Simplified Voltage Optimization (VO)

Measurement and Verification Protocol

1.0 Introduction

1.1 Purpose

The Simplified Voltage Optimization (VO) Measurement and Verification (M&V) Protocol provides a basic approach to determine end-use energy savings when operating the electric distribution system more efficiently and within the lower band of the ANSI Standard voltage level. The protocol covers utility electric distribution systems serving mostly residential and light commercial load as defined by the utility. System loads do not need to be uniformly distributed throughout the distribution system. This Protocol identifies the procedure to determine the average annual voltage for a distribution primary system with source voltage regulation. Minimum system stability thresholds, system data requirements, and measurement and verification formulations are included as part of this Protocol.

1.1.1 Attachments

- End-use VO Factors are identified in tables for use with this Protocol in Appendix A.
- Examples of data collected are included with this document to provide an understanding of the level of effort and detail to perform VO Assessments. See Examples: Data Collection Templates.

1.1.2 Clarification of issues throughout this document.

The items in **bold** will appear frequently throughout the document.

- When **adjusted annual kW peak demand** is mentioned, 'adjusted' refers to common efforts by the utility to adjust for temperature, abnormal switching, or unusual loading conditions that would cause artificial peak demand information. Unusual loading conditions could, for example, be due to outage or maintenance.
- When **system modeling** is mentioned, it refers to using industry accepted distribution system power flow simulation tools for analysis of distribution system electric characteristics.
- When **end-use VO Factor** is mentioned, it refers to the tables in Appendix A that are derived from the 2007 NEEA Distribution Efficiency Initiative Study for end-use consumption (Load Research Project) and included 395 randomly selected residential homes throughout the Northwest using 12 plus months of day VO-On/ day VO-Off recordings. This information was presented to the NWPCC Regional Technical Forum (RTF) in 2008.
- When **voltage control zone** is mentioned, it consists of all distribution lines that are controlled by a tap changing source voltage regulator. Several voltage-control-zones may exist within one substation area

- When **minimum operating performance thresholds** are mentioned, they refer to a set of specifications to achieve higher efficiency. These specifications, called performance thresholds, are described in the NEEA Distribution Efficiency Guidebook, January 2008, which provides guidelines for industry best practices for distribution system efficiency based on the research performed during the NEEA Distribution Efficiency Initiative Study.
- **Annual estimated or historical annual peak kW demand data** may be used for estimation of end use VO savings during study/assessment periods; however, actual metered annual kW peak demand data is used during the verification process.
- Calculations of all system improvements (reduction of line losses and no-load losses) will be made using industry accepted engineering methodologies. This Protocol does not propose new methods of calculating reduction of losses due to system improvements nor are Appendix A Tables used for non end-use VO calculations.
- Metering periods must not occur during a holiday or unusual circumstance that would lead to abnormal patterns in residential use.

1.2 Simplified Voltage Optimization Overview

The Simplified VO Protocol encompasses three basic source voltage regulation techniques described below:

Voltage Fixed Reduction (VFR): The Voltage Fixed Reduction methods require that the distribution substation source voltage regulator and line regulators voltages be lowered by a fixed amount. It is assumed that the pre-installation voltage is fixed at a known value. No remote automated voltage feedback controls are applied.

Line Drop Compensation (LDC): The Line Drop Compensation methods require that the distribution substation source voltage regulator and line regulators apply automatic voltage controls to control voltage up and down based on line load levels. When the feeder or substation load is changing, the voltage regulator simulates (calculates) an EOL voltage level and adjusts the regulator voltage to hold the EOL voltage constant. The voltage is locally sensed at the substation and line voltage regulator locations.

Automated Voltage Feedback Control (AVFC): The Automated Voltage Feedback Control methods require that the distribution substation source voltage regulator and line regulators voltages apply automatic voltage controls to control voltage up and down based on remote EOL voltage sensing. When the EOL voltage rises or falls below the pre-determine set point, the substation and line voltage regulators raise or lower their voltages as necessary to hold the remote EOL voltage constant. The voltage is locally and remotely sensed at the substation and line voltage regulator locations. Continuous voltage monitoring is required at EOL to feedback voltage.

All methods require voltage monitoring by the utility to periodically check that the end-of-line (EOL) voltages do not fall below a pre-determined set point.

All methods must be maintained annually in order to meet performance thresholds and VO guidelines.

2.0 Simplified VO M&V Approach

2.1 FEMP Measurement and Verification

The Simplified VO M&V Protocol follow Option D as described in "Measurement & Verification for Federal Energy Projects, Version 2.2
www.eere.energy.gov/femp/financing/superespcs_mvresources.html
and "International Performance Measurement & Verification Protocol (IPMVP)", Volume I, March 2002 (www.ipmvp.org).

Option D is utilized because the VO M&V Protocol is applied to a single whole facility (substation or feeder) with many subparts requiring a collective approach and where the energy savings will be less than 10 percent. Option D allows for a minimum of pre and post metered data points, and includes some simulation modeling and/or calculations to arrive at the energy saved for each chosen facility or system.

2.2 Simplified VO M&V; Four Stages

The Simplified VO M&V Protocol approach has four stages. The general steps of each stage are identified below. Processes that will be used throughout the stages are explained in 2.3 through 4.0.

1. Stage One - *Existing Performance Assessment and VO Implementation Plan*
    a. Gather actual or estimated distribution system historical data that is readily available including voltage settings and voltage operational standards.
    b. Perform preliminary assessment of distribution system's existing level of performance using system modeling.
    c. Develop a preliminary improvement plan describing the system improvements needed to meet minimum operating performance thresholds for VO.
    d. Develop preliminary plan for implementation of VO.
    e. Estimate costs and propose preliminary schedules.
    f. Calculate VO Factor from the VO Factor Tables.
    g. Estimate potential savings of VO application.
    h. Document all activities and results.

2. Stage Two - *System Improvements and Baseline Pre-VO measurements*
    a. Implement cost effective system improvements necessary to meet performance thresholds.
    b. Install source voltage regulating equipment necessary for operation of VO with controls set to mimic pre-VO average voltage conditions (non-VO operation). Pre-VO control settings are determined using system modeling. Perform pre-VO baseline measurements for 7-day period (168 hours). The detailed measurements are averaged over each hour.

c. Each voltage control zone must meet performance thresholds during this Pre-VO measurement period.
d. Determine baseline pre-VO overall average voltage for all VO voltage control zones included as part of the VO plan.
e. Identify final installation cost of system improvements including VO equipment.
f. Document all activities and results.

3. Stage Three - *VO Implementation and Post-VO Measurements and Verification*
    a. Prepare an initial estimate of end-use energy savings resulting from VO using results of pre-VO baseline measurements, planned post-VO conditions, and distribution system known or estimated customer load characteristics.
    b. Initiate post-VO operational voltage controls.
    c. Perform post-VO measurements for 7-day period (168 hours). The detailed measurements are averaged over each hour.
    d. Each voltage control zone must meet performance thresholds during this Post-VO measurement period.
    e. Determine post-VO overall average voltage for the voltage control zone. Prepare a final post-VO verified estimate of energy savings resulting from change in average annual voltage for baseline pre-VO and post-VO.
    f. Document all activities and results

4. Stage Four – Persistence of Energy Savings
    a. Complete annual self-certification checklist to ensure;
        i. Voltage settings are still in operation as prescribed within all VO voltage control zones.
        ii. Voltage control zones continue to meet performance thresholds. The annual VO performance self-certification is measured over a 12-month period.

2.3 About Minimum Operating Performance Thresholds

The voltage control zones must meet or exceed performance thresholds during normal system switching configurations for the measurement periods; 7 days and/or 168 hours in Stage 2, 7 days and/or 168 hours in Stage 3, and there after during the Persistence period in Stage 4. All measurements during the measurement period are averaged over a one hour period.

In some cases it may be needed to perform system improvements to comply with performance thresholds (i.e. addition of line regulators, shunt capacitors, phase upgrades, line reconfigurations, and line reconductoring). If multiple VO voltage control zones are included as part of a substation system, the performance thresholds apply to each VO voltage control zone. System performance is determined from measurements at each VO voltage control zone source. Performance thresholds do not apply for non-VO voltage control zones.

For calculation purposes, load adjustment for temperature, abnormal switching configuration, or seasonal load anomalies may be performed to reflect normal annual loading operations.

1. The feeder-source <u>minimum power-factor</u> must be greater than 0.96. Power-factor

is total 3φ kW divided by total 3φ kVA.

2. The average of feeder-source power-factor must be greater than 0.98. Power-factor is defined in item 1 above.

3. Feeder-source phase-load-unbalance per unit (p.u.) must be less than 0.15 on 3φ lines. The p.u. unbalance is the average of (1-[Average 3φ peak hourly demand Amps] / [maximum 1φ hourly demand Amps]) over the measurement-period. Phase-load-unbalance is determined for each VO voltage-control-zone. Maximum 1φ hourly demand Amps is measured for each line phase (e.g. line phases A, B, or C). Feeder-source neutral-current must be less than 40 amps on 3φ lines.

4. Substation VO voltage-control-zone maximum adjusted voltage-drop must be less than 3.3%. The calculation uses voltage measurements over the period and adjusts them for peak load periods. For pre-VO and post-VO assessments, the maximum adjusted voltage-drop is the average of all voltage-drops over the measurement period multiplied by the ratio [annual 3φ peak kW hourly demand / average 3φ kW demand for measurement period]. Primary voltage-drop is difference between regulator bus and EOL (lowest voltage location).

   Note: Voltage-drop is the reduction in voltage on primary line between regulator source and lowest voltage points. The voltage-drop % is the reduction in volts divided by source volts times 100. Substation VO regulator or VO line regulator annual 3φ peak kW hourly demand for a 12 month historical data period may be used with power flow simulations to determine the annual maximum voltage-drop for use with system assessment (Stage One) and self-certification monitoring (Stage Four). The peak kW demand is allocated across the VO voltage-control-zone feeder system.

5. Line Regulator voltage-control-zone maximum adjusted voltage-drop must be less than 3.3%. The calculation uses voltage measurements over the period and adjusts them for the peak load periods. For pre-VO and post-VO assessments, the maximum adjusted voltage-drop is the average of voltage-drops over the measurement-period multiplied by the ratio [annual 3φ peak kW hourly demand / average 3φ kW demand for measurement period]. Primary voltage-drop is difference between regulator bus and EOL (lowest voltage location).

6. Secondary maximum allowed voltage-drop must be less than 4.0% for all VO voltage control zones. This value is difficult to obtain, and therefore, it may be established from utility standards and design guidelines. Any time the secondary voltage-drop exceeds 4.0%, the solution should be to fix the problem and not to increase the source voltage. Secondary systems include the distribution transformer, secondary conductors, and service wires.

7. Maximum voltage-drop variance between multiple feeders served within a substation VO voltage-control-zone must be less than 2 volts (on a 120V base). The voltage-drop p.u. variance is determined by comparing the maximum voltage-drops of each feeder measured over the measurement-period.

8. The VO primary line minimum hourly voltage must be greater than [114 Volts + ½ the voltage regulation bandwidth + secondary maximum allowed voltage-drop]. Acceptable voltage regulation bandwidth is in the range of 2V to 3V (on 120V base.) Primary line minimum-voltage must be measured near the expected lowest voltage location on the primary line at EOL.

9. The VO primary line maximum hourly voltage must be less than [126 Volts - ½ the voltage regulation bandwidth]. Acceptable voltage regulation bandwidth is in the range of 2V to 3V on 120V base. Primary line maximum voltage must be measured near the expected highest voltage location on the primary line at or near the voltage-control-zone regulator measured over the measurement-period averaged over each hour.

   Note: The Customer Service Voltage must be between 126 Volts to 114 Volts for normal system switching configuration measured line to ground on a 120 Volt base over the measurement period integrated over the interval period of one hour. For infrequent abnormal operating conditions, the customer service voltage range is 127 Volts to 110 Volts.

2.4 About Distribution System Load and Operating Data Collection

Additional system data is collected for all VO voltage control zones from annual historical data, during the pre-VO and post-VO measurement periods, and through annual certification measurement periods. The system data is needed to determine the average voltage reduction and resultant energy savings for each VO voltage control zone.

Annual load peak demand or annual energy adjustments for temperature, abnormal switching configuration, or seasonal load anomalies may be performed to reflect normal annual loading operations.

This data is determined for each VO voltage control zone and includes:

1. Annual 3φ peak kW hourly demand and annual energy kWh. The VO assessment must also include an actual or adjusted annual kW peak demand and energy delivered by substation and assigned to each VO feeder and voltage control zone. This data is used to calculate annual load factor [annual 3φ kWh energy delivered / [maximum annual 3φ peak kW hourly demand * 8760 h]]
2. Hourly demand phase Amps for each VO voltage control zone source over the measurement period averaged over each hour.
3. Hourly demand kW over the measurement period for each VO voltage control zone, adjusted for normal conditions as required.
4. Hourly demand kvar over the measurement period for each VO voltage control zone, adjusted for normal conditions as required.
5. Maximum primary voltage-drop at the time of the 3φ peak kW demand (on 120V base). The voltage-drop is the average value measured over the peak hour. Distribution system modeling may be performed to determine system maximum primary voltage-drop. Source substation and line regulator Set-Point-Voltage settings on 120V base (in Volts)
6. Source substation and line regulator Current Transformer (CT) Primary Rating (in Amps)
7. Source substation and line regulator Potential Transformer (PT) Ratio (line-to-ground)
8. Source substation and line regulator real volts ‘R’ and reactive volts ‘X’ control setting on 120V base (in Volts)

9. Calculated regulator maximum voltage-rise at maximum 3φ peak kW hourly demand on 120V base (in Volts). Distribution system modeling and simulation may be performed to determine system maximum voltage-rise at maximum peak demand.

   *Note: The VO regulator voltage-rise is based on the peak load, control zone power factor and regulator control settings. For example, for most common conditions with average power factor greater than 0.98 and a 'X' setting equal to zero, the regulator maximum voltage-rise is ['R' setting (Volts) * average annual power factor (p.u.) * maximum annual 3φ peak hourly demand (Amps) / Current Transformer Primary Rating (Amps)]. All measurements are averaged over each hour.*

2.5 About Distribution System Equipment Data

In addition to the measured or determined system parameters, additional information must be available to ensure correct system modeling, power flow simulations, and determine maximum voltage-drops and maximum voltage rises for all VO voltage control zones. The electric utility distribution system data is collected for system preliminary assessments, baseline pre-VO, post-VO, and annual self-certification M&V assessments for each VO application. The modeling data set includes:

1. Primary kV line-to-line voltage class (typically identified as the Distribution Transformer primary line-to-ground kV voltage rating.)
2. Distribution system maps and/or models depicting conductor sizes, phase configuration, and connected kVA size and location of distribution transformers.
3. Location, size, and type of all station regulators and line regulators including control settings for each (e.g., set-point-voltage, R & X settings, time delay, CT Rating and PT ratio, regulator bandwidth, and regulator first house protection settings.)
4. Location and size of Shunt Capacitor banks and control settings (if applicable). For simplified VO application, switch capacitor control must be 'var' control only.
5. Overall utility characteristics, design guidelines, construction standards, historical system studies, customer information, and equipment data.

2.6 About Metering Requirements

Metering equipment is required to provide the measurement and verification of data for all VO voltage control zones for pre-VO, post-VO, and annual self-certification monitoring. Meters must collect kW demand, kvar demand, ampere demand, and volts measured over the measurement-period with measurements averaged over each hour. Metering locations include:

- Substation power transformer (on regulated voltage side).
- Substation feeder breakers.
- Line Regulator equipment (on regulated voltage side).
- Remote primary line EOL low voltage point locations (voltage recording meters only) for each VO voltage control zone.

Metering installations and calibration must be performed by qualified personnel. If feasible, it is desirable that all metering instrumentation complies with ANSI Standard C57.13

metering accuracy specifications. Substation and regulator metering data can be collected from energy/demand meters, electronic relays, or controllers provided they provide data on all phases present. Utility field self-verification and inspections are required to verify correct meter installation and correct register readings.

For VFR and LDC systems, one remote primary line EOL voltage-recording meter must be installed at the lowest voltage point locations on each of the primary feeders for each voltage-control-zone. For AVFC systems, there must be three-volt recording meters and volt remote feedback-sensing devices installed on each primary feeder at independent locations. The meters should measure voltage on all phases present for VRF, LDC, and AVFC systems.

3.0 About VO Factor and Energy Savings Calculations

3.1 Customer Data

Customer load information is required for each distribution substation where VO may be applied. This customer information is used to determine the end-use VO Factor from Appendix A Tables, which are used in energy savings calculations. Based on known customer information available for the electric utility (e.g. customer information systems, utility mapping records, and customer billing system) the customer load characteristics are determined. It may be necessary to provide an estimate of customer load characteristics using typical load research data or other similar analysis. The required customer load characteristics are as follows:

1. Heating and cooling climate zone classification for each substation area.
2. Percentage of substation area total annual load (kWh) that is classified as residential class load.
3. Percentage of existing residential class consumers that have electric heat (hot water, space heating, and/or heat pump). Non electric heat is typically provided by gas, oil, or wood.
4. Percentage of existing residential class consumers that have any type of electric air conditioning.

3.2 About End Use VO Factor

The end-use VO Factor is a ratio of expected % change in energy delivered for each 1% change in average voltage supplied at the end-use service entrance. The end use VO Factor is given as a p.u. ratio for a given system and is determined from VO Factor Tables in Appendix A of this Protocol. Enter the table identified for the Heating and cooling climate zone associated for each substation and select the appropriate VO Factor using the percent customers with Non-Electric Heating (and Heat Pumps) and percent of customers with Air-conditioning.

3.3 About Determination of Average Voltage Reduction

For each VO voltage control zone (pre-VO and post-VO conditions), the average voltage formulation depends upon the voltage control method chosen (e.g., VFR, LDC, or AVFC.) The normalized average annual voltages are determined at the baseline pre-VO measurements (Stage 2) and post-VO measurements (Stage 3) from 168 metered-hours emulating a 7-day period as follows:

A = Calculated Feeder Maximum Annual Volt-Drop

= Average_of_all_Volt-Drop(hourly) * [maximum_annual_3φ_peak_kW_demand(hourly) / average_kW_demand(hourly)]

B = Calculated Regulator Maximum Annual Volt-Rise

= [Average_of_all_Regulator_Output_Voltages(hourly) – (Regulator_Set_Point_Voltage_Setting)] * [maximum_annual_3φ_peak_kW_demand(hourly) / average_kW_demand(hourly)]

Note: The Volt-Drop (hourly) is the metered Regulator_Output_Voltage minus the lowest EOL voltage averaged over each hour. All values are calculated over the measurement-period. Variables A and B may be determined via system modeling simulations for initial VO average voltage estimates and annual self-certification assessments.

The final post-VO verified average annual voltage reduction is the difference between the adjusted pre-VO and post-VO average annual voltages weighted by VO voltage control zone kW load and depends on the pre-VO and the post-VO voltage control techniques applied.

The annual 3φ peak kW hourly demand and Annual Load Factor are known from the measured historical data.

The baseline pre-VO overall average voltage for all VO voltage control zones is determined by applying the existing non-VO control settings and applying control setting adjustments to mimic pre-VO average voltage conditions (non-VO operation). Pre-VO control settings are determined using system modeling.

The adjusted average voltage calculation formulation for pre-VO and post-VO measurements for each voltage-control-zone is described as follows:

***** VFR Methods****

For VFR applications, the regulator R and X control settings are zero.

Adjusted Average Voltage for VFR =
[Regulator_Set_Point_Voltage_Setting – ½ * A * Annual_Load_Factor]

***** LDC and AVFC Methods****

For LDC applications, the regulator R and X control settings should be set so that the maximum voltage rise B is equal to or greater than the maximum annual voltage-drop A.

Adjusted Average Voltage for LDC or AVFC =
[Regulator_Set_Point_Voltage_Setting + Annual_Load_Factor *[B - 1/2 *A]]

3.4 About Determination of Average Annual Energy Reduction

For each voltage-control-zone, the average voltage is calculated as shown in Section 3.3 above for the baseline pre-VO and post-VO conditions. If there are multiple voltage-control-zones within each VO application area, the overall system average annual voltage is the average of the control zone voltages weighted by control zone loads. All average annual voltages are on a 120V base.

Variables A and B can be determined via system modeling for initial VO average voltage estimates and annual self-certification assessments. The VO energy savings used for determining the initial VO estimate, final post-VO verification, or annual assessment is calculated as follows:

Overall Average Voltage Reduction (in volts) =
[Weighted Average Voltage (pre-VO) - Weighted Average Voltage (post-VO)]

Overall Average Voltage Reduction (p.u.) =
[Overall Average Voltage Reduction (in volts) / 120]

Energy Change (p.u.) = Overall Average Voltage Reduction (p.u.) * VO Factor

VO Energy Change (MWh) = Annual 3φ kWh energy load * Energy Change (p.u.)

The VO design should not yield voltages for customers outside the nominal ANSI C84.1 Standard Voltage Range of 126-114 Volts (on 120V base). In practice it is desired to achieve an overall average voltage for primary lines in the range of 122-118 Volts and depends on the secondary maximum allowed voltage-drop. At the residential and light commercial customer service meter, the goal is to have an average voltage between 120-114 Volts.

4.0 Recommendations for Ensuring Persistence of Energy Savings

System improvements typically have a useful life exceeding 35 years. However, control settings are easily altered over time unless they are integrated into utility operating and design standards. For new operating design standards to become entrenched, a three-year monitoring and documentation period is recommended. Standards that become entrenched tend to extend the life of VO perpetually.

This 3-year period includes the following:

1. On a monthly basis, a utility must document that voltage control settings within each the VO voltage control zone are maintained as necessary to be consistent with those determined during the original VO project.
2. On an annual basis, provide total kWh usage on the voltage control zone and provide average voltage at Substation and EOL.
3. A utility must maintain this documentation (or provide it to the appropriate organization) annually for a 3-year period.
4. During this three year period, if the voltage control settings have been off-line, either intentionally or unintentionally for a period of 30 days or longer, the utility must continue to maintain the voltage control setting documentation for a period equal to 30 days or longer beyond the original 3 year documentation period.
5. Verify performance thresholds for each voltage-control-zone and corrective actions taken if any. Thresholds include:
    a. Feeder power factor – Average hourly > 0.98 from <u>*metered*</u> data

b. Feeder power factor – Maximum hourly > 0.96 from *metered* data

c. EOL primary voltage must be > [114 Volts + ½ the voltage regulation bandwidth + secondary maximum allowed voltage-drop] from *metered* data

d. Regulator primary voltage must be < [126 Volts - ½ the voltage regulation bandwidth + secondary maximum allowed voltage-drop] from *metered* data

e. Feeder load unbalance must be < 0.15 from system modeling

f. Feeder Source 3φ feeder neutral current < 40 Amps from *metered* data

g. Feeder maximum adjusted primary voltage-drops <3.3% from system modeling

h. Feeder maximum voltage-drop variance < 2.0 V on a 120V base.

APPENDIX A
VO FACTOR TABLES
FOR USE WITH SIMPLIFIED VO M&V PROTOCOL

Source of VO Factors is 2007 NEEA DEI Project Load Research Survey Reported Results

Instructions: These End-Use VO Factors are for use with the Simplified VO M&V Protocol. The End-Use VO Factor Tables are for use with distribution system customers classified as residential and small commercial as defined by the utility. To identify the appropriate VO Factor, locate the VO Factor Table for the known heating and cooling zone. The end-use VO Factor is derived by selecting the percent of customers with non-electric heat (and heat pumps) and percent of customers with air-conditioning. VO Factors are shown as percent of change in energy to percent change in average annual voltage. The tables are obtained from the NEEA Distribution Efficiency Initiative project 2003-2007, which performed VO load research evaluation on end-use loads throughout the Northwest for different climate zone.

Table 1 – End-Use VO Factors for Climate Zone Heating 1 and Cooling 1

	% of Customers with Non Electric Heat and Heat Pumps (e.g. gas, oil, or wood heat)										
%AC	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	0.27	0.29	0.32	0.35	0.38	0.42	0.46	0.51	0.56	0.63	0.70
10	0.27	0.30	0.33	0.36	0.39	0.43	0.47	0.51	0.57	0.63	0.70
20	0.27	0.31	0.33	0.36	0.40	0.43	0.47	0.52	0.57	0.63	0.70
30	0.29	0.31	0.34	0.37	0.40	0.44	0.48	0.52	0.57	0.63	0.69
40	0.29	0.32	0.35	0.38	0.41	0.45	0.49	0.53	0.58	0.63	0.69
50	0.30	0.33	0.36	0.39	0.42	0.45	0.49	0.54	0.58	0.63	0.69
60	0.31	0.34	0.36	0.39	0.43	0.46	0.50	0.54	0.59	0.63	0.69
70	0.32	0.35	0.37	0.40	0.44	0.47	0.51	0.55	0.59	0.64	0.69
80	0.33	0.36	0.38	0.41	0.44	0.48	0.51	0.55	0.59	0.64	0.68
90	0.34	0.37	0.39	0.42	0.45	0.49	0.52	0.56	0.60	0.64	0.68
100	0.35	0.38	0.40	0.43	0.46	0.49	0.53	0.56	0.60	0.64	0.68

Table 2 – End-Use VO Factors for Climate Zone Heating 1 and Cooling 2

	% of Customers with Non Electric Heat and Heat Pumps (e.g. gas, oil, or wood heat)										
%AC	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	0.27	0.29	0.32	0.35	0.38	0.42	0.46	0.51	0.56	0.63	0.70
10	0.27	0.30	0.33	0.36	0.39	0.43	0.47	0.51	0.57	0.63	0.70
20	0.28	0.31	0.33	0.36	0.40	0.43	0.47	0.52	0.57	0.63	0.69
30	0.29	0.31	0.34	0.37	0.40	0.44	0.48	0.52	0.57	0.63	0.69
40	0.29	0.32	0.35	0.38	0.41	0.45	0.49	0.53	0.58	0.63	0.69
50	0.30	0.33	0.36	0.39	0.42	0.45	0.49	0.53	0.58	0.63	0.69
60	0.31	0.34	0.37	0.40	0.43	0.46	0.50	0.54	0.58	0.63	0.69
70	0.32	0.35	0.37	0.40	0.44	0.47	0.51	0.55	0.59	0.63	0.68
80	0.33	0.36	0.38	0.41	0.44	0.48	0.51	0.55	0.59	0.64	0.68
90	0.34	0.37	0.39	0.42	0.45	0.49	0.52	0.56	0.60	0.64	0.68
100	0.35	0.38	0.40	0.43	0.46	0.49	0.53	0.56	0.60	0.64	0.68

Table 3 – End-Use VO Factors for Climate Zone Heating 1 and Cooling 3

	% of Customers with Non Electric Heat and Heat Pumps (e.g. gas, oil, or wood heat)										
%AC	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	0.27	0.29	0.32	0.35	0.39	0.42	0.46	0.51	0.55	0.61	0.66
10	0.27	0.30	0.33	0.36	0.39	0.43	0.47	0.51	0.56	0.61	0.66
20	0.28	0.31	0.34	0.37	0.40	0.44	0.47	0.52	0.56	0.61	0.66
30	0.29	0.31	0.34	0.37	0.41	0.44	0.48	0.52	0.56	0.61	0.66
40	0.29	0.32	0.35	0.38	0.41	0.45	0.49	0.53	0.57	0.61	0.66
50	0.30	0.33	0.36	0.39	0.42	0.46	0.49	0.53	0.57	0.61	0.66
60	0.31	0.34	0.37	0.40	0.43	0.46	0.50	0.54	0.57	0.62	0.66
70	0.32	0.35	0.38	0.41	0.44	0.47	0.50	0.54	0.58	0.62	0.66
80	0.33	0.36	0.39	0.42	0.45	0.48	0.51	0.55	0.58	0.62	0.66
90	0.34	0.37	0.40	0.42	0.45	0.49	0.52	0.55	0.59	0.62	0.66
100	0.35	0.38	0.41	0.43	0.46	0.49	0.52	0.56	0.59	0.62	0.66

Table 4 – End-Use VO Factors for Climate Zone Heating 2 and Cooling 1

	% of Customers with Non Electric Heat and Heat Pumps (e.g. gas, oil, or wood heat)										
%AC	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	0.27	0.29	0.32	0.34	0.38	0.42	0.46	0.51	0.58	0.66	0.75
10	0.27	0.30	0.32	0.35	0.38	0.42	0.47	0.52	0.58	0.66	0.75
20	0.28	0.30	0.33	0.36	0.39	0.43	0.47	0.52	0.58	0.66	0.74
30	0.29	0.31	0.34	0.37	0.40	0.44	0.48	0.53	0.59	0.66	0.74
40	0.29	0.32	0.35	0.37	0.41	0.44	0.49	0.54	0.59	0.66	0.73
50	0.30	0.33	0.35	0.38	0.42	0.45	0.49	0.54	0.59	0.66	0.73
60	0.31	0.34	0.36	0.39	0.42	0.46	0.50	0.55	0.60	0.66	0.73
70	0.32	0.34	0.37	0.40	0.43	0.47	0.51	0.55	0.60	0.66	0.72
80	0.33	0.35	0.38	0.41	0.44	0.48	0.52	0.56	0.61	0.66	0.72
90	0.34	0.36	0.39	0.42	0.45	0.49	0.52	0.56	0.61	0.66	0.71
100	0.35	0.37	0.40	0.43	0.46	0.49	0.53	0.57	0.61	0.66	0.71

Table 5 – End-Use VO Factors for Climate Zone Heating 2 and Cooling 2

	% of Customers with Non Electric Heat and Heat Pumps (e.g. gas, oil, or wood heat)										
%AC	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	0.27	0.29	0.32	0.34	0.38	0.42	0.46	0.51	0.58	0.66	0.75
10	0.27	0.30	0.32	0.35	0.38	0.42	0.47	0.52	0.58	0.66	0.75
20	0.28	0.30	0.33	0.36	0.39	0.43	0.47	0.52	0.58	0.66	0.74
30	0.29	0.31	0.34	0.37	0.40	0.44	0.48	0.53	0.59	0.66	0.74
40	0.29	0.32	0.32	0.37	0.41	0.44	0.49	0.54	0.59	0.66	0.73
50	0.30	0.33	0.35	0.38	0.42	0.45	0.49	0.54	0.59	0.66	0.73
60	0.31	0.34	0.36	0.39	0.42	0.46	0.50	0.55	0.60	0.66	0.73
70	0.32	0.34	0.37	0.40	0.43	0.47	0.51	0.56	0.60	0.66	0.72
80	0.33	0.35	0.38	0.41	0.44	0.48	0.52	0.56	0.61	0.66	0.72
90	0.34	0.36	0.39	0.42	0.45	0.49	0.52	0.56	0.61	0.66	0.71
100	0.35	0.37	0.40	0.43	0.46	0.49	0.53	0.57	0.61	0.66	0.71

Table 6 – End-Use VO Factors for Climate Zone Heating 2 and Cooling 3

	% of Customers with Non Electric Heat and Heat Pumps (e.g. gas, oil, or wood heat)										
%AC	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	0.27	0.29	0.32	0.34	0.38	0.42	0.46	0.51	0.58	0.65	0.75
10	0.27	0.30	0.32	0.35	0.39	0.42	0.47	0.52	0.58	0.65	0.75
20	0.28	0.30	0.33	0.36	0.39	0.43	0.47	0.52	0.58	0.65	0.74
30	0.29	0.31	0.34	0.37	0.40	0.44	0.48	0.53	0.59	0.66	0.74
40	0.29	0.32	0.35	0.37	0.41	0.45	0.49	0.54	0.59	0.66	0.73
50	0.30	0.33	0.35	0.38	0.42	0.45	0.49	0.54	0.59	0.66	0.73
60	0.31	0.34	0.36	0.39	0.42	0.46	0.50	0.55	0.60	0.66	0.72
70	0.32	0.34	0.37	0.40	0.43	0.47	0.51	0.55	0.60	0.66	0.72
80	0.33	0.35	0.38	0.41	0.44	0.48	0.52	0.56	0.60	0.66	0.72
90	0.34	0.36	0.39	0.42	0.45	0.49	0.52	0.56	0.61	0.66	0.71
100	0.35	0.37	0.40	0.43	0.46	0.49	0.53	0.57	0.61	0.66	0.71

Table 7 – End-Use VO Factors for Climate Zone Heating 3 and Cooling 1

	% of Customers with Non Electric Heat and Heat Pumps (e.g. gas, oil, or wood heat)										
%AC	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	0.27	0.29	0.32	0.35	0.38	0.42	0.46	0.51	0.57	0.64	0.73
10	0.27	0.30	0.32	0.35	0.39	0.42	0.47	0.52	0.58	0.64	0.73
20	0.28	0.30	0.33	0.36	0.39	0.43	0.47	0.52	0.58	0.65	0.72
30	0.29	0.31	0.34	0.37	0.40	0.44	0.48	0.53	0.58	0.65	0.72
40	0.29	0.32	0.35	0.38	0.41	0.45	0.49	0.53	0.59	0.65	0.72
50	0.30	0.33	0.35	0.38	0.42	0.45	0.49	0.54	0.59	0.65	0.71
60	0.31	0.34	0.36	0.39	0.43	0.46	0.50	0.54	0.59	0.65	0.71
70	0.32	0.35	0.37	0.40	0.43	0.47	0.54	0.55	0.60	0.65	0.71
80	0.33	0.35	0.38	0.41	0.44	0.48	0.51	0.56	0.60	0.65	0.70
90	0.34	0.36	0.39	0.42	0.45	0.49	0.52	0.56	0.60	0.65	0.70
100	0.35	0.38	0.40	0.43	0.46	0.49	0.53	0.57	0.61	0.65	0.70

Table 8 – End-Use VO Factors for Climate Zone Heating 3 and Cooling 2

	% of Customers with Non Electric Heat and Heat Pumps (e.g. gas, oil, or wood heat)										
%AC	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	0.27	0.29	0.32	0.35	0.38	0.42	0.46	0.51	0.57	0.64	0.73
10	0.27	0.30	0.32	0.35	0.39	0.42	0.47	0.52	0.58	0.64	0.73
20	0.28	0.30	0.33	0.36	0.39	0.43	0.47	0.52	0.58	0.65	0.72
30	0.29	0.31	0.34	0.37	0.40	0.44	0.48	0.53	0.58	0.65	0.72
40	0.29	0.32	0.35	0.38	0.41	0.45	0.49	0.53	0.59	0.65	0.72
50	0.30	0.33	0.35	0.38	0.42	0.45	0.49	0.54	0.59	0.65	0.71
60	0.31	0.34	0.36	0.39	0.43	0.46	0.50	0.54	0.59	0.65	0.71
70	0.32	0.35	0.37	0.40	0.43	0.47	0.51	0.55	0.60	0.65	0.71
80	0.33	0.35	0.38	0.41	0.44	0.48	0.51	0.56	0.60	0.65	0.70
90	0.34	0.36	0.39	0.42	0.45	0.49	0.52	0.56	0.60	0.65	0.70
100	0.35	0.38	0.40	0.43	0.46	0.49	0.53	0.57	0.61	0.65	0.70

Table 9 – End-Use VO Factors for Climate Zone Heating 3 and Cooling 3

	% of Customers with Non Electric Heat and Heat Pumps (e.g. gas, oil, or wood heat)										
%AC	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
0	0.27	0.29	0.32	0.35	0.38	0.42	0.46	0.51	0.57	0.64	0.73
10	0.27	0.30	0.32	0.35	0.39	0.42	0.47	0.52	0.58	0.64	0.73
20	0.28	0.30	0.33	0.36	0.39	0.43	0.47	0.52	0.58	0.65	0.72
30	0.29	0.31	0.34	0.37	0.40	0.44	0.48	0.53	0.58	0.65	0.72
40	0.29	0.32	0.35	0.38	0.41	0.45	0.49	0.53	0.59	0.65	0.72
50	0.30	0.33	0.35	0.38	0.42	0.45	0.49	0.54	0.59	0.65	0.71
60	0.31	0.34	0.36	0.39	0.43	0.46	0.50	0.54	0.59	0.65	0.71
70	0.32	0.35	0.37	0.40	0.43	0.47	0.51	0.55	0.60	0.65	0.71
80	0.33	0.35	0.38	0.41	0.44	0.48	0.51	0.56	0.60	0.65	0.70
90	0.34	0.36	0.39	0.42	0.45	0.49	0.52	0.56	0.60	0.65	0.70
100	0.35	038	0.40	0.43	0.46	0.49	0.53	0.57	0.61	0.65	0.70

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