predict demand and energy savings for utilities employing CVR, and resulting CVR factors. The evaluation focuses on tools that NEEA partner utilities, large and small, can use to reliably predict CVR demand and energy savings. These tools range from comprehensive simulation models using rigorous evaluation techniques and extensive data input used by larger utilities with extensive CVR deployment, to less rigorous tools with fewer data requirements for use by smaller utilities or those with limited CVR deployment.

Methodology

The benefits of CVR can be verified using statistical (i.e. regression analysis) or simulation analysis using distribution feeder models such as CYME, SynerGEE, WindMil, and ETap. Navigant compared the strengths and weaknesses of these models, contacted utilities, and researched numerous published reports and documents to identify tools and methods utilities have or plan to use to derive CVR impacts and benefits. Navigant compared these tools and practices to those employed by utilities within and outside NEEA, including jurisdictions where CVR has been mandated by regulatory agencies.

Findings

Distribution models are used by many utilities that are responsible for short- and long-term distribution planning. Forecasted loads, expected changes in configuration, new devices, and distributed resources are incorporated in model databases, and simulation studies are conducted for each of these changes to determine when feeder upgrades, modification or other types of mitigation may be required. The use of traditional models to evaluate CVR presents a challenge to program M&V staff, as accurate savings estimates typically require time series simulation and a more detailed load model that fully captures the end-use characteristics and behaviors described above. Nonetheless, many utilities rely on traditional models for estimating savings.

Table 1 shows a list of representative distribution planning models along with their developers or vendors. Some models are provided by vendors and others by research laboratories and agencies. Some are in the process of linking to distribution management systems (DMSs) for near-real-time analysis, enhanced planning, and energy efficiency evaluation, including the ability to use very accurate state information provided by smart devices located on distribution feeders or from AMI at customer premises.

Distribution simulation tools have evolved to include sophisticated DMSs that integrate data from field measurement devices and communications to enable real-time control, automation, and evaluation, including voltage control functionality. However, few would be acquired and installed solely for CVR applications or measurement, as DMSs typically include a suite of applications to provide visualization and control of many equipment components and systems to improve operations, performance, and reliability of distribution assets.

The availability of distribution voltage data from installation of smart meters and integrated communications systems (i.e., AMI) provides an opportunity to monitor and collect real-time voltages at selected locations along distribution feeders. Vendors have developed solutions and product offerings to leverage AMI to provide an integrated solution to CVR control and measurement. Typically, only a small subset of AMI meters is needed as voltage sensors to provide sufficient feedback for use in measurement protocols or centrally controlled CVR algorithms.

Table 1. Distribution Planning Models Matrix

Distribution System Planning Models	Developer/Vendor
CYMDist	Cooper Power Systems/CYME
ETAP Distribution Software Suite	ETAP
Electricity Distribution Grid Evaluator (EDGE)	Rocky Mountain Institute (RMI)
ES-Grid	DNV KEMA
GridLAB-D	PNNL
LoadSEER	Integral Analytics, Inc.
Open Distribution System Simulator (OpenDSS)	EPRI
SynerGEE	GL Group
WindMil	Milsoft Solutions

Source: Navigant

Conclusions

Utilities currently use a wide range of methods and tools to measure and verify CVR performance and savings. Many use traditional feeder simulation models, conducting before-and-after studies under a set of assumptions accounting for seasonal and time of day variations. The more sophisticated applications recognize the relationship between voltage and load characteristics that traditional simulation modeling applications may not fully capture. One of these initiatives is currently under development by WSU on behalf of Avista Utilities. Like other initiatives, the WSU model is still under development and currently limited to beta applications.

Because of the cost and effort associated with the implementation of sophisticated tools, many utilities continue to use industry-accepted protocols that rely on field measurements and statistical verification, particularly those with CVR programs designed to comply with regulatory mandates or for recovery of energy efficiency investments. Increasingly, vendors are incorporating CVR into integrated Smart Grid, AMI, and distribution management systems, some of which use statistical methods to predict savings. Thus far, CVR pilots utilizing advanced control schemes and integrated AMI have demonstrated solid results. However, there has not been widespread application and confirmation of the validity and cost-effectiveness of integrated systems. A greater number of proven, peer-reviewed studies, with quantifiable benefits versus cost, need to be undertaken to confirm their use for CVR M&V. Further, even for proven technologies and tools, the cost and scope of a fully implemented, integrated system may exceed the needs and available funds of many utilities.

Table 2 summarizes the advantages and disadvantages of the approaches used to predict CVR factors and savings. Significantly, there appear to be few tools available that combine ease of use with highly accurate and defendable savings verification.

The increasing number of reported CVR measurements, study results, and publicly available data suggests that it may soon be possible to develop industry benchmarks to predict CVR savings for small utilities or those seeking to estimate benefits without the same degree of rigor as accepted protocols or integrated AMI/IVVC systems. As the database of reported results grows for feeders with similar attributes in different regions and climate zones, there may be sufficient commonality in reported results to develop reasonably accurate benchmarks. The benchmarks would include demand and energy savings for a range of feeder types, loads and regions, developed using weighted averages and statistical methods to confirm results within accepted precision and accuracy.

Table 2. CVR Tools

Description	Advantages	Disadvantages
Conventional Distribution Simulation Models (Load Flow)	• Models extensively used by utilities • Able to perform related DE analyses	• Only provides a snapshot of savings • Many unable to perform time series analysis • Possible inaccurate predicted savings or CVR factors • Costly initial setup
Open-Source, Time Series Simulation Models	• Free, open-source license • Most accurate of distribution simulation models	• Requires extensive data input and simulation time series analysis that may be burdensome to many users
High-Level Screening/Evaluation Tools	• Inexpensive or free software • Easy to apply • Relatively accurate economic screening	• May not provide CVR factors, or factors are very high-level • May not pass regulatory scrutiny
Integrated DMSs	• Real-time, predictive methods of CVR impacts and performance • Multiple applications and benefits beyond CVR	• Expensive and complex systems • Burdensome to implement (esp. smaller utilities)
Standard Evaluation Protocols	• Proven approach used by many utilities • Accepted by regulatory authorities	• Long and costly evaluation • Significant data collection effort

Source: Navigant

1 Introduction

This report documents part of Navigant Consulting, Inc.'s (Navigant's) research into the current status of distribution efficiency (DE) in the Pacific Northwest (PNW). As part of the Long-Term Monitoring and Tracking of the Northwest Energy Efficiency Alliance's (NEEA's) work in promoting DE, NEEA contracted with Navigant in spring 2013 to conduct a three-part research project:

1. Provide a general assessment and market characterization of the breadth and depth of DE activity based on a sample of utilities within the PNW.

2. Provide an assessment of the applicability of tools available to utilities in assessing the cost/benefit of implementing DE measures, including potential alternative tools and/or approaches.

3. Conduct specific evaluation efforts related to Avista Utilities and their respective service territory, including the evaluation of savings for the purposes of I-937 (WA) measurement.

This report presents the results of Navigant's work on these objectives.

1.1 Motivation for this Research

Although NEEA's Distribution Efficiency Initiative (DEI) demonstrated conclusively that conservation voltage regulation (CVR)—the practice of reducing distribution voltage to improve end-use efficiency and reduce distribution losses—can be implemented cost effectively without negative impacts on electricity consumers, few regional utilities have implemented the practice on their distribution systems since the first phase of the DEI terminated in 2008.[2] Wishing to understand the current market dynamics and utility decision making regarding CVR, and more generally DE, in the PNW, NEEA issued a solicitation for research into this issue.

As NEEA requested in its solicitation, Navigant has conducted market research to elucidate the following:

- The degree to which regional utilities understand and are aware of opportunities to improve the efficiency of their distribution systems

- The degree to which regional utilities have already implemented measures, such as CVR, to improve DE

- Attitudes toward a variety of potential DE measures among utility personnel who are responsible for planning decisions regarding their utilities' distribution systems

[2] NEEA completed the first of the three phases in 2008 but its regional stakeholders did not elect to continue funding regional DE efforts.

- Factors that have promoted the adoption of DE measures among utilities that have implemented them
- Barriers that inhibit adoption of DE measures
- Utility efforts to evaluate energy and/or demand savings from DE projects they have conducted
- Plans for future DE projects

Section 2 of this report describes Navigant's market characterization methodology, the findings resulting from a series of market characterization interviews, and Navigant's conclusions and recommendations based on those findings.

In addition to investigating the dynamics of the market for DE, NEEA also wished to develop an updated list of evaluation tools that large and small utilities can use to estimate savings from DE measures. The tools and techniques that are available to utilities to assess real or potential savings from implementing DE have evolved considerably since the conclusion of the DEI, and continue to improve as more utilities deploy advanced metering infrastructure (AMI) and elements of distribution automation. As utilities and regulatory bodies express increasing interest in CVR, several vendors and research organizations have developed or expanded the capabilities of the software tools they offer to evaluate these savings. Section 3 of this report presents the results of Navigant's research into the available tools.

1.2 Recent History of Distribution Efficiency in the Pacific Northwest

Between January 2003 and the end of 2007, NEEA implemented its DEI, a multiyear project aimed at demonstrating the potential to improve electric distribution system efficiency in the PNW through CVR. The intended goal of the DEI was to increase the implementation of CVR among the utilities in the region.[3] When DEI started in 2003, only about ten U.S. utilities practiced CVR, including Snohomish County Public Utility District (PUD) and Idaho Power in the PNW (Global Energy Partners, 2008).

The DEI program covered both load research and pilot demonstration project phases, including activities to assist with measurement and verification of savings from CVR. Six utilities participated in demonstration projects, including Avista, Clark Public Utilities, Douglas PUD, Idaho Power, Puget Sound Energy, and Snohomish PUD. Pilot demonstrations included ten substations and 31 distribution feeders across these utilities.

[3] Thirteen utilities participated in the DEI—Avista, Clark Public Utilities, Douglas PUD, Eugene Water & Electric Board, Franklin PUD, Hood River, Idaho Falls Power, Idaho Power, PacifiCorp, Portland General Electric, Puget Sound Energy, Skamania PUD, and Snohomish PUD.

During DEI, the PNW led the country in voltage regulation activity. Demonstration and research projects suggested that, at least for feeders similar to those studied by the DEI, CVR had the potential to provide one to three percent savings for energy, two to four percent savings for peak demand, and four to ten percent savings for kilovolt-amperes-reactive (kVAR) demand. The DEI project showed these savings were achievable without negatively affecting customers (R.W. Beck, 2007).

After the completion of the first phase of DEI in 2007, the majority of feeders affected were returned to operation at their previous voltage levels. While the DEI activities did not spur widespread adoption of CVR in the region, they did establish CVR as a potential approach for utilities to meet energy efficiency targets. As a result, the Northwest Power and Conservation Council included CVR in their sixth power plan, estimating a potential of 400 average megawatts of reduction via CVR by 2029 (NWPCC 2010).

From 2010 through 2011, the Bonneville Power Administration (BPA) funded the Energy Smart Utility Efficiency (ESUE) program. The ESUE program conducted scoping studies and cost/benefit analyses to determine the feasibility of CVR at many utilities in the region. As part of the scoping studies, the ESUE program identified distribution system upgrades that needed to take priority over implementation of CVR. The ESUE program identified many scenarios where end-of-line voltages were too low or where feeder voltage profiles needed to be flattened before utilities could implement CVR. The ESUE program presented system stability thresholds and recommended that utilities meet them prior to implementing CVR.

In contrast to the DEI program, BPA sought to spur distribution system upgrades by offering distribution-level efficiency improvement measures through the ESUE program. This included incentives and reimbursements for high-efficiency transformer replacements, load balancing, re-conductoring, capacitor banks, substation upgrades, and voltage optimization. Utilities were able to access capital to perform distribution system efficiency upgrades. BPA has continued to provide incentives for distribution efficiency over the years.

Starting in 2009, the Pacific Northwest Smart Grid Demonstration Project (PNSGDP) became another motivator for CVR work in the PNW. The PNSGDP seeks to validate new Smart Grid technologies, increase communication techniques and technologies, quantify Smart Grid costs and benefits, validate new business models, and to advance interoperability standards and cyber security approaches. The U.S. Department of Energy (DOE), through money provided by the American Recovery and Reinvestment Act of 2009 (ARRA), provides funding for the PNSGDP.

Several utilities in the PNW are involved in the PNSGDP.[4] Avista, NorthWestern Energy, Milton-Freewater, and Peninsula Light are currently pursuing CVR demonstration projects through the PNSGDP. These utilities are continuing to test the feasibility of CVR over the next two years.

[4] Utilities participating include: BPA, Avista, Benton PUD, City of Ellensburg, Flathead Electric, Idaho Falls Power, Lower Valley Energy, Milton-Freewater City Light and Power, NorthWestern Energy, Peninsula Light Company, Portland General Electric, and Seattle City Light.

2 Market Characterization

As an initial part of the market characterization task, Navigant developed a stand-alone "viewpoint memo" to outline past and current developments in the PNW regarding DE, focusing primarily on CVR. In developing this memo, Navigant conducted an extensive literature review (sources are presented in a table at the end of Appendix A) and conducted phone interviews with two stakeholders intimately involved with DE in the PNW. For the literature review, Navigant referenced web articles, presentations, electric utility integrated resource plans (IRPs), and conference and industry reports to inform current CVR activities in the PNW. The memo is included as Appendix A to this report.

The bulk of Navigant's market characterization effort consisted of a set of structured, in-depth interviews (IDIs) with a sample of subject matter experts at large and small utilities throughout the region.

The following subsection provides a detailed description of Navigant's methodology for this task, including sample selection, interview guide development, interview scheduling and conduct, and data analysis. Subsection 2.2 presents Navigant's findings based on the information collected during the interviews. In subsection 2.3, Navigant presents the conclusions it draws from the factual information in subsection 2.2, and recommendations based on those conclusions.

2.1 Methodology

The following subsections present Navigant's approach to achieving the market characterization research objectives. This includes sample design and selection, interview guide development, and scheduling and conducting the interviews.

2.1.1 Sample Frame Stratification

The sample frame for the IDI effort consisted of all NEEA funders that are distribution utilities in the PNW.

The solicitation that resulted in this project indicated that NEEA's goal was to attempt to sample across the spectrum of utility types, sizes, and distribution efficiency experience to arrive at a qualitatively representative picture of the current status of awareness, attitudes, barriers, drivers, and accomplishments regarding DE in the PNW, but that the sample need not be designed to achieve any specific level of statistical significance. Subsequent discussions with the NEEA project manager and BPA personnel clarified that characteristics such as utility ownership (public vs. investor-owned) and degree of activity in assessing DE opportunities were more important considerations for selecting a representative sample than are utility geography or size. Accordingly, in consultation with NEEA and BPA personnel, Navigant developed market stratification and sampling methodology designed to represent the diversity of regional utilities in ownership type and degree of activity in assessing DE opportunities. In addition to these two strata, BPA had specified a set of six utilities as a "Certainty" stratum for inclusion in the sample.

Navigant segmented the population of utilities in the NEEA region into two groups: investor-owned utilities (IOUs) and public utilities (including municipal utilities, co-ops, and PUDs). Table 3 presents the number of each type of utility and their absolute and relative shares of megawatt-hour (MWh) sales, aggregate peak summer demand, and number of customers.

Table 3. Utility Population by Ownership Type

	Value		Percent of Population	
	Public	IOU	Public	IOU
Number of Utilities	135	6	96%	4%
Aggregate MWh Sales	72,011,682	88,980,695	45%	55%
Aggregate Summer MW	11,304	47,245	19%	81%
Aggregate Winter MW	14,776	45,881	24%	76%
Aggregate # of Consumers	2,510,818	3,854,218	39%	61%

Source: U.S. Energy Information Administration (EIA), 2011 data

As this table demonstrates, although IOUs account for just four percent of the number of regional utilities, they account for over half of total energy sales and well over half of aggregate demand and customer count. Due to their size and the fact that the regulatory requirements and economic incentives for implementing DE measures can be distinctly different between IOUs and public utilities, Navigant selected the entire stratum of IOUs for inclusion in the sample for IDIs.

Navigant further stratified the population of public utilities based on information identifying BPA customer utilities that have actively assessed the potential for DE on their systems. At BPA's recommendation, Navigant used a utility's participation in BPA's ESUE program as the indicator that a utility had actively assessed the potential for DE improvements. The ESUE program offers utilities incentives to implement DE measures such as CVR and a wide range of other measures, such as re-conductoring, transformer replacements, and load balancing. Participation in this program requires that utilities work with a qualified technical service provider to identify DE opportunities and develop a measurement and verification (M&V) plan to assess benefits in advance of implementing such measures.

Note that while participation in the ESUE program indicates that a utility has been actively engaged in evaluating DE and may or may not have implemented or developed plans to implement DE measures, the converse is not necessarily true. Utilities that have **not** participated in the ESUE program **cannot** be said with certainty to have no knowledge of DE opportunities or experience in evaluating or implementing DE opportunities. The project team had no a priori information on the extent of this group of utilities' understanding of or experience in evaluating or implementing DE opportunities. Accordingly, Navigant segmented all BPA ESUE participants into a "DE Active" stratum, and all other public utilities into a "DE Unknown" stratum. Since all members of the "Certainty" stratum (Tacoma Power, Central Lincoln PUD, City of McMinnville, Flathead Electric Coop, Inland Power & Light Company, and Cowlitz County PUD) were ESUE participants, they were all included in the "DE Active" stratum.

Table 4 presents the number of utilities as well as the absolute and relative shares of MWh sales, aggregate peak summer and winter demand, and number of customers in each stratum.

Table 4. Final Population Stratification

	Statistic	Percent of Population

	DE Active	DE Unknown	IOU	DE Active	DE Unknown	IOU
Number of Utilities	14	121	6	10%	86%	4%
Aggregate MWh Sales	33,074,666	38,937,016	88,980,695	21%	24%	55%
Aggregate Summer MW	4,554	6,751	47,245	8%	12%	81%
Aggregate Winter MW	6,394	8,382	45,881	11%	14%	76%
Aggregate # of Consumers	1,147,059	1,363,759	3,854,218	18%	21%	61%
Source: U.S. EIA, 2011 data						

2.1.2 Sample Selection

Following completion of the sample frame stratification described above, Navigant selected a sample of 30 utilities for IDIs. Again, Navigant select this number to achieve any predetermined degree of statistical precision; it was merely Navigant's estimate of the number of utility interviews needed to provide a reasonably representative sample.

Sample selection proceeded as follows:

1. Each utility was assigned to one of the three strata. The six utilities designated in the request for proposals for this project as the "Certainty" utilities were identified as a substratum within the "DE Active" stratum.

2. Each utility was assigned a random number.

3. The sample frame was sorted using the following indices:

    a. "Certainty" indicator (binary within the "DE Active" stratum)

    b. Stratum (alphabetical)

    c. Random number (highest to lowest)

4. As the six IOUs account for a large proportion of energy sales, peak demand, and number of customers, all six were included in the sample. Since aggregate energy sales, peak demand, and number of customers were similar between the "DE Active" and "DE Unknown" strata, the remaining 24 sampled utilities were split evenly between these strata. In the DE Active stratum, Navigant selected the six members of the Certainty substratum, and six additional stratum members by random number. In the DE Unknown stratum, Navigant selected the 12 utilities with the highest random numbers.

Table 5 presents the number of utilities sampled in each stratum, as well as the aggregate energy sales, peak summer and winter demand, and number of customers in each stratum. The three columns on the right side of the table indicate the percentage of the total stratum value represented by the sampled utilities.

Table 5. Data on Sampled Utilities

	Value			Percent of Stratum		
	DE Active	DE Unknown	IOU	DE Active	DE Unknown	IOU
Number of Utilities	12	12	6	86%	10%	100%
Aggregate MWh Sales	32,054,911	4,962,401	88,980,695	97%	13%	100%
Aggregate Summer MW	4,376	713	47,245	96%	11%	100%
Aggregate Winter MW	6,186	777	45,881	97%	9%	100%
Aggregate # of Consumers	1,111,597	149,230	3,854,218	97%	11%	100%

Source: U.S. EIA, 2011 data

Table 6 presents the utilities selected for IDIs.

Table 6. Sampled Utilities

DE Active	DE Unknown	IOU
Tacoma Power*	City of Sumas	Avista Corp.
Central Lincoln PUD*	City of Weiser	NorthWestern Energy, LLC.
City of McMinnville*	PUD No. 3 of Mason County	PacifiCorp
Flathead Electric Coop Inc.*	PUD No. 1 of Benton County	Idaho Power Co.
Inland Power & Light Company*	City of Milton	Portland General Electric Co.
PUD No. 1 of Cowlitz County*	Ohop Mutual Light Company, Inc.	Puget Sound Energy, Inc.
Seattle City Light	PUD No. 1 of Ferry County	
PUD No. 1 of Clark County	Clatskanie Peoples Util. Dist.	
Lakeview Light & Power	Northern Wasco County PUD	
PUD No. 1 of Clallam County	PUD No 1. of Skamania County	
Eugene Water & Electric Board	City of Rupert	
Peninsula Light Company		

*Indicates that utility was a member of the Certainty substratum
Source: Navigant

In order to better characterize the diversity of awareness of and attitudes toward DE at regional utilities, Navigant's goal was to interview two individuals at each sampled utility: one with primary responsibilities in transmission and distribution (T&D) planning, and another whose job responsibilities focused primarily on demand-side management (DSM).

2.1.3 Interview Guide Development

In parallel with sample design and selection, Navigant prepared a draft interview guide to elicit information on the following research questions:

- What have utilities done to investigate DE?
- Are respondents aware of the energy savings and peak demand reduction that DE offers?
- Are respondents aware of the Regional Technical Forum's (RTF's) tools for analyzing savings from CVR?
- What attitudes do respondents have regarding CVR and DE more generally?

- What real and perceived barriers do PNW utilities face in implementing DE measures such as CVR?
- What factors have promoted the adoption of CVR and other DE practices by utilities that have implemented them?
- What DE practices have utilities implemented?
- What is the magnitude of estimated savings relative to annual sales for those utilities that have implemented CVR and other DE measures?
- What evaluation activities have utilities conducted to assess the impact of their DE efforts?
- How have utilities that have implemented DE measures monitored customer complaints that may be related to DE measures?
- What are respondents' perceptions of customer awareness of CVR? Do respondents have any anecdotal evidence of adverse customer impacts from CVR?

Navigant submitted the interview guide for NEEA and BPA review in late July 2013. Navigant received comments from interested parties within two weeks and submitted a final interview guide in mid-August 2013. The final interview guide is attached as Appendix B.

2.1.4 Scheduling

Once the utility sample had been selected, the NEEA project manager and interested parties at BPA began the process of gathering names and contact information for T&D engineers/planners and DSM contacts at each sampled utility. As these individuals were identified, the NEEA project manager sent introductory emails explaining project objectives and Navigant's role in conducting interviews.

Following closely on the delivery of these introductory emails, Navigant personnel made initial telephone contact to schedule the IDIs. Navigant periodically made follow-up calls as necessary until either the interview was scheduled, the utility contact declined to be interviewed, or Navigant had tried and failed to reach the contact seven times.

Navigant's scheduling script included questions to ascertain whether the initial utility contact was in fact the person within the distribution engineering or demand-side management department most responsible for making decisions about investments in the utility's distribution system. In some cases, Navigant learned that the initial contact was not the most appropriate contact at that utility for an interview. In these cases, Navigant asked the initial contact for the name and contact information for the most appropriate person, and relayed this information to the NEEA project manager, who then forwarded the introductory email to the new contact.

Scheduling calls began in early October 2013 and continued into January 2014.

2.1.5 Interview Process

For ease of entering, reviewing, and analyzing the information provided by survey respondents, Navigant chose to implement the interview guide in a web-based survey tool. However, respondents were not asked to use this tool. Instead, Navigant collected all information via live telephone interviews, transcribing respondents' statements directly into the survey tool. This method allowed the interviewer to interpret the respondents' answers and ask follow-up questions as necessary to elicit details about each response.

Prior to beginning each interview, the Navigant interviewer informed the respondent that nothing he or she said would be attributed to either the respondent or his/her utility without prior written consent. The intent of this policy was to encourage respondents to provide information that they might otherwise be reluctant to share if they believed they would be identified as the source.

Navigant conducted the first DE market characterization interview on October 16, 2013. Navigant completed 14 interviews in October, 13 in November, four in December, and three in January 2014, for a total of 34 interviews at 28 of the 30 utilities in the sample, as shown in Table 7. The interviews ranged in length from about 30 minutes to over an hour.

As noted earlier, Navigant's goal was to conduct two interviews at each sampled utility: one with a T&D planner and one with primary responsibilities in the DSM department. Had Navigant achieved this goal, it would have conducted a total of 60 interviews. However, a number of factors made this infeasible, including difficulties identifying appropriate utility personnel, delays in communications and in scheduling interviews, individuals declining to participate in interviews, project time constraints, and the fact that at many smaller utilities the responsibilities for planning the T&D system and operating DSM programs reside in a single individual. At the time Navigant concluded the interview phase of the project, it had completed 34 interviews with individuals representing 28 utilities. Although fewer in number than Navigant originally envisioned, these interviews provided important information on each of the questions NEEA set out as research objectives for this project.

Table 7. Number of Interviews Conducted at Sampled Utilities

DE Active		DE Unknown		IOU	
Utility Name	Number of Interviews	Utility Name	Number of Interviews	Utility Name	Number of Interviews
Tacoma Power*	2	City of Sumas	0	Avista Corp.	1
Central Lincoln PUD*	1	City of Weiser	1	NorthWestern Energy, LLC.	1
City of McMinnville*	1	PUD No. 3 of Mason County	1	PacifiCorp	2
Flathead Electric Coop Inc.*	2	PUD No. 1 of Benton County	1	Idaho Power Co.	1
Inland Power & Light Company*	1	City of Milton	1	Portland General Electric Co.	1
PUD No. 1 of Cowlitz County*	2	Ohop Mutual Light Company, Inc.	2	Puget Sound Energy Inc.	1
Seattle City Light	1	PUD No. 1 of Ferry County	1		
PUD No. 1 of Clark County	2	Clatskanie People's Utility District	0		
Lakeview Light & Power	1	Northern Wasco County PUD	1		
PUD No. 1 of Clallam County	1	PUD No. 1 of Skamania County	1		
Eugene Water and Electric Board	1	City of Rupert	1		
Peninsula Light Company	1	Salmon River Electric Coop Inc.	1		

*Indicates that utility was a member of the Certainty substratum
Source: Navigant

2.2 Findings

The research objectives for the market characterization task were to gather information on the level of PNW utilities' awareness and understanding of DE, individuals' attitudes about DE and other factors that promote or impede the adoption of DE measures, and the DE measures that utilities either already have implemented or plan to implement within the next few years. The following three subsections present Navigant's findings in each of these areas.

In the following discussion, Navigant occasionally uses the term "small rural residential" (SRR) to identify a subset of public utilities that purchase their electricity from BPA. BPA has used the SRR designation in previous work, and defines SRR utilities as having the following characteristics:

- Forecast demand of less than ten average megawatts
- Fewer than ten customers per mile of distribution line
- More than 66 percent of customer load is residential, according to U.S. EIA data

Although Navigant did not use the SRR designation to stratify the population of PNW public utilities for sampling, the designation is useful in interpreting responses for some questions, as it is a clear indication of small, rural utilities that may have more limited resources (both in terms of capital and personnel) to investigate or implement DE measures than their larger counterparts. Note that in the tables below, the designation "non-SRR" refers to co-ops, municipal utilities, or PUDs that do not fulfill one or more of the SRR characteristics listed above. As a result, the sum of SRR and Non-SRR responses is equal to the total number of responses from non-IOU utilities, and therefore the sum of responses from all respondents in the DE Active and DE Unknown strata.

Table 8 presents information on the sampled utilities using the SRR and non-SRR designations. The table includes data on sampled IOU utilities for scale. As a group, the SRR utilities (all SRR utilities, not just those sampled) represent about ten percent of energy sales in the region. Among BPA customers, SRR utilities accounts for about 26 percent of sales.

Table 8. Data on Sampled SRR Utilities

	Value			Percent of Category		
	SRR	Non-SRR	IOU	SRR	Non-SRR	IOU
Number of Utilities	10	14	6	12%	28%	100%
Aggregate MWh Sales (000)	2,219	34,382	88,981	13%	62%	100%
Aggregate Summer MW	319	4,709	47,245	10%	59%	100%
Aggregate Winter MW	515	6,344	45,881	14%	57%	100%
Aggregate # of Consumers	93,489	1,143,938	3,854,218	16%	59%	100%
Source: U.S. EIA, 2011 data						

2.2.1 Distribution Efficiency Practices, Evaluations, and Plans

Navigant attempted to obtain overall perspective of the state of implementation and progress of DE in the region by exploring several key areas with the sample utilities. Navigant asked questions to assess the level of DE technology deployment and related practices that are used in the sample utilities. In an attempt to ascertain the level of detail and rigor used in DE, Navigant also explored approaches and high-level findings for energy efficiency evaluation and measurement activities. Finally, to understand the trajectory of DE technology deployment, Navigant explored plans for future implementation of the technologies over three different time frames.

Implementation Progress and Practices

Navigant explored the areas above for the following ten technology approaches, each of which has the potential to increase DE.

a. CVR
b. Conductor Replacement
c. Higher Distribution Primary Voltage
d. Transformer Load Management
e. Balancing Loads and Phases
f. Adding Parallel Feeders
g. Seasonally Unloaded Transformers
h. Existing Distribution Transformers with High-Efficiency
i. Power Factor Improvements

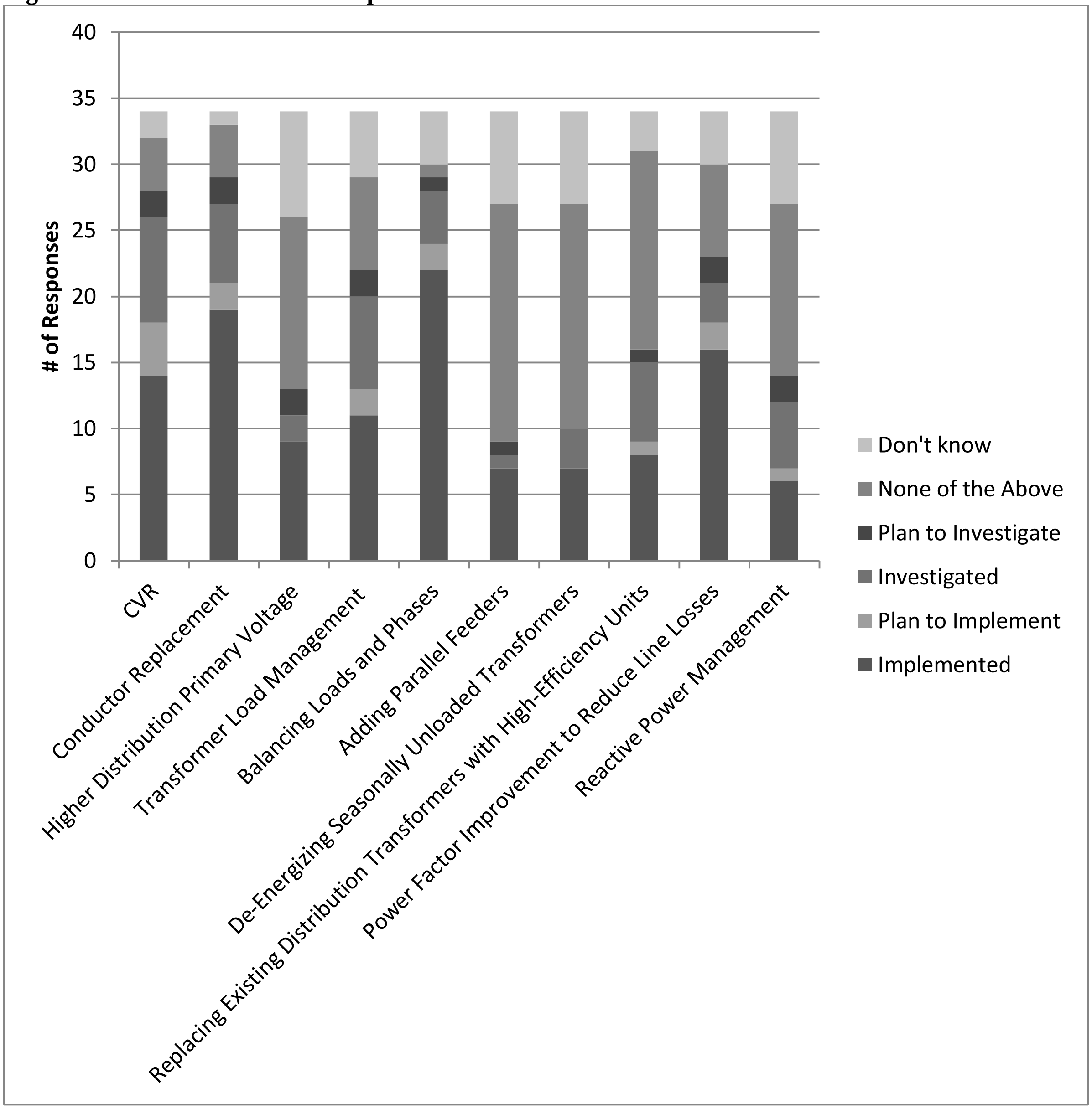
j. Reactive Power Management

In the remainder of this report, Navigant refers to these distribution technology approaches as DE "measures," using the vernacular typical in energy efficiency and conservations projects. Navigant recognizes that "measure" is not a term used widely in distribution engineering, operations or system planning, but it is fitting here as this report focuses on energy efficiency. To understand the level of maturity and progress the utility has made in DE, we asked interviewees to categorize each of the ten measures using one of the following "states" at their utility:

- Implemented
- Planning to Implement
- Investigated
- Planning to Investigate
- Don't Know
- None of the above

Figure 1 below indicates the number of responses in each category by DE measure.

Figure 1. Status of DE Measure Implementation



Source: Navigant analysis

The figure shows that many of these measures are broadly implemented or planned across the sample utilities. In addition, many other utilities have investigated the range of measures.
A small number of the implementations and investigations occurred many years ago, as much as a decade or more. This was the case in a limited number of utilities (less than five). The majority of implementations and investigations are more contemporary and indicate the activity and thinking of current staff.

One other notable point that complicates the picture from an efficiency perspective is that energy efficiency is not the primary rationale for implementing or investigating many of these measures. The only two of these ten measures that are implemented solely to improve energy efficiency are *CVR* and *De-Energizing Seasonally Unloaded Transformers*. Each of the others plays a key role in some aspect of system design for meeting capacity growth, reliability goals, and/or operational flexibility. Furthermore, typically, energy efficiency is a secondary driver or even an afterthought for these measures. For example, *Balancing Loads and Phases* provides energy efficiency benefits, but implementation is driven by operational best practices, system flexibility, and reliability. Thus, although the figure shows significant implementation and planning activity around these measures, it is not safe to assume that efficiency plays the primary role contributing to this progress.

Of the utilities that have implemented or are investigating CVR, the majority (12 of 14) are those utilities that have participated in BPA's ESUE program, or are IOUs that have received regulatory pressure or directive to implement DE. The utilities that have implemented or are investigating *De-Energizing Seasonally Unloaded Transformers*, all mentioned this was done for agricultural load, to turn off pumps during the non-growing season. Many utilities in the sample are pursuing a broad range of the other DE measures, but primarily for standard asset management and operational practices reasons, where efficiency is not a driver to implement the measure.

2.2.2 Awareness and Understanding of Distribution Efficiency Opportunities

Interview questions in this area assessed each respondent's understanding of the term "distribution efficiency", efforts to learn about DE, awareness of the RTF's DE analysis tools, and perceptions of customer awareness of CVR where it had been implemented.

Awareness and understanding of "Distribution Efficiency and CVR"

Most utilities in the region appear to be aware of the concept of DE and are able to articulate a reasonably accurate definition of the term. Respondents indicated similar levels of awareness of CVR, although familiarity with CVR is far lower among SRR utilities.

Navigant assessed respondents' understanding of DE by their responses to the following three questions:

1. Are you familiar with the term distribution efficiency?
2. What does that term mean to you?
3. Are you familiar with the term conservation voltage regulation?

Table 9 summarizes the responses to these questions. All but two of the respondents stated that they were familiar with the term "DE." Those two were from SRR utilities in WA, each serving less than 6,000 customers.

Respondents offered a range of definitions for the term distribution efficiency, but most respondents provided reasonably accurate generic descriptions, such as "Minimizing losses on the distribution system", and 22 respondents provided specific examples of DE measures without prompting by the interviewer. Three respondents, all of which were SRR utilities in the DE Unknown stratum, were unable to provide definitions of the term.

Table 9. Responses to DE Awareness Questions

	IOUs (n = 7)	Public Utilities			
		DE Active (n = 16)	DE Unknown (n = 11)	SRR (n = 10)	Non-SRR (n = 17)
Familiar with DE	7	16	9	8	17
Unfamiliar with DE	0	0	2	2	0
Inaccurate or no definition	0	0	3	3	0
Accurate general definition	2	2	5	3	4
Accurate definition with DE examples	5	14	3	4	13
Familiar with CVR	7	16	5	4	17
Unfamiliar with CVR	0	0	6	6	0

Source: Navigant analysis

Six of the 34 respondents indicated that they were unfamiliar with CVR. All of these were SRR utilities in the DE Unknown stratum. This indicates that the lack of CVR familiarity resides in the smallest and most rural public utilities.

Utility Research and Education Efforts Regarding DE

Navigant asked the following questions to gather information about utility activities to educate personnel about DE and to research the potential for DE:

1. Has your utility conducted any analysis to determine potential savings from DE?
2. Have you, or to your knowledge has anyone else at your utility conducted any research or attended any seminars or classes about this subject?

Not surprisingly, utilities in the IOU and DE Active strata have been more active in educating staff and conducting research on DE than have their peers in the DE Unknown stratum. Respondents from small rural utilities were much less likely to have engaged in either activity. Table 10 summarizes responses to these questions.

Table 10. Responses to DE Research and Education Questions

	IOUs (n = 7)	Public Utilities			
		DE Active (n = 16)	DE Unknown (n = 11)	SRR (n = 10)	Non-SRR (n = 17)
Conducted analysis of DE potential?					
Don't know	1	1	3	4	0
No study	0	0	4	2	2
Study currently in process	0	0	1	0	1
Limited scoping study	3	11	3	4	10
Advanced / detailed study	3	4	0	0	4
Conducted research or attended DE seminars?					
None	1	2	7	6	3
One or more employees trained	6	14	4	4	14

Source: Navigant analysis

Twenty-five of the 34 respondents indicated that their utilities had conducted some level of analysis, or that analysis was currently underway, to determine potential savings from DE. Respondents from five utilities were unaware of such analysis, and four respondents indicated that their utilities had not conducted any analysis of DE potential. These four respondents represented utilities in the DE Unknown stratum; two were SRR utilities, two were not.

All of the DE Active respondents and all but one of the IOU respondents indicated that their utilities had conducted some level of research into DE potential for their systems. Notably, four of the 11 respondents in the DE Unknown stratum also indicated that their utilities had conducted some level of analysis of the potential for DE improvements. The data make it clear that such analysis is much less common among SRR utilities. While nearly all IOUs and 88 percent of non-SRR respondents indicated some level of utility activity to investigate DE potential, only 40 percent of the SRR respondents did so.

Ten respondents, nine from PUDs or co-ops and one from an IOU, indicated that no one at their utilities had conducted research or attended any form of training regarding DE. This group includes two utilities in the DE Active stratum (both of which are also in the Certainty stratum). The other 24 respondents indicated that they or someone at their utilities had participated in training on DE. Three of these, including representatives of two of the IOUs and one from a large municipal utility, described extensive training efforts involving multiple employees.

As was the case with utility research into DE potential, utility efforts to train employees about DE appears to be a function of size. All but one IOU respondent and 82 percent of non-SRR respondents indicated that at least one utility employee had conducted research or participated in seminars or classes on DE. This contrasts with only 40 percent of the SRR respondents.

Awareness of RTF DE Analysis Tools

Navigant asked respondents four questions to gauge their awareness with the RTF analysis tools:

1. The RTF's has approved two protocols for calculating energy savings from CVR. Are you aware of these protocols for analyzing savings from CVR?

2. Have you ever used either of the RTF analysis protocols?

3. Do you recall the name of the protocol you used? How useful did you find it? How accurate?

4. Do you have any recommendations for improvements to these protocols?

While familiarity with the RTF protocols is widespread among IOUs and utilities in the DE Active stratum, it is rare at utilities in the DE Unknown stratum. Only about half of the IOU respondents and less than one-third of DE Active respondents indicated that they had used an RTF protocol.

As Table 11 indicates, nineteen respondents (56 percent) stated that they were aware of the RTF protocols for evaluating savings from CVR. Eight of these, all of which were in either the IOU or DE Active strata, indicated that they had used an RTF protocol. None of the ten SRR respondents was familiar with these protocols, and only one of the 11 respondents in the DE Unknown stratum was aware of these analysis tools.

Table 11. Responses to RTF Protocol Familiarity Questions

	IOUs (n = 7)	Public Utilities			
		DE Active (n = 16)	DE Unknown (n = 11)	SRR (n = 10)	Non-SRR (n = 17)
Aware of RTF protocols	6	12	1	0	13
Have used an RTF protocol	3	5	0	0	5

Source: Navigant analysis

Four of the eight respondents indicating that they had used an RTF protocol were able to provide the protocol name, and all four of these referred to the "Simplified Protocol."

Among those aware of the RTF protocols, five respondents offered substantive comments on their usefulness and accuracy:

- *"We used the RTF's 2010 Simplified Protocol. We found it insufficient. Several of us from [three utility names] submitted a document—a page long outline– to the RTF's Automated CVR subcommittee describing what changes we felt would make the protocol more usable. The crux is that our company does not feel that the RTF should be in the business of developing a CVR protocol at this time. There can be benefits to having a protocol available, but the science behind accurate M&V is very much in flux. It is still being researched in industry consortiums and academic environments, so the RTF is almost a competitor to the market. It's premature now, but it might be appropriate in a few years when the industry is more settled on M&V for CVR."*

  "Most of our circuits are not in the scope of the RTF protocol. They didn't pass the required circuit performance thresholds, so the calculation errors were deemed to be non-trivial. The circuits were too long, and their energy density too low. We have discussed the protocol's scope with Dr. Bob Fletcher, who was heavily involved in its creation..[5] He performed a protocol robustness test on a short underground circuit; we found that the protocol didn't account for a 20-mile circuit with a regulator on it. Even a fixed capacitor would make a line out of scope. For us, the error was large relative to the energy savings being measured."

- *"We developed our own protocol in house. The first RTF protocol was too costly, the second was okay. We covered all the bases, issues with testing and confirmation. Reliably substantiating the reduction is difficult, due to tremendous changes in day-to-day load, and customer variability masks the reductions of one to two percent, so we would have to run an analysis over many years to meet requirements. We found a way to monitor from July 15 to January 15, based on reduction vs. load. We can compare between years, take data points each minute at each Supervisory Control and Data Acquisition (SCADA) station and at remote end-of-line monitoring stations. We did day on/day off implementation with control stations to minimize day-to-day bias. We took elements from other protocols and improved upon them."*

[5] Robert Fletcher, Ph.D., sat on the DEI steering committee and has promoted CVR at utilities throughout the PNW both prior to the DEI and since its conclusion.

- *"We're currently working with the Simplified M&V protocol. It is useful, and I like that there's a regional approach. I have some concerns about when it comes to rural vs. urban utilities. It's a blanket approach. [The protocol] doesn't give information about how much voltage drop, so it's applicable if you drop one volt or six volts. I have concerns about that."*

  "As I've talked to other IOUs in WA, what they're seeing in the savings isn't what's predicted by the protocol. They were ahead of us in implementing DE efforts. They had concerns about cost-effectiveness and how much savings they were really getting. I'd like to work with the RTF to resolve some of these issues and have more real world examples—more utilities that can compare actual savings with those predicted by the protocol. We would then need to update the CVR factors accordingly."

- *"We comply with BPA reporting requirements, which is what we are ultimately trying to accomplish. My role was to usher in efficiency to T&D group, not to do the work. At time of NEEA [DEI] study, there was a certain configuration of end-uses in home, but this is changing. Those shifts in end-uses are affecting the percent of savings available, which is not considered in the protocols. For example, CFL's replacing incandescent is diminishing potential."*

- *"I'm most familiar with the simplified one: "Simplified Voltage Optimization M&V Protocol". I'm less familiar with the day on/day off protocol. Is it useful? It's what state auditor requires, so it's useful in that sense, but it doesn't necessarily direct a utility toward lowest hanging fruit. It requires the utility to do an entire voltage zone at one point (entire substation). A utility could do cheap fixes, but these would not meet all the requirements in the protocol without a lot of work. If we didn't have to follow the protocol, we would have addressed CVR on a feeder-by-feeder basis. We have had really high voltage historically, so we could reduce it a bit and capture some savings, but if a feeder doesn't meet the 40 amp imbalance requirement CVR could make it more efficient but the utility would not get credit."*

Perceptions of Customer Awareness of CVR

Customer awareness of CVR appears to be a rarity where the practice has been implemented, and complaints associated with CVR are rarer still.

Among the 14 respondents indicating that their utility had implemented CVR (either as a pilot or a full-scale deployment), Navigant investigated respondents' perceptions of their customers' awareness of CVR. Navigant asked the following questions to probe this topic:

1. Do you think your customers are aware that your utility has implemented CVR?

2. How do you think they became aware of CVR?

3. Are you aware of any customer complaints that can be directly attributed to CVR?

4. What was the nature of these complaints?

5. How did you determine that the complaint(s) was/were due to CVR?

As Table 12 indicates, only two of the 14 respondents from utilities that had implemented CVR believed their customers were aware of that fact. Both of these respondents represented SRR utilities, one in the DE Active stratum and one in the DE Unknown stratum. When asked how customers might have become aware that their utility had implemented CVR, one clarified that coop members learned of that fact when the utility manager discussed CVR during an annual meeting. The other respondent indicated that his utility had initially been too aggressive with CVR and created "a lot of outages."

Table 12. Responses to Questions on Customer CVR Awareness

	IOUs (n = 7)	Public Utilities			
		DE Active (n = 16)	DE Unknown (n = 11)	SRR (n = 10)	Non-SRR (n = 17)
CVR Implemented	6	7	1	3	5
Believe customers are aware of CVR	0	1	1	2	0
Customer complaints attributed to CVR	1	1	0	1	0

Source: Navigant analysis

Two respondents, one from an IOU and one from a coop in the DE Active stratum, discussed customer complaints attributed to CVR. Both indicated that the problems were due to excessive voltage reduction when the utilities first implemented CVR:

- *"We did a really poor job the first time we tried CVR. We over-exercised the regulators, so we had catastrophic failures."*

- *"When we first started we pushed the voltage too low, so a refrigerator in a supermarket malfunctioned. It didn't ruin the equipment, it just wouldn't start. We realized that we were getting more voltage reduction than we had modeled, so we increased the set point and the problem disappeared."*

2.2.3 Distribution Efficiency Attitudes, Barriers, and Drivers

Interview questions in this area addressed the various attitudes, barriers, and drivers for the implementation of DE and related distributed efficiency measures. Responses within this section underwent two rounds of coding. The first round of coding grouped *attitudes* towards DE into four categories: 1) Positive, 2) Conditional, 3) Neutral, and 4) Negative. Exemplary quotes are provided for each coding type:

- **Positive** – Responses coded in this manner were uniformly positive in nature. Positive responses revealed no conditions or reservations about their response. Example quote: "Yes, they should [invest in DE]…If the system is more efficient, then we are providing more efficient power to customers, plus cutting costs to the residents. No reason not to invest in DE."

- **Conditional** – Responses coded in this manner were generally positive, but respondents placed a condition or reservation on their attitude – "Yes [in favor of DE], but ***only if*** it makes economic sense."

- **Neutral** – Responses coded neutral were neither overwhelmingly negative nor positive. These responses also might indicate a lack of knowledge on the subject such that they could not voice a strong opinion positively or negatively –"Don't know whether we should be [investing in DE]. I guess it depends."

- **Negative** – Responses coded negative were uniformly negative in nature – "I don't see how this would work in our system [DE]" or "[Our system] is not a good candidate [for CVR]."

Attitudes Regarding Distribution Efficiency

The individuals Navigant spoke with overwhelmingly believe that there are opportunities for efficiency improvements on their distribution systems, and that utilities should be investing in those opportunities, though many caution that the cost-effectiveness of such investment is not always clear. The respondents were more cautious when asked specifically about CVR.

Navigant asked respondents four questions related to their current attitudes towards DE measures:

1. Do you believe there are opportunities for energy or demand savings by making the distribution system more efficient?

2. Do you think utilities should be making investments in the efficiency of their distribution systems? Why or why not?

3. Do you think CVR would be useful? Why or why not?

4. What are your thoughts about the concept of reducing voltage to improve customer efficiency?

As Table 13 shows, respondents overwhelmingly reported that there are opportunities for energy or demand savings improvements. Twenty-eight of the 34 respondents, representing utilities across the ownership spectrum and in both the DE Active and DE Unknown strata, held positive attitudes or conditionally positive attitudes about the opportunities for efficiency improvements in their system.

Table 13. Summary of Perceived Opportunities for DE Measures (attitudes)

	IOUs (n = 7)	Public Utilities			
		DE Active (n = 16)	DE Unknown (n = 11)	SRR (n = 10)	Non-SRR (n = 17)
Positive Attitude	3	10	6	6	10
Conditional Attitude	4	3	2	2	3
Neutral Attitude	0	1	2	1	2
Negative Attitude	0	2	1	1	2

Source: Navigant analysis

Only three respondents did not see *any* opportunities for efficiency in their distribution system. Interestingly, two of these respondents represented utilities in the DE Active stratum. These respondents' comments included statements indicating that they see few remaining opportunities following the work they have already conducted to make their systems efficient:

- "We've worked with BPA, looking at lowering voltage. It doesn't seem like a great fit for us. Our load profile is such that it won't work at this point. We also considered distribution transformer specs, but we're already using low loss transformers. We completed a work plan that evaluated all feeders making sure that conductor sizes are optimized. We've looked at DE, but there's obviously a point where the economics don't make sense."

- "We conducted a study in July 2010 looking at system improvements. There is not as much opportunity as most utilities because we're already running at pretty much optimal voltage. There is little room remaining for improvement. We were part of NEEA's DEI and it didn't find a lot of opportunity here."

Respondents with conditional attitudes frequently questioned whether existing opportunities for DE improvements would be cost effective.

As Table 14 shows, when asked whether utilities should be making investments in DE, a majority of respondents held positive attitudes that they should make these investments. Among the 16 respondents that held positive attitudes towards investment in DE, a majority reported that if the project is cost effective, that would be the primary reason for investment. Only four utilities were unsure (neutral) about whether distribution efficiency investments are likely to be a good investment by the utility—citing concerns that DE measures may not be the most cost effective strategy. Among those 14 respondents that held conditional attitudes towards investment in DE, the primary concern was also cost-effectiveness. When asked, the most common response among conditional respondents was, "Yes [utilities should be investing in DE], but only to the extent that it is cost effective." Overwhelmingly, those respondents that held positive attitudes towards investment in DE reported cost-effectiveness would be the primary driver for investment. No respondents expressed negative attitudes towards utility investment in DE.

Table 14. Summary of Utility Attitudes Towards Investment in DE

	IOUs (n = 7)	Public Utilities			
		DE Active (n = 16)	DE Unknown (n = 11)	SRR (n = 10)	Non-SRR (n = 17)
Positive Attitude	3	8	5	6	7
Conditional Attitude	4	7	3	2	8
Neutral Attitude	0	1	3	2	2
Negative Attitude	0	0	0	0	0

Source: Navigant analysis

As Table 15 shows, respondents were less positive when Navigant asked specifically about CVR. Few respondents had strongly negative attitudes about CVR, but some expressed reservations about whether CVR would be viable on their systems, mostly for technical reasons. Respondents cited system design issues and cost-effectiveness as reasons for their neutral or negative attitudes: "[CVR] would get expensive…and would be hard to put into perfect spots," or "[Our utility] has very high pump loads for irrigation. We need higher voltage at substations in order to ensure adequate voltage at the end." The sole IOU respondent expressing a negative attitude about CVR holds the belief that inductive loads will draw more power at reduced voltage.

Table 15. Summary of Utility Attitudes Towards CVR

	IOUs (n = 7)	Public Utilities			
		DE Active (n = 16)	DE Unknown (n = 11)	SRR (n = 10)	Non-SRR (n = 17)
Positive Attitude	2	3	1	1	3
Conditional Attitude	3	6	1	2	5
Neutral Attitude	1	7	7	5	9
Negative Attitude	1	0	2	2	0

Source: Navigant analysis

Respondents reported similar attitudes when interviewers asked about the "concept" of reducing voltage versus "CVR" explicitly. Table 16 summarizes this finding. Among the respondents with neutral or negative attitudes about the concept, several cited concerns about the technical viability of reducing voltage while maintaining adequate voltage at the end of long feeders. Others were skeptical that the savings that would be gained by reducing voltage would pay for the cost of the system upgrades necessary to enable voltage reduction.

Table 16. Summary of Attitudes Towards the Concept of CVR

	IOUs (n = 7)	Public Utilities			
		DE Active (n = 16)	DE Unknown (n = 11)	SRR (n = 10)	Non-SRR (n = 17)
Positive Attitude	1	7	1	2	4
Conditional Attitude	3	3	3	2	3
Neutral Attitude	2	5	5	3	8
Negative Attitude	1	1	2	3	2

Source: Navigant analysis

Barriers Towards Distribution Efficiency

To assess the barriers that utilities perceive in implementing DE technologies and practices, Navigant first asked the following broad question:

- Are there any barriers that prevent your utility from improving the efficiency of its distribution system?

Later in the interview, Navigant asked whether each utility had investigated or implemented the following list of DE measures:

- CVR
- Conductor Replacement
- Higher Distribution Primary Voltage
- Transformer Load Management
- Balancing Loads and Phases
- Adding Parallel Feeders
- Seasonally Unloaded Transformers
- Existing Distribution Transformers with High-Efficiency

- Power Factor Improvements
- Reactive Power Management

Where a respondent indicated that his or her utility had investigated one of the above measures but that it had neither implemented nor developed a plan to implement the measure in the future, Navigant followed up with a question about barriers specific to that technology.

To establish and understand the primary drivers and barriers to DE measures, Navigant coded the barrier- and driver-related question response data in two rounds. In the first round of coding, each response type was categorized as either a barrier or a driver for implementation. The analysis team then placed each response into one of four broad categories: 1) Technology, 2) Policy, 3) Finance, and 4) Internal Capabilities. Navigant then conducted a second round of coding in which each response was more narrowly coded into nine specific barriers: 1) System constraints, 2) Regulation, 3) Customer satisfaction, 4) Knowledge, 5) Personnel, 6) Priority, 7) Capital, and 8) Cost-Effectiveness. Table 17 summarizes each of these barriers with exemplary quotes.

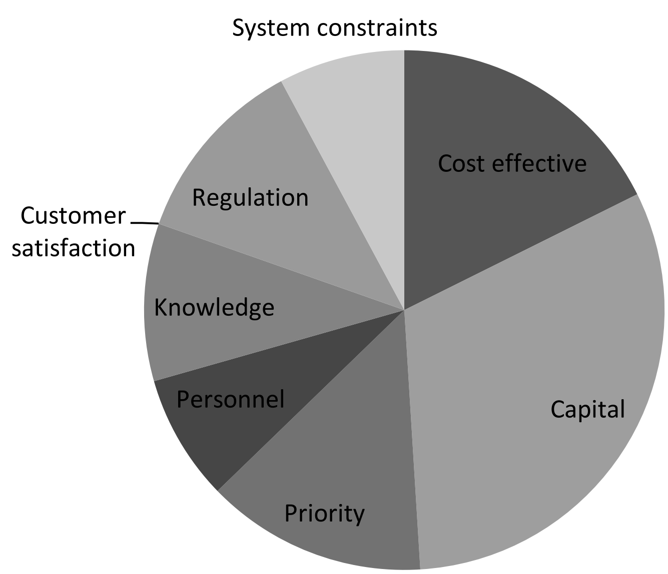
As Figure 2 shows, when asked generally about barriers to improving efficiency in their distribution system, respondents overwhelmingly reported that capital availability and cost-effectiveness were the two biggest barriers. Respondents reported capital constraints as the biggest barrier to DE: "Cost is only real barrier. Eventually has to be made a priority, but currently is not. If energy prices escalate, then economics might change." In some cases, utilities reported that after careful analysis, DE measures would not pay back with a sufficient return on investment (cost-effectiveness): "There are other conservation opportunities that are way more cost effective." In other cases, utilities reported that a key hurdle to any investment is cost-effectiveness, thus indicating that they may not have sufficient analysis yet to show these DE investments pay back: "Costs could be a problem [with investment in DE]. Takes years to pay off, but you need the money now to improve the system…we don't know that much about it." Responses such as this one were coded as a knowledge barrier *and* cost-effectiveness barrier. Nearly half of the respondents mentioned cost-effectiveness or capital availability as either a primary or secondary barrier to efficiency measures, with nearly one-third of all respondents listing capital availability as their primary barrier to improving efficiency in their distribution system.

Table 17. Summary of Coded Barriers to DE and Related Measures

Barrier	Representative Quote
System constraints	*On our system, I can't see how [CVR] would work. It would create problems in other areas.*
Regulation	*Primary barrier is regulatory design. A significant component of recovery is pegged to energy as opposed to fixed cost that would cover the distribution system fully. If you make the distribution system more efficient, less energy is sold on the customer side of meter, so it's a revenue reduction.*
Customer satisfaction	*Usually customers are complaining about voltage […when implementing reduced voltage programs].*
Knowledge	*Don't know whether we should be. Guess it depends on the cost and rate of return. Those are both things I don't know enough about to make a judgment.*
Personnel	*[We] don't have enough people in house to do [DE] work.* *Manpower to do the necessary investigations into what we could or should be doing [is the primary barrier].*
Priority	*Barriers are where these projects fall in priority order in terms of other projects that are ongoing. If power is getting to customers, lines aren't falling and everything is running smoothly, and then can get to it. DE doesn't get done because it gets pushed to the back burner. Still some skepticism on part of engineers. If they can put it off, they'll do so.*
Capital	*Trying to get funding to do those projects. We're experiencing a decline in sales. Reducing losses would be a positive for us though. Availability of capital is the main thing.*
Cost- effectiveness	*Current market conditions are a barrier. Right now it's hard to get efficiency under the $35 per MWh that we can buy power at. This is purely financial analysis.*

Source: Survey responses

Figure 2. Summary of Primary and Secondary Barriers to Efficiency Improvements in Distribution System



Source: Navigant analysis

Table 18. Summary of Top Reported Barriers to Improving Efficiency in Distribution System[6]

		Public Utilities			
	IOUs (n = 7)	DE Active (n = 16)	DE Unknown (n = 11)	SRR (n = 10)	Non-SRR (n = 17)
Cost Effective	3	4	2	2	4
Capital Availability	3	7	6	7	6
Priority	1	6	0	1	5
Personnel	0	2	2	0	3
Regulation	3	3	0	1	2
Knowledge	0	2	3	3	2
System Constraints	1	1	0	2	1

Source: Navigant analysis

Consistent with the findings regarding attitudes, the greatest barrier reported to the adoption of CVR was capital availability and cost-effectiveness. Among respondents that had not implemented CVR, all reported capital or cost-effectiveness as one of the reasons for not doing so. The following quotes summarize the specific challenges to CVR:

- *"…doesn't pass cost-effectiveness test."*
- *"Capital costs are holding [CVR] back."*
- *"Analysis done by head of engineering said that it wasn't cost effective at this time."*

Navigant notes that differences in utility operating practices (such as standard voltage settings at the substation), physical assets (such as the presence or absence of voltage regulators or capacitor banks), and service area characteristics (such as feeder length and load densities) have a profound effect on the potential for savings from CVR and the magnitude of expenses to conduct the remedial work that would be necessary to enable CVR. Utilities with relatively short, energy dense feeders with relatively flat voltage profiles and that have already regulated voltage toward the lower end of the acceptable envelope may find little remaining potential for energy savings through CVR. Utilities that keep voltage at the high end of the envelope at the substation in order to ensure adequate voltage for loads at the end of long, rural feeders might have high potential for CVR savings, but might have to invest substantial capital in new feeders and VAR support that could challenge CVR cost-effectiveness. In addition, two utilities with identical system characteristics might come to different conclusions about CVR cost-effectiveness if they use different cost-effectiveness tests. Given these differences, it is not suprising that some regional utilities have the perception (which in some cases is backed up by analysis) that CVR is not cost-effective, while others view it as highly cost-effective.

In addition to cost-effectiveness, respondents also reported system constraints as a major barrier to CVR. In fact, among the three respondents with negative attitudes towards the usefulness of CVR, two cited system constraints as the primary barrier:

[6] Both primary and secondary barriers are included in this table, thus the reason for the discrepancy between number of respondents in each category and number of responses. Responses were coded for primary and secondary barriers.

- *"Have very high pump loads for irrigation. Need higher voltage at substation in order to ensure adequate voltage at the end."*
- *"We don't own any substations, and don't have any voltage regulation beyond the substation."*

Drivers for Implementation of DE

In some instances, when Navigant asked respondents "Do you think utilities should be making investments in the efficiency of their distribution systems? Why or why not?" they reported barriers, drivers, or some combination of both. The analysis team coded the responses accordingly in order to summarize the primary reasons for implementing DE and associated measures. Navigant also asked respondents to provide any special conditions that helped motivate their utility to move forward with each of the ten measures outlined in the previous section. Finally, as relates to drivers for implementation, Navigant asked respondents: "Did state regulations play any role in your utility's decision to investigate and/or implement any DE measures?" The coding scheme used to assess drivers was similar to that depicted in Table 16.

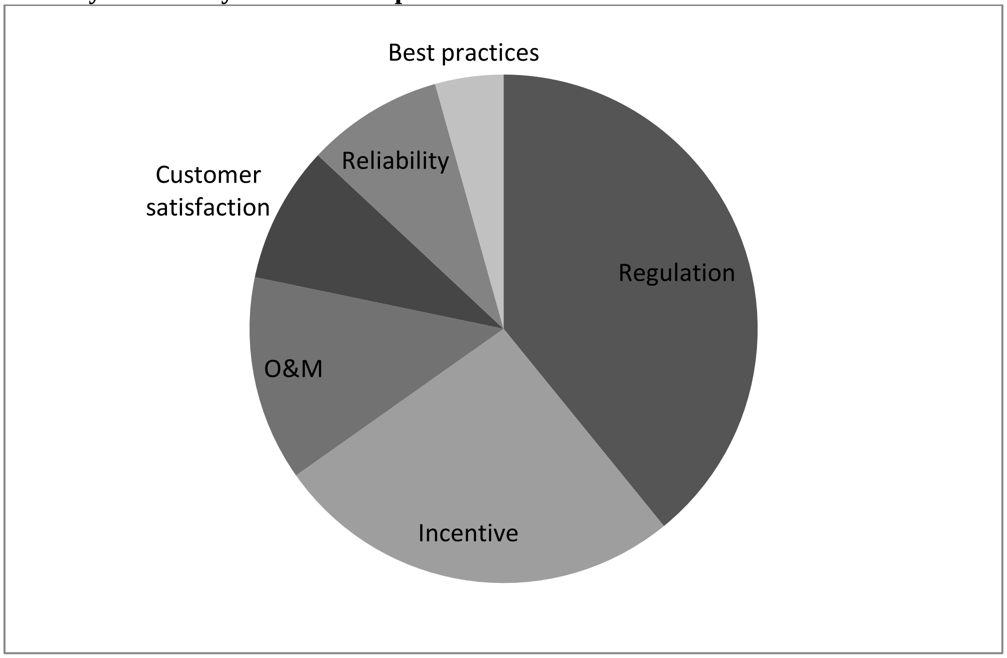
When interviewers asked if utilities should be making investments in the efficiency of the distribution system, respondents overwhelmingly stated that the main driver for doing so should be cost-effectiveness. According to at least one respondent, utilities should not invest in DE for the sake of being 'green': "[Distribution efficiency] needs to be cost effective. [DE] has to benefit ratepayers. Can't go out and spend money blindly." In fact, 25 of the respondents mentioned cost-effectiveness as the primary reason for implementing a DE measure. Therefore, the primary driver for implementing DE was cost-effectiveness; however, often the biggest hurdle or barrier to greater investments in DE arose when DE solutions were not cost effective *enough* to take priority over other investments. Further, utilities reported that it is often the case that they do not have the available capital to invest in a specific solution.

One respondent reported, "Benefits and conservation need to be assigned monetary value." Another stated, "Yes [utilities] should [invest in the efficiency of the distribution system]…Tends to be highly cost effective. If we reduce losses, we keep rates down for everybody." Nine respondents mentioned customer satisfaction as a driver for implementation, but always in the context of providing cost effective solutions to their customers: "As long as you can prove that it's cost effective and [in the] interests of the ratepayer."

Figure 3 shows that over half of the respondents reported incentives and regulations as the primary motivation that has led to CVR implementation. I-937[7], funding from DOE's Smart Grid Investment Grant program, and BPA were mentioned as the explicit drivers for implementation. One respondent said, "The state law generated pressure [I-937]. They felt it was better to do a soft start instead of wait until it was mandatory." Another respondent representing a BPA customer utility said, "Probably the biggest thing was that we could use BPA efficiency dollars for [CVR]." The primary drivers for each of the other DE measures are summarized in Table 19. Regulation, incentives, and reliability/operations and maintenance (O&M) appeared most frequently as drivers to implementing each DE measure.

[7] Initiative number 937 (I-937), passed by voters in Washington state, mandates that utilities obtain increased portions of their electricity from renewable sources and undertake cost-effective energy conservation measures.

Figure 3. Summary of Primary Drivers to Implement CVR[8]



Source: Navigant analysis

[8] Chart is based on the responses from 20 respondents. Responses were coded to include what was interpreted as the two most influential drivers to the implementation of each DE measure.

Table 19. Summary of Primary Drivers of Each DE Measure [9]

Measure	Primary Driver	Exemplary Quote	No. of Respondents
CVR	Regulation / Incentives	*…driven by WA initiative 937. Compliance issue. If it hadn't been passed, probably would not have gotten attention.*	20
Higher Dist. Primary Voltage	O&M (System design)	*Aging physical system required that this be re-done.*	11
Conductor Replacement	Reliability (System design)	*Never packaged as an efficiency project, rather its packaged with reliability.*	21
Transformer Load Mgmt.	Best practices / Reliability	*[We were] shocked when [we] learned how much money and energy was being wasted in over-sized transformers.*	12
Balancing Loads & Phases	Reliability / Best Practices (System design)	*This is just an operating standard and has been in place for years.*	24
Adding Parallel Feeders	Best Practices	*Always been that way. Nobody seems to question it.*	7
De-energizing Seasonally Unloaded Transformers	Efficiency	*Irrigation system is driver. They have huge irrigators that have four summer months of need.*	11
Distribution Transformers with High-Efficiency Units	O&M (System design)	*This is part of your normal lifecycle process. Replacing with new DOE high-efficiency units*	7
Power Factor Improvements to Reduce Line Losses	Regulation	*Purchase all power from BPA. [BPA has] a power factor penalty charge at each delivery point.*	17
Reactive Power Management	Regulation	*BPA penalty*	6

Source: Survey responses

Navigant asked respondents if state regulations played a role in their utility's decision to investigate or implement DE measures. IOUs and larger public utilities operating within Washington overwhelmingly mentioned I-937 as a regulatory driver for their decisions related to DE. Eleven respondents mentioned I-937 as a driver for the implementation of DE measures. As I-937 applies only to Washington utilities with at least 25,000 customers, most respondents indicated that state regulations did not have a role in their utilities' DE decisions.

2.2.4 Distribution Efficiency Evaluation Practices and Progress

Navigant explored the range of practices and progress in measuring and evaluating DE impacts based on the following question:

Did your utility conduct any evaluation of DE to estimate savings or customer impacts?

This exploration was intended to help illuminate the motivation for a level of rigor in estimating energy efficiency impacts, and should indicate the level of focus on this issue.

[9] Multiple answers were accepted in response to this question. Responses were coded and enumerated to include what was deemed the most influential driver(s) to the implementation of each DE measure.

Twenty-five respondents (representing 19 utilities) described studies, ranging in depth of analysis, which we categorized into the following three levels:

1. One respondent described an initial study in process or limited study
2. Sixteen respondents (representing 14 utilities) described some level of study/analysis, to determine potential impacts and benefits, had been performed at some point in the past
3. Eight respondents (representing six utilities) described detailed studies—some resulting in positive and some in negative decisions about moving forward. Utilities in this category mentioned doing "extensive" or "in-depth" analyses around at least one of the DE technologies—typically CVR.

Among the 24 respondents, CVR is mentioned most frequently as the technology being examined (22 times, representing 17 utilities); however, other technologies are mentioned as measurement targets: re-conductoring or conductor upgrades four times, transformer measurements three times, and phase balancing was mentioned twice.

Four respondents had not conducted studies, and did not indicate plans to do so. All of these were publics, three of them with fewer than 10,000 customers.

Five respondents did not know if they had conducted any analyses. Two of these were public utilities with fewer than 5,000 customers, one was a small cooperative utility, one was a mid-sized coop, and one an IOU. For these latter utilities, the answers may indicate that Navigant had not reached the most knowledgeable person at the utility for the interview.

The evaluation effort and level of sophistication correlated fairly well with the size of the utility (in sales MWh), although there were some smaller utilities that had performed an in-depth study/analysis.[10] Also, some of the larger utilities (typically IOUs) did not describe using sophisticated approaches to analysis.

Of the 16 respondents in category two above, all but one described some type of study being conducted.

- One described a pilot with CVR, and two described receiving ARRA grants (one SGDG, one SGIG) to test CVR, among other capabilities.
- Eight other respondents mentioned some type of "study"—all of these described CVR as the focus of the study, but several other capabilities were mentioned, including re-conductoring, voltage optimization, and phase balancing.
- By far the most common reason mentioned for studies was the study assistance proposed and/or given by BPA. This was a driver for 11 respondents representing nine utilities.

[10] One of the mid-sized PUDs uses a load flow model to monitor their system and performs annual evaluation to find problem areas and improve efficiencies, and also worked with BPA in 2011 to perform the detailed CVR scoping study).

- The initial sample stratification (DE Active, Unknown, IOU) is quite consistent with answers received. Navigant discovered only one utility in the initial DE Unknown category that is actually conducting a study to determine savings from DE.

In summary, most of the utilities are doing some level of efficiency impact measurement and evaluation from their CVR programs.

2.2.5 Future Plans for Implementing DE

Navigant explored this issue by asking the following question:

Does your utility have any plans for conducting or expanding DE efforts within the next 2 years, 2 to 5 years, or beyond 5 years from now?

Respondents' future plans for DE projects varied along several dimensions, including the following:

- The specific measures of focus and interest, as well as additional technologies mentioned, but of secondary interest or longer term future consideration

- The goals or rationale for pursuing these plans

- The timing of plans

The most common measure for future implementation was CVR. Fourteen respondents indicated future plans for CVR projects. All of the respondents indicating future plans were in the DE Active stratum or were IOUs. Six respondents indicated plans within the next two years, and eight had plans in the two- to five-year range. Other respondents had plans five or more years out or did not know.

The scope of plans ranged from initial studies to pilots at a limited number of substations, to more complete rollouts. Many of the plans are contingent on a number of factors, including availability of personnel and resources for executing the projects, i.e., whether higher priorities would arise, and availability of conservation funding—primarily from BPA. The following quote is illustrative of both reasons:

- *"The plan for CVR was developed and approved by BPA. It was supposed to be undertaken a year ago at least, and was actually in our conservation potential assessment, and will be in it for '14 and '15. It was put off because there were basically some higher priorities."*

For the utilities with *CVR* plans, several other measures were mentioned as planned, including transformer resizing, conductor replacement to ready the infrastructure, as well as other Smart Grid and AMI technology related to metering and reliability.

The measure mentioned next most often was *Conductor Replacement*, being identified by five respondents as a priority. However, the motivation for these plans was not efficiency, but rather standard operational practices for asset management, replacement of failed units, capacity expansion, and reliability. These respondents indicated that the timing of these efforts was “ongoing” as part of their annual process, rather than scheduled several years in the future.

General DE investigation was planned by three other respondents, without reference to specific measures. Reasons given for the timing of these plans included rising retail rates, resource availability, and fitting in with their normal operational practices. In fact, seven of the respondents indicated that their primary reasons for implementing any of the DE measures was to keep their system within standard operational parameters.

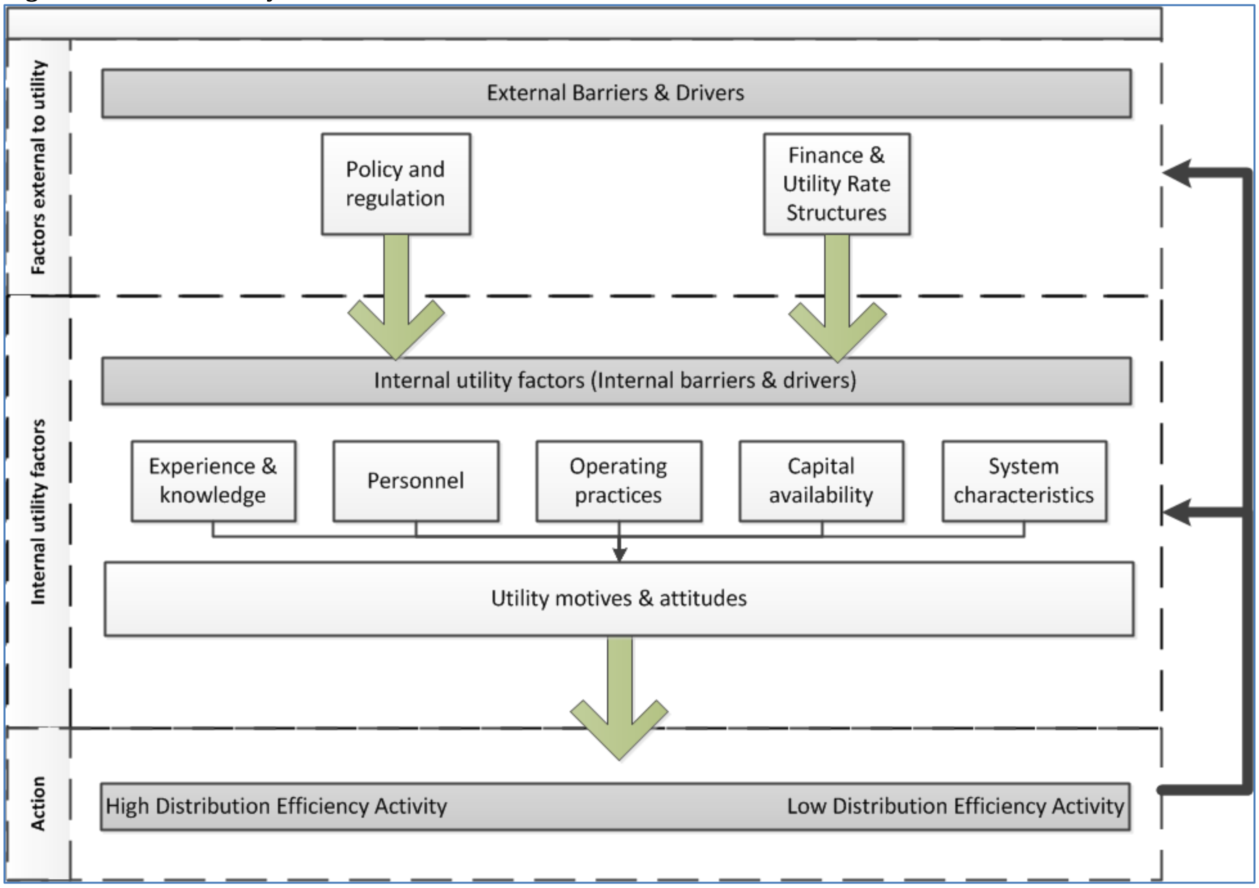
Four respondents indicated they had no plans to pursue DE, and three others “didn’t know” if there were plans.

Overall, when examining the specific energy savings goals as motivators of these plans, 15 of the respondents had efficiency as a clear motivator for the plans, four had efficiency as a partial or secondary consideration and for the other ten, efficiency did not play a role in the plans.

2.2.6 Distribution Efficiency Market Dynamics Model

Figure 4 summarizes the relationship between external factors, internal factors, and the implementation of DE measures in the PNW. Navigant developed this model inductively from the interview data and improved the model iteratively as it coded each interview and compared responses.

Figure 4. DE Market Dynamics Model



Source: Navigant

External Barriers and Drivers: Policy, regulation, and finance are both barriers and external drivers to the implementation of DE measures. Regulations (I-937), policy (e.g., BPA penalties for low power factor), and finance (utility rate structure or constraints) drove a utility's internal decision-making process. Regulatory changes, financial incentives (or penalties), and finance structures altered a utility's attitudes, motives, and ultimately the internal factors shaping the utility decision-making process.

Internal Factors: Utility personnel experience and knowledge of operating practices, capital availability, and system characteristics are also barriers and drivers that influence utilities' motivations and attitudes towards DE. Ultimately, this interaction between internal and external factors, and each utility's motives and attitudes framed their decision-making process, either promoting or inhibiting DE implementation. Upon implementation, the success or failure of a particular measure influenced other utilities' decisions (updating external factors) *and* updated internal utility factors. For instance, a successful DE project might simultaneously improve that utility's attitude towards DE and a utility's external attitudes towards that type of measure.

The model depicted in Figure 4 combines a number of identified barriers and drivers from previous sections into singular factors affecting implementation of DE. For example, operating practices represent barriers (and drivers) related to the entire operating practice of the utility. This includes system design, O&M, reliability, customer satisfaction, and cost-effectiveness. The analysis team coded for each response type (as described in previous sections), but combined these factors into a singular driver or barrier referred to as operating practices. Operating practices represent the entire set of factors for how the utility has been structured, and how they might evaluate investment decisions, as well as define cost-effectiveness, or the established best practices at that utility. System characteristics represent a number of technical or regionally based drivers (or barriers) to a utility. For instance, utilities with a number of agricultural customers might have a different set of motives or attitudes towards DE, thus affecting their implementation decisions.

To test this model, Navigant constructed a "DE Activity Index" (DAI) by awarding points to each utility based on interview responses as a measure of the degree to which a utility had demonstrated a focus on distribution efficiency. The details of this calculation are presented in Appendix B. The DAI is based on qualitative information and subjective judgment, and as such, Navigant views the DAI as a coarse indicator of whether a given utility has done very little, a moderate amount, or quite a bit in the area of DE *relative to other utilities*. Accordingly, Navigant used the DAI to split the sampled utilities into three groups: Those with a DAI ranging from zero to 33 percent (there were 11 in this group), those with a DAI greater than 33 percent but less than 66 percent (there were 16 in this group), and those with a DAI above 66 percent (there were seven in this group).Table 20 presents the distribution of DAI groupings across utility types.

Table 20. Distribution Activity Index Grouping by Utility Type

	IOUs (n = 7)	Public Utilities			
		DE Active (n = 16)	DE Unknown (n = 11)	SRR (n = 10)	Non-SRR (n = 17)
DAI High	4	3	0	0	3
DAI Medium	3	12	1	2	11
DAI Low	0	1	10	8	3

Source: Navigant analysis

The following discussion presents Navigant's observations about the attitudes and perceptions of barriers to and drivers of DE within each of these groups. For each group, Navigant presents a case study of a representative respondent.

Low DAI Group

All 11 of the respondents whose answers placed them in this group represent public utilities, and eight of them are from SRR utilities. Only one respondent represented a utility in the DE Active stratum. In their responses to interview questions about opportunities for DE and whether utilities should be investing in DE, this group revealed no negative attitudes toward DE in general, though when asked specifically about CVR, three expressed skepticism that it would be viable on their largely rural systems. Two respondents in this group mentioned cost-effectiveness and two mentioned lack of information as barriers to DE. Others mentioned scarcity of capital and personnel as barriers.

This group mentioned several barriers specific to CVR. One respondent was from an SRR utility that does not own a substation, and so had little ability to control voltage. Another respondent stated that CVR would be infeasible because his utility shares a substation with three other rural utilities, each of which has large irrigation loads at the end of very long feeders. Others mentioned cost or competition for resources with other distribution projects as barriers to implementing CVR.

In response to Navigant's questions about drivers for DE, several respondents mentioned their utilities' desire to minimize the cost of supplying power to customers. Three of the utilities in this group are in Washington and have more than 25,000 customers, and are therefore subject to I-937. These utilities mentioned I-937 as a driver for CVR.

Low DAI Case Study: Navigant selected an SRR municipal utility in Idaho from the DE Unknown stratum as representative of this group. The respondent from this utility is the utility's superintendent.

The respondent from this utility exhibited a generally positive attitude towards DE when asked if there were opportunities for efficiency improvements on the utility distribution system and whether utilities should invest in DE. However, this utility had made no effort to educate employees about DE, nor had it conducted any analysis of DE opportunities on its system. When asked for his opinion about CVR, this respondent mentioned a lack of knowledge and the opinion that "things run better with higher voltage".

When the interviewer asked for the respondent's opinion about whether CVR would be useful for his utility service area, his response was:

- *"We have very high pump loads for irrigation. We need higher voltage at the substation in order to ensure adequate voltage at the end of the line. We share substations with three other utilities, so CVR might make sense for* <the municipal utility>*, but not for the rural utilities it shares with that have long feeders with heavy motor loads on them."*

This response indicates two types of barriers to CVR implementation: technical feasibility and shared control of the substation resources that would need to be modified with neighboring utilities.

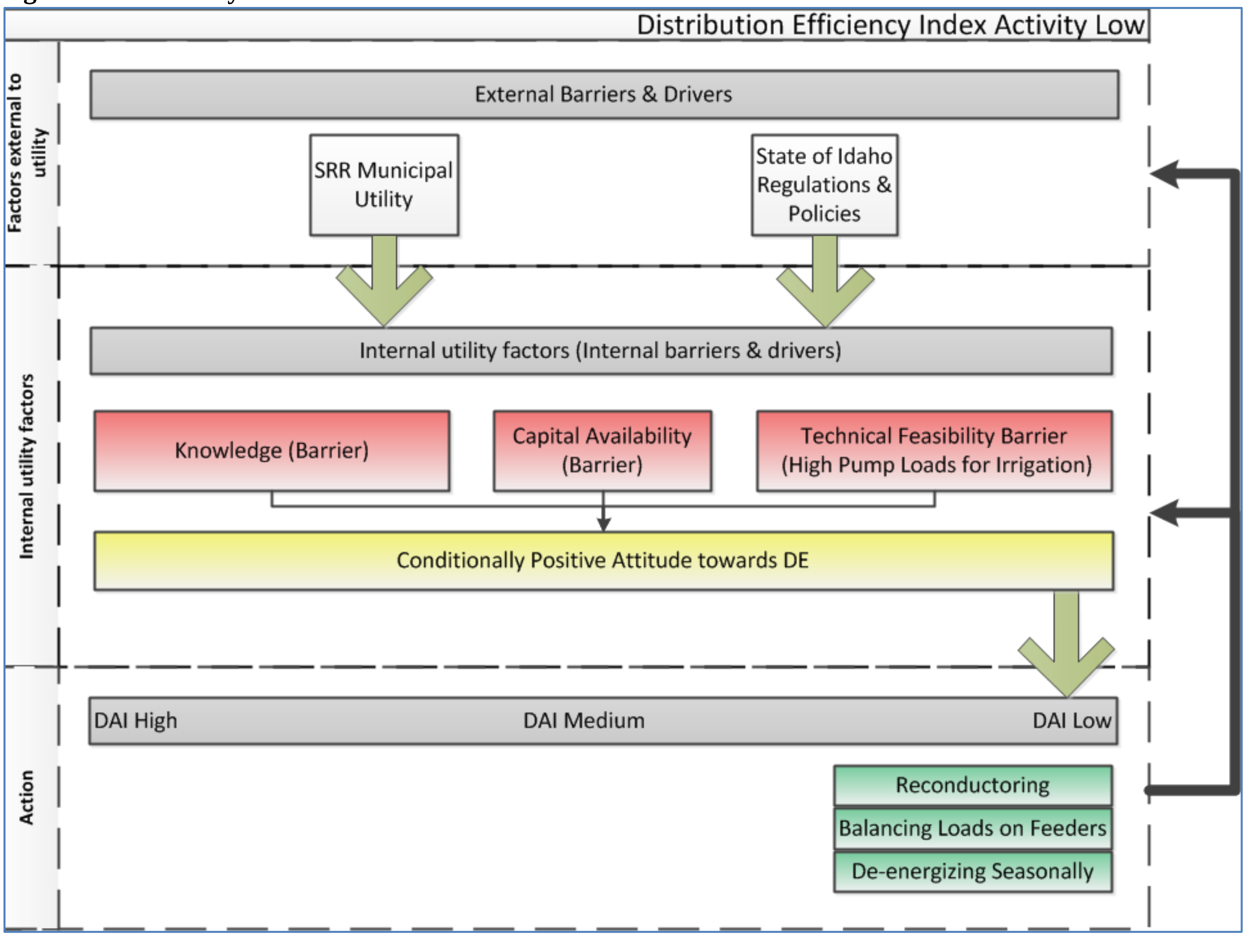
When the interviewer asked the respondent to name any barriers that might inhibit investments to make the distribution system more efficient, this respondent mentioned access to capital and a knowledge gap:

- "*Costs could be a problem. It takes years to pay off, but you need the money now to improve the system. Knowledge is another barrier--we don't know that much about it."*

This utility had already implemented several other DE measures, such as a project that re-conductored several feeders and switched the distribution system to a higher primary voltage. The respondent mentioned two additional measures that the utility implemented primarily to reduce losses: balancing loads on feeders and de-energizing seasonally unloaded transformers for agricultural irrigation loads.

Figure 5 demonstrates how the market dynamics model applies to this utility, and results in low DE activity.

Figure 5. Market Dynamic Model for Low DAI Case



Source: Navigant

Medium DAI Group

Thirteen of the 16 respondents in this group represent public utilities, the others represent IOUs. Among the public utilities, two are SRR, and all but one is in the DE Active stratum.
Like the members of the low DAI group, none of the respondents in this group expressed negative attitudes about DE in general, although some expressed reservations about whether there were opportunities to improve the efficiency of their system or whether such improvements would be cost effective. Unlike the low DAI group, these respondents expressed no negative attitudes about CVR. However, some did discuss barriers to implementing CVR. These were: insufficient knowledge (one respondent), already optimized system efficiency (one respondent), sensitivity to lost revenues (one respondent), lower priority relative to other distribution projects (two respondents), and the potential reliability issues CVR could pose during a contingency (two respondents).

Navigant's question about barriers to implementing DE measures elicited the following responses:

- Five respondents mentioned project costs or access to capital.

- Two respondents mentioned limits on personnel time available for DE projects.
- One respondent from a utility that purchases power from BPA noted that his utility has a “slice” contract with BPA, requiring the utility to pay for a fixed amount of energy, whether it was used or not, which removes any incentive for efficiency improvements.
- One respondent indicated that DE projects would have low priority relative to other distribution reliability-related projects.
- Barriers mentioned by the respondents in this group from IOUs reflected concerns about rate impacts, lost revenues, and cost recovery risks.

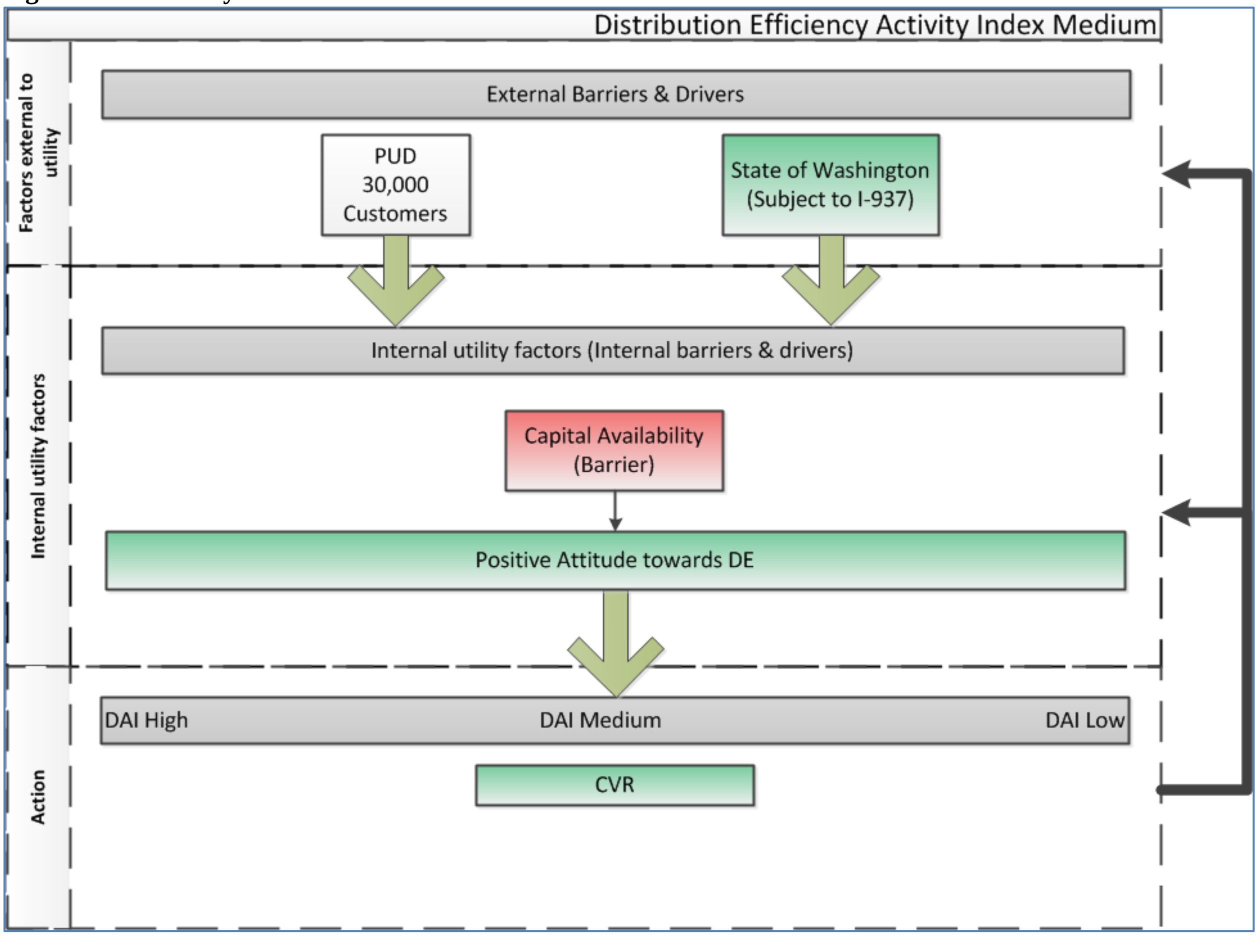
Seven utilities in this group had implemented CVR on part or all of their systems. Three larger public utilities in Washington State indicated that I- 937 was an important driver behind their CVR implementation. Respondents from IOUs with service areas in Oregon and Montana mentioned that regulatory policies had motivated their utilities to implement CVR. One respondent mentioned the subsidy available from BPA as a motivator, and two others noted that their utilities had received funding from the U.S. DOE through the Pacific Northwest Smart Grid Investment Grant project, and that this was an important driver behind CVR at their utilities.

Medium DAI Case Study: The utility Navigant selected as representative of this group is a Washington PUD with about 30,000 customers. This utility is in the DE Active stratum. It is currently implementing a CVR pilot. The respondent from this utility is the utility’s engineering manager.

The respondent exhibited a generally positive attitude about DE when asked if there were opportunities for efficiency improvements on the utility’s distribution system and whether utilities should invest in DE. He indicated that the utility had not made extensive efforts to educate staff about DE opportunities, but that he participates in a group that discusses distribution system design for small utilities. When Navigant asked if the participant’s utility had analyzed savings potential from DE measures, the respondent described a rigorous analysis that uses a load flow model and SCADA data to evaluate “problem areas” on an annual basis. He also described a CVR scoping study that his utility conducted in conjunction with BPA a few years ago that resulted in CVR implementation on a portion of the utility distribution system. When the interviewer asked for his opinion about CVR, this respondent stated that CVR is an important concept, and that I-937 is an important motivator for the utility to implement CVR. In response to Navigant’s question about barriers that would prevent his utility from implementing DE measures, project cost was the only potential barrier this respondent mentioned.

Figure 6 demonstrates how the market dynamics model applies to this utility, and results in moderate DE activity.

Figure 6. Market Dynamic Model for the Medium DAI Case



Source: Navigant

High DAI Group

This group consists of seven respondents, four of whom are from IOUs. The other three represent large public utilities in the DE Active stratum serving between 150,000 and 200,000 customers.

In response to Navigant's questions about opportunities for DE and whether utilities should be investing in DE, none of the respondents expressed negative attitudes about DE. A few, however, mentioned barriers to implementing DE measures such as the following:

- Prioritizing DE projects relative to other demands on available utility capital
- The cost of M&V needed to demonstrate savings (When savings are small, M&V costs can make a project non-cost effective)
- Lost revenues if DE results in efficiency improvements on the customer side of the meter

DE drivers that this group discussed include customer satisfaction (two respondents), the ability to make a return on DE investments (one respondent), and cost-minimization (two respondents).

When Navigant asked for their opinions about lowering voltage to improve customer efficiency, most respondents in this group had either positive or neutral attitudes, as long as it's implemented carefully and minimum voltage is maintained. The one respondent with a negative response indicated that he wasn't sure that lowering voltage necessarily saves the customer any energy.[11] This group did not raise any significant barriers to implementing CVR other than ensuring that reliability is not compromised, and that implementation is cost effective. All but one utility in this group had already implemented CVR. The respondent from the utility that had not implemented CVR questioned whether there was much potential for savings at his utility. All of the utilities in this group that had implemented CVR mentioned I-937 as a driver. One also mentioned the importance of the 50 percent cost sharing his utility received from the U.S. DOE through the Pacific Northwest Smart Grid Investment Grant project. Surprisingly, a large WA IOU respondent stated that he didn't think that regulation had much impact on his utility, because his utility was investigating CVR in advance of the regulation. One respondent from a utility with a service area in Oregon also mentioned that state's IRP rules require the utility to investigate DE measures.

High DAI Case Study: The utility that Navigant selected as representative of this group is a large IOU that participated in the DEI. The respondent from this utility is the analytical manager in the utility's DSM department.

The respondent's answers exhibited positive attitudes about DE. He frequently cautioned that DE should only be implemented where it is cost effective; however, he noted that unlike efficiency improvements on the customer side of the meter, DE does not cause lost revenues for the utility, driving both rates and bills down over the long run. This respondent indicated that "A lot of the engineers at <utility> are very much up to speed on DE issues and participate in industry events to learn about it." He also expressed the belief that his utility is "way out in front of DE generally."

When Navigant asked if the participant's utility had analyzed savings potential from DE measures, the respondent noted that the utility had identified CVR potential by participating in the DEI, and referred to state regulations requiring independent measurement of DE savings. This respondent had a favorable attitude about CVR. "We have to stay between 114 and 126 volts. The cheap and easy way to do this is to provide 126 volts—it makes those meters spin like mad. If you can maintain 117 volts and be 99.5% reliably above 114 volts, then I see no reason not to do it. The responsible thing to do is reduce voltage."

When Navigant asked about barriers that would prevent his utility from implementing DE measures, the respondent mentioned competition for limited capital funds with other high-priority utility projects as a potential barrier. He also noted that if DE results in significant reduction of consumption on the customer side of the meter, lost revenues could present a barrier for utilities that have rate cases infrequently.

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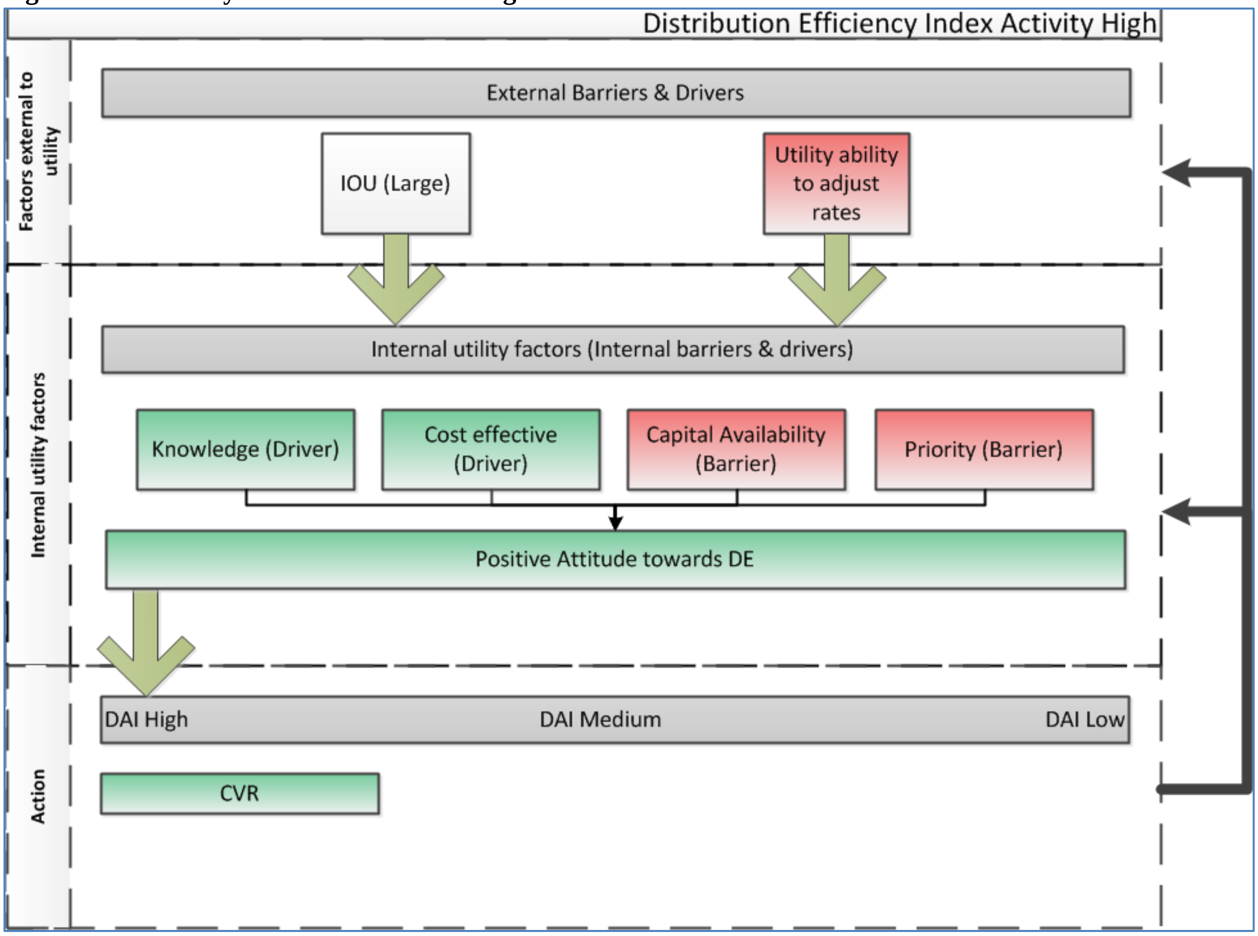
[11] This respondent believes that inductive loads (motors) will draw more power at reduced voltage. In reality, partially loaded motors operate at higher efficiency, and therefore draw less power at the very limited voltage reductions implemented by CVR.

Figure 7 demonstrates how the market dynamics model applies to this utility, and results in high DE activity.

Figure 7. Market Dynamic Model for the High DAI Case



Source: Navigant

2.3 Conclusions and Recommendations

Conclusion: SRR utilities are not subject to the external driver of PUC regulations, but do face significant informational barriers to implementing DE measures. As a result, SRR utilities are much less informed about DE opportunities, are much less likely to have knowledgeable employees and much less likely to have conducted research into DE potential on their systems. As an example, 60 percent of respondents from SRR utilities had never heard of CVR prior to the interview. All others in the sample had. None of the respondents from SRR utilities were aware of RTF protocols for evaluating CVR, whereas 80 percent of the remaining respondents were familiar with those protocols.

Recommendation: If NEEA and/or BPA wish to promote distribution efficiency in the PNW, either, or both, could play a role in lowering the informational barrier these utilities face by providing an educational resource, focused primarily on SRR utilities, detailing the most frequently cost effective opportunities for DE. This resource could take the form of a series of web pages, an online course or perhaps a live webinar offered periodically, perhaps for continuing education credit. Whatever form the resource takes, Navigant recommends that in order to minimize potential barriers to accessing the information it provides, this resource be available free of charge or at very low cost, and that it not require participants to travel. If it is created, use of this resource could translate directly into greater awareness of and participation in BPA's ESUE program.

Conclusion: Although there are financial and informational barriers to DE, there do not appear to be attitudinal barriers. All 34 survey respondents indicated that utilities should be investing in the efficiency of their distribution systems, as long as such investments are cost-effective. Over two-thirds of the respondents believe that opportunities exist for cost effective DE improvements on their distribution systems, and another ten percent believe they have already captured the cost effective DE opportunities. However, the respondents Navigant spoke with frequently commented that utilities rarely conduct distribution system improvements solely or even primarily to achieve energy or demand savings. Most often, utilities conduct system improvements to serve a growing load or to improve service reliability, and these improvements often improve efficiency as a side benefit. Often, although the utilities are aware that their distribution system improvements bring efficiency benefits, those benefits go un-analyzed.
Recommendation: There are frequently opportunities to capture cost effective efficiency improvements when utilities are replacing distribution system components or expanding service into new areas that would not likely be cost effective at other times. Examples are "right-sizing" transformers, examining conductor upgrades or replacements, and specifying higher efficiency transformers. If NEEA and/or BPA wish to promote DE in the PNW, either or both could develop an informational campaign focusing on these "lost-opportunity" measures, and offer incentives to encourage utilities to adopt such measures when they are making system improvements for other purposes.

Conclusion: Financial incentives have been effective in motivating utilities to investigate the potential CVR on their systems, and in many cases making implementation financially advantageous to the utility.
Recommendation: If BPA wishes to continue promoting the diffusion of CVR to more of the utilities it serves, it should continue to offer and promote the incentives available through its ESUE program or other mechanisms.

Conclusion: While few respondents expressed negative opinions about CVR, several indicated that the technique is unworkable on their systems because of the expense of the changes that would be necessary (such as adding reactive power compensation) to flatten feeder voltage profiles to make voltage reduction possible. This appears to be a problem most frequently for utilities with rural, low customer-density service territories, such as those, for example, serving irrigation loads at the ends of long feeders.
Recommendation: It is true that many feeders in the PNW have been poor candidates for CVR due to the costs of remediation necessary to enable CVR. However, in addition to the MicroPlanet voltage regulators investigated as part of the DEI, there are new technologies that support voltage at the end of the line (and upstream as needed) by sensing feeder load and injecting reactive power on the secondary side of the distribution transformer. There is emerging evidence (Handley 2014) that, under some conditions at least, these technologies can be very cost-effective, and allow utilities to implement greater voltage reductions, and thus obtain greater savings, without extensive modifications to the feeder. As SRR utilities appear to be a

particularly hard to reach sector within the PNW utility market, Navigant suggests that NEEA and/or BPA follow the results of early deployments of these technologies. If these early results prove promising, Navigant recommends that NEEA and/or BPA consider funding a pilot to investigate the extent to which these technologies can enable CVR on long rural feeders at SRR utilities, and to characterize the costs and benefits of doing so.

2.4 Avista Impact Evaluation

As part of the same solicitation that resulted in the market characterization effort discussed above and the evaluation tool assessment described in Section 3, NEEA requested an impact evaluation of a CVR program that Avista Utilities (Avista) implemented in the fall and winter of 2013 as part of larger Smart Grid projects. Navigant's full report on this impact evaluation is included as Appendix D. What follows is the executive summary from that report.

2.4.1 Overview of Program

Avista's CVR program is a part of its two Smart Grid 2.0 projects. Both projects incorporate Integrated Volt Var Control (IVVC). The IVVC module issues commands to the station or midline regulators to maintain the minimum voltage set-point within a specified voltage dead-band. Avista based the business case for IVVC on the avoided cost of energy resulting from the reduction of load by lowering the distribution line voltage.

Commissioning of IVVC in the Washington service territory, including the cities of Spokane and Pullman, began in September 2013 and concluded on December 31, 2013.

2.4.2 Description of the Evaluation

The Washington Utilities and Transportation Commission required that Avista have distribution efficiency savings evaluated using the Regional Technical Forum's (RTF's) Automated CVR Protocol No. 1, but allowed Avista to develop additional methodology (UTC 2012).

The protocol specifies an approach for verifying energy savings on electric power distribution circuits and substations on which a utility has implemented CVR. It is flexible with respect to type of load and the utility can apply the approach to circuits serving any combination of residential, commercial, and industrial customers. The main requirements include the ability to measure and record voltage levels and energy usage at uniform intervals, and the ability to vary circuit target voltage levels on each controlled circuit at the same time every day for periods of up to a year. The protocol consists of an experimental design prescribing the procedures to follow for generating experimental data, and a recommended method for statistically estimating the conserved energy from the experimental data.

Navigant also considered two alternative methodologies.

2.4.3 Washington State University (WSU) Voltage Optimization Validation Methodology

WSU has developed a methodology to derive CVR savings as part of a research effort it is conducting on behalf of Avista. WSU developed its approach to address limitations associated with RTF Automated CVR Protocol No. 1, including the need to conduct day-on, day-off measurements over an extended period. Navigant assessed the applicability of the WSU model to derive accurate energy savings for CVR.

2.4.4 Navigant Regression Methodology

Navigant developed parallel savings estimation methodologies to evaluate alternative calculations in comparison to RTF Automated CVR Protocol No. 1. Navigant used the same data set as that specified in RTF Automated CVR Protocol No. 1, but relied instead on direct regression modeling to estimate energy savings. Navigant formulated several alternative model specifications and relied on empirical testing methods to select the ones with the most desirable properties.

2.4.5 Summary of Results

Navigant completed an impact evaluation of Avista's CVR program. Navigant explored three methods:

1. RTF Automated CVR Protocol No. 1
2. WSU Voltage Optimization Validation Methodology
3. Navigant Regression Methodology

When fully implemented and tested, the WSU approach may present an acceptable alternative to savings estimated using industry protocols (or other methods). However, only two feeders have been modeled thus far (out of the more than seventy feeders with CVR), and Avista has not fully integrated the enhanced SynerGEE model with its Distribution Management System (DMS). Thus, at this time, Navigant is unable to conduct a rigorous comparison of savings calculated by the WSU model versus those estimated using RTF Automated CVR Protocol No. 1.

The RTF and Navigant approaches yielded savings estimates as shown in Table 21.

Table 21. Summary of Savings Estimates

Approach	Savings Estimates (MWh)
RTF Automated CVR Protocol No. 1	42,292
Navigant Regression Methodology	42,374

The two estimates are statistically indistinguishable, giving confidence that the RTF method's value is reasonable. Navigant expects that inclusion of summer data would not substantially change the savings estimate and might well increase it.[12]

2.4.6 Recommendations

Navigant recommends that Avista continue to cycle the CVR voltage levels per the RTF Automated CVR Protocol No. 1 for the remainder of 2014. This will enable a more robust estimate of annual savings.

Navigant also recommends that the RTF consider adopting Navigant's alternative regression approach for the evaluation, measurement and verification (EM&V) of savings for automated CVR programs. It produces similar results to the RTF Automated CVR Protocol No. 1, and is somewhat less burdensome to implement.

[12] In previous evaluations, Navigant has found significantly higher savings during summer periods relative to the rest of the year.

3 Evaluation Tool Assessment

This section presents Navigant's assessment of tools available from or used by utilities, vendors, consultants, and organizations responsible for evaluating CVR. It includes an assessment of tools that have been applied to support pilot studies, industry research, and ongoing utility programs, with a primary objective of establishing the effectiveness of these tools to derive CVR factors to accurately predict or measure CVR demand and energy savings.

The following describes industry tools, attributes, assumptions, and how various organizations and vendors that supply or develop tools expect to enhance them in subsequent evaluation efforts. The assessment includes evaluation of tools and methods utilities now use to measure CVR impacts, savings, lessons learned, and Navigant's assessment of the effectiveness of these tools for current and future DE programs for CVR and volt/VAR control.

3.1 Task Objectives

The primary objective of the assessment is to identify tools that have been used to evaluate and predict demand and energy savings for utilities employing CVR, and resulting CVR factors. The term CVR includes related control strategies such as voltage stabilization, reactive power controls, power factor correction, and VAR optimization, as each of these functions can be used to effect CVR savings.

The outcome of the evaluation focuses on tools that NEEA utilities, large and small, can use to reliably predict CVR demand and energy savings. These tools range from comprehensive simulation models using rigorous evaluation techniques and extensive data input used by larger utilities with extensive CVR deployment, to less rigorous tools with fewer data requirements for use by smaller utilities or those with limited CVR deployment.

3.2 Methodology

The benefits of CVR can be verified using statistical or simulation analysis, the former using regression analysis, the latter via distribution feeder models such as CYME, SynerGEE, WindMil, and ETap. Navigant compared the strengths and weaknesses of these models, contacted utilities, and researched numerous published reports and documents to identify tools and methods utilities have or plan to use to derive CVR impacts and benefits. Navigant compared these tools and practices to those employed by utilities within and outside NEEA, including jurisdictions where CVR has been mandated by regulatory agencies.

M&V approaches entail first capturing relevant voltage and usage metrics from the distribution system, and then using statistical methods to accurately quantify the changes due to CVR. One such protocol endorsed by the RTF (Standard Protocol #1 for Automated CVR) specifies data collection standards and methods for computing savings. The protocol follows similar methods to those described by DOE in their guidelines for calculations of energy savings from federal energy projects.

Navigant evaluated the RTF's protocol, and researched a broader set of CVR evaluation tools, to provide a comparison of calculation methodologies. Navigant included questions in the market characterization survey to determine the relevance of alternative options to regional utilities.

Navigant also determined the extent to which measurement methods are already employed and the methods used to verify accuracy of the measurements.

3.3 Findings

3.3.1 Utility CVR Program Overview

Utilities throughout North America, large and small, have recently implemented CVR programs, or plan to pursue CVR in the future. Many utility programs have received funding support for voltage control under the DOE Smart Grid Investment Program (SGIG).[13] Of the 99 organizations awarded SGIG funds, 26 include voltage control measures. Many of these include Interactive Volt-VAR Control (IVVC) as part of a broad suite of applications, often as part of a distribution management system (DMS), where demand and energy savings measurement is not a primary objective or reported metric. For utilities implementing voltage and VAR control, some use local controllers (e.g., directly mounted on capacitor banks) to set voltages or power factor, whereas others are collectively automated via centralized controls. A few have collected sufficient data to demonstrate measureable savings. Of this subset, about one-half are peak demand reduction only, focusing on capacity deferral.

Using publicly available reports, Navigant reviewed methods utilities used to estimate CVR savings. They include M&V protocols using statistical verification methods and predictive simulation models using traditional approaches to estimate pre- and post-CVR savings. For example, one large utility with significant CVR deployment is applying a least squares statistical approach as an enhancement to current evaluation protocols. For utilities focusing on peak demand reduction, savings are measured via SCADA data or feeder simulation models.

The Electric Power Research Institute (EPRI) is leading a multiyear effort to evaluate Smart Grid performance for about six utilities over a five-year period. Part of this initiative leverages data and performance information from EPRI's Green Circuit program. While these utilities are implementing Smart Grid across a spectrum of applications, many include voltage control programs such as CVR. Navigant also has worked with other utilities to measure CVR savings, some under state-mandated programs, and has tracked other utilities' CVR programs. The models, tools, and predictive methods used by these utilities are described in the sections that follow.

3.3.2 Utility Survey

Navigant evaluated feedback from respondents who provided comments on the RTF protocol during the market characterization interviews. Among those aware of the RTF protocols, several respondents offered substantive comments on their usefulness. Several also described tools and approaches they used to verify savings from CVR and voltage management strategies; comments and observations are summarized below.

[13] The DOE is responsible for administering over $4 billion of grants issued under ARRA. Ninety-nine organizations received grants under SGIG, up to a maximum of $200 million.

- Applied SynerGEE feeder simulation model and SCADA data to evaluate feeder performance and capability to deploy CVR. Followed BPA approach to estimate savings.
- Used engineering analysis to balance phase loadings to reduce losses and address overloads.
- Several cited DE savings achieved via distribution feeder upgrades, some tangentially related to CVR and voltage control strategies.
- Several worked with consultants, such as SAIC, using feeder simulation software (SynerGEE) to evaluate feeder performance and upgrade requirements.
- Participated in the Smart Grid demo project for Volt-VAR control and CVR, with no conclusive results.
- Several performed trial assessments. One applied day on, day off protocol for a trial seven-day period with inconclusive results (measurements too small to detect).
- Some rural utilities with longer lines and low energy density cited low savings predicted by simulation models as reasons not to pursue CVR.
- One utility reported development of its own protocol, consistent with the RTF, to measure savings.
- A large urban utility suggested AMI will provide data that it can leverage for optimizing its distribution system, including use of ETap model for feeder analysis and evaluation.
- Several cited use of the Simplified Voltage Optimization M&V Protocol to estimate or report savings.

3.4 Review of Available Tools

3.4.1 Statistical Analysis

Energy and peak demand savings from CVR, unlike voltage changes, cannot be directly measured since wattage and energy usage on a distribution circuit are functions of multiple factors besides voltage. Other drivers include customer class and density, load characteristics (e.g., proportions of thermostatically controlled loads, lighting types, motor sizes, and their loadings), as well as time of day, day-type, and ambient weather conditions. Due to the multifactorial nature of energy and power determination, statistical methods, typically regression analyses, are needed to disentangle the energy savings impacts of CVR net of these other drivers. The data required for this type of analysis consist of periodic meter readings for voltage and energy usage at intervals of one hour or less, generally at the distribution feeder level. To generate analytical data for such an analysis, the utility should alternate the voltage set-points of the feeders or substations involved on a preset schedule, preferably over a period of at least 30 days during each season of the year.[14] Besides the metered voltage and usage readings, this approach requires ambient temperature data for the region served by the distribution feeders involved in order to control for weather effects; these are available from the nearest available weather station.

The simplest statistical approach models energy usage on a feeder circuit as a function of the measured voltage on the circuit, along with weather conditions (e.g., cooling and/or heating degree-days), season, time of day, and day-type. When data from multiple feeders are available, the analysis typically develops a separate regression for each feeder, in order to allow the model to reflect different mean energy levels across circuits, as well as differential voltage, weather, and time/day effects of the loads served by each feeder.

The net effect of voltage reduction on circuit energy usage is then estimated as the partial derivative of the regression function with respect to voltage.[15] The mean system CVR effect can be estimated as the weighted average of the measured effects on the individual circuits using the energy shares as weights.

A related approach, recommended by the RTF Protocol No. 1, is to use regression analysis to separately estimate 24-hour demand profiles ("load shapes") by season for the CVR controlled and non-CVR controlled regimes. In this approach, the CVR factor (CVRf) is estimated as the ratio of the 24-hour sum of the difference between the two profiles, to the mean voltage reduction under the CVR control.

Once the analyst has calculated an estimate of CVRf, gross energy savings on the circuit are simply calculated as the product of the aggregate energy flow on the circuit, the CVRf estimate, and the average percentage voltage reduction due to CVR.

3.4.2 Simulation Model Requirements

Simulation models that predict demand and energy savings from CVR must be able to accurately account for differences in load and external variables such as temperature and humidity that vary over time. The impact of changes in voltage on energy consumption can be highly nonlinear due to the types of loads connected to distribution feeders. For highly resistive loads, a reduction in voltage can result in a proportional reduction in energy consumption. In contrast, the impact of a reduction in voltage on constant power load or highly nonlinear load such as digital devices (e.g., liquid-crystal display television) may not produce the desired reduction in consumption. For constant power loads with high reactive power requirements, energy consumption may be constant or possibly increase.

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[14] Alternating between the normal voltage set-point and the reduced-voltage CVR set-point on a daily basis is common. For example, the RTF Automated CVR Protocol No. 1 prescribes cycling CVR voltage controls on and off on a daily schedule. However, less frequent cycling, such as every two, three or four days, is also reasonable as long as the schedule is exogenously set. Less frequent cycling may also be more logistically feasible.

[15] In the special case where the logarithm of usage is modeled as a linear function of the logarithm of voltage, the regression coefficient on log voltage gives the CVR factor (CVRf), which is the expected percentage change in usage from a one percent change in average voltage.

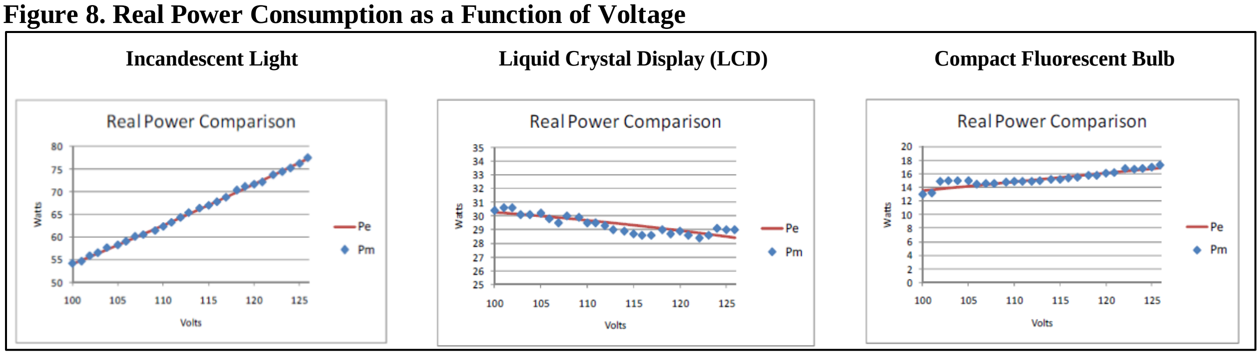
The importance of accurate representation of loads is highlighted in a 2010 DOE Pacific Northwest National Laboratory (PNNL) study that sought to identify demand and energy savings potential from CVR (PNNL 2010).[16] A critical finding in the study confirmed the dependency of energy consumption on load characteristics, concluding:

"*Voltage dependent multi-state models must be used to accurately represent the effects of CVR*."

Additionally, the PNNL study emphasized the need for time series analysisis to reflect changes in load patterns, and weather and load characteristics over time. Electric loads are represented in simulation models as either constant impedance (Z), constant current (I), or constant power (P), commonly referred to as a ZIP model. Because feeder loads are comprised of a mix of loads with different ZIP characteristics that define the degree to which real and reactive power respond to a change in voltage, the modeler must be careful to ensure that the feeder model includes an accurate ZIP representation of actual loads.

Examples of variances in real power consumption in response to changes in voltage are highlighted below.

Figure 8. Real Power Consumption as a Function of Voltage



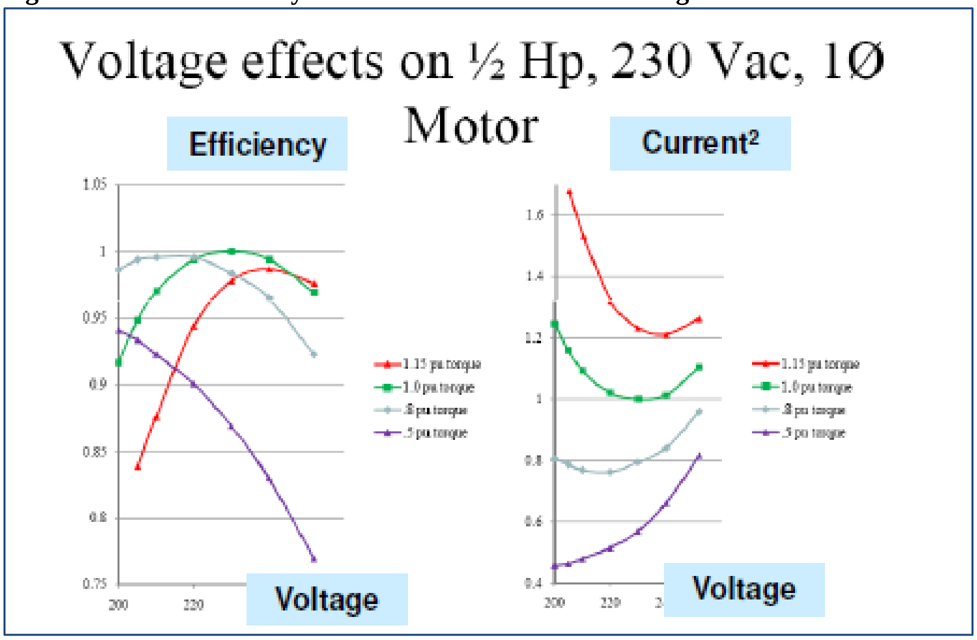
Source: PNNL 2010

Additional complications result from resistive loads such as space heating, where electric demand will decline in response to a reduction in voltage; however, total energy output is constant due to thermostats that maintain temperatures at desired levels – the electric load is enabled for a longer period of time to maintain desired temperature. However, if the electric heating elements are energized during hours when incremental line losses are lower compared to peak intervals, net energy consumption may still be lower due to CVR.[17]

The behavior of loads also can be unpredictable or counterintuitive. A commonly held assumption that constant power loads such as motors will experience increased loading (current) as voltages decline is not always the case. Figure 9 illustrates the complexity of motor load output, which confirms that motor load currents increase as voltage declines when loaded at rated output or higher. However, when loaded at 50 percent of full rating, efficiency improves and current declines as voltages are lowered.

[16] The study included detailed simulations of 24 prototypical feeders for different regions in the U.S. Results were extrapolated to predict CVR savings potential at the national level.
[17] Incremental line losses at peak are commonly near or above ten percent, sometimes approaching twenty percent on heavily loaded feeders. Off-peak losses typically are one-half peak losses.

Figure 9. Motor Efficiency and Load as a Function of Voltage



Source: Chen, Shoults, and Fitzer, 1981

There are many distribution feeder simulation models that accurately predict voltage, energy consumption, and losses at a fixed point in time; these models often are static, providing a snapshot based on a single simulation for a given hour. However, energy savings achieved by CVR must account for time-varying loads and an accurate ZIP model for all hours when voltage reduction is applied. Further, the model must be able to accurately predict energy consumption and losses both with and without CVR enabled. Further, most feeder models have very accurate primary voltage line and equipment impedances, but often do not model secondary lines and services, or use rough estimates of line impedances. Nonetheless, these models need to accurately predict voltages at secondary levels for feeders where CVR is deployed.

Typically, distribution feeder simulation models have not been designed to rigorously calculate CVR savings on a time-varying basis. For CVR implemented over an entire year, the model would need to perform up to 8,760 hourly simulations, pre- and post-CVR, and account for critical load attributes and behaviors described above. However, commonly available models are not structured to evaluate the impact of variable loads and adjusted voltage on a time series basis. These limitations and level of rigor required to perform accurate simulations have led to the development of evaluation protocols described in published literature, industry reports, and RTF documentation, each of which are based on field measurements and statistical methods.

3.4.3 Distribution Simulation Models

Distribution models are used by many utilities that are responsible for short- and long-term distribution planning. Forecasted loads, expected changes in configuration, new devices, and distributed resources are incorporated in model databases, and simulation studies are conducted for each of these changes to determine when feeder upgrades, modification or other types of mitigation may be required. Typical upgrades include line or cable upgrades, feeder re-configuration, new protective devices or new feeders and substations.

Most traditional and commonly used distribution simulation models (often referred to as "Feeder Load Flow") provide similar functionality and capability. The primary objective of these models is to represent and analyze radial circuits for studies evaluating performance and loading. Virtually all models provide voltage and loading information throughout the entire circuit to identify voltage or line-loading violations. These models are also used for operational decisions, such as feeder re-configuration, consolidation, and tie transfers to ensure no violations or problems would occur if these activities were to be undertaken. Many distribution models also are used for fault analysis and protection device coordination, such as determining whether fault current exceeds equipment ratings for changes in the transmission supply or when new distributed generation is added.

The use of traditional models to evaluate CVR presents a challenge to program M&V staff, as accurate savings estimates typically require time series simulation and a more detailed load model that fully captures the end-use characteristics and behaviors described above. Further, utilities are experiencing increased penetration of local distributed energy resources (DER). Although feeder simulation tools typically are capable of accurately modeling DER impacts, the impact of highly variable output from intermittent resources on primary and secondary voltage profiles often are not fully represented in feeder models, particularly feeders with high DER penetration. Nonetheless, many utilities rely on traditional models for estimating CVR savings despite these shortcomings.

EPRI has acknowledged the use of traditional distribution simulation models in a paper it recently presented on voltage and VAR control strategies, and M&V alternatives (EPRI 2011A). It suggested these models may be appropriate if they can accurately predict the change in real and reactive power, given the following criteria and steps:

1. Collect and include actual real and reactive information from SCADA into simulation model database

2. Develop and apply accurate load models by customer class

3. Use standard controls for regulator and capacitor operation

4. Compare predicted values from the simulation model with CVR enabled and disabled

In its paper, EPRI confirms the need for an accurate load model that properly accounts for end-use response to a change in voltage. . Further complicating this issue is the limited availability of customer class data at the feeder level to support derivation of ZIP models. With the advancement of AMI, utilities should be able to improve ZIP model accuracy.

Often, model results, methods, and assumptions are verified by comparing predicted results to field measurements and savings estimated using industry-accepted protocols. EPRI's Green Circuits program uses predictive methods and distribution simulation models to estimate CVR savings. As noted, these approaches recognize the need for accurate load models, and EPRI and other research organizations have made efforts in the last several years to properly model customer loads for feeder simulation analyses (EPRI 2011B). The EPRI paper confirms that CVR factors can vary seasonally and by time of day. The significance of an accurate load model is succinctly stated in the following excerpt cited in EPRI's Green Circuits paper:

- "*If we are going to use CVR and voltage optimization as an important tool for managing load and achieving energy savings, it is necessary to justify this with accurate system models, including the response of the load.*"

Table 22 shows a list of representative distribution planning models along with their developers or vendors. Virtually all perform detailed distribution load flows at the nodal level suitable for derivation of line-end voltage. Some models are provided by vendors and others by research laboratories and agencies. The latter include open-source software, used to analyze prototype distribution feeders, and databases for use in industry research. Some are in the process of linking to DMSs for near-real-time analysis, enhanced planning, and energy efficiency evaluation, including the ability to use very accurate state information provided by smart devices located on distribution feeders or from AMI at customer premises. Many utilities have included grid coordinate data in conjunction with AMI installations, which provides an opportunity to improve derivation of secondary lengths and impedances needed to accurately predict voltage impacts at the customer level.

Table 22. Distribution Planning Models Matrix

Distribution System Planning Models	**Developer/Vendor**
CYMDist	Cooper Power Systems/CYME
ETAP Distribution Software Suite	ETAP
Electricity Distribution Grid Evaluator (EDGE)	Rocky Mountain Institute (RMI)
ES-Grid	DNV GL
GridLAB-D	PNNL
LoadSEER	Integral Analytics, Inc.
Open Distribution System Simulator (OpenDSS)	EPRI
SynerGEE	DNV GL [18]
WindMil	Milsoft Solutions

Source: Navigant analysis

Key features and attributes of some of these models are highlighted below.

CYMDist

CYMDist is a comprehensive distribution system planning software package widely used by utilities and industry analysts throughout North America. Key features include built-in data libraries, with a fully detailed single and multi-phase circuit model including individual customers, inline and endpoint devices, and distributed generation. Similar to other widely used distribution load flow models, the analytical capabilities encompass power flow and voltage drop modeling, reliability analysis, contingency and sectionalizing studies, short-circuit and fault current calculations, protective device coordination, and arc flash hazard analysis. CYMDIST

[18] SynerGEE was previously offered by the GL Group, which was acquired by DNV KEMA in 2013.

also offers three optional modules including “Volt/VAR Optimization,” “Long-Term Dynamics” and “Energy Profile Manager” among its suite of applications, which makes it suitable for CVR evaluation.

GridLAB-D

GridLAB-D is an open-source (BSD license[19]) simulation and analysis tool that models emerging Smart Grid energy technologies. It couples power flow calculations with distribution automation models, building energy use and appliance demand models, and market models. It is used primarily to estimate the benefits and impacts of Smart Grid technology. GridLAB-D was used by PNNL in its August 2010 study cited earlier to predict CVR savings on a time series basis. However, the level of detail and model assumptions can be daunting to many users if it is to be applied to predict CVR savings.[20]

EPRI OpenDSS

The model is a general-purpose model for a wide variety of storage technologies designed for the OpenDSS framework. It can be used for static power flow calculations and various time-varying simulations. It is basically used to investigate impacts of time-varying resources or applications (such as CVR) on distribution systems. These models are intended for sequential power flow solution with a time step size of no less than one second. The model requires a considerable degree of background on distribution systems and modeling applications.

WindMil

WindMil is a distribution system planning software package that will accurately represent a fully detailed circuit model including individual customers, inline and endpoint devices, and even distributed generation. The analytical capabilities encompass power flow and voltage drop modeling, reliability analysis, contingency and sectionalizing studies, short-circuit and fault current calculations, protective device coordination, and arc flash hazard analysis.

SynerGEE

SynerGEE is a widely used tool that performs detailed load modeling and a host of analyses on radial, looped, and mesh network systems comprised of multiple voltages and configurations. It is the model that Washington State University used as part of its research effort to address feeder load model limitations, presented below.

Avista/Washington State University (WSU) Model

The limitations of several traditional load flow models, particularly those related to time series analysis and varying load characteristics, are currently being addressed in a research project by WSU on behalf of Avista Utilities. Findings and observations presented herein are based on WSU’s May 17, 2013 report and discussion with WSU, Avista, and NEEA representatives.[21] The objective of the review is to assess the applicability of the WSU model, to derive energy savings for CVR and assess the applicability of the model for use by other NEEA utilities.

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[19] A BSD license is a descriptive term for free software, with licenses that are nonrestrictive with regard to the redistribution of the software.

[20] The PNNL study performed minute-by-minute simulations over 8,760 hours, with time-varying representation on constant thermal loads.

[21] For example, the research effort performed by WSU under AVISTA SGDP Contract No. R-37414, WSU No. OGRD 11574.

WSU Methodology

WSU's May 17 report is one of a series of reports it has prepared or will prepare on behalf of Avista. The report highlights progress WSU has made with respect to feeder simulation model algorithms, assumptions, and data. All analyses presented are for distribution feeders located in Pullman, WA. WSU has developed "Solver Code" logic that it has linked to the SynerGEE feeder simulation model to better analyze feeders via use of real-time data and dispatch strategies for voltage control devices (i.e., load tap changers and capacitors). WSU's use of data collected via smart meters on Viper switches and the development of an alternative approach to represent loads (i.e., the accurate measurement of power, current, and impedance via the "ZIP" model described earlier in this section) that vary as a function of feeder voltage is a significant advance over earlier modeling capabilities.

This initiative highlights ongoing efforts by Avista Utilities to obtain a "behind the meter" model of WSU's loads distributed among many 4kV feeders. Currently, Avista's feeder model treats all WSU loads as a single delivery point. The objective is to accurately predict CVR energy savings using real-time feeder data obtained from the smart meters. A series of tests were performed on a representative feeder using both the SynerGEE model and the DOE/PNNL GridLAB-D model to predict real-time energy savings (RTES) using the ZIP loads and the IVVC algorithm.

Overall Assessment of WSU Methodology

The WSU report highlights several key advancements in the modeling of distribution feeder loads and integration of real-time data via supplemental logic used in the SynerGEE model, each of which should improve the accuracy of real-time estimation of energy savings achieved via CVR. Initial results for a representative feeder appear to confirm the accuracy of the algorithm and model results. As the report states, additional studies need to be performed for a broader range of feeders and conditions. Notably, results obtained from GridLAB-D closely match those obtained from SynerGEE; however, the GridLAB-D model typically performed much more detailed simulations.

The algorithms and model logic WSU has developed appear to be intended for use for real-time CVR decisions by distribution control center operators. Navigant assumes the model or adjunct systems would be designed to collect CVR RTES based on pre- and post-model calculations. When fully implemented and tested, it may present an acceptable alternative to savings estimated using industry protocols (or other methods). Navigant has not completed a rigorous comparison of savings calculated by the WSU model versus those estimated using RTF protocols, as the WSU project was still in the early stages of testing at the time of this report. Discussions with WSU and Avista clarified future steps to integrate the WSU model/tool with Avista's DMS to measure savings. However, Navigant is not yet able to opine on the effectiveness of the integration of model logic to Avista's DMS or the systems that will be used to collect RTES data, and whether they will be a suitable alternative to current measurement protocols.

Navigant also notes that the methodology and systems described above are highly sophisticated and require advanced modeling that smaller utilities may not be able (or need) to employ. In particular, many smaller utilities do not plan on acquiring detailed feeder simulation models or DMSs similar to those described above. Hence, the applicability of the WSU model, DMS integration and approach to measure savings may be most suitable for larger utilities.

3.4.4 DMSs

Distribution simulation tools have evolved to include sophisticated DMSs that integrate data from field measurement devices and communications to enable real-time control, automation, and evaluation, including voltage control functionality. The product offerings from the various vendors differ in functionality, reach of network visibility, and control. DMSs with certain outage management system functionality are called Advanced DMS. Increasingly, these systems integrate distribution feeder simulation modeling capability for near-real-time modeling based on loading and equipment status information collected by the DMS. Advanced applications include determination of line loadings, operating issues, and benefits that can be achieved via use of distribution resources, including energy storage. At minimum, advanced applications based on integrated DMS/feeder simulation provide distribution operators with the capability to monitor the status of distributed resources, a first step toward fully integrated and automated operation.

Several vendors whose software is used to view, control, and operate distribution grids are listed in Table 23. Each of these systems offers various degrees of functionality and sophistication. However, few would be acquired and installed solely for CVR applications or measurement, as DMSs typically include a suite of applications to provide visualization and control of many equipment components and systems to improve operations, performance, and reliability of distribution assets.

Table 23. DMSs Matrix

Real-Time Grid Operation (DMSs)	**Developer/Vendor**
GE DMS	GE
Distribution System Operations Solution	Ventyx
OSI Spectra DMSs	OSI
Decentralized Energy Management System	Siemens
Oracle DMS	Oracle
Alstom DMS **-** Demand Response Distributed Generation	Alstom
Source: Navigant analysis	

3.4.5 Smart Grid and AMI Integration

The availability of distribution voltage data from installation of smart meters and integrated communications systems (i.e., AMI) provides an opportunity to monitor and collect real-time voltages at selected locations along distribution feeders. These data can also be used for measurement protocols that rely on line-end voltages. However, smart grid programs that install AMR meters that are unable to measure voltage have limited CVR-related benefits. Limits to utility communications system bandwidth can also constrain both the frequency and number of reporting points. The need to plan proactively is critical, as utilities that select smart meters without considering CVR often select less capable systems.

A recent EPRI summary paper on its Green Circuits program emphasizes the value of integrated systems:

- *"This approach [for CVR] has been used for decades, but what is changing with the Smart Grid is the ability to optimize performance by integrating data from new communications infrastructures, lower-cost voltage sensors being deployed along distribution feeders, smart meters, and flexible operational strategies."(EPRI 2013)*

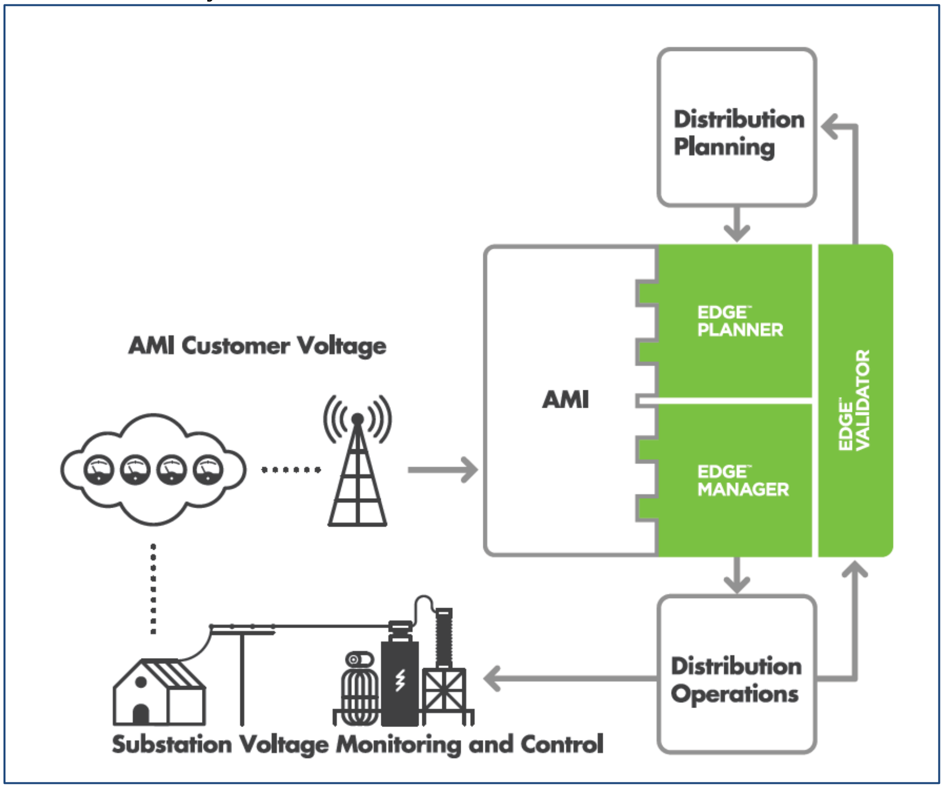
The EPRI study for CVR evaluation includes results that are still preliminary. Nonetheless, increasingly, vendors have developed solutions and product offerings to leverage AMI to provide an integrated solution to CVR control and measurement. Typically, only a small subset of AMI meters is needed as voltage sensors to provide sufficient feedback for use in measurement protocols or centrally controlled CVR algorithms. Centrally controlled solutions include stand-alone evaluation of CVR and voltage control schemes, or full integration with DMSs. However, very few North American utilities have implemented integrated AMI and CVR, although smart meter functionality provides the means to do so.

Dominion EDGE®

Dominion Energy Holdings Inc., a large holding company with electric and gas retail utility services throughout Virginia, has developed a suite of simulation products and voltage control solutions. The suite of products and software, coined as EDGE®, is offered by a Dominion subsidiary, Dominion Voltage, Inc.[22] Dominion's product description emphasizes a process that relies on expertise provided by other business units "to develop sustainable alternative energy solutions." Figure 10 presents a high-level illustration of key modules and interfaces.

[22] Dominion Voltage, Inc. (DVI) is a subsidiary of Dominion Energy Holdings, Inc. DVI received the following patent for its EDGE® technology from the U.S. Patent and Trademark Office: "Voltage Conservation Using Advanced Metering Infrastructure (AMI) and Substation Centralized Voltage Control."

Figure 10. Dominion EDGE℠ System



Source: Dominion Voltage, Inc.

The system is described as one where "Your Smart Grid will keep getting smarter." This is accomplished by algorithms designed to capture feeder voltage and performance data over time to provide more granular and detailed information to self-adjust available voltage bandwidth, thereby enabling the user to achieve greater reduction without violating minimum requirements. It is designed to integrate with existing SCADA systems to collect, measure, and analyze real-time customer voltages from AMI meters. Significantly, it does not require modeling of circuits to adjust voltages, but collects real-time voltage data from dynamically selected meters at customer premises to manage CVR operations, the number of which increase as large voltage swings are detected at any location equipped with a smart meter.

The following describes the functionality of three primary modules within the EDGE℠ suite of products and optimization software, which includes processes to plan, manage, and validate CVR operations and measurements. It includes recommended voltage set-points based on algorithms that determine the preferred control strategy.

Planning Module

- Integrates AMI data with existing simulation models, enabling planners to identify feeder improvement based on continuous voltage and loading measurements

- Includes error checking and identifies potential voltage problems at utilization levels for correction prior to engaging CVR

Manager

- Optimizes voltage regulation using AMI voltage readings and dynamic capability based on field data
- Leverages DMS and SCADA systems to drive local substation load tap changer controllers, line voltage regulators, and capacitors to implement CVR for each substation and circuit
- Displays voltage levels for each feeder deploying CVR and allows the operators to engage and disengage voltage controls

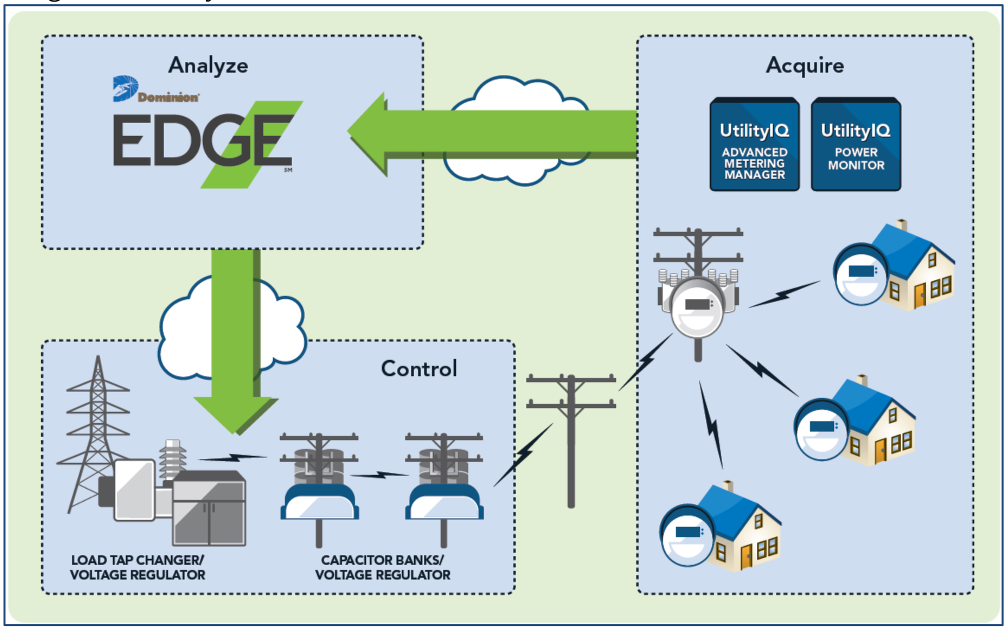
Validation Module

- Uses statistical analysis methods to measure and confirm expected energy and demand savings on each circuit

3.4.6 Related Technologies

Dominion EDGE and other vendor products have capitalized on advances in AMI and DMS technology and increasing presence of these systems to implement sophisticated CVR controls and measurement. Figure 11 presents an integrated AMI/CVR system currently available from Silver Springs Networks, which has partnered with Dominion to offer a self-contained system to optimize voltage control via real-time access to distributed feeder voltages via AMI meters. Its UtilityIO Voltage Optimizer software provides meter data management features for voltage data collected from smart meters, linking the data to centralized voltage management systems to ensure voltage remains within prescribed limits while maximizing energy savings. The vendor reports the system is designed to automatically adjust for feeder topology changes and measures circuit efficiency to derive CVR savings. The literature suggests utilities consider a pilot to demonstrate and confirm CVR performance and savings for selected feeders.

Figure 11. Integrated AMI System



Source: Dominion Voltage, Inc.

3.5 Conclusions

Utilities currently use a wide range of methods and tools to measure and verify CVR performance and savings. Many use traditional feeder simulation models, conducting before-and-after studies under a set of assumptions accounting for seasonal and time of day variations. The more sophisticated applications recognize the relationship between voltage and load characteristics that traditional simulation modeling applications may not fully capture. One of these initiatives is currently under development by WSU on behalf of Avista Utilities. Like other initiatives, the WSU model is still under development and currently limited to beta applications. Table 24 summarizes the advantages and disadvantages of the approaches used to predict CVR factors and savings. Significantly, there appear to be few tools available that combine ease of use with highly accurate and defendable savings verification.

Because of the cost and effort associated with the implementation of sophisticated tools, many utilities continue to use industry-accepted protocols that rely on field measurements and statistical verification, particularly those with CVR programs designed to comply with regulatory mandates or for recovery of energy efficiency investments. Increasingly, vendors are incorporating CVR into integrated Smart Grid, AMI, and distribution management systems, some of which use statistical methods to predict savings. Thus far, CVR pilots utilizing advanced control schemes and integrated AMI have demonstrated solid results. However, there has not been widespread application and confirmation of the validity and cost-effectiveness of integrated systems. A greater number of proven, peer-reviewed studies, with quantifiable benefits versus cost, need to be undertaken to confirm their use for CVR M&V. Further, even for proven technologies and tools, the cost and scope of a fully implemented, integrated system may exceed the needs and available funds of many utilities.

Table 24. CVR Tools

Description	Advantages	Disadvantages
Conventional Distribution Simulation Models (Load Flow)	• Models extensively used by utilities • Able to perform related DE analyses	• Only provides a snapshot of savings • Many unable to perform time series analysis • Possible inaccurate predicted savings or CVR factors • Costly initial setup
Open-Source, Time Series Simulation Models	• Free, open-source license • Most accurate of distribution simulation models	• Requires extensive data input and simulation time series analysis that may be burdensome to many users
High-Level Screening/Evaluation Tools	• Inexpensive or free software • Easy to apply • Relatively accurate economic screening	• May not provide CVR factors, or factors are very high-level • May not pass regulatory scrutiny
Integrated DMSs	• Real-time, predictive methods of CVR impacts and performance • Multiple applications and benefits beyond CVR	• Expensive and complex systems • Burdensome to implement (esp. smaller utilities)
Standard Evaluation Protocols	• Proven approach used by many utilities • Accepted by regulatory authorities	• Long and costly evaluation • Significant data collection effort

Source: Navigant

In closing, it is the authors' opinion that the increasing number of reported CVR measurements, study results, and publicly available data suggests that it may soon be possible to develop industry benchmarks to predict CVR savings for small utilities or those seeking to estimate benefits without the same degree of rigor as accepted protocols or integrated AMI/IVVC systems. As the database of reported results grows for feeders with similar attributes in different regions and climate zones, there may be sufficient commonality in reported results to develop reasonably accurate benchmarks. The benchmarks would include demand and energy savings for a range of feeder types, loads and regions, developed using weighted averages and statistical methods to confirm results within accepted precision and accuracy. Benchmark feeders could be grouped by voltage class, length, loads (percent residential, commercial, and industrial), and region.

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Appendix A Distribution Efficiency Development in the Pacific Northwest: Background and Literature Review

To: **NEEA**

From: **Ryan Powanda, Erik Gilbert, and Dan Greenberg—Navigant Consulting, Inc.**

Date: **1/6/2014**

Re: **DE Development in the Pacific Northwest: Background and Literature Review**

This memo summarizes Navigant Consulting, Inc.'s (Navigant's) research into the development and implementation of DE approaches in the Pacific Northwest (PNW), focusing primarily on CVR.[23] This memo references several sources from the literature, and leverages discussions with stakeholders involved in DE implementation in the PNW.[24]

A.1 Distribution Efficiency Overview in the PNW

CVR implementation progress and approach vary among utilities in the PNW. Implementation ranges from no activity, to demonstration and research projects, to full implementation of CVR on large portions of the distribution system. As part of the PNW Smart Grid Demonstration Project, many utilities are currently implementing CVR demonstration projects to test new approaches, and in some cases investing in distribution system health and maintenance to allow for advanced distribution technologies to be tested.

Among the IOUs in the region, Avista is currently upgrading substation and distribution feeders with plans to implement CVR on a large scale throughout the distribution system. This program is due in large part to Initiative number 937 (I-937) in Washington,[25] mandating utilities to obtain increased portions of their electricity from renewable sources and to undertake cost effective energy conservation measures. Avista has chosen to meet these targets, in part, through CVR. Additional motivators for CVR in the region beyond just the IOUs include the RTF's initiatives, the Northwest Power and Conservation Council (NWPCC) target for demand reductions, and incentives that have been provided by BPA's ESUE program.

PacifiCorp deemed CVR not cost effective for their distribution systems, mainly because most of the utility's circuits already operate at relatively low voltage levels, leaving small margins for CVR to operate cost effectively.

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[23] Conservation Voltage Reduction (CVR) is a practice designed to operate electric distribution feeders at the lower end of the American National Standards Institute (ANSI) voltage band (114–126V). This results in a reduction in energy consumption (kWh) and demand (kW). Average savings range from one to three percent for energy savings and two to four percent for demand savings. CVR is closely related to volt/VAR optimization (VVO), which focuses more on improving the power factor on a distribution feeder.

[24] Navigant performed phone interviews with Bob Helm (formerly with the Northwest Energy Efficiency Alliance [NEEA]) and an industry stakeholder who requests to remain anonymous.

[25] http://www.secstate.wa.gov/elections/initiatives/text/i937.pdf.

The Pacific Northwest was leading the nation in CVR research and demonstration until recently, but has experienced a slowdown in momentum in comparison to other regions of the U.S. Other areas of the country are now implementing CVR approaches, including “advanced/dynamic” forms of CVR.[26] Many utilities in the PNW are still in the demonstration project and experimentation phase with CVR, and thus far have had limited motivation to implement on a large scale.

Barriers still exist for many utilities, including access to capital for distribution system improvements. CVR has proven cost effective for many utilities, but often requires significant amounts of capital to perform distribution system improvements. Utilities have been keen to participate in demonstration projects largely because these projects have often provided funding and support. Lost revenue constitutes another significant barrier for utilities unable to recover reduced revenues from CVR through an overall rate-case process. Additionally, due to the low relative cost of electricity in the PNW, the cost/benefit is low for many DE technologies, including CVR. Other barriers include lack of awareness by key decision makers and perceived lack of vendor diversity.

A.2 Historical Arc of CVR in the Pacific Northwest

Below, Navigant provides a brief synopsis of the important DE efforts in the PNW over the past ten years to provide context on the discussion of today’s market.

A.2.1 2003–2007 DEI

From 2003 through 2007, NEEA funded the DEI, a multiyear program aimed at demonstrating the potential of CVR to increase the efficiency of the distribution system in the PNW. The intended goal of the DEI was to increase the implementation of CVR among the utilities in the region.[27] When DEI started in 2003, only about ten U.S. utilities practiced CVR, including Snohomish County PUD and Idaho Power in the PNW.[28]

The DEI program covered both load research and pilot demonstration project phases, including activities to assist with M&V of savings from CVR. Six utilities participated in demonstration projects, including Avista, Clark Public Utilities, Douglas PUD, Idaho Power, Puget Sound Energy, and Snohomish PUD. Pilot demonstrations included ten substations and 31 distribution feeders across these utilities. Through the DEI program, utilities and stakeholders learned that improvements to the distribution system are often needed before CVR can be implemented on a larger scale within the utility service territories. Necessary improvements ranged from increasing

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[26] “Advanced” or dynamic forms of CVR use computer algorithms to regulate and optimize voltage levels on various time scales. The State of Maryland has mandated this technology. Other large utilities active in CVR include Duke Energy, American Electric Power, and PECO. Many of these utilities are implementing dynamic forms of CVR, where line voltages are optimized on short time scales, and incorporate other capabilities including capacity release for generation, reliability, real-time voltage optimization, and integration of renewables.

[27] Thirteen utilities participated in the DEI—Avista, Clark Public Utilities, Douglas PUD, Eugene Water & Electric Board (W&EB), Franklin PUD, Hood River, Idaho Falls Power, Idaho Power, PacifiCorp, Portland General Electric, Puget Sound Energy, Skamania PUD, and Snohomish PUD.

[28] Global Energy Partners, LLC. 2008. Utility Distribution System Efficiency (DEI): Phase 1 - Final Market Progress Evaluation Report. Portland, OR: Northwest Energy Efficiency Alliance.

conductor sizes, to installing capacitor banks, to balancing feeder loads. While NEEA provided funds for demonstration projects, it did not fund utility distribution system upgrades through the DEI project.

During DEI, the PNW was leading the country in voltage regulation activity. Demonstration and research projects suggested that CVR has the potential for energy savings, including one to three percent savings for energy, two to four percent savings for peak demand, and and four to ten percent savings for kVAR demand. The DEI project showed these savings are achievable without negatively affecting customers.

After the completion of the DEI program in 2007, the majority of feeders participating in the DEI were returned to operation at their previous voltage levels. The DEI activities did not spur widespread adoption of CVR in the region.

A.2.2 2010–2011 BPA's ESUE Program

From 2010 through 2011, the BPA funded the ESUE program. As an add-on phase to DEI, the ESUE program conducted scoping studies and cost/benefit analyses to determine the feasibility of CVR at many utilities in the region. As part of the scoping studies, the ESUE program identified distribution system upgrades that needed to take priority over implementation of CVR. The ESUE program identified many scenarios where end-of-line voltages were too low or where feeder voltage profiles needed flattening before utilities could implement CVR. The ESUE program presented system stability thresholds and recommended that utilities meet them prior to implementing CVR.

In contrast to the DEI program, BPA sought to spur distribution system upgrades by offering distribution-level efficiency improvement measures through the ESUE program. This included incentives and reimbursements for high-efficiency transformer replacements, load balancing, re-conductoring, capacitor banks, substation upgrades, and voltage optimization. Utilities were able to access capital to perform distribution system efficiency upgrades. BPA has continued to provide incentives for DEIs over the years.

Cowlitz PUD was one of the largest utilities participating in the ESUE program. However, after the completion of the ESUE program, Cowlitz was unable to invest further capital into the distribution system initiatives. This appears to be a common situation, as to date, most of the utilities involved in CVR in the PNW continue to work on upgrading distribution system equipment and have not started implementing CVR on a widespread basis.

A.2.3 2009–2013 PNSGDP

Starting in 2009, the PNSGDP became another motivator for CVR work in the PNW. The PNSGDP seeks to validate new Smart Grid technologies, increase communication techniques and technologies, quantify Smart Grid costs and benefits, validate new business models, and to advance interoperability standards and cyber security approaches. The U.S. DOE, through the American Recovery and Reinvestment Act of 2009 (ARRA), provides funding for the PNSGDP.

Several utilities in the PNW are involved in the PNSGDP.[29] Avista, NorthWestern, Milton-Freewater, and Peninsula Light are currently pursuing CVR demonstration projects through the PNSGDP. These utilities are continuing to test the feasibility of CVR over the next two years.

A.3 Current State of CVR in the PNW

In the PNW and across the U.S., the ARRA/stimulus-backed deployments, including the PNSGDP, are nearing completion in the next few years. A recent report from Navigant Research suggests that growth in the adoption of CVR will be slow initially; growth is expected in the market as utilities begin to integrate CVR into their utility resource plans.

Based on the literature review, Navigant has determined that the following utilities (Table 25) have ongoing CVR activities in the PNW. Navigant notes that this list is not exhaustive of all utility activity in the region at this time. Additional survey work that Navigant is performing will inform participation rates by other utilities in the region.

Table 25. Utilities with Known CVR Activity in the Pacific Northwest

Entity	Sample Frame Stratum	CVR Activity
Avista	IOU	PNSGDP participant. Upgrading distribution system, plans to implement CVR on large scale
Portland General Electric	IOU	PNSGDP participant. Currently performing studies on CVR and looking for pilot projects
Idaho Falls Power	DE Active	PNSGDP participant
Puget Sound Energy	IOU	Currently performing studies on CVR and looking for pilot projects
NorthWestern	IOU	PNSGDP participant. Active CVR demonstration project underway
Milton-Freewater	DE Active	PNSGDP participant. Testing CVR on distribution system
Peninsula Light	DE Active	PNSGDP participant. Installing capacitor and regulator banks monitored by SCADA to optimize distribution feeder voltage
Central Lincoln PUD	DE Active	Implemented AMI. CVR demonstration project underway

Source: Navigant analysis

Among regional utilities, access to capital remains a hurdle for CVR implementation in the PNW. Utilities often must prioritize required distribution maintenance before implementing CVR. This maintenance can include upgrades to improve feeder health and to add metering, monitoring, and communications equipment. Upfront investment in CVR is often risky for many utilities.

Another hurdle to CVR implementation includes the lost customer revenue due to CVR rollout. End users reduce energy consumption with CVR and thus lower utility revenue. Utilities are

[29] Utilities participating include: BPA, Avista, Benton PUD, City of Ellensburg, Flathead Electric, Idaho Falls Power, Lower Valley Energy, Milton-Freewater City Light and Power, NorthWestern Energy, Peninsula Light Co., Portland General Electric, and Seattle City Light.

often reluctant to recuperate lost revenue through rate increases, especially during times of slow or no load growth in the utility service area. Utilities can recuperate lost revenue from CVR more easily during periods of more rapid load growth. BPA currently offers incentives for CVR initiatives, which can help with utility cost recovery.

Energy efficiency standard I-937[30] is currently a main driver for CVR implementation for IOUs in Washington State. I-937 mandates IOUs to undertake cost effective energy efficiency measures, such as CVR. Navigant is not aware of other statewide efficiency standards similar to I-937 in the PNW.

[30] http://www.secstate.wa.gov/elections/initiatives/text/i937.pdf.

A.4 Literature Review Sources

Author	Author Organization/ Source	Document Title	Publication Date – Year-Month	Document Summary
Not specifically identified	ABB Inc.	Avista - At the Forefront of Smart Grid 2.0	2013	Avista will upgrade 14 substations and 59 distribution feeders.
Mike Smith	Utility Analytics Institute	Avista's Smart Grid Journey: Technology, Innovation, and Success Along the Way	2013-04	Avista is increasing sensors on distribution system, which allows them to lower grid voltage and maintain reliability.
Not specifically identified	Various Authors	Distribution System Efficiency and Voltage Optimization Scoping Studies - BPA: Clark County Public Utilities District, Benton REA, Clallam County PUD, Cowlitz, Inland, Lakeview, and Tacoma	2010 - 2011	Scoping studies for various utility districts are meant as a high-level planning effort to determine the feasibility and costs related to implementing Dist. efficiency and VO projects. Identify the potential energy and monetary savings associated with BPA's VO programs.
G. Wikler and D. Ghosh	Global Energy Partners, LLC	Utility Distribution System Efficiency (DEI): Phase 1 - Final Market Progress Evaluation Report	2006-08	Provides interview findings from sample of utilities. NEEA is funding phases of the Utility Distribution System Efficiency Initiative (DEI). Multiyear project aimed at demonstrating the potential to improve electric distribution efficiency in the PNW. Report says that utilities can achieve large energy and demand savings by lowing service voltages on distribution feeders.

Author	Author Organization/ Source	Document Title	Publication Date – Year-Month	Document Summary
Not specifically identified	NWPCC	Sixth Northwest Conservation and Electric Power Plan	2010-02	States CVR has large savings potential, approximately 2% of load. NEEA study results indicate energy savings of 1-3%, kW peak demand reduction of 2-5%, and reactive power reduction of 5-10%. Approximately 10-40% of savings are on the utility side of the meter. 6 utilities participating in pilot study with CVR/DE.
K.P. Schneider, F.K. Tuffner, J.C. Fuller, R. Singh	PNNL	Evaluation of CVR on a National Level	2010-07	Estimates benefits of CVR on national level, extrapolates benefits to national level. 0.5-4% savings depending on the specific feeder. Complete deployment of CVR on 100% of distribution feeders provides 3.04% reduction in annual energy consumption.
Lee Hall	-	BPA Smart Grid Initiatives	2010-11	BPA heavily involved in Smart Grid and DE projects. Member of PNSGDP.
K.C. Fagen, R.W. Beck, Robert Utility Planning Solutions PLLC	T&D World	Distribution Systems Get Efficiency Upgrades	2010-02	Pilot demonstration included six utilities, 10 substations, and 31 distribution feeders. Distribution system enhancements include: phase balancing, reactive power management, areas with low voltage, and feeder meter capacity, included substation metering.

Author	Author Organization/ Source	Document Title	Publication Date – Year-Month	Document Summary
Not specifically identified	Ecotope	The Power of Efficiency: Pacific Northwest Energy Conservation Potential Through 2020	2009-04	Reference R.W. Beck Study (2007). Solutions for substations and feeders could result in a 1-3% savings. More savings could be achieved with upgrades to transformers at the end of the distribution system and voltage management at the individual consumer level.
Not specifically identified	R.W. Beck Inc.	DEI	2007-12	Lists the participating DEI Utilities, load research, pilot projects, and results/tools.
T. Kristoffer, T.L. Callaway, B. Lockhart	Navigant Research	Distribution Automation - Distribution Switchgear, Volt-VAR Systems, Fault Detection/Isolation, and Feeder Protection/Control: Global Market Analysis and Forecasts	2013-Q2	Overview of Distribution Automation on a Global Level. Overview of CVR technology, average savings, and benefits/costs.
Not specifically identified	Global Energy Partners, LLC	DEI - Market Progress Evaluation Report, No. 1	2005-05	Overview of DE, state of DE in 2005, key market players, costs/benefits, savings.
Not specifically identified	Global Energy Partners, LLC	Interim Evaluation of the Utility Distribution System Efficiency Initiative (DEI) - Market Progress Evaluation Report	2006-11	Overview of current progress of DEI and the likelihood for future DE implementation.
Robert Fletcher	-	Distribution System Improvement & Voltage Optimization - A New Energy Efficiency Measure	2010-08	Includes overview of technology, benefits, perceived risks, M&V approaches.
Not specifically identified	R.W. Beck Inc.	DEI	2007-12	Summary of the DEI, list of participants, findings from the DEI, pilot project and research results.
Not specifically identified	Global Energy Partners, LLC	NEEA Report: Market Characterization of Industrial Voltage Optimization	2011-02	Market characterization of CVR potential for small and medium-sized commercial applications (1-10 aMW) at the end-use customer level.

Author	Author Organization/ Source	Document Title	Publication Date – Year-Month	Document Summary
Not specifically identified	-	NorthWestern Energy - PNSGDP	DK	Overview of Smart Grid technologies tested by NorthWestern Energy.
Not specifically identified	-	Milton-Freewater - PNSGDP	DK	Overview of Smart Grid technologies tested by Milton-Freewater.
Not specifically identified	-	Avista - PNSGDP	DK	Overview of Smart Grid technologies tested by Avista.
Not specifically identified	-	Peninsula Light Company - PNSGDP	DK	Overview of Smart Grid technologies tested by Peninsula Light Company.
Not specifically identified	Pacificorp	2013 Integrated Resource Plan - Volume II - Appendices	2013-04	Overview of CVR work at Pacificorp. Feasibility projects have been completed in Washington. Pacificorp found the pilot projects to not meet their feasibility criteria, and are not currently planning to implement CVR in other states.
Not specifically identified	DOE - Electricity Delivery & Energy Reliability	Smart Grid Savings and Grid Integration of Renewables in Idaho	2013-04	Idaho Power is using data from customer smart meters to inform CVR opportunities.
Not specifically identified	Portland General Electric	Portland General Electric 2009 Integrated Resource Plan - 2012 Integrated Resource Plan Update	2012-11	Modeling results are completed; feasibility pilot projects are scheduled to occur between 2013 and 2014.
Not specifically identified	Puget Sound Energy Inc.	Puget Sound Energy 2013 Integrated Resource Plan - Chapter 5 (Draft)	2013-06	In 2012, PSE began analysis of CVR. Implementation at the three initial substations is scheduled for 2013.
Not specifically identified	PR Newswire	Landis+Gyr, Central Lincoln PUD Sign Agreement for Dynamic Voltage Management Project	2012-12	Central Lincoln PUD starting demonstration CVR project after implementation of AMI in service territory.

Author	Author Organization/ Source	Document Title	Publication Date – Year-Month	Document Summary
R. Melton and D. Hammerstrom	Battelle	PNSGDP	2012	Overview of PNSGDP. Includes examples of project initiatives and participants.

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Appendix B Market Characterization Interview Guide

B.1 Introduction, screening & scheduling

Hello, my name is ___ and I'm calling from Navigant. The Northwest Energy Efficiency Alliance has hired my company to help them gather information on distribution efficiency practices among utilities in the Northwest. NEEA wants to understand what utilities in the region know about distribution system efficiency (things like voltage optimization and power factor correction) and any actions they may have taken to improve the efficiency of their systems.
[Ask Q1.1 if respondent is in the T&D planning/engineering department. Otherwise, skip to Q1.2]
Q1.1 Are you the person <u>in your department</u> who has primary responsibility for decisions regarding distribution system investments?

a. Yes

b. No

[Ask Q1.1A if Q1.1 is No. Otherwise, skip to SCHEDULING]
Q1.1A We are specifically focusing on the individuals that are involved in distribution efficiency investment decisions. Is there someone else in your department that would be better for us to speak with? [collect name, title, and contact information]
Thank you very much for your time today. I really appreciate your assistance…[TERMINATE CALL]
Q1.2 Are you the person <u>in your department</u> who has primary responsibility for planning <utility name>'s energy efficiency investments?

a. Yes

b. No

[If 1.2 is No, ask Q1.2A, otherwise skip to Q1.3]
Q1.2A Who does have that responsibility? [Record name, title, email, phone, then thank and terminate call]
Q1.3 If your utility were contemplating new investments in the efficiency of its distribution system, is it likely that you would be involved in the decision making process?

a. Yes

b. No

[If 1.2 and 1.3 are Yes, skip to SCHEDULING]
Q1.4 We are specifically focusing on the individuals that are involved in distribution efficiency investment decisions. Is there someone else in your department that would be better for us to speak with?

a. Yes

b. No

[If 1.3 is Yes and 1.4 is No, skip to SCHEDULING. If both 1.3 and 1.4 are No, thank & terminate call.]

Q1.5 Who would that be? [collect name, title, and contact information]

Thank you very much for your time today. I really appreciate your assistance…[TERMINATE CALL]

SCHEDULING

The purpose for this effort is to develop a representative view of the market dynamics related to distribution efficiency in the Northwest. To that end, we are relying upon utility professionals such as yourself to contribute your thoughts and expertise to produce the most accurate view of distribution efficiency in the region.

We're gathering information by telephone interviews, and I'd like to schedule an interview at a time that would be convenient for you, or if you prefer, we could conduct the interview now. I want you to know that none of your responses will be associated directly with you or your utility without your prior written consent. All information I collect during the interview will be aggregated with the responses of all the other individuals we interview.

Q 1.6 The interview should take between 20 and 40 minutes to complete. You don't happen to have time for this now, do you?

a. Yes

b. No

[If response is Yes, go to INTERVIEW INTRO.]

Q 1.7 OK, we're conducting these interviews over the course of the next three weeks. Is there a particular date or time that would be most convenient for you? [Schedule interview]

Q 1.8 Thanks. Before I let you go, is there someone else in the distribution planning or energy efficiency departments at <utility> that would be involved in making distribution efficiency investments? [collect name, title, and contact information]

Thanks very much. I or one of my colleagues will be back in touch on <scheduled date>. [TERMINATE CALL]

B.2 Interview Intro

Thanks for agreeing to participate in this interview. Again, I'm working on behalf of the Northwest Energy Efficiency Alliance to gather information about utility awareness of distribution system efficiency (DE) measures and the degree to which regional utilities have either implemented or plan to implement DE measures. I'll be asking you questions about both of those things, as well as your attitudes towards DE measures. I want you to know that we won't attribute any of your responses to you or your utility, so you can be confident that your answers will remain anonymous. If we think there is a reason to release any specific information from this discussion, we will contact you first and obtain your written approval. This interview should last about 20-40 minutes.

B.3 Distribution Efficiency Awareness

3.1.Are you familiar with the term “Distribution Efficiency”?

a. [if answer to question #1 is yes] What does that term mean to you? [if necessary, ask for specific examples of DE measures, but do not offer examples]

b. [If answer to question #1 is no] Distribution efficiency refers to a variety of changes to the distribution system, such as conservation voltage reduction, reconductoring, load balancing, and transformer replacement that improve energy efficiency at customer facilities, on the distribution system, or both.

c. [If response to question #1 is no] Is there another person in your department at <utility> that you believe is more informed about distribution efficiency? [If so, collect contact information, thank and terminate interview.]

3.2.Do you believe that there are opportunities for energy and/or demand savings by making the <utility name> distribution system more efficient?

3.3.Have you, or to your knowledge has anyone else at <utility name> conducted any research or attended any seminars or classes about this subject?

3.4.Has <utility name> conducted any analysis to determine potential savings from DE? [We’ll ask for details later.]

3.5.Are you familiar with the term conservation voltage reduction (CVR), also known as voltage optimization (VO)?

a. [if no] CVR is the practice of reducing feeder voltage at the substation to a level that continues to maintain minimum voltage requirements at the end of the line, but that improves the efficiency of customer end-use equipment throughout the feeder. CVR comes in several varieties. Sometimes automated feedback control systems are used and sometimes transformer settings are calculated using a practice engineers refer to as line drop compensation.

b. [if yes] The Regional Technical Forum has approved two protocols for calculating energy savings from CVR. Are you aware of these tools for analyzing savings from CVR?

i. [If yes] Have you ever used either of the RTF analysis tools? [If yes] How useful did you find the tool? How accurate? Do you have any recommendations for improvements to these tools?

B.4 Attitudes about DE

For each of the following questions, probe for details about the reasons for the respondent's perceptions/attitudes. For example: "Why do you think CVR degrades power quality?" or "Are you aware of customer complaints regarding low voltage?" or "Can you tell me more about why you think <utility name> should be working on distribution efficiency?"]

4.1. Do you think utilities should be making investments in the efficiency of their distribution systems? Why or why not?

4.2. What are your thoughts about the concept of reducing voltage to improve customer efficiency?

4.3. Do you think CVR/VO would be useful at <utility>? Why or why not?

4.4. Are there any barriers that prevent <utility> from improving the efficiency of its distribution system? If so, please describe them.

B.5 DE analysis, Implementation, and Plans

5.1. I'm going to read you a list of distribution efficiency options. For each one, please confirm if 1) you have investigated the option for your distribution system, 2) you plan to investigate the option, 3) you have implemented the option on part or all of your system, or 4) if you plan to implement it.

Measure	Investigated	Plan to Investigate	Implemented	Plan to Implement	Don't Know	None of the Above
CVR						
Conductor replacement						
Higher distribution primary voltage						
Transformer load management (replacement of improperly sized transformers for loss improvements)						
Balancing loads and phases						
Adding parallel feeders						
De-energizing seasonally unloaded transformers						
Replacing existing distribution transformers with high-efficiency units						
Power factor improvement to reduce line losses						
Reactive power management						

5.2. [Ask for each measure implemented by the utility] Are there any special conditions at <utility name> that you think helped motivate the utility to move forward with implementing <DE measure(s) implemented by utility>?

Probe for details on these factors. Was there a specific champion? If so, what motivated this person, and what title did s/he hold? Did the utility participate in the BPA ESUE program? If so, what role did that play? Were the measures implemented driven by a contractor? If so, what gave that contractor credibility with the utility?

5.3. [Ask for each measure implemented by the utility] Did knowledge of successful <DE measure> projects implemented by other utilities have any influence on your utility's decision to implement that measure?

5.4. [Ask for each measure that was implemented] Did <utility name> conduct any evaluation of <implemented DE measure> to estimate savings or customer impacts? [If so, gather a description of evaluation conducted and in particular the tools used for the evaluation.]

5.5. [Ask for each measure that was investigated but not implemented & no plan to implement] Can you provide a brief description of why <utility name> decided not to implement <measure>?

5.6. Are there any other DE measures that <utility name> has investigated or implemented? [if so, gather projected or estimated actual savings, reasons for not implementing if that was the decision]

5.7. [Ask only if utility has implemented CVR]

   a. Do you think your customers are aware that <utility name> has implemented CVR?

      i. [If yes] How do you think they became aware of CVR?

   b. Are you aware of any customer complaints that can be directly attributed to CVR?

      i. [if yes] What was the nature of these complaints?

      ii. [if yes] How did you determine that the complaint(s) was/were due to CVR?

5.8. [Ask only if utility has implemented one or more DE measure] Did state regulations play any role in your utility's decision to investigate and/or implement any DE measures? If so, what was that role?

5.9. [Ask only if utility has implemented one or more DE measure] Do you think that your utility's experience with DE in the past will make it more or less likely that the utility will implement other DE measures in the future? Why or why not?

5.10. Does <utility name> have any plans for conducting or expanding DE efforts within the next 2 years, 2 to 5 years, or beyond 5 years from now? [If so, gather description of plans and timeframe (<=2, 2-5,>5 yrs).]

B.6 utility decision making process

At your utility, would any departments or business units other than yours typically be involved in decisions about efficiency improvements on the utility side of the meter?
[If other departments are involved] Who would be the best person to speak with in the <other department(s)> about distribution system efficiency investments? Can you provide [his/her/their] phone number(s)?

B.7 Close

Thank you very much for your time and for all the information you've given me today. If you're interested in the results of our work, we'll be delivering a final report to NEEA at the end of January, and it should be available on the NEEA website in early 2014. We will email you a link to the report once it's posted.

Appendix C Calculation of the Distribution Activity Index

Navigant calculated the DAI as follows:

- Public utilities that had participated in BPA's ESUE program received three points, as this participation indicates that they have completed scoping studies and implemented DE measures on their systems.
- Utilities that participated in the DEI received three points, as this is an indication of awareness of CVR and of interest in improving distribution efficiency.
- Utilities received up to two points depending on their DE educational efforts as follows:
    - Zero points if the respondent indicated that on one at the utility had conducted research into DE or attended any classes on the subject.
    - One point if the respondent indicated that at least one employee had conducted research or attended at least one class on the subject.
    - Two points if the respondent indicated an extensive effort on DE education (this rating required evidence that DE was a specific focus of the utility and that multiple employees had received training.
- Utilities received up to three points based on their efforts to assess DE potential on their systems, as follows:
    - Zero points if the utility either did not answer the question or indicated no effort to assess DE potential
    - One point if the utility had a study currently in process
    - Two points if the utility had conducted a limited scoping study on DE opportunities
    - Three points if the utility had conducted a detailed, thorough analysis of DE opportunities on its system.
- Utilities received three points if they had already implemented CVR on at least a portion of their distribution system, and one point if they had a plan in place to implement CVR.

Navigant calculated the DAI as the sum of each utility's points divided by the maximum possible points for the utility category (11 points for IOUs and 14 points for public utilities). This resulted in DAI values ranging from zero to 100 %.

Impact Evaluation

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Northwest Energy Efficiency Alliance

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The Navigant Consulting, Inc. team included Kevin Cooney (managing director), Dan Greenberg (project manager for the distribution efficiency project), Frank Stern (task manager), Paul Higgins (statistical analysis), and Eugene Shlatz (distribution engineer lead).

Executive Summary

Avista Utilities (Avista) implemented a conservation voltage reduction (CVR) program in 2013 as part of larger Smart Grid projects. This report presents Navigant Consulting, Inc.'s (Navigant's) evaluation of the energy efficiency acquisition impact of that program.

Overview of Program

CVR is a type of distribution efficiency, also known as conservation voltage regulation or voltage optimization. CVR is the long-term practice of controlling distribution voltage levels in the lower range of acceptable levels, as defined by the American National Standards Institute, to reduce demand and energy consumption.

Avista's CVR program is a part of its two Smart Grid 2.0 projects. Both projects incorporate Integrated Volt Var Control (IVVC). The IVVC module issues commands to the station or midline regulators to maintain the minimum voltage set-point within a specified voltage dead-band. Avista based the business case for IVVC on the avoided cost of energy resulting from the reduction of load by lowering the distribution line voltage.

Commissioning of IVVC in the Washington service territory, including the cities of Spokane and Pullman, began in September 2013 and concluded on December 31, 2013.

Regulatory Requirement

Washington's public utilities (public utility districts, municipals) are required to report to the state Department of Commerce on their progress in the preceding biennium in meeting regulatory targets. Investor-owned utilities are required to supply the same information to the Utilities and Transportation Commission (UTC). Utilities are also required to make these reports available to their customers and the general public.

The UTC issued an order requiring Avista to provide third-party verification of distribution efficiency savings:

> *For savings claimed from distribution efficiency, Avista Corporation must provide third-party verified values calculated using applicable parts of the RTF's Automated CVR Protocol No. 1, Voltage Optimization Protocol, or any other protocol recognized by the RTF following the date of this order. This requirement does not prevent Avista Corporation from developing an additional EM&V methodology for distribution efficiency and advocating at a future Commission proceeding for the recognition of third-party verified savings calculated using that methodology.* (UTC 2012)

Description of the Evaluation

As noted above, the UTC required that Avista have distribution efficiency savings evaluated using the Regional Technical Forum's (RTF's) Automated CVR Protocol No. 1, but allowed Avista to develop additional methodology.

The protocol specifies an approach for verifying energy savings on electric power distribution circuits and substations on which a utility has implemented CVR. It is flexible with respect to type of load and the utility can apply the approach to circuits serving any combination of residential, commercial, and industrial customers. The main requirements include the ability to measure and record voltage levels and energy usage at uniform intervals, and the ability to vary circuit target voltage levels on each controlled circuit at the same time every day for periods of up to a year. The protocol consists of an experimental design prescribing the procedures to follow for generating experimental data, and a recommended method for statistically estimating the conserved energy from the experimental data.

Navigant also considered two alternative methodologies.

Washington State University (WSU) Voltage Optimization Validation Methodology

WSU has developed a methodology to derive CVR savings as part of a research effort it is conducting on behalf of Avista. WSU developed its approach to address limitations associated with RTF Automated CVR Protocol No. 1, including the need to conduct day-on, day-off measurements over an extended period. Navigant assessed the applicability of the WSU model to derive accurate energy savings for CVR.

Navigant Regression Methodology

Navigant developed parallel savings estimation methodologies to evaluate alternative calculations in comparison to RTF Automated CVR Protocol No. 1. Navigant used the same data set as that specified in RTF Automated CVR Protocol No. 1, but relied instead on direct regression modeling to estimate energy savings. Navigant formulated several alternative model specifications and relied on empirical testing methods to select the ones with the most desirable properties.

Summary of Results

Navigant completed an impact evaluation of Avista's CVR program. Navigant explored three methods:

4. RTF Automated CVR Protocol No. 1
5. WSU Voltage Optimization Validation Methodology
6. Navigant Regression Methodology

When fully implemented and tested, the WSU approach may present an acceptable alternative to savings estimated using industry protocols (or other methods). However, only two feeders have been modeled thus far (out of the more than seventy feeders with CVR), and Avista has not fully integrated the enhanced SynerGEE model with its Distribution Management System (DMS). Thus, at this time, Navigant is unable to conduct a rigorous comparison of savings calculated by the WSU model versus those estimated using RTF Automated CVR Protocol No. 1.

The RTF and Navigant approaches yielded savings estimates as shown in Table 26.

Table 26. Summary of Savings Estimates

Approach	Savings Estimates (MWh)
RTF Automated CVR Protocol No. 1	42,292
Navigant Regression Methodology	42,374

The two estimates are statistically indistinguishable, giving confidence that the RTF method's value is reasonable. Navigant expects that inclusion of summer data would not substantially change the savings estimate and might well increase it.[31]

Recommendations

Navigant recommends that Avista continue to cycle the CVR voltage levels per the RTF Automated CVR Protocol No. 1 for the remainder of 2014. This will enable a more robust estimate of annual savings.

Navigant also recommends that the RTF consider adopting Navigant's alternative regression approach for the evaluation, measurement and verification (EM&V) of savings for automated CVR programs. It produces similar results to the RTF Automated CVR Protocol No. 1, and is somewhat less burdensome to implement.

[31] In previous evaluations, Navigant has found significantly higher savings during summer periods relative to the rest of the year.

D.1 Introduction

Avista Utilities (Avista) implemented a conservation voltage reduction (CVR) program in 2013 as part of larger Smart Grid projects. This report presents Navigant Consulting, Inc.’s (Navigant’s) evaluation of the energy efficiency acquisition impact of that program.

D.1.1 Description of the Program

CVR is a type of distribution efficiency, also known as conservation voltage regulation or voltage optimization. CVR is the long-term practice of controlling distribution voltage levels in the lower range of acceptable levels, as defined by the American National Standards Institute (ANSI; ANSI 1995), to reduce demand and energy consumption.

The Northwest Energy Efficiency Alliance (NEEA) conducted a major study on the effects of CVR, known as the NEEA Distribution Efficiency Initiative (Leidos 2007). The objective of this initiative was to establish the viability of CVR as a conservation measure through pilot projects and demonstrations starting in 2003 through 2007. The results of the study conclusively showed that operating a utility distribution system in the lower half of the acceptable voltage range (120–114 volts) saves energy, reduces demand, and reduces reactive power requirements without negatively affecting the customer.

Avista’s CVR program is a part of its two Smart Grid 2.0 projects, implemented in 2013. In Spokane, the utility smart circuits project involves upgrading fourteen substations and fifty-eight distribution feeders (Avista 2009).[32] In Pullman, Avista’s Smart Grid Demonstration project encompasses updating and automating the distribution system, installing an advanced metering infrastructure, implementing a Web portal where customers can monitor their energy use, and a demand response pilot project, with upgrades to three substations and thirteen feeders (Avista 2010).

Both projects incorporate Integrated Volt Var Control (IVVC). The IVVC predictive application leverages existing power flow models, loading information, and network topology to calculate the minimum voltage on the feeder. The IVVC module issues commands to the station or midline regulators to maintain the minimum voltage set-point within a specified voltage dead-band. Avista based its business case for IVVC is on the avoided cost of energy resulting from the reduction of load by lowering the distribution line voltage (Avista 2010).

Commissioning of IVVC in Spokane and Pullman began in September 2013 and concluded on December 31, 2013.

[32] This does not include one feeder originating at the Post Street substation in Spokane, PST12F1, which was part of the Smart Grid 2.0 project but does not currently have a smart voltage regulator and thus is not CVR-enabled.

D.1.2 Regulatory Requirements

The Energy Independence Act, enacted by voters in 2006 as Initiative 937, imposes targets for energy conservation and the use of eligible renewable resources on all electric utilities that serve more than 25,000 customers in Washington. By January 1, 2010, utilities were required to identify their "achievable cost-effective conservation potential" through 2019. Each utility must set a biennial target consisting of a certain share of this achievable cost-effective conservation potential, and will have to meet that share of conservation.

Utilities that fail to comply with either the energy conservation or the renewable energy targets will pay a penalty of fifty dollars for each megawatt-hour of shortfall, adjusted annually for inflation. Penalty payments will go into a special account that utilities can only use for the purchase of renewable energy credits or for energy conservation projects at state and local government facilities or publicly owned educational institutions.

Each year beginning in June 2012, Washington's public utilities are required to report to the state Department of Commerce on the utilities' progress in the preceding biennium in meeting the targets. Investor-owned utilities are required to supply the same information to the Utilities and Transportation Commission (UTC). Utilities are also required to make these reports available to their customers and the general public.

The UTC issued an order (UTC Docket UE-111882) requiring that Avista provide third-party verification of distribution efficiency savings:

> *For savings claimed from distribution efficiency, Avista Corporation must provide third-party verified values calculated using applicable parts of the RTF's Automated CVR Protocol No. 1, Voltage Optimization Protocol, or any other protocol recognized by the RTF following the date of this order. This requirement does not prevent Avista Corporation from developing an additional EM&V methodology for distribution efficiency and advocating at a future Commission proceeding for the recognition of third-party verified savings calculated using that methodology.* (UTC 2012)

D.1.3 Overview of the Impact Evaluation

As noted above, the UTC required that Avista have distribution efficiency savings evaluated using the Regional Technical Forum's (RTF's) Automated CVR Protocol No. 1, but allowed Avista to develop additional methodologies. The following sections discuss the RTF Automated CVR Protocol No. 1 and two other methodologies.

D.1.3.1 RTF Automated CVR Protocol No. 1

The protocol specifies an approach for measuring and verifying energy savings on electric power distribution circuits and substations on which a utility has implemented CVR. It is flexible with respect to type of load and the utility can apply the approach to circuits serving any combination of residential, commercial, and industrial customers. The main requirements include the ability to measure and record voltage levels and energy usage at uniform time intervals[33], and the ability to vary circuit target voltage levels on each controlled circuit at the same time every day for periods of up to a year.[34] The protocol consists of an experimental design prescribing the procedures to follow for generating experimental data, and a recommended method for statistically estimating the conserved energy from the experimental data (RTF 2004).

Experimental Design

The protocol calls for an initial verification period lasting for one year, beginning with three months of alternating, on successive days, among full voltage reduction (CVR on), voltage set at the legacy level (CVR off), and voltage set at the nominal midpoint between CVR on and CVR off. During the next nine months, the protocol specifies that all test circuits are to be on full CVR reduction continuously except for three months, selected based on season and other factors, when the utility alternates the voltage between full voltage reduction and the controlled nominal midpoint on successive days.

During the verification period, the utility measures and records end-of-line voltages and low-side circuit loads at each time interval. The only additional information required to measure energy savings is local ambient temperatures, at uniform intervals of no more than one hour. The protocol recommends collecting the temperatures at each substation to which experimental circuits connect, as well as at the feeder end-of-line locations, in order to reduce the possibility of confounding due to localized microclimates.[35]

Recently Utilidata, the principal author of the RTF Automated CVR Protocol No. 1, proposed altering the experimental design of the protocol to eliminate the third set-point at the nominal voltage midpoint, so that all cycling of voltage settings occurs between full voltage reduction (CVR on) and CVR off on alternate days. Utilidata proposed this change because they now consider the third set-point unnecessary.[36]

Data Preparation

The protocol recommends grouping the experimental voltage and load observations into twenty-four-hour periods, aggregating them up to hourly intervals, matching them to their corresponding hourly weather series, and separating the resulting twenty-four-hour ensembles into CVR and non-CVR categories.

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[33] Preferred interval length is anywhere between 5 seconds and 15 minutes (Donohue July 25, 2013).

[34] The need for systematic changes in voltage settings to take place at the same time every day over long periods makes this approach most suitable for automated CVR systems; hence, the title of the protocol document.

[35] However, hourly National Weather Service data from the closest available weather station is also acceptable (Donohue, July 25, 2013).

[36] The third set-point called for in the 2004 protocol at the nominal midpoint between the on and off CVR settings was originally included out of concern for the possibility that there may be significant nonlinearities in the relationship between voltage and load that would not be captured if the only experimental data corresponded to the extremes of full voltage reduction and removing CVR control altogether. However, with the benefit of experience it has become clear that this is unnecessary because CVR programs generally reduce nominal voltage settings by relatively small amounts, typically one to three percent. Over such short intervals, the third set-point is extraneous (Donohue, July 25, 2013; Utilidata 2011).

Statistical Estimation Procedure

The protocol recommends using robust time-series econometric techniques to identify "integrated demand profiles" for CVR-on and CVR-off periods, separately for each combination of season (summer, winter, shoulder) and day-type (weekday, weekend/holiday). The twenty-four-hour sums of the differences between the CVR-on and CVR-off demand profiles constitute the daily energy savings due to CVR for each season and day-type. To estimate the CVR factor (CVRf), or percent difference in energy usage per unit reduction in voltage, this difference is expressed as a percentage reduction relative to the non-CVR usage, and divided by the average percentage reduction in measured end-of-line voltage for the circuit over the same time interval.

No control group is required because with on-off and variable voltage set-point capability, the application group can act as its own control group during testing periods. Essentially, the protocol requires conducting an experiment with voltage control.

D.1.3.2 The Experimental Design

Avista began daily cycling between CVR and non-CVR set-points on a representative sample of test circuits on January 1, 2014, and concluded on April 8, 2014. Given the constraints of implementation and report timing, it was not possible to conduct a full year of cycling. Navigant worked with Avista personnel to conduct as thorough and defensible an evaluation as possible using the RTF Automated CVR Protocol No. 1, given the existing time constraints.

D.1.3.3 Alternative Methodologies

Navigant also considered two alternative methodologies.

Washington State University (WSU) Voltage Optimization Validation Methodology

WSU has developed an enhanced methodology to derive CVR savings as part of a research effort it is conducting on behalf of Avista. As part of the research effort, Avista and WSU have prepared two reports (Avista 2013 and Chanda 2014) that highlight progress it has made with respect to applying advanced algorithms and feeder simulation models to calculate CVR savings to a high degree of accuracy. WSU developed its approach to address limitations associated with RTF Automated CVR Protocol No. 1, including the need to conduct day-on, day-off measurements over an extended period. Navigant assessed the applicability of the WSU model to derive accurate energy savings for CVR.

Navigant Regression Methodology

Navigant developed parallel savings estimation methodologies to evaluate alternative calculations in comparison to RTF Automated CVR Protocol No. 1. Navigant used the same data set as that specified in RTF Automated CVR Protocol No. 1, but relied instead on direct regression modeling to estimate energy savings. Navigant formulated several alternative model specifications and relied on empirical testing methods to select the one(s) with the most desirable properties.

D.1.4 Overview of Report

The next section describes the available data. Section D.3 discusses the RTF Automated CVR Protocol No. 1 analysis. Section D.4 presents Navigant's review of the WSU model. Section D.5 presents the Navigant methodology. Section D.6 summarizes findings and recommendations.

D.2 Description of Data

The primary data Navigant used to evaluate Avista's CVR program savings consists of automated distribution line measurements recorded at fifteen-minute intervals on the quarter-hours by Avista's IVVC system on a representative sample of twenty-five distribution feeder circuits. The measurements include phase-specific kilovolts (kV), amperes (Amps), kilowatts (kW), and kilovolt-amperes-reactive (kvar). Because Navigant's primary purpose was estimating the total energy savings from the CVR program, Navigant focused mainly on aggregate kW and kV. Navigant evaluated measurements at several distinct points along each feeder: at the circuit breaker immediately downstream of the substation transformer, at up to three "smart" reclosers, and at a voltage regulator. Navigant also evaluated limited information at up to three capacitor banks. Besides these quantitative measurements, qualitative information pertaining to status of the IVVC system and its components was also provided at fifteen-minute intervals, including the date-time stamp, the feeder identifier, the measurement location on the feeder, whether CVR voltage reduction was on or off, whether capacitor banks were on or off, and whether the IVVC reporting and communication system was functioning. The system automatically delivered files containing each day's data to Navigant via the internet.

In addition to the interval data covering all of the sample feeders continuously from the point at which daily voltage cycling began on January 1, 2014, Avista provided Navigant with limited additional data from the commissioning phase of the IVVC program (i.e., September through December 2013). Avista recorded these observations while installing the system and testing it on each feeder participating in the program and, as such, the observations are intermittent and sparse, covering only some of the sample on any given day, and for only limited periods. Nevertheless, Navigant welcomed the opportunity to include these data, as they allowed Navigant to extend its analysis period back into the fall 2013 season.[37]

Navigant designed the sample of feeders studied for this evaluation in conjunction with Avista staff. Navigant used information provided by Avista on the distribution of loads by customer class on each of the seventy-one feeder circuits in Spokane and Pullman on which Avista commissioned IVVC to draw a representative sample of 25 feeders. The sample drawn targeted a maximum program-level relative precision of 10 percent with a one-tailed 90 percent confidence interval, stratified over five customer strata.[38] Navigant included in the sample all available

[37] Navigant statistically tested whether inclusion of these data altered the results before including these data and found no evidence that they did so. Navigant's main purpose in including commissioning period data was to increase the reliability of the statistical results by increasing the sample size, and to strengthen the ability to identify "shoulder season" (i.e., spring and fall) CVR effects.

[38] Avista provided Navigant with a table of kilovolt-ampere (kVa) loadings attributable to each of several customer classes by feeder. Navigant used this information to sort the seventy-one IVVC feeder circuits into five broad strata:

circuits in the industrial and rural/agricultural categories, and randomly sampled from the residential and commercial-mixed strata in proportion to their relative shares in the number of IVVC feeders. Navigant also selected two Pullman feeders dedicated to delivering power to the WSU grid. Table 27 shows the list of sample feeders, along with their locations and characteristics.

Table 27. Feeder Circuit Sample

No.	City	Substation	Feeder	Category
1	Spokane	GLN	GLN12F1	Predominantly residential (7 of 26)
2		L&S	L&S12F2	
3		SE	SE12F5	
4		9CE	9CE12F4	
5	Pullman	SPU	SPU123	
6		TUR	TUR113	
7			TUR117	
8	Spokane	3HT	3HT12F1	Commercial/mixed (9 of 32)
9			3HT12F7	
10		F&C	F&C12F4	
11			F&C12F5	
12			F&C12F6	
13		L&S	L&S12F1	
14		ROS	ROS12F6	
15		SE	SE12F4	
16		SUN	SUN12F1	
17	Spokane	GLN	GLN12F2	Significant rural/ agricultural (census)
18		NE	NE12F3	
19	Spokane	3HT	3HT12F5	Predominantly industrial (census)
20		BEA	BEA12F3	
21			BEA12F4	
22			BEA12F5	
23		NE	NE12F5	
24	Pullman	TVW	TVW131	Express feeder (13.2 kV)
25		SPU	SPU125	Express feeder (13.2 kV to 4 kV)

Notes: Data from LoadingByFeederAndZone.xlsx (Avista) and Navigant analysis.

residential (at least 85 percent residential load); rural/agricultural (20-30 percent agricultural loads or with significant rural stretches); industrial (at least 50 percent industrial load); commercial/mixed (either predominantly commercial or mixed commercial-residential); and dedicated lines providing power to WSU.

Table 28 provides selected descriptive statistics on the wattage and voltage measurements observed in the interval data for each sample circuit.

Table 28. Descriptive Statistics for Sample Feeder Circuits

#	Feeder	kW at Circuit Breaker				kV at Regulator			
		Mean	Std Dev	Min	Max	Mean	Std Dev	Min	Max
1	3HT12F1	4,834	871	2,899	7,382	7.75	0.09	7.59	7.92
2	3HT12F5	5,010	1,074	2,694	8,515	7.79	0.08	7.60	7.94
3	3HT12F7	2,191	463	1,305	3,524	7.74	0.09	7.57	7.91
4	9CE12F4	3,734	1,025	1,921	8,149	7.78	0.07	7.57	7.91
5	BEA12F3	3,288	1,012	1,462	9,002	7.75	0.11	7.58	7.99
6	BEA12F4	3,846	1,180	1,441	7,150	7.75	0.09	7.56	7.95
7	BEA12F5	3,919	1,634	798	8,168	7.80	0.08	7.61	7.93
8	F&C12F4	4,281	869	2,325	7,299	7.78	0.08	7.60	7.91
9	F&C12F5	3,402	959	1,598	7,917	7.78	0.07	7.54	7.91
10	F&C12F6	4,367	929	2,144	7,309	7.78	0.08	7.61	7.91
11	GLN12F1	4,426	961	2,317	7,770	7.79	0.08	7.60	7.92
12	GLN12F2	4,193	1,016	2,122	8,212	7.78	0.07	7.60	7.91
13	L&S12F1	3,697	541	1,702	5,231	7.74	0.10	7.58	7.91
14	L&S12F2	5,938	1,108	3,087	9,509	7.77	0.08	7.61	7.92
15	NE12F3	2,526	542	1,198	4,741	7.82	0.09	7.60	7.97
16	NE12F5	3,008	1,537	991	6,801	7.78	0.08	7.57	7.92
17	ROS12F6	4,707	890	2,472	7,409	7.78	0.07	7.61	7.93
18	SE12F4	4,593	1,010	2,469	8,531	7.80	0.07	7.62	7.95
19	SE12F5	3,521	825	1,702	6,134	7.80	0.08	7.62	7.95
20	SPU123	4,350	728	2,648	6,664	7.81	0.11	7.62	8.01
21	SPU125	3,079	597	1,977	6,581	7.86	0.06	7.73	8.05
22	SUN12F1	4,654	1,134	1,970	12,944	7.78	0.10	7.59	7.99
23	TUR113	3,482	907	1,688	6,555	7.79	0.11	7.59	8.03
24	TUR117	5,125	1,033	2,883	8,921	7.85	0.10	7.66	8.08
25	TVW131	1,492	282	917	5,065	7.81	0.06	7.63	7.96

Notes: The interval dataset contains separate kW and kV measurements for the A, B, and C phases on each feeder taken at the circuit breaker, at up to three reclosers, and at the voltage regulator. For purposes of this analysis, Navigant aggregated the phase-specific readings for each feeder and time interval. Navigant chose to use the kV measurements taken at the regulator and the kW measurements taken at the circuit breaker because they are the most complete, appear to be the most reliable, and conform most closely to the evaluation methodology described in RTF Automated CVR Protocol No. 1.

Table 29 shows the mean voltage reductions between IVVC-off and IVVC-on states at each of the sample feeders.

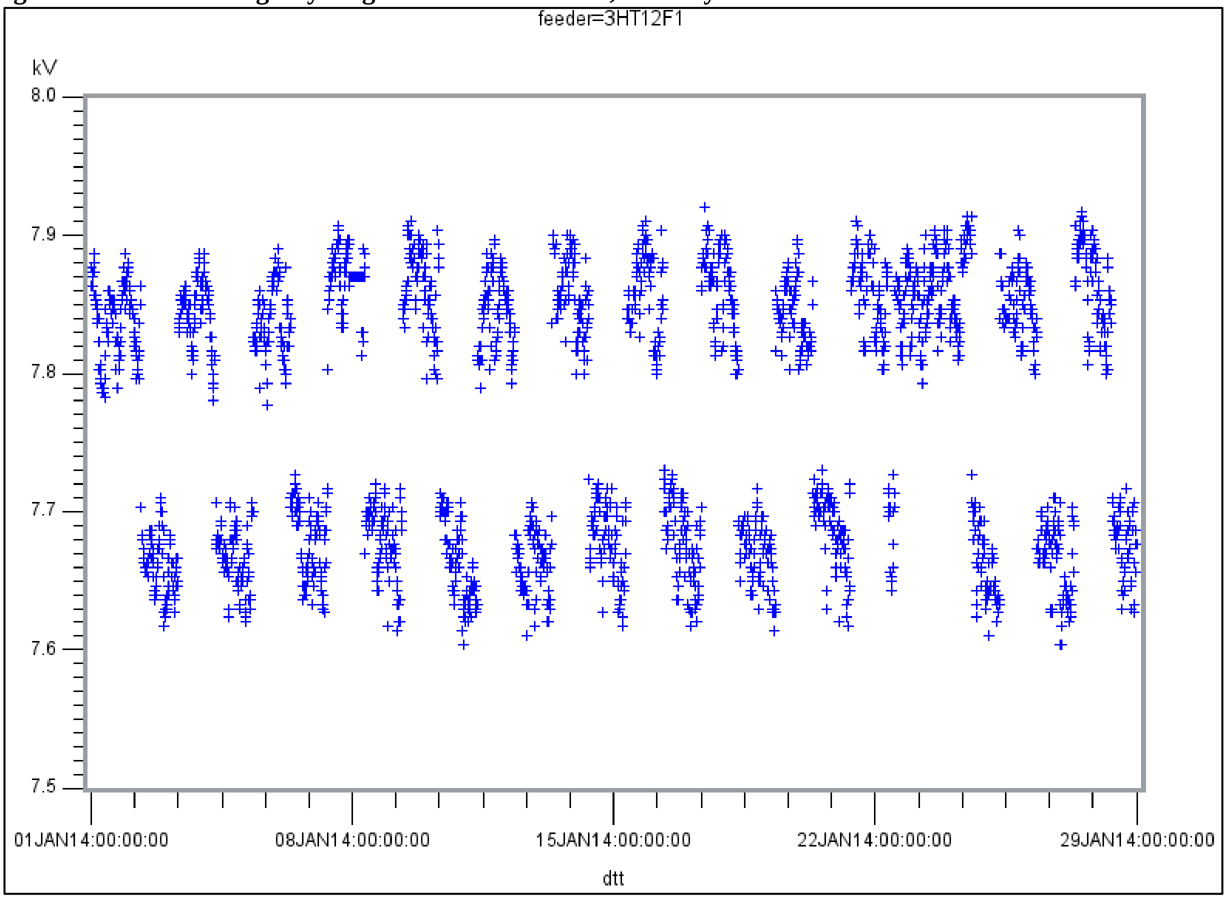
Table 29. Voltage Reductions Observed in Sample

#	Feeder	Mean kV Measured at Regulator		
		IVVC Off	**IVVC On**	**% Difference**
1	3HT12F1	7.853	7.676	2.304%
2	3HT12F5	7.843	7.698	1.875%
3	3HT12F7	7.837	7.669	2.190%
4	9CE12F4	7.837	7.716	1.562%
5	BEA12F3	7.870	7.670	2.606%
6	BEA12F4	7.843	7.676	2.177%
7	BEA12F5	7.848	7.703	1.890%
8	F&C12F4	7.837	7.687	1.955%
9	F&C12F5	7.833	7.700	1.729%
10	F&C12F6	7.835	7.693	1.847%
11	GLN12F1	7.844	7.684	2.090%
12	GLN12F2	7.836	7.707	1.675%
13	L&S12F1	7.846	7.662	2.400%
14	L&S12F2	7.849	7.708	1.833%
15	NE12F3	7.875	7.711	2.135%
16	NE12F5	7.833	7.692	1.824%
17	ROS12F6	7.853	7.725	1.661%
18	SE12F4	7.847	7.726	1.565%
19	SE12F5	7.863	7.719	1.861%
20	SPU123	7.928	7.716	2.746%
21	SPU125	7.911	7.816	1.215%
22	SUN12F1	7.884	7.701	2.369%
23	TUR113	7.911	7.691	2.858%
24	TUR117	7.959	7.761	2.545%
25	TVW131	7.827	7.762	0.828%
Weighted Average		7.861	7.705	2.020%

Notes: To obtain weighted averages, Navigant weighted the individual feeder values by their estimated 2014 annual MWh (see Table 12). All values are rounded to three decimal places.

A representative example of the daily voltage cycling that was performed on the twenty-five sample feeders is shown in Figure 12, which is a time plot of the fifteen-minute interval kV measurements on one sample feeder (3HT12F1) for the month of January 2014.

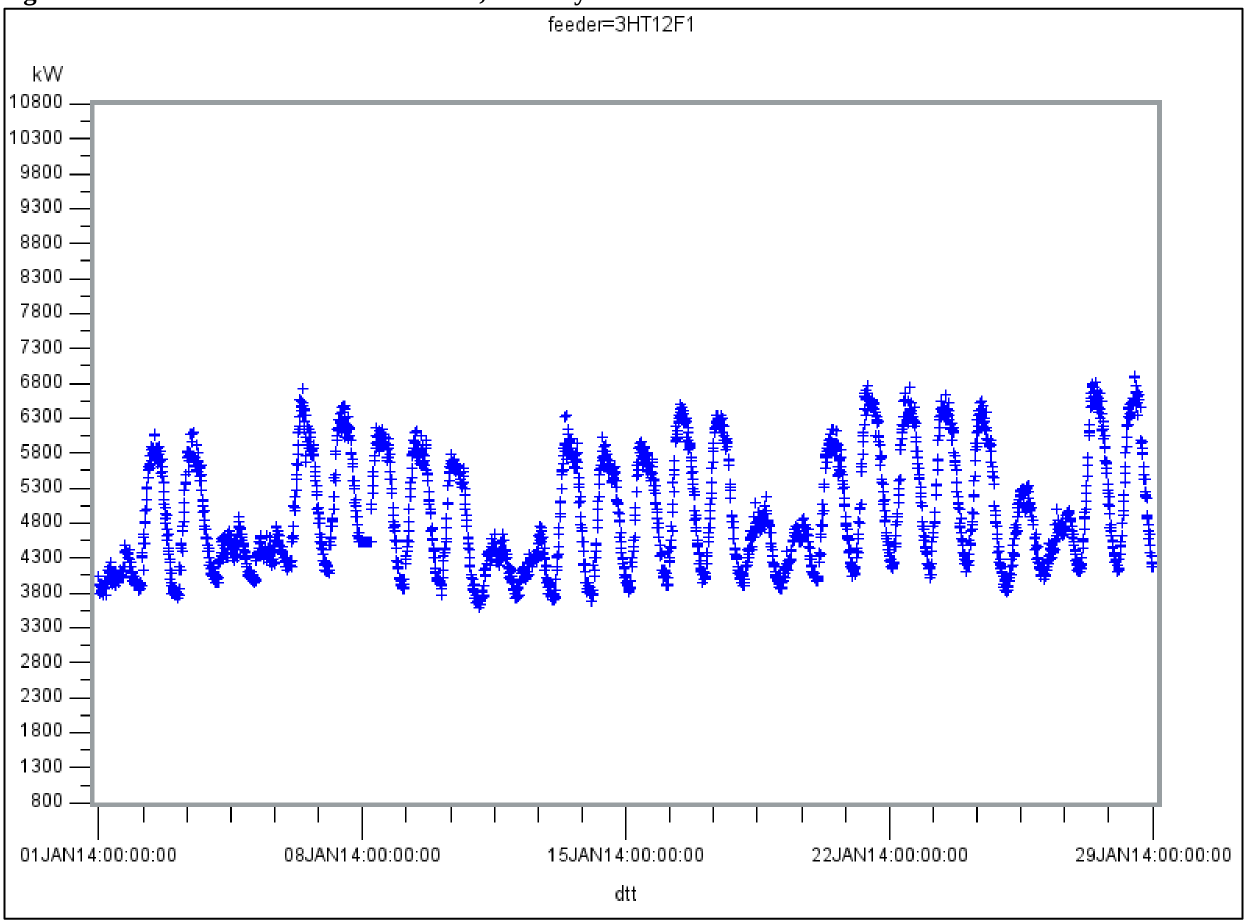
Figure 12. Plot of Voltage Cycling on Feeder 3HT12F1, January 2014



The figure illustrates how CVR works: a target reduction of approximately two percent is set. During each IVVC state (on and off) voltage continues to fluctuate about the set-point, but the separation between the set-points during the on and off states is clear.

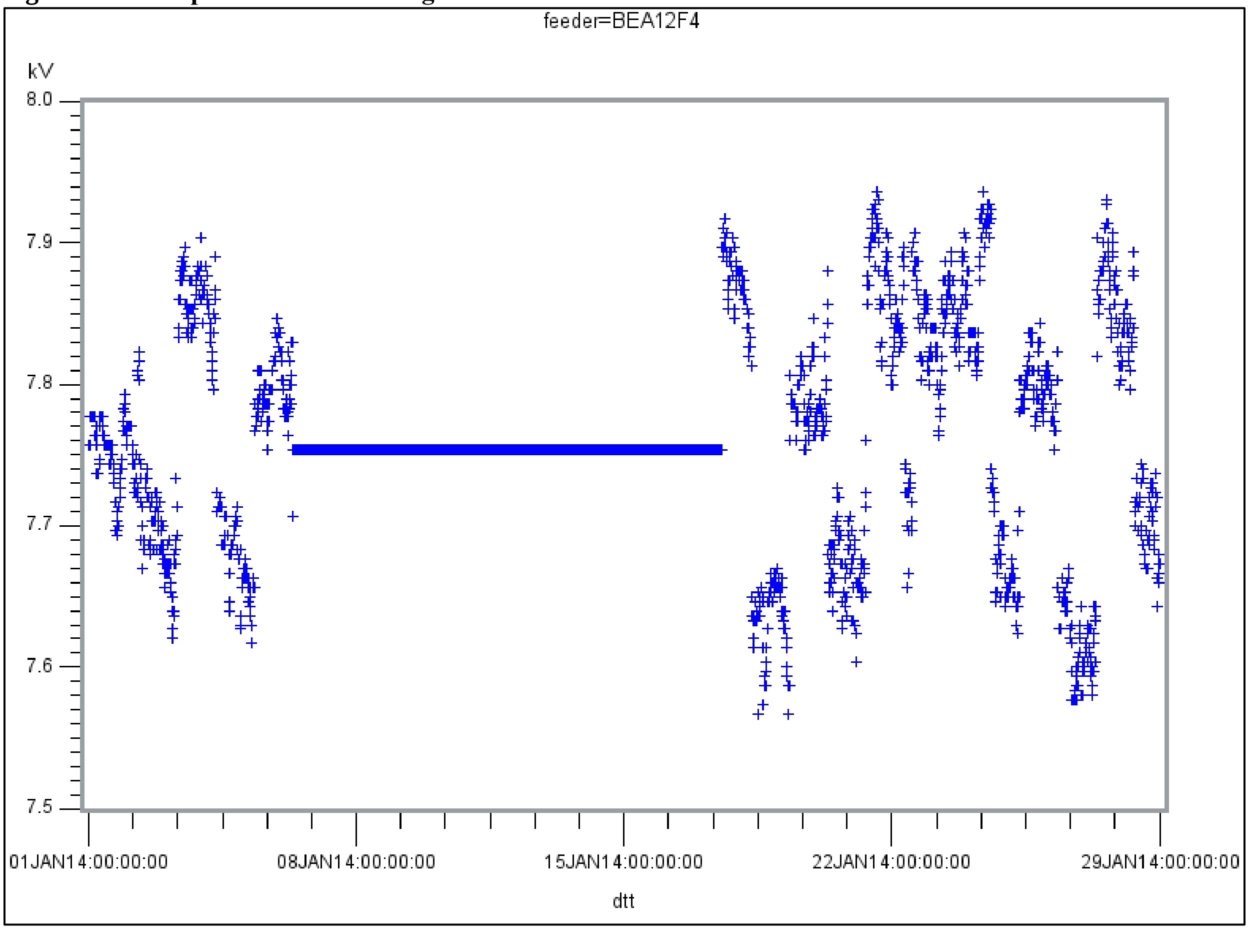
Figure 13 shows the time plot of the corresponding kW series for the same feeder and period (3HT12F1, January 2014). What is notable here is the strong daily cyclical pattern of aggregate load, with a characteristic humped or saw tooth shape with load rising to a peak during the day and falling back at night, superimposed on a clear weekly pattern with five similar weekday load shapes followed by notches on the weekends when the daily peaks are much less pronounced. The pattern observed in the kW series in Figure 13 underscores the need to develop a statistical model for explaining load fluctuations that accommodates these intra-day, daily, and weekly patterns. Failure to do so runs the risk of attributing load fluctuations to CVR that are actually due to these secular patterns.

Figure 13. Plot of kW on Feeder 3HT12F1, January 2014



For the most part, the IVVC interval data were clean and free from obvious problems. However, Navigant did discover a string of problematic data from two of the sample feeders in January 2014. The kV readings measured at the voltage regulator for BEA12F4 (shown in Figure 14 below) and BEA12F5 remained constant for a period of more than eleven continuous days; over the same period, the kW measured at the circuit breaker was flat at zero. Navigant dropped these values, as well as observations when the IVVC system reported being down, before performing any statistical analyses.

Figure 14. Example of "Stuck" Voltage



The other data Navigant used to evaluate Avista's CVR program savings consists of weather data obtained from the National Climatic Data Center (NCDC) of the National Oceanic and Atmospheric Administration (NOAA). Navigant downloaded hourly temperature and humidity series from the NCDC's Quality Controlled Local Climatological Data site (NOAA 2014) for Spokane International Airport and Pullman/Moscow Regional Airport. After aligning the series to the nearest whole hour, Navigant used cubic spline interpolation to generate fifteen-minute series for each weather station that were then merged with the IVVC interval data (i.e., fifteen-minute observations on the quarter-hour).

D.3 RTF Automated CVR Protocol No. 1

RTF Automated CVR Protocol No. 1 establishes a method for measuring and verifying energy savings from CVR voltage reductions using experimental data produced by alternating the voltage set-points on a set of distribution circuits on successive days. The protocol uses data collected during an extended period of voltage cycling to estimate energy savings using time-series analysis and robust statistical methods.

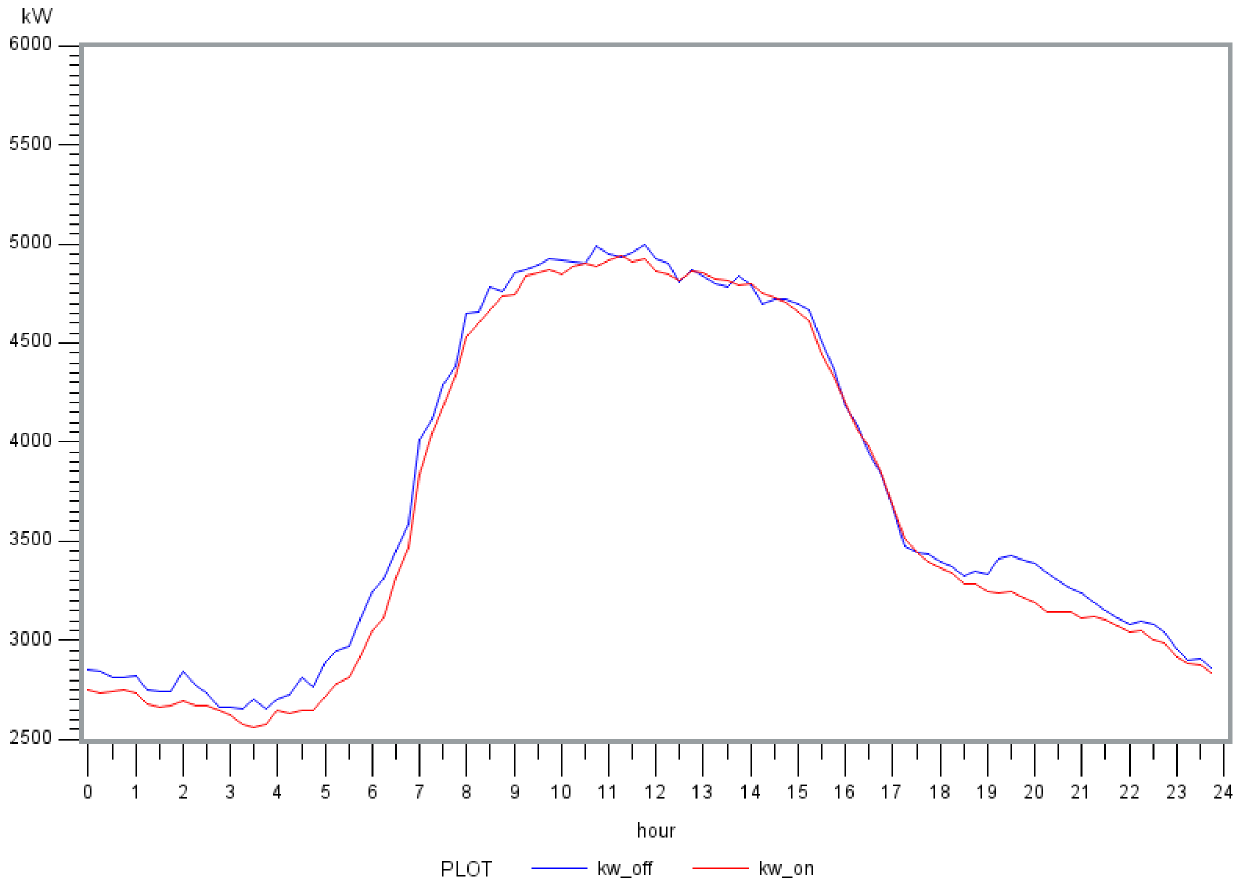
To implement the protocol, Navigant worked with Avista staff to develop a sampling methodology that resulted in a representative sample selection of twenty-five distribution feeder circuits, as described in section D.2. Avista began daily cycling of the voltage set-points on these circuits between full CVR voltage control (IVVC on) and no CVR control (IVVC off) on January 1, 2014, a process that continued through April 8, 2014.

Avista provided Navigant with fifteen-minute interval data from the twenty-five sample feeders collected over the ninety-eight-day period, as described in section D.2. Navigant grouped the data for each feeder into twenty-four-hour ensembles identified by day-type (weekday or weekend/holiday), season (winter or shoulder), and IVVC system state (IVVC on, IVVC off, or IVVC system not operational). Navigant aggregated phase-specific data to feeder level by summing the phase-specific loads (kW) and taking the arithmetic means of the phase-specific voltages (kV). Navigant eliminated observations where IVVC reported being non-operational, or where kW was zero or kV was stuck (as described in section D.2).

Navigant produced integrated demand profiles for each feeder by day-type, season, and IVVC state using robust time-series methods to isolate the effects of voltage reduction from the effects of other factors, such as weather, load characteristics, and customer behavior.[39] This resulted in two demand profiles per sample feeder for each combination of day-type and season: one when IVVC is off, the other when it is on. Figure 15 shows plots of the demand profiles for one of the feeder circuits in the sample, BEA12F3, for winter weekdays.

[39] Weather effects were explicitly modeled using data on ambient temperature and season. Load characteristics and customer behavior with respect to loads generally occur behind the customer meter and are thus not directly observed. However, the effects of time-invariant load characteristic differences across feeders are reflected in the load profiles estimated separately for each feeder. Time-varying effects due to shifting customer loads (intra-day, inter-day, inter-week) are accommodated through the use of high-frequency (15-minute) interval data; time-varying effects over longer intervals are accommodated by estimating separate load profiles by season.

Figure 15. Integrated Demand Profiles, Feeder BEA12F3, Winter Weekdays



Summing the vertical differences between the two demand profiles for each feeder over the twenty-four-hour period estimates the CVR energy savings for each day-type/season combination. To estimate the CVRf[40] for a given feeder, season and day-type, this sum is expressed as a percentage reduction relative to the corresponding baseline energy usage for the same feeder, day-type, and season, and divided by the corresponding mean percentage reduction in voltage on the circuit.

The resulting CVR factors range from 0.705 on weekends/holidays in the winter and 0.942 in the shoulder period on weekdays. Corresponding energy savings range from 1.440 to 1.919 percent. Table 30 summarizes these results.[41]

[40] The CVR factor (CVRf) is defined as the ratio of the mean percentage energy saved to the mean percentage voltage reduction: $CVRf = \%\Delta E/\%\Delta V$.

[41] Detailed results by feeder, season and day-type are presented in Appendix A.

Table 30. Summary of Findings from RTF Automated CVR Protocol No. 1

Day-Type	Measurement	Season: Winter	Season: Shoulder
Weekday	%ΔVolts	2.020%	2.016%
	%ΔkWh	1.694%	1.919%
	CVRf*	0.833	0.942
Weekend/Holiday	%ΔVolts	1.984%	1.810%
	%ΔkWh	1.440%	1.520%
	CVRf*	0.705	0.834

* Weighted average of individual CVRfs shown in Table 12, these do not equal average %ΔkWh/ΔVolts.

To estimate the annual energy savings attributable to Avista's CVR program, Navigant calculated an average annual CVRf value of 0.881 as the weighted average of the four season/day-type specific factors by their relative shares of the year, and applied them to the post-implementation estimated annual energy usage for the seventy-one IVVC-controlled distribution circuits. Total estimated usage is 2,442,217 MWh (see Appendix E). Multiplying the estimated annual energy usage by the weighted-average 2 percent voltage reduction and 0.881 CVRf yields an estimated energy savings of 42,292 MWh.

The basis for these savings does not include summer data values; Navigant has extrapolated the results of winter and spring periods for the year. A recent study of CVR savings in Pennsylvania (Navigant 2011) found CVR factors and savings were significantly higher in summer periods than in the rest of the year. Therefore, the savings resulting from a year-round experimental design may well be higher than what is shown here.

D.4 WSU Voltage Optimization Validation Methodology

WSU developed its approach to address limitations associated with RTF Automated CVR Protocol No. 1, including the need to conduct day-on, day-off measurements over an extended period. Navigant assessed the applicability of the WSU model to derive accurate energy savings for CVR. Navigant's findings are informed by several discussions held with WSU and Avista in 2013 and early 2014.

The two WSU reports previously referenced in section D.1 highlight several key advancements in the modeling of distribution feeder loads and integration of real-time data via supplemental logic used in the SynerGEE model. Each of these advancements should improve the accuracy of real-time estimation of energy savings achieved with CVR. The WSU approach calculates CVR savings using feeder simulation models (i.e., SynerGEE), with predicted savings tallied on a daily basis. All analyses and tests presented in the WSU reports are for distribution feeders located in Pullman, Washington.[42] Initial results for two representative feeders appear to confirm the accuracy of the algorithm and model results. As the reports state, additional studies need to be performed for a broader range of feeders and operating conditions.

When fully implemented and tested, the WSU approach may present an acceptable alternative to savings estimated using industry protocols (or other methods). However, only a few feeders have been modeled (out of the more than seventy feeders with CVR) and Avista has not fully integrated the enhanced SynerGEE model with its Distribution Management System (DMS). Thus, at this time, Navigant is unable to conduct a rigorous comparison of savings calculated by the WSU model versus those estimated using RTF Automated CVR Protocol No. 1. Discussions with WSU and Avista confirm that it is necessary to have additional testing and integration of the WSU model with Avista's DMS in order to measure savings for the full set of feeders with CVR control. Accordingly, Navigant is not yet able to develop an opinion on the effectiveness of the integration of model logic to Avista's DMS or the systems that Avista will use to collect RTES data, nor can Navigant speak to whether they will be a suitable alternative to current measurement protocols.

D.5 Navigant Regression Methodology

In addition to the measurement and verification (M&V) methodology specified in RTF Automated CVR Protocol No. 1, Navigant pursued a parallel statistical analysis to produce an alternative estimate of CVR savings using the same dataset described in section D.2. The approach, which applies regression analysis to the data using a flexible, semi-parametric functional form, employs robust time-series econometric techniques similar to those used in the RTF approach. It has the advantage of producing CVRf estimates directly, rather than having to calculate them in a separate post-hoc analysis, which can save time and resources. It also permits direct estimation of standard program evaluation metrics, including statistical confidence and precision.

[42] To test the accuracy of its approach, WSU conducted series of tests for representative feeders using both the SynerGEE model and the U.S. Department of Energy/Pacific Northwest National Laboratory's GridLAB-D model to predict real-time energy savings (RTES) using the advanced load models and an interactive IVVC algorithm.

To estimate the net effect of CVR voltage reductions on energy usage, Navigant performed regression analyses, modeling the average load in each fifteen-minute interval as a function of interval average voltage, interval heating degree-hours (HDH), and a set of time-of-day and day-type indicators. To allow the model to reflect differences in the characteristics of the loads served by each test feeder, which are largely unobserved, Navigant ran separate regressions for each feeder, as well as for each season.[43] The model is as follows:

$$f(kW_{it}) = \beta_{i1} g(kV_{it}) + \beta_{i2} HDH_t + \beta_{i3} HDH_t \cdot g(kV_{it}) + \sum_{t=1}^{96} \sum_{j=Weekday}^{Weekend} \beta_{itj}^{DTYPE} TOD_t \cdot DayType_j + \varepsilon_{it}$$

where:

- $i, t, and\ j$ are index feeder circuits, time intervals, and day-types, respectively;
- kW_{it} and kV_{it} are the instantaneous power demand and voltage, measured at the circuit breaker and voltage regulator, respectively, on feeder i at time interval t;
- TOD_t and $DayType_j$ are sets of ninety-six time-of-day and two day-type indicators, respectively; and
- $f(\cdot)$ and $g(\cdot)$ are functions of the variable contained in the parentheses.[44]

Navigant used robust regression methods to estimate the parameters of the above model for each combination of feeder and season, and calculated the system average CVRf as the weighted average of the individual feeder estimates, using the annual feeder MWh as weights. Table 31 summarizes these results.

[43] This is a common method used in applied statistics when confronting panel data (i.e., multiple observations over time on a set of individual sample units) reflecting the influence of multiple unobserved factors that vary systematically across individual units – in this case, customer load characteristics. This technique allows the model results to reflect not only different mean load levels, but also differential effects of voltage, weather, time of day, day-type and season on the loads served by different circuits (Wooldridge 2010).

[44] Navigant tested several functional forms and selected the double-logarithmic form based on statistical testing.

Table 31. Alternative Regression CVRf Values

		CVRf Estimates		
#	**Feeder**	**Winter**	**Shoulder**	**Combined**
1	3HT12F1	0.711	0.847	0.813
2	3HT12F5	0.564	0.642	0.623
3	3HT12F7	0.447	0.592	0.556
4	9CE12F4	0.604	0.823	0.769
5	BEA12F3	1.167	1.276	1.249
6	BEA12F4	1.063	1.059	1.060
7	BEA12F5	0.692	0.744	0.731
8	F&C12F4	0.727	0.929	0.879
9	F&C12F5	1.466	1.692	1.636
10	F&C12F6	1.743	1.951	1.900
11	GLN12F1	0.729	0.733	0.732
12	GLN12F2	0.412	0.487	0.469
13	L&S12F1	0.498	0.671	0.628
14	L&S12F2	0.683	0.726	0.715
15	NE12F3	0.294	0.299	0.298
16	NE12F5	1.687	1.996	1.920
17	ROS12F6	0.074	0.117	0.106
18	SE12F4	0.348	0.518	0.476
19	SE12F5	0.193	0.236	0.225
20	SPU123	0.476	0.545	0.528
21	SPU125	1.093	1.207	1.179
22	SUN12F1	0.223	0.211	0.214
23	TUR113	1.428	1.438	1.436
24	TUR117	1.577	1.764	1.718
25	TVW131	0.967	1.124	1.085
Weighted Average		0.797	0.911	0.883

Notes: Navigant weighted the individual feeder values by their cumulative kWh over the sample period to obtain the weighted averages. All values shown are rounded.

To obtain estimates of the annual energy savings attributable to Avista's CVR program, Navigant applied the weighted average CVRf value above to the estimated annual energy usage for the seventy-one IVVC-controlled distribution circuits in calendar 2014, as was done for the RTF Automated CVR Protocol No. 1 calculation. Multiplying the estimated annual energy usage by the weighted-average 2 percent voltage reduction and 0.883 CVRf yields an estimated energy savings of 42,374 MWh, very similar to that produced by the RTF Protocol No. 1.

As with the RTF Automated CVR Protocol No. 1 results, the basis for these savings does not include summer data values. As noted previously, an analysis that includes summer data could well result in higher savings.

D.6 Summary

D.6.1 Findings

Navigant completed an impact evaluation of Avista's CVR program. Navigant explored three methods:

1. RTF Automated CVR Protocol No. 1
2. WSU Voltage Optimization Validation Methodology
3. Navigant Regression Methodology

When fully implemented and tested, the WSU approach may present an acceptable alternative to savings estimated using industry protocols (or other methods). However, only two feeders have been modeled (out of the over seventy feeders with CVR) and Avista has not fully integrated the enhanced SynerGEE model with its DMS. Thus, at this time, Navigant is unable to conduct a rigorous comparison of savings calculated by the WSU model versus those estimated using RTF Automated CVR Protocol No. 1.

The RTF and Navigant approaches yielded savings estimates as shown in Table 32.

Table 32. Summary of Savings Estimates

Approach	CVRf	Savings Estimates (MWh)
RTF Automated CVR Protocol No. 1	0.881	42,292
Navigant	0.883	42,374

The two estimates are statistically identical, giving confidence that the RTF estimate is reasonable. Navigant expects that inclusion of summer data would not substantially change the savings estimate and might well increase it.

D.6.2 Recommendations

Navigant recommends that Avista continue to cycle the CVR voltage levels per the RTF Automated CVR Protocol No. 1 for the remainder of 2014. This will enable a more robust estimate of annual savings.

Navigant also recommends that the RTF consider adopting Navigant's alternative econometric approach to EM&V of savings for automated CVR programs. It produces similar results to the RTF Automated CVR Protocol No. 1, and is somewhat less burdensome to implement.

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Appendix E RTF Automated CVR Protocol No. 1 Results

E.1 Feeder-Level Estimates using RTF Automated CVR Protocol No. 1 Methodology

Table 33 shows the mean voltage reductions, energy savings, and CVR factors for winter weekdays.

Table 33. RTF Protocol Results, Winter Weekdays

#	Feeder	Mean Voltage Reduction	Mean Energy Saved	CVRf
1	3HT12F1	2.354%	1.747%	0.742
2	3HT12F5	1.893%	1.111%	0.587
3	3HT12F7	1.538%	0.743%	0.483
4	9CE12F4	1.633%	1.138%	0.697
5	BEA12F3	2.681%	3.348%	1.249
6	BEA12F4	2.223%	2.386%	1.073
7	BEA12F5	1.998%	1.373%	0.687
8	F&C12F4	1.968%	1.519%	0.772
9	F&C12F5	1.765%	2.623%	1.486
10	F&C12F6	1.887%	3.620%	1.918
11	GLN12F1	2.097%	1.497%	0.714
12	GLN12F2	1.683%	0.667%	0.396
13	L&S12F1	2.424%	1.232%	0.508
14	L&S12F2	1.832%	1.184%	0.646
15	NE12F3	2.209%	0.625%	0.283
16	NE12F5	1.647%	3.247%	1.971
17	ROS12F6	1.657%	0.139%	0.084
18	SE12F4	1.571%	0.600%	0.382
19	SE12F5	1.947%	0.358%	0.184
20	SPU123	2.714%	1.273%	0.469
21	SPU125	1.227%	1.389%	1.132
22	SUN12F1	2.448%	0.570%	0.233
23	TUR113	2.834%	3.984%	1.406
24	TUR117	2.555%	4.029%	1.577
25	TVW131	0.788%	0.773%	0.981
Weighted Average		2.020%	1.694%	0.833

Notes: To obtain weighted averages, Navigant used the 2014 feeder-level estimated annual MWh as weights (see Table 12). All values are rounded to three decimal places.

Table 34 shows the mean voltage reductions, energy savings, and CVR factors for winter weekends and holidays.

Table 34. RTF Protocol Results, Winter Weekends/Holidays

#	Feeder	Mean Voltage Reduction	Mean Energy Saved	CVRf
1	3HT12F1	2.268%	1.399%	0.617
2	3HT12F5	1.900%	0.905%	0.476
3	3HT12F7	2.083%	0.819%	0.393
4	9CE12F4	1.602%	0.553%	0.345
5	BEA12F3	2.491%	2.431%	0.976
6	BEA12F4	1.990%	2.024%	1.017
7	BEA12F5	1.781%	1.167%	0.655
8	F&C12F4	2.012%	1.270%	0.631
9	F&C12F5	1.815%	2.580%	1.422
10	F&C12F6	1.855%	2.367%	1.276
11	GLN12F1	2.023%	1.560%	0.771
12	GLN12F2	1.621%	0.677%	0.418
13	L&S12F1	2.414%	1.180%	0.489
14	L&S12F2	1.814%	1.381%	0.761
15	NE12F3	2.210%	0.670%	0.303
16	NE12F5	1.948%	1.923%	0.987
17	ROS12F6	1.536%	0.083%	0.054
18	SE12F4	1.523%	0.437%	0.287
19	SE12F5	1.818%	0.404%	0.222
20	SPU123	2.630%	1.365%	0.519
21	SPU125	1.080%	1.083%	1.003
22	SUN12F1	2.376%	0.461%	0.194
23	TUR113	2.709%	4.004%	1.478
24	TUR117	2.442%	3.893%	1.594
25	TVW131	0.818%	0.784%	0.959
Weighted Average		1.984%	1.440%	0.705

Notes: To obtain weighted averages, Navigant used the 2014 feeder-level estimated annual MWh as weights (see Table 12). All values are rounded to three decimal places.

Table 35 shows the mean voltage reductions, energy savings, and CVR factors for shoulder-season weekdays.

Table 35. RTF Protocol Results, Shoulder-Season Weekdays

#	Feeder	Mean Voltage Reduction	Mean Energy Saved	CVRf
1	3HT12F1	2.233%	1.966%	0.881
2	3HT12F5	1.869%	1.213%	0.649
3	3HT12F7	2.176%	1.306%	0.600
4	9CE12F4	1.538%	1.238%	0.805
5	BEA12F3	2.591%	3.530%	1.363
6	BEA12F4	2.266%	2.473%	1.091
7	BEA12F5	1.875%	1.407%	0.751
8	F&C12F4	1.942%	1.839%	0.947
9	F&C12F5	1.680%	2.878%	1.714
10	F&C12F6	1.846%	3.775%	2.045
11	GLN12F1	2.076%	1.489%	0.717
12	GLN12F2	1.703%	0.811%	0.476
13	L&S12F1	2.309%	1.578%	0.683
14	L&S12F2	1.839%	1.327%	0.722
15	NE12F3	2.194%	0.676%	0.308
16	NE12F5	1.940%	4.051%	2.088
17	ROS12F6	1.780%	0.195%	0.110
18	SE12F4	1.736%	0.923%	0.532
19	SE12F5	1.859%	0.445%	0.239
20	SPU123	2.644%	1.578%	0.597
21	SPU125	1.246%	1.549%	1.243
22	SUN12F1	2.252%	0.616%	0.274
23	TUR113	2.732%	4.661%	1.706
24	TUR117	2.402%	4.250%	1.770
25	TVW131	0.743%	0.859%	1.156
Weighted Average		2.016%	1.919%	0.942

Notes: To obtain weighted averages, Navigant used the 2014 feeder-level estimated annual MWh as weights (see Table 12). All values are rounded to three decimal places.

Table 36 shows the mean voltage reductions, energy savings, and CVR factors for shoulder-season weekends and holidays.

Table 36. RTF Protocol Results, Shoulder-Season Weekends/Holidays

#	Feeder	Mean Voltage Reduction	Mean Energy Saved	CVRf
1	3HT12F1	1.993%	1.575%	0.790
2	3HT12F5	1.691%	1.013%	0.599
3	3HT12F7	1.921%	1.120%	0.583
4	9CE12F4	1.310%	1.129%	0.862
5	BEA12F3	2.122%	2.288%	1.078
6	BEA12F4	1.977%	1.935%	0.979
7	BEA12F5	1.579%	1.147%	0.726
8	F&C12F4	1.688%	1.468%	0.870
9	F&C12F5	1.530%	2.510%	1.641
10	F&C12F6	1.600%	2.755%	1.722
11	GLN12F1	2.047%	1.550%	0.757
12	GLN12F2	1.529%	0.786%	0.514
13	L&S12F1	2.112%	1.356%	0.642
14	L&S12F2	1.607%	1.202%	0.748
15	NE12F3	1.715%	0.496%	0.289
16	NE12F5	1.738%	3.072%	1.767
17	ROS12F6	1.455%	0.194%	0.133
18	SE12F4	1.312%	0.644%	0.491
19	SE12F5	1.640%	0.413%	0.252
20	SPU123	2.648%	1.107%	0.418
21	SPU125	1.187%	1.321%	1.113
22	SUN12F1	2.046%	0.125%	0.061
23	TUR113	2.723%	2.094%	0.769
24	TUR117	2.468%	4.316%	1.749
25	TVW131	0.699%	0.715%	1.022
Wt'd Average		1.810%	1.520%	0.834

Notes: To obtain weighted averages, Navigant used the 2014 feeder-level estimated annual MWh as weights (see Table 12). All values are rounded to three decimal places.

Appendix F Post-Implementation Sales Estimate

F.1 Estimated 2014 Annual MWh Sales for IVVC Feeders

Table 37. Avista Estimated 2014 Energy Sales

#	Feeder	Annual MWh (mid-2012 to mid-2013)	Assumed Annual Growth Rate	Annual MWh (Calendar 2014)*
1	3HT12F1	36,278.27	1.9%	37,317.10
2	3HT12F2	35,670.13	1.9%	36,691.54
3	3HT12F3	27,477.03	1.9%	28,263.83
4	3HT12F4	35,185.73	1.9%	36,193.27
5	3HT12F5	39,725.97	1.9%	40,863.52
6	3HT12F6	28,745.10	1.9%	29,568.21
7	3HT12F7	18,989.12	1.9%	19,532.87
8	3HT12F8	46,023.45	1.9%	47,341.33
9	9CE12F1	45,768.91	2.1%	47,218.17
10	9CE12F4	33,008.18	2.1%	34,053.38
11	BEA12F2	40,060.15	2.0%	41,267.94
12	BEA12F3	26,862.57	2.0%	27,672.46
13	BEA12F4	33,961.58	2.0%	34,985.50
14	BEA12F5	5,618.23	2.0%	5,787.62
15	C&W12F1	33,191.42	2.0%	34,192.12
16	C&W12F2	25,350.52	2.0%	26,114.83
17	C&W12F3	40,244.70	2.0%	41,458.06
18	C&W12F4	50,006.74	2.0%	51,514.42
19	C&W12F5	23,604.21	2.0%	24,315.87
20	C&W12F6	35,052.69	2.0%	36,109.51
21	F&C12F1	40,414.59	2.2%	41,755.58
22	F&C12F2	28,812.37	2.2%	29,768.39
23	F&C12F3	32,184.98	2.2%	33,252.90
24	F&C12F4	36,652.51	2.2%	37,868.67
25	F&C12F5	30,786.56	2.2%	31,808.08
26	F&C12F6	37,615.24	2.2%	38,863.35
27	FWT12F1	29,581.19	2.1%	30,517.87
28	FWT12F2	31,378.49	2.1%	32,372.08
29	FWT12F3	33,066.91	2.1%	34,113.97

#	Feeder	Annual MWh (mid-2012 to mid-2013)	Assumed Annual Growth Rate	Annual MWh (Calendar 2014)*
30	FWT12F4	28,245.42	2.1%	29,139.81
31	GLN12F1	36,992.32	2.3%	38,275.87
32	GLN12F2	34,428.48	2.3%	35,623.07
33	L&S12F1	35,582.96	2.1%	36,709.69
34	L&S12F2	46,081.43	2.1%	47,540.59
35	L&S12F3	28,880.17	2.1%	29,794.65
36	L&S12F4	38,074.55	2.1%	39,280.17
37	L&S12F5	23,287.06	2.1%	24,024.44
38	NE12F1	30,860.67	2.1%	31,837.87
39	NE12F2	36,954.35	2.1%	38,124.50
40	NE12F3	19,459.38	2.1%	20,075.56
41	NE12F4	25,749.62	2.1%	26,564.98
42	NE12F5	40,324.68	2.1%	41,601.55
43	NW12F2	26,375.69	2.1%	27,210.87
44	NW12F4	33,351.94	2.1%	34,408.02
45	ROS12F1	50,209.41	1.4%	51,267.49
46	ROS12F2	44,648.77	1.4%	45,589.67
47	ROS12F3	29,395.92	1.4%	30,015.39
48	ROS12F4	43,290.52	1.4%	44,202.80
49	ROS12F5	57,493.33	1.4%	58,704.91
50	ROS12F6	43,336.62	1.4%	44,249.87
51	SE12F1	31,086.65	2.4%	32,212.46
52	SE12F2	49,494.83	2.4%	51,287.29
53	SE12F3	39,678.51	2.4%	41,115.47
54	SE12F4	38,713.39	2.4%	40,115.40
55	SE12F5	28,096.71	2.4%	29,114.24
56	SPU121	36,601.55	1.9%	37,649.63
57	SPU122	31,068.99	1.9%	31,958.65
58	SPU123	33,228.29	1.9%	34,179.78
59	SPU124	47,467.80	1.9%	48,827.04
60	SPU125	29,975.82	1.9%	30,834.18
61	SUN12F1	33,631.60	2.3%	34,798.54
62	SUN12F3	34,042.05	2.3%	35,223.23
63	SUN12F6	26,865.83	2.3%	27,798.01

#	Feeder	Annual MWh (mid-2012 to mid-2013)	Assumed Annual Growth Rate	Annual MWh (Calendar 2014)*
64	TUR111	28,154.34	1.9%	28,960.54
65	TUR112	30,857.00	1.9%	31,740.59
66	TUR113	24,569.53	1.9%	25,273.08
67	TUR115	30,818.36	1.9%	31,700.84
68	TUR116	28,836.07	1.9%	29,661.79
69	TUR117	38,576.25	1.9%	39,680.88
70	TVW131	34.49	1.9%	35.48
71	TVW132	14,607.37	1.9%	15,025.65
	Total	2,370,746.26		2,442,216.96

Notes: Annual MWh sales (7/2012 to 7/2013) and assumed annual growth rate obtained from Avista Utilities, April 18, 2014.
** Annual mid-2012 to mid-2013 figures are Avista audited sales data. Calendar 2014 annual figures were obtained by applying the assumed annual growth rates to the mid-2012 to mid-2013 values for a period of 18 months.*