DNV·GL

Evaluation, Measurement, and Verification Report for Virginia Electric and Power Company (Dominion)

Case No. PUE-2016-00111 (Virginia)
Docket No.: E-22 Sub 545 (North Carolina)

VOLUME 4 OF 4
PUBLIC VERSION

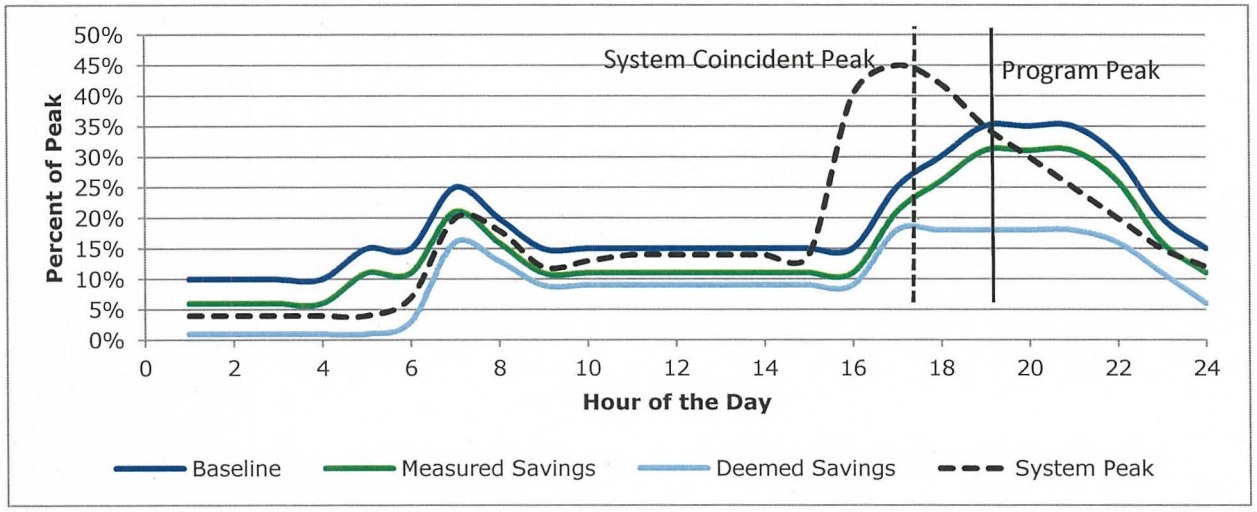
Prepared by DNV GL (KEMA, Inc.)

Date: May 1, 2018

Appendix G

APPENDIX G. RESIDENTIAL INCOME AND AGE QUALIFYING HOME IMPROVEMENT PROGRAM EM&V PLAN (VERSION 8.0)

Program Summary	The Income and Age Qualifying Home Improvement Program is designed to provide qualifying low-income (60% or less of Virginia state median income) and elderly (60+ and household income of up to 120% Virginia state median income) residential customers of the Company with a free energy audit that identifies certain areas where they can save money on their monthly electric bill. If homeowners (or authorized renters) approve, auditors may immediately make certain improvements while at the home.
Measures	The following high efficiency measures are covered by the program: • Incandescent lighting changed to LEDs (up to 6 lamps per home) • Pipe wrap installed on any exposed and accessible hot water supply lines from electric water heater • Showerhead changed from 2.5 GPM to low flow 2.0 GPM for electric heaters • Kitchen and bathroom aerators changed from 2.2 GPM to low flow 1.5 GPM for electric heaters • Attic insulation of a maximum of R-49

EM&V Method	International Performance Measurement and Verification Protocol (IPMVP - Option C): The savings measurement approach defined in IPMVP Option C and ASHRAE Guideline 14 determines energy and demand savings through the use of whole-facility energy (end-use) data, which may be measured by utility meters or data loggers. This approach will involve the use of monthly utility billing data from a main meter for a twelve-month period before and after the audit/install date, and adjust the savings estimates derived from engineering algorithms applied to the Company's program participation data. The adjustment factor, also called a realization rate,[1] is then applied to the population of participants to estimate program savings. This approach will capture Company-specific customer usage data, which will be applied to actual participating households to quantify energy and peak demand savings. The following figure illustrates the various components used to arrive at the savings estimates. **Illustrative Load Shape: Residential Income and Age Qualifying Home Improvement Program**  1. Baseline Estimation Approach (Dark blue line): The baseline wattage of all installed measures will be computed

[1] The "realization rate" is the proportion of assumed or estimated energy and peak demand savings that is actually realized by a customer or project. It is expressed as a percentage, and is derived from follow-up research (billing analyses and customer surveys) to verify that measures were in fact installed and are operating as intended, and/or actions were taken.

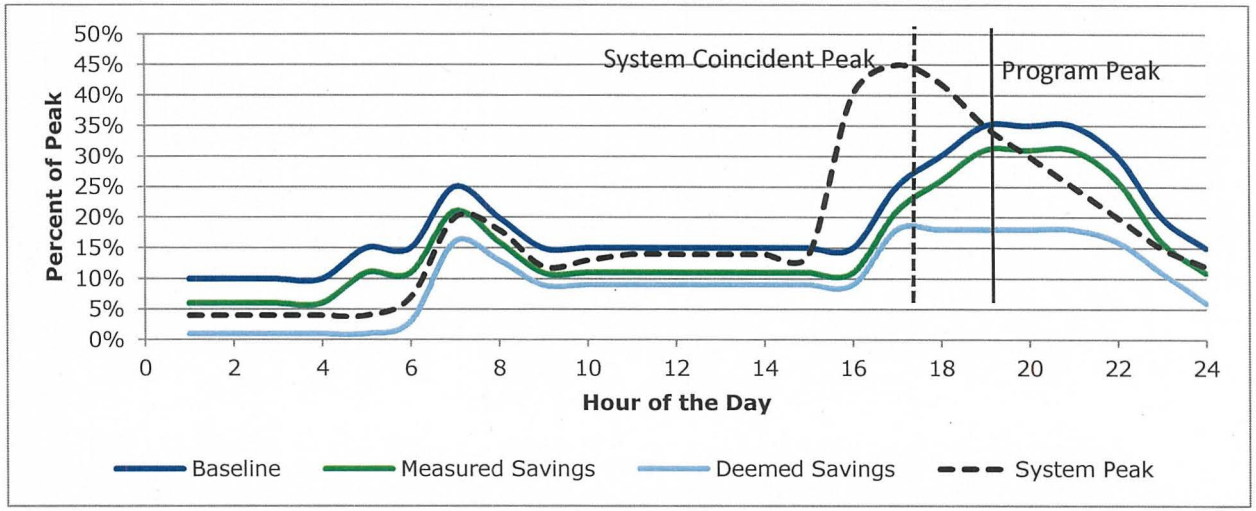
	using baseline conditions tracked in the program participation data using the DNV GL Energy Standard Tracking and Engineering Protocols (STEP) Manual. The original source of these deemed savings approaches is derived from the Mid-Atlantic Technical Resource Manual (TRM) and other TRMs. The baseline will also be represented in the billing analysis by the pre-retrofit data period for the household overall, and will be analyzed for measure-specific impacts. 2. Deemed Savings Approach (Light blue line): Deemed savings values will be estimated from the DNV GL Energy STEP Manual. The original source of this deemed savings approach is derived from the Mid-Atlantic TRM. 3. Measured Savings Approach (Green line): The energy savings will be estimated from a billing analysis of participants based on comparing pre-installation and post-installation data.
Deemed Savings Approach	Refer to the Residential Income and Age Qualifying Home Improvement Program section of the STEP Manual for the standard deemed savings approach for the measures in this program.
EM&V Measurement, Timeline, and Scope of Work	• Analysis of program tracking data: Annual Report (May 1 of each year following program launch). • Annual updates to STEP Manual for updates that occurred to its referenced sources. • Develop baseline, measure savings, and efficient load shapes. • Provide regulatory support as necessary
Document Revision History	Version 7.0 • New version.
	Version 8.0 • Edited "EM&V Measurement, Timeline, and Scope of Work" section to be consistent with other programs.

APPENDIX H. RESIDENTIAL APPLIANCE RECYLING PROGRAM EM&V PLAN (VERSION 8.0)

Program Summary	This program incentivizes households to recycle their qualifying refrigerators and freezers. Qualifying equipment must be between 10 and 32 cubic feet, must be at least 10 years old, and must still be operational and in use upon pickup. Each household is limited to up to two units per account over the life of the program.
Measures	• Operational refrigerators between 10 ft^3 and 32 ft^3 that are at least 10 years old • Operational freezers between 10 ft^3 and 32 ft^3 that are at least 10 years old
EM&V Method	International Performance Measurement and Verification Protocol (IPMVP) Option A: Because specific equipment is involved, IPMVP Option A is the appropriate EM&V method to apply. IPMVP Option A is a partially measured retrofit isolation study that meters the selected parameters leading to the change in energy and demand of an installed efficiency measure from a representative sample of participants, and adjusts the savings estimates derived from engineering algorithms applied to the Company's program participation data. The ratio of deemed savings and adjusted savings, also called a realization rate,[2] is then applied to the population of participants to estimate program savings The following figure illustrates the various components used to arrive at the savings estimates.

[2] The "realization rate" is the proportion of assumed or estimated energy and peak demand savings that is actually realized by a customer or project. It is expressed as a percentage, and is derived from follow up research (on-site inspections or customer surveys) to verify that measures were in fact installed and are operating as intended, and/or actions were taken.

Illustrative Load Shape: Residential Appliance Recycling Program



1. Baseline Estimation Approach (Blue line): The baseline wattage of all installed measures will be computed using baseline conditions tracked in the program participation data using protocols developed in the DNV GL Energy Standard Tracking and Engineering Protocols (STEP) Manual.

2. Deemed Savings Approach (Green line): Deemed savings values will be estimated using calculation approaches in the DNV GL Energy STEP Manual, which are derived primarily from the Mid-Atlantic Technical Resource Manual (TRM) and other TRMs.

3. Measured Savings Approach (Red line): The wattage and hours of use data for the installed efficiency measure will be collected and metered through an on-site study of installed rebated measures from a representative sample of participants.

Deemed Savings Approach	Refer to the Residential Appliance Recycling Program section of the STEP Manual for the standard deemed savings approach for the measures in this program.
EM&V Measurement, Timeline, and Scope of Work	• Analysis of program tracking data: Annual Report (May 1 of each year following program launch). • Annual updates to STEP Manual for updates that occurred to its referenced sources. • Develop baseline, measure savings, and efficient load shapes. • Provide regulatory support as necessary

Revision History	Version 8.0 • Edited "EM&V Measurement, Timeline, and Scope of Work" section to be consistent with other programs.

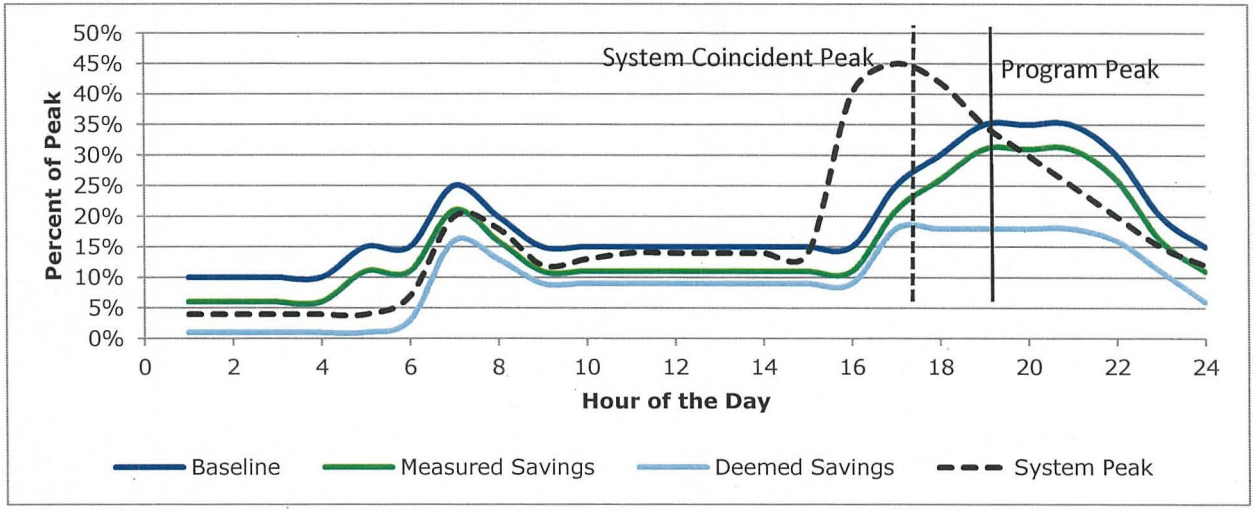
Appendix I

APPENDIX I. RESIDENTIAL RETAIL LED LIGHTING PROGRAM EM&V PLAN (VERSION 8.0)

Program Summary[3]	The Residential Retail LED Lighting Program is an instant discount for a variety of qualifying Light-Emitting Diode (LED) light bulb purchases from participating retailers. Participating vendors will pay manufacturers of eligible bulbs an incentive, which will enable the manufacturer to sell the eligible bulbs at a discount to area retailers, who then would sell the bulbs to consumers at the agreed discounted price. The incentive participants will receive is in the form of a discount on the price of the bulbs at the point of sale. Dominion estimates it will pay an average[4] incentive of $3.00 per LED bulb. Customers are limited to 12 discounted bulbs per purchase. This program would operate the Program on a North Carolina-only basis. The benefits and the costs of the Program would flow 100% to North Carolina. The company is offering the Program for a two-year period, with the intent that a system-wide program which includes a residential lighting component is planned to be offered in the future.
Measures	Refer to the Residential Retail LED Lighting Program section of the STEP Manual for a list of the eligible lighting measures.
EM&V Method	International Performance Measurement and Verification Protocol (IPMVP) Option A: Because specific equipment is involved, IPMVP Option A is the appropriate EM&V method to apply. IPMVP Option A is a partially measured retrofit isolation study that meters the selected parameters leading to the change in energy and demand of an installed efficiency measure from a representative sample of participants, and adjusts the savings estimates derived from engineering algorithms applied to the Company's program participation data. The ratio of deemed savings and adjusted savings, also called a realization rate,[5] is then applied to the population of participants to estimate program savings The following figure illustrates the various components used to arrive at the savings estimates.

[3] Program eligibility requirements are based on the Residential Heat Pump Upgrade Program's terms and conditions and FAQ web pages accessed on March 3, 2015, which is no longer available, as the program has expired as designed..
[4] Through a data request, this was determined to be a weighted average across all bulb types and incentive amounts.
[5] The "realization rate" is the proportion of assumed or estimated energy and peak demand savings that is actually realized by a customer or project. It is expressed as a percentage, and is derived from follow up research (on-site inspections or customer surveys) to verify that measures were in fact installed and are operating as intended, and/or actions were taken.

Illustrative Load Shape: Residential Retail LED Lighting Program



4. Baseline Estimation Approach (Blue line): The baseline wattage of all installed measures will be computed using baseline conditions tracked in the program participation data using protocols developed in the DNV GL Energy Standard Tracking and Engineering Protocols (STEP) Manual.

5. Deemed Savings Approach (Green line): Deemed savings values will be estimated using calculation approaches in the DNV GL Energy STEP Manual, which are derived primarily from the Mid-Atlantic Technical Resource Manual (TRM) and other TRMs.

6. Measured Savings Approach (Red line): The wattage and hours of use data for the installed efficiency measure will be collected and metered through an on-site study of installed rebated measures from a representative sample of participants.

Deemed Savings Approach	Refer to the Residential Retail LED Lighting Program section of the STEP Manual for the standard deemed savings approach for the measures in this program.
EM&V Measurement, Timeline, and Scope of Work	• Analysis of program tracking data; Annual Report (May 1 of each year following program launch). • Annual updates to STEP Manual for updates that occurred to its referenced sources. • Develop baseline, measure savings, and efficient load shapes. • Provide regulatory support as necessary.

Lost Revenue Methodology	Measured and verified lost revenues for this program will be calculated as follows: 1. Calculate program savings by applying the realization rate derived from the measured data based off the on-site studies. 2. Apply the measured data to the actual participant data to arrive at program level energy and demand savings, reflected on a monthly basis. Program savings are annualized in the EM&V tracking reports based on monthly participation data. 3. Develop cumulative monthly energy savings based on measured and verified data to represent the lost sales (kWh) associated with the program. 4. Multiply the cumulative monthly energy savings by the monthly marginal base distribution and generation rate derived using a marginal rate analysis of the participants in this program (such analysis will exclude the Basic Customer Charges, and exclude Fuel Charge Rider A and all other applicable riders) for the rate period to arrive at lost revenues.
Document Revision History	Version 8.0 • New version

Appendix J

APPENDIX J. NON-RESIDENTIAL LIGHTING SYSTEMS AND CONTROLS PROGRAM EM&V PLAN (VERSION 8.0)

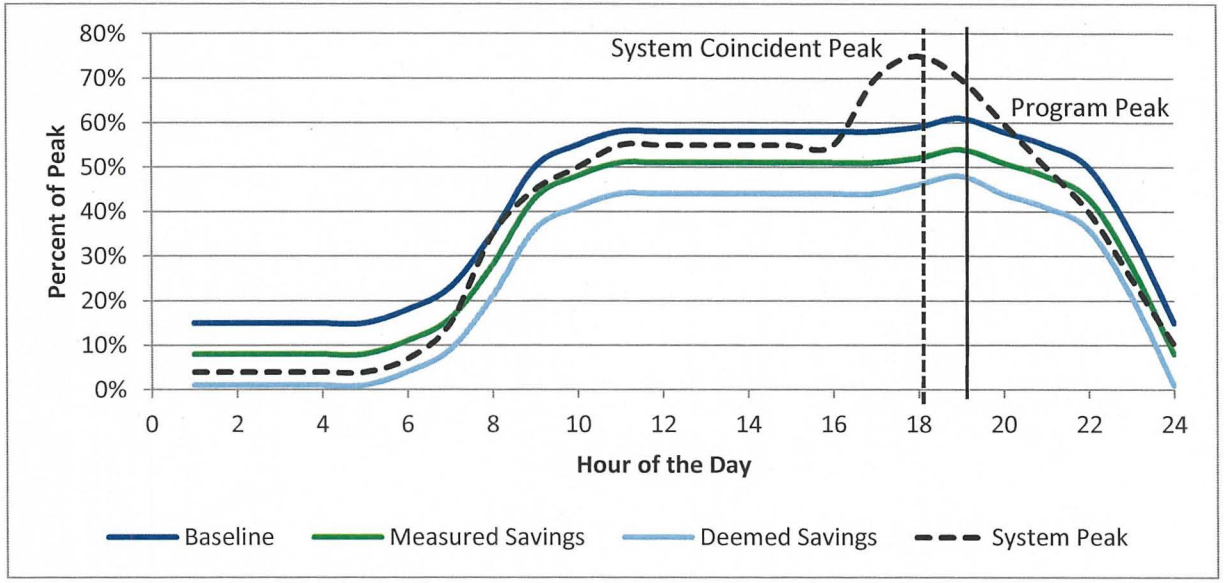
Program Summary	The Non-residential Lighting Systems and Controls Program is designed to provide commercial and industrial customers with an incentive to retrofit, or upgrade, inefficient lighting to qualifying high efficiency lighting systems. The incentive consists of a menu of rebates for over 75 different combinations of upgrades involving various types of efficient lighting measures.
Measures	The following high efficiency lighting measures are included in the program: • T8 and HPT8 fixtures • T5 fixtures • LEDs and LED Exit Signs retrofits • CFLs and CFL fixtures • Occupancy sensor and controls installations

EM&V Method

International Performance Measurement and Verification Protocol (IPMVP - Option A): Since this program focuses on specific lighting replacements, IPMVP Option A is the appropriate EM&V method to apply. IPMVP Option A is a partially measured retrofit isolation study that meters the actual energy and demand of an installed efficiency measure from a representative sample of participants, and adjusts the savings estimates derived from engineering algorithms applied to the Company's program participation data. The adjustment factor, also called a realization rate,[6] is then applied to the population of participants to estimate program savings.

The following figure illustrates the various components used to arrive at the savings estimates.

Illustrative Load Shape: Non-Residential Lighting Systems and Controls



1. Baseline Estimation Approach (Dark blue line): The baseline wattage will be computed using the prescriptive replacement combinations presented in the Standard Tracking and Engineering Protocols (STEP) Manual. The replaced lighting fixtures from the rebate application data will be used, applying hours of use as metered in

[6] The "realization rate" is the proportion of assumed or estimated energy and peak demand savings that is actually realized by a customer or project. It is expressed as a percentage, and is derived from follow up research (on-site inspections or customer surveys) to verify that measures were in fact installed and are operating as intended, and/or actions were taken.

	onsite studies of installed rebated measures from a representative sample of participants in Virginia. 2. Deemed Savings Approach (Light blue line): Deemed savings values will be estimated from the DNV GL Energy STEP Manual. The original source of this deemed savings approach is derived from the Mid-Atlantic Technical Resource Manual (TRM). 3. Measured Savings Approach (Green line): The wattage and hours of use data for the installed efficiency measure will be collected and metered through an on-site study of installed rebated measures from a representative sample of participants.
Deemed Savings Approach	Refer to the Non-Residential Lighting Systems and Controls Program section of the STEP Manual for the standard deemed savings approach for the measures in this program.
EM&V Summary and Sampling Strategy	The evaluation of the Non-Residential Lighting Program will use a statistically adjusted engineering (SAE) analysis approach, consistent with IPMVP Option A. Engineering-based savings estimates will be adjusted based on a sample of on-site metering and inspections that verify measure installation, type, location, and facility reported hours of operation. Load shapes will be used from time-of-use data loggers installed at the time of inspection and in place for 6 to 8 weeks. A modified load shape will also be prepared to represent the program's energy savings. The evaluation of this program will consist of tracking customer penetration and applying the measured savings values from the sample to the population of lighting upgrades installed. Deemed savings values calculated using existing and installed wattages in the STEP Manual will be recalibrated based on the sample of on-site measurements. In order to satisfy PJM requirements for Energy Efficiency Resources, phone verification will be conducted on an annual basis between January 1 and May 30 of the program year, through 2015, which will be the final year Dominion bids this program's capacity to PJM. Phone surveys will verify installation of new lighting for a sample of new participants. Surveys will also verify persistence of a sample of all lighting installations eligible for auction during that delivery year. **Lighting Persistence Study Sampling Strategy:** • Random sample of participants who installed lighting through the program and are eligible for auction in the PJM EE resource market during that delivery year. To satisfy PJM requirements for Energy Efficiency Resources, phone verification will be conducted on an annual basis between January 1 and May 30 of the program year. Phone surveys will verify installation of new sample of program participants. Surveys will also verify persistence of a sample of all installations eligible for auction during that delivery year. • Sample design will cover a proportion of lighting installations in the following technology groups: LED, CFL, Incandescent, Metal Halide, and "Other". Occupancy sensors and controls are not included in the PJM EE

	Resource auction and thus these installations are not surveyed. • Stratified per energy savings per premise with Model Based Statistical Sampling (MBSS) methodology.
Sampling Confidence Level, Relative Precision, and Assumed Error Ratio	A sample of 100 will be drawn for M&V after sufficient program participation is realized (approximately 2,000 participants). Planned sample sizes and design are based on participation projections upon a sufficient participant population to support such a study and may change. Standard sampling approach will consider the following: • Confidence interval: 90% • Relative Precision: 10% • Error Ratio: to be updated prior to sample selection.
EM&V Measurement, Timeline, and Scope of Work	• Analysis of program tracking data: Annual Report (May 1 of each year following program launch). • Annual updates to STEP Manual for updates that occurred to its referenced sources. • Develop baseline, measure savings, and efficient load shapes. • Provide regulatory support as necessary.
Document Revision History	Version 6.0 • New version • Deleted program penetrations section
	Version 7.0 • Added clarification on year PJM resource nomination ends for this program. • Removed requirement for semi-annual program tracking, as the North Carolina submission has been changed to line up with Virginia. • Removed Persistence study for PJM resource nomination: Annual (Completed May, 2014). • Updated Deemed Savings Approach section to reference the STEP Manual.
	Version 8.0 • Updated "April 1" report date to "May 1" in "EM&V Measurement, Timeline, and Scope of Work" section

Appendix K

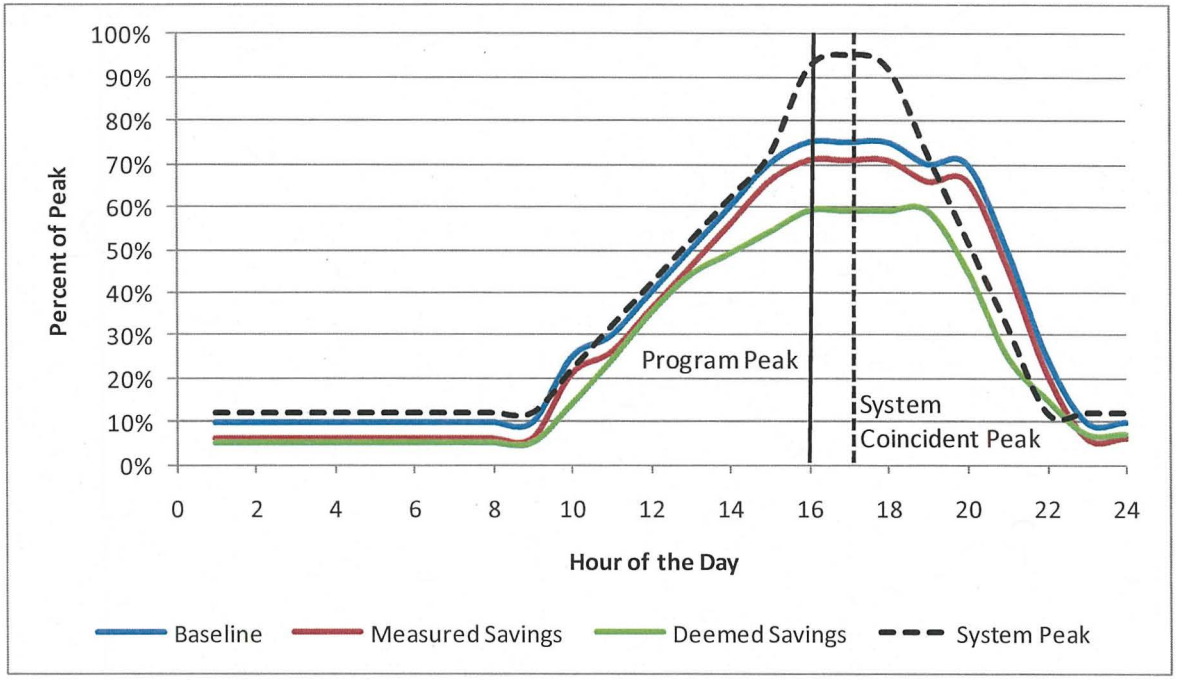
APPENDIX K. NON-RESIDENTIAL HEATING AND COOLING EFFICIENCY PROGRAM EM&V PLAN (VERSION 8.0)

Program Summary	The Non-residential Heating and Cooling Efficiency Program is designed to induce customers to replace or upgrade inefficient HVAC units to qualifying high efficiency units by offering rebates that reduce the incremental cost of the new units.
Measures	High efficiency models of the following types of equipment are covered by the rebates: • Package Terminal Air Conditioners and Package Terminal Heat Pumps • Unitary and Split Air Condition Systems and Air Source Heat Pumps (not gas)[7] • Variable Frequency Drives • Economizer (Replacements and New Installations) • Water and Air Cooled Chillers • Geothermal Heat Pumps • Variable refrigerant flow system and mini split heat pumps
EM&V Method	International Performance Measurement and Verification Protocol (IPMVP) Option A: This will be used for HVAC system replacement measures. IPMVP Option A is a partially measured retrofit isolation study that meters the actual energy and demand of an installed efficiency measure from a representative sample of participants, and adjusts the savings estimates derived from engineering algorithms applied to the Company's program participation data. The adjustment factor, also called a realization rate,[8] is then applied to the population of participants to estimate program savings. IPMVP Option D: This will be used for installed or replaced economizer measures. IMPVP Option D is a calibrated simulation study that uses computer simulation software (e.g., DOE-2.2 software) to predict the change in energy and demand of efficiency measures from a representative sample of participants, and adjusts the savings estimates derived from engineering algorithms applied to the Company's program participation data. The computer simulation is developed using economizer system inputs collected on-site or through interviews with installation and service contractors. On-site hourly meter data is collected from the cooling systems and is used to calibrate the simulation for accuracy.

[7] The heat pumps and any supplemental electric resistance heating will be analyzed, but not gas-fired supplemental heating. This also applies to the packaged terminal heat pumps.
[8] The "realization rate" is the proportion of assumed or estimated energy and peak demand savings that is actually realized by a customer or project. It is expressed as a percentage, and is derived from follow up research (on-site inspections or customer surveys) to verify that measures were in fact installed and are operating as intended, and/or actions were taken.

The following figure illustrates the various components used to arrive at the savings estimates.

Illustrative Load Shape: Non-residential HVAC Efficiency Program



1. Baseline Estimation Approach (Blue line): The baseline load shape will be computed based on pre-retrofit capacity data from the rebate application data, applying Equivalent Full Load Hours (EFLH) as metered in on-site studies of installed rebated measures from a representative sample of participants.
2. Deemed Savings Approach (Green line): Deemed savings values will be estimated from the DNV GL Energy Standard Tracking and Engineering Protocols (STEP) Manual for complete heating and cooling system measures as well as VFD and economizer installations. The original source of these deemed savings approaches are derived from the Mid-Atlantic Technical Resource Manual (TRM) and other TRMs.
3. Measured Savings Approach (Red line): The wattage and hours of use data for the installed efficiency measure will be collected and metered through an on-site study of installed rebated measures from a representative sample of participants.

	The ratio of the weighted deemed and measured and verified savings, also called a realization rate,[9] is then applied to the population of participants to estimate program savings. This approach will capture Company-specific customer usage data, which will be applied to the actual measures installed to quantify energy and peak demand savings.
Deemed Savings Approach	Refer to the Non-Residential Heating and Cooling Efficiency Program of the STEP Manual for the standard deemed savings approach for the measures in this program.
EM&V Measurement, Timeline, and Scope of Work	• Analysis of program tracking data: Annual Report (May 1 of each year following program launch). • Annual updates to STEP Manual for updates that occurred to its referenced sources. • Develop baseline, measure savings, and efficient load shapes. • Provide regulatory support as necessary.
Document Revision History	Version 6.0 • New Version • Deleted program penetrations section
	Version 7.0 • Removed requirement for semi-annual program tracking, as the North Carolina submission has been changed to line up with Virginia. • Updated Deemed Savings Approach section to reference the STEP Manual.
	Version 8.0 • Updated "April 1" report date to "May 1" in "EM&V Measurement, Timeline, and Scope of Work" section

[9] The "realization rate" is the proportion of assumed or estimated energy and peak demand savings that is actually realized by a customer or project. It is expressed as a percentage, and is derived from follow-up research (on-site inspections or customer surveys) to verify that measures were in fact installed and are operating as intended, and/or actions were taken.

APPENDIX L. NON-RESIDENTIAL WINDOW FILM PROGRAM EM&V PLAN (VERSION 8.0)

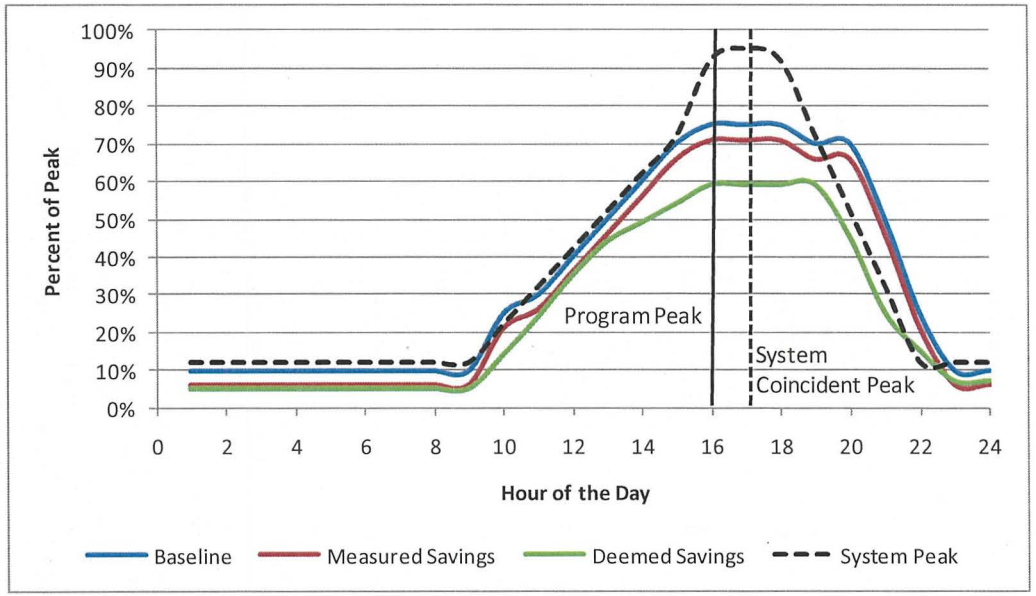
Program Summary	The Non-residential Window Film Program is designed to induce customers to install qualifying window film to existing windows to reduce solar heat gain and reduce cooling energy use by offering rebates that reduce the incremental cost of the window film.
Measures	Solar window film installation(s) are eligible for rebate through the program under the following conditions: • Existing windows only • All windows are eligible regardless of the direction they are facing • Program eligibility applies to both single and double pane window • SHGC (Solar Heat Gain Coefficient) of window film of ≤ 0.40 and not less than 0.25

EM&V Method

International Performance Measurement and Verification Protocol (IPMVP) Option D: IPMVP Option D will be used. IMPVP Option D is a calibrated simulation study that uses computer simulation software (e.g. DOE 2 or Energy Plus softwares) to predict the change in energy and demand of efficiency measures from a representative sample of participants, and adjusts the savings estimates derived from engineering algorithms applied to the Company's program participation data. The computer simulation is developed using building and window film parameters collected on-site or through interviews with installation and service contractors.

The following figure illustrates the various components used to arrive at the savings estimates.

Illustrative Load Shape: Non-residential Window Film Program



1. Baseline Estimation Approach (Blue line): The baseline load shape will be computed based on pre-retrofit capacity data from the rebate application data, applying Equivalent Full Load Hours (EFLH) as metered in on-site studies of installed rebated measures from a representative sample of participants.
2. Deemed Savings Approach (Green line): Deemed savings values will be estimated from the DNV GL Energy

	Standard Tracking and Engineering Protocols (STEP) Manual. The source of the deemed savings values will be models of 21 prototypical building types using Database for Energy Efficiency Resources (DEER) average values for building parameters (building sq. ft., EFLH, etc.). Variations in deemed savings values are provided in the STEP manual for some important parameters reported on customer rebate applications, including: weather zone, window orientation, and heating system type. 3. Measured Savings (Red Line): Solar emittance spot measurement data and operation schedules will be collected through an on-site study of installed rebated measures from a representative sample of participants. Load data from applicable non-residential HVAC measures across all other Dominion programs will be used in the simulation model as the basis of the measured savings load shape. The ratio of the weighted deemed and measured and verified savings, also called a realization rate,[10] is then applied to the population of participants to estimate program savings. This approach will capture Company-specific customer usage data, which will be applied to the actual measures installed to quantify energy and peak demand savings.
Deemed Savings Approach	Refer to the Non-Residential Window Film Program section of the STEP Manual for the standard deemed savings approach for the measures in this program.
EM&V Measurement, Timeline and Scope of Work	• Analysis of program tracking data: Annual Report (May 1 of each year following program launch). • Annual updates to STEP Manual for updates that occurred to its referenced sources. • Develop baseline, measure savings, and efficient load shapes. • Provide regulatory support as necessary.
Document Revision History	Version 6.0 • New version. • Deleted program penetrations section
	Version 7.0 • Removed requirement for semi-annual program tracking, as the North Carolina submission has been changed to line up with Virginia. • Updated Deemed Savings Approach section to reference the STEP Manual.

[10] The "realization rate" is the proportion of assumed or estimated energy and peak demand savings that is actually realized by a customer or project. It is expressed as a percentage, and is derived from follow-up research (on-site inspections or customer surveys) to verify that measures were in fact installed and are operating as intended, and/or actions were taken.

	Version 8.0 • Removed references to the "NRDUCT" and "NRHVAC" programs in the "EM&V Method" section. Replaced with references to "non-residential HVAC measures across all other Dominion programs." • Updated "April 1" report date to "May 1" in "EM&V Measurement, Timeline, and Scope of Work" section

Appendix M

APPENDIX M. NON-RESIDENTIAL SMALL BUSINESS IMPROVEMENT PROGRAM EM&V PLAN (VERSION 8.0)

Program Summary	The Non-Residential Small Business Improvement Program provides low cost energy assessments, direct install measures, and incentives for energy efficiency improvements to small businesses meeting certain size and need-based requirements. It is available to non-residential, small business customers in the Company's Virginia service territory with historic demand not exceeding 100 kW more than 3 times in the past 12 months. Participants must be privately-owned small businesses with five or fewer qualifying locations within the Company's service territory. Participation in this program is strictly voluntary. This program is part of demand side management (DSM) Phase V in Virginia and North Carolina.
Measures	<u>HVAC Retrofit Measures</u> 1. Unitary/split AC & HP upgrades 2. Variable frequency drives (VFDs) 3. Dual enthalpy, air-side economizers 4. Mini-split heat pumps 5. Programmable thermostats <u>HVAC Re-commissioning Measures</u> 6. Duct testing and sealing 7. AC/HP tune-ups 8. AC/HP Refrigerant charge adjustment <u>Lighting Measures</u> 9. T8/T5 lamps/fixtures 10. LED lamps/fixtures 11. Occupancy sensors & controls <u>Other Measure</u> 12. Air compressor leak repairs
EM&V Method	<u>International Performance Measurement and Verification Protocol (IPMVP) Option A:</u> For physically accessible equipment measures, an EM&V method like IPMVP Option A is applied. IPMVP Option A is a partially-measured retrofit isolation study that measures the selected parameters leading to the change in energy and demand of an installed efficiency measure from a representative sample of participants, and adjusts the savings estimates derived from engineering algorithms applied to the Company's program participation data. IPMVP Option A shall be applied to a

sample of unitary/split AC & HP upgrades, variable frequency drives, mini-split heat pumps, and air compressor leak repairs.

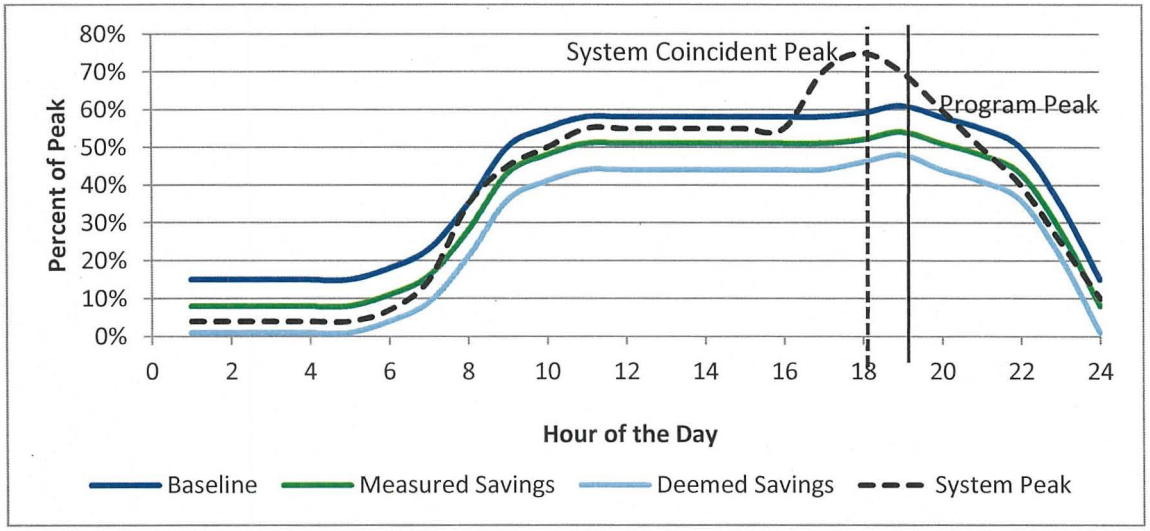
IPMVP Option D: IPMVP Option D is a calibrated simulation study that uses computer simulation software (e.g. DOE-2.2 software) to predict the change in energy and demand of the installed efficiency measures from a representative sample of participants, and adjusts the savings estimates derived from engineering algorithms applied to the Company's program participation data. IPMVP Option D shall be applied to sample of economizer measures.

For all measures, the evaluation will select a sample for on-site verification. Savings will be based on the DNV GL Energy STEP Manual deemed values with adjustments to key inputs that can be verified while on-site.

The ratio of the weighted, measured, and verified savings to the weighted deemed savings, also called a realization rate,[11] is then applied to the population of participants to estimate program savings. This approach will capture Company-specific customer usage data, which will be applied to the actual measures installed to quantify energy and peak demand savings.

The following figure illustrates the various components used to arrive at the savings estimates.

[11] The "realization rate" is the proportion of assumed or estimated energy and peak demand savings that is actually realized by a customer or project. It is expressed as a percentage, and is derived from follow-up research (on-site inspections or customer surveys) to verify that measures were in fact installed and are operating as intended, and/or actions were taken.

	Illustrative Load Shape: Non-Residential Small Business Improvement Program  Baseline Estimation Approach (Dark blue line): The baseline load shape will be computed based on pre-retrofit capacity data from the rebate application data, applying Equivalent Full Load Hours (EFLH) as metered from an on-site study of installed rebated measures from a representative sample of participants. Deemed Savings Approach (Light blue line): Deemed savings values will be developed and incorporated into the DNV GL Energy Standard Tracking and Engineering Protocols (STEP) Manual for planning purposes. Measured Savings Approach (Green line): The wattage and hours of use data for each measure will be collected and metered through an on-site study of installed efficiency measures from a representative sample of participants.
Deemed Savings Approach	Refer to the Non-Residential Small Business Improvement Program section of the STEP Manual for the standard deemed savings approaches for the measures in this program.
EM&V Measurement, Timeline and Scope of Work	• Analysis of program tracking data; Annual Report (May 1 of each year following program launch). • Annual updates to STEP Manual for updates that occurred to its referenced sources. • Develop baseline, measure savings, and efficient load shapes. • Provide regulatory support as necessary.
Document Revision History	Version 7.0 New version

	Version 8.0 Updated "April 1" report date to "May 1" in "EM&V Measurement, Timeline, and Scope of Work" section

Appendix N

APPENDIX N. NON-RESIDENTIAL PRESCRIPTIVE PROGRAM EM&V PLAN (VERSION 8.0)

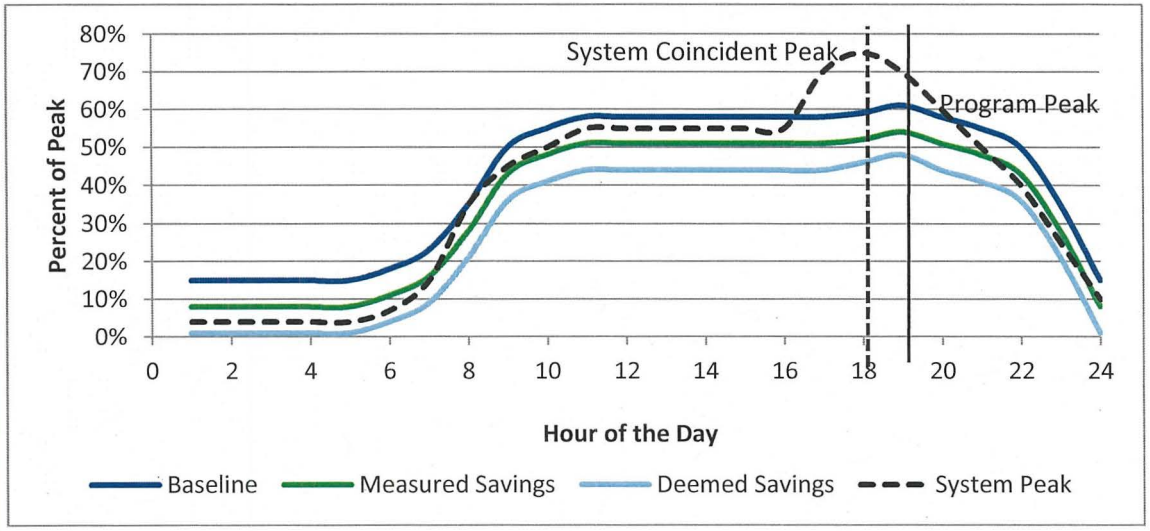
Program Summary	In the Non-residential Prescriptive program, qualifying customers are eligible to pursue one or more of the qualified energy efficiency measures through a local, participating contractor in Dominion's contractor network. To qualify for this program, the customer must be responsible for the electric bill and must be the owner of the facility or reasonably able to secure permission to complete the measures. This program is part of demand side management (DSM) Phase VI in Virginia and North Carolina.

Measures	

	• Cooking
	  ○ Commercial Convection Oven
	  ○ Commercial Electric Combination Oven
	  ○ Commercial Electric Fryer
	  ○ Commercial Griddle
	  ○ Commercial Hot Food Holding Cabinet
	  ○ Commercial Steam Cooker
	• HVAC
	  ○ Duct Testing & Sealing
	  ○ Unitary/Split AC & HP Tune-up
	  ○ Variable Speed Drives on Kitchen Fan
	• Plug Load
	  ○ Smart Strip
	• Refrigeration
	  ○ Door Closer
	  ○ Door Gasket
	  ○ Evaporator Fan Control
	  ○ Floating Head Pressure Control
	  ○ Refrigeration Night Cover
	  ○ Refrigeration Coil Cleaning
	  ○ Suction Pipe Insulation
	  ○ Strip Curtain
	  ○ Vending Machine Miser
	  ○ Commercial Freezers and Refrigerators – Solid Door
	  ○ Ice Maker
	  ○ Low/No-Sweat Door Film

EM&V Method	International Performance Measurement and Verification Protocol (IPMVP) Option A: For physically accessible equipment measures, an EM&V method like IPMVP Option A is applied. IPMVP Option A is a partially-measured retrofit isolation study that measures the selected parameters leading to the change in energy and demand of an installed efficiency measure from a representative sample of participants, and adjusts the savings estimates derived from engineering algorithms applied to the Company's program participation data. IPMVP Option A shall be applied to a sample of all implemented measures For all measures, the evaluation will select a sample for on-site verification. Savings will be based on the DNV GL Energy STEP Manual deemed values with adjustments to key inputs that can be verified while on-site. The ratio of the weighted, measured, and verified savings to the weighted deemed savings, also called a realization rate,[12] is then applied to the population of participants to estimate program savings. This approach will capture Company-specific customer usage data, which will be applied to the actual measures installed to quantify energy and peak demand savings.

[12] The "realization rate" is the proportion of assumed or estimated energy and peak demand savings that is actually realized by a customer or project. It is expressed as a percentage, and is derived from follow-up research (on-site inspections or customer surveys) to verify that measures were in fact installed and are operating as intended, and/or actions were taken.

	The following figure illustrates the various components used to arrive at the savings estimates. **Illustrative Load Shape: Non-Residential Prescriptive Program**  Baseline Estimation Approach (Dark blue line): The baseline load shape will be computed based on pre-retrofit capacity data from the rebate application data, applying Equivalent Full Load Hours (EFLH) as metered from an on-site study of installed rebated measures from a representative sample of participants. Deemed Savings Approach (Light blue line): Deemed savings values will be developed and incorporated into the DNV GL Energy Standard Tracking and Engineering Protocols (STEP) Manual for planning purposes. Measured Savings Approach (Green line): The wattage and hours of use data for each measure will be collected and metered through an on-site study of installed efficiency measures from a representative sample of participants.
Deemed Savings Approach	Refer to the Non-Residential Prescriptive Program section of the STEP Manual for the standard deemed savings approaches for the measures in this program.
EM&V Measurement, Timeline and Scope of Work	• Analysis of program tracking data; Annual Report (May 1 of each year following program launch). • Annual updates to STEP Manual for updates that occurred to its referenced sources. • Develop baseline, measure savings, and efficient load shapes. • Provide regulatory support as necessary.

Document Revision History	Version 8.0 New version

Appendix O

APPENDIX O. RESIDENTIAL AIR CONDITIONER CYCLING PROGRAM EM&V PLAN (VERSION 8.0)

Program Summary	The Residential Air Conditioner (AC) Cycling Program, marketed as "Smart Cooling Rewards," compensates customers who allow the Company to reduce the cycle of their central air conditioning during peak load conditions by 50%. The AC cycling control switch is controlled by a radio frequency signal and installed near the outdoor air-conditioning (AC) unit. A $40 incentive is credited to participating customers following event season.
Measures	The program measure is the number of controlled AC units per participant and their associated connected loads. The eligible classes of air conditioners and heat pumps in the AC Cycling Program are: • Electric Residential Central A/C System • HVAC - Gas Furnace / Central A/C • HVAC - Heat Pump / Electrical Backup • Dual Fuel – Heat Pump with Alternate Fuel Back-Up

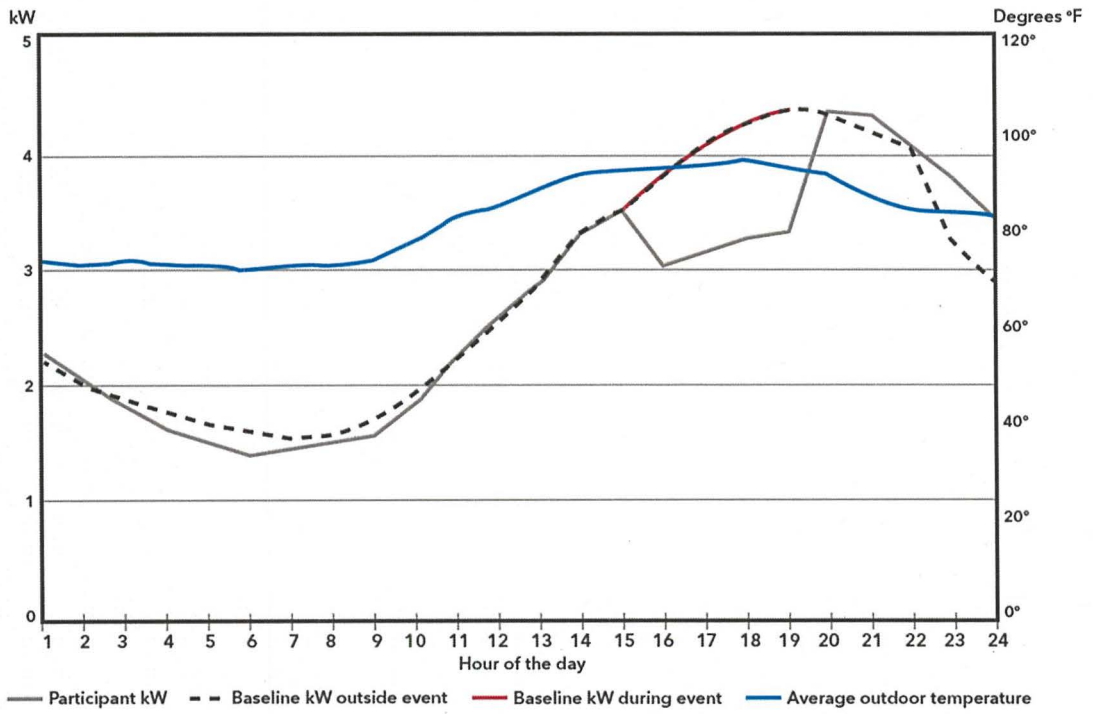
EM&V Method

International Performance Measurement and Verification Protocol (IPMVP - Option C): Because program impacts are estimated using whole premise 30-minute interval consumption data, IPMVP Option C is the appropriate EM&V protocol. IPMVP Option C is a whole facility EM&V standard using meter data from the entire site for a sample of participants.

The AC cycling event impacts will be measured as the differences between baseline reference load and actual load during AC cycling events. The baselines will be calculated using accepted methodologies for residential demand response programs. Ex ante regression models will quantify the relationship of participating customers, the equipment, weather data, and load reduction during dispatch events. The ex-ante impact models will be used to quantify the nominated load for the program under peak conditions (using temperature humidity index given by Dominion), and calibrate the census of AMI participants in the program to the population.

The following figure illustrates the various components used to arrive at the savings estimates.

Figure O-1. Illustrative Load Shape for an A/C Cycling participant



Event baseline estimation approach (red line): The event baselines will be estimated for every customer in the sample using a regression model based on 3 non-event day loads with similar weather conditions.

Estimated ex ante estimate: The ex ante impact value is derived from the STEP Manual 8.0 for hour ending 17:00 at a temperature humidity index (THI) of 83.4, which is considered Dominion's peak. The ex-ante approach is based on regression models and utilizes the ex post impact estimates with month-ending average connected load in the program.

Measured load reduction approach (brown line): The measured average load reduction is computed from the interval load data of all participants with advanced metering infrastructure (AMI). DNV GL will follow the standard requirements for demand reduction resources. This will include:

- Distributional analysis comparing the program population to the sample of customers with AMI meters
- Extrapolation of the impacts for the sample to the overall population, accounting for location and weather differences
- Production of event trackers for the program population

EM&V Summary and Sampling Strategy

DNV GL Energy tracked the dispatchable resource of the AC Cycling Program throughout the evaluation period by applying the STEP savings protocol to represent the expected peak shaving value of dispatchable resource. The STEP savings calibrates customized nominated peak shaving estimates for the program history to annual program performance.

The estimated ex ante kW impacts for 2017 are presented below with respect to hour of the day and THI. It should be noted that the impacts for hours 20:00 and 21:00 are identical to the impacts for hour 19:00 and the impacts in hours 13:00 and 14:00 are identical to the impacts for hour 15:00. These assignments were made using the closest hour where sufficient model data existed.

Table S-2. 2017 Ex ante Impacts by THI and Hour Ending per Participant

Per participant Ex Ante Impacts in kW by THI and Event-hour Ending									
THI	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
79	0.42	0.42	0.42	0.43	0.48	0.50	0.40	0.40	0.40
80	0.47	0.47	0.47	0.47	0.53	0.56	0.48	0.48	0.48
81	0.53	0.53	0.53	0.52	0.58	0.62	0.56	0.56	0.56
82	0.58	0.58	0.58	0.57	0.63	0.67	0.64	0.64	0.64
83	0.64	0.64	0.64	0.61	**0.68**	0.73	0.72	0.72	0.72
84	0.69	0.69	0.69	0.66	**0.73**	0.79	0.80	0.80	0.80
85	0.75	0.75	0.75	0.70	0.79	0.85	0.88	0.88	0.88
86	0.80	0.80	0.80	0.75	0.84	0.90	0.96	0.96	0.96
87	0.86	0.86	0.86	0.79	0.89	0.96	1.04	1.04	1.04
88	0.91	0.91	0.91	0.84	0.94	1.02	1.12	1.12	1.12

Given the investment in this program and the planned peak shaving reductions, this EM&V plan calls for ex post impact evaluation using interval data collected from all participating accounts with AMI meters. Consumption data is collected at 30-minute intervals for each sampled household and is transferred to the EM&V contractor monthly.

Representative 8,760-hour load shapes for the program resource will be updated following each event season.

EM&V Measurement, Timeline, and Scope of Work	• Analysis of program tracking data: Annual • Monthly program tracking summary table • AMI interval data analysis • Annual updates to STEP Manual for updates that occurred to its referenced sources. • Develop baseline, measure ex ante and ex post demand reduction estimates, and load shapes. • Provide regulatory support as necessary.
Confidence Level, Relative Precision	• Confidence interval: 90% • Relative Precision: 10%
Lost Revenue Methodology	Not applicable.
Document Revision History	Version 1.0 • Added semi-annual program tracking summary table in the "Frequency of EM&V Measurement & Timeline" section. • Changed assumed error ratio from 0.5 to 0.96 (computed) with an error margin of 9.12%.
	Version 2.0 • Updated document formatting. • Updated "KEMA" to "DNV KEMA." • Modified the required sample size from 300. • Changed "Program Penetration & Initial Baseline Assumptions" section title to "Program Penetration" and removed initial baseline assumptions. • Updated planned penetrations and added "Source" column to the "Program Penetration" table. • Changed "Revision History" section title to "Document Revision History."
	Version 3.0 • Updated "EM&V Summary and Sampling Strategy" section with description of experimental design analysis for 2013.
	Version 4.0 • Update Program Penetration Table based on 2013 IRP.
	Version 5.0 • Removed 2013 planned customer penetration numbers. • Added sentence on PJM requirements to end of "EM&V Method." • Updated deemed savings approach to utilize ex ante estimates for aggregate program impacts conditional on temperature humidity index and hour, developed from a regression analysis of historical program performance. Changes affected EM&V Method and EM&V Summary and Sampling Strategy sections.
	Version 6.0

	• Updated DNV KEMA to DNV GL Energy. • Updated EM&V method to IPMVP Option C to reflect impact estimation using premise level AMI data • Added description of analytical tasks to meet requirements for PJM compliance. • Updated error ratio to reflect results used in 2014 sample design • Added planned annual updates to the representative load shape of the program resource. • Renamed "Frequency of EM&V Measurement and Timeline" section title to "EM&V Measurement, Timeline and Scope of Work" to more accurately reflect the content in that section • Added on-going scope that was not explicitly mentioned to "EM&V Measurement, Timeline and Scope of Work" section. • Deleted program penetrations section
	Version 7.0 • Updated "EM&V Summary and Sampling Strategy" section with description of the 2016 study population which includes all participants with AMI meters. • Changed "semi-annual" to "monthly" program tracking summary table in the "Frequency of EM&V Measurement & Timeline" section. • Prior to 2016, the measured average load reduction was computed from the interval load data of a sample of participating homes with AMI. Starting in 2016 the measured average load reduction is computed from the interval load data of all participants with AMI. • Removed reference to a 96% operability rate • Added scope description for ex ante and ex post demand reduction estimates in EM&V Measurement, Timeline and Scope of Work (Table S-2)
	Version 8.0: Updated with 2017 ex ante evaluated results

Appendix O-1

DNV·GL

RESIDENTIAL AC CYCLING PROGRAM

Appendix O-1: Impact Evaluation of 2017 Dispatch Events

Dominion Energy

Date: 5/1/2018

Table of contents

List of figures

List of tables

1 EXECUTIVE SUMMARY

This report summarizes the load impacts of the Dominion Energy (the Company) AC Cycling Program (Residential) in Virginia and North Carolina for 2017. The AC Cycling Program, marketed as Smart Cooling Rewards, began in 2010 as a resource to help the Company reduce summer peak demand, either at its own discretion or when directed by PJM Interconnection.

DNV GL conducts an evaluation of the AC Cycling Program on an annual basis. The objectives of this annual evaluation are to estimate average kW impacts per AC Cycling participant for each 2017 dispatch event, and to estimate the expected kW of peak shaving impact of the AC Cycling resource in different weather conditions and times of day, including summer peak conditions.

Under the program, when AC Cycling events are called, a radiofrequency (RF) paging signal is broadcast throughout the Company's service area. The signal is received by load curtailment switches installed on central air conditioners (AC) and heat pumps of participating residential customers. The dispatch of the RF signal to the load curtailment switch reduces the duty cycle of the registered AC units up to 50% while the event is in progress.

In 2017, evaluated impacts were 0.68 kW per participant at Dominion Energy's planned summer peak.[1] In 2017, the AC Cycling Program called the most events, resulting in more controlled hours since the beginning of the program in 2010.

... the expected load impact for weather conditions observed during Dominion Energy's peak day conditions in 2017 was 0.68 kW per participant

In 2017, there were 29 events for a total of 96 controlled hours. Ex post program impacts ranged from an average of -0.13 kW to 1.13 kW per event hour across all control hours under varying weather conditions. This yielded a modeled program impact for peak conditions of 0.68 kW per participant, a decrease from the modeled impact of 0.97 in 2016, but virtually identical to 2015.

There were three four-day consecutive events and three three-day consecutive events in 2017 representing 72% of all events. Two of the four-day consecutive events occurred on consecutive weeks on the hottest days of the season and returned some of the greatest impacts. There were also eight partial-dispatch events that excluded a subset of participants in the Eastern Division. The exclusions were done to preserve events and hours within Surry-Skiffes Creek in case peak shaving was needed later in the summer to help with potential reliability issues. These potential constraints remain through 2018 and will be handled similarly.

[1] Peak conditions correspond with an 83.4 temperature-humidity index at hour ending 17. This is equivalent to a temperature of 95°F and a relatively humidity of 43%.

2 INTRODUCTION

Peak load reduction estimates for peak shaving programs are critical, both for Dominion Energy internal stakeholders and for registration with PJM when applicable. When the AC Cycling Program was launched in 2010, the estimated impacts were initially based on a statistical regression model of consumption data from other utilities in the region. Since 2011 the modeled impact estimates have used site-level interval data, considering the connected load of the unit, actual weather conditions during Dominion Energy's summer event season, and the adaptive 50% cycling strategy programmed for curtailment switches. In compliance with the order from the Virginia State Corporation Commission (the Commission), the evaluation transitioned from evaluating a random sample of AMI-enabled participants to using site-level interval data from every Dominion Energy Smart Cooling Rewards AMI-enabled participant.[2] In 2017 the evaluation was conducted on all 9,026 AMI metered participants.

In 2016, the Company conducted a new-recruit trend study which analyzed changes in connected load and efficiency of new recruits and active participants over time, and the AMI vs. non-AMI participant comparison study, which compared demographics and other variables that influence air-conditioning loads. The trend study found that, over time, AC efficiency has increased while connected load has remained flat. Since the participant pool has not changed, neither study was repeated in 2017.

Load reduction is driven by more than just temperature on the day of the event. Long hot periods and/or stretches of consecutive event-days affect AC usage and response to events. Conversely, a single hot day in the midst of an otherwise cool period also produces different load reductions. Because load reduction is a function of both the amount of cooling demanded at the time of an event (i.e., potential load reduction) and the customer response (i.e.,does the customer turn on a room AC?), the complex relationship between load reduction, long-term temperature trends, and event call schedules is difficult to predict.

Additionally, a high-performing subset of the AC population in the Eastern Division was not included in a number of events, which means that not all households experienced the same set of events. This exclusion was a a result of potential transmission constraints in the Surry-Skiffes Creek area. Dominion Energy's Market Operations group called events that excluded some Eastern Division zip code areas during certain AC Cycling events in the 2017 season to preserve events and hours within that area in case events were needed later in the summer to help with potential reliability issues. These potential constraints remain through 2018 and will be handled similarly. The lower estimates of predicted load reduction may reflect the different underlying schedule of events and temperature trends. For the first time the event season extended into late September. Additionally, for the first time in the program's history there were three four-day events, three three-day events, and eight partial events.

The following sections include a comparison between program operations and temperatures since 2013, a description of the analysis steps, evaluation methodology, ex post and ex ante results.

[2] Required as part of the Final Order, State Corporation Commission of Virginia, Case #PUE-2015-00089, April 19, 2016. The trend analysis was also requested by PJM so it could assess the reliability of any future measurement and verification (M&V) that used a sample consisting of a subset of AMI customers to represent all program participants.

3 2017 AC CYCLING EVENTS

The 2017 AC Program event schedule continued a general trend toward more events and longer events compared to prior years' programs. This section describes the 2017 program in the context of the prior four years of the program.

Table 3-1. 2013–2017 Comparison of Event Seasons

	2013	2014	2015	2016	2017
Number of days between first and last event	79	86	90	66	105
Number of events	14	15	20	24	29
Average length of each event in hours	2.9	2.7	3.7	3.3	3.3
Total controlled hours over the event season	40	41	73	79	96
Number of events during peak hours 17:00–18:00	12	10	20	21	29
Number of partial-dispatch events	0	2	0	3	8
Partial-dispatch events as a % of full-dispatch events	0%	13%	0%	13%	28%

3.1 Frequency

The AC Cycling program called 29 events during the summer of 2017. The frequency of events has increased on average, by approximately 3.75 per year since 2013, and has slightly more than doubled since 2013, from a total of 14 to 29 events per year.

Dominion Energy replaced a server on the paging system that sends control messages to the AC control units. Although the pages were going out immediately after the server replacement and were being received by a test pager, they were not in the correct format to be decoded by the control units. Due to this, switches were not able to be controlled between June 26 and July 10. Therefore, the events called on July 3 and July 7 did not result in any load drop from the AC Cycling program.[3]

Year over year, increases in controlled hours have a higher degree of variability than the frequency of events. Accordingly, an average increase across years can be misleading. However, overall event hours have increased from 40 to 96 since 2013.

During 2017, Dominion Energy territory experienced hot weather in all four summer months, June through September. The first 2017 event occurred on June 12th, and the last event occurred on September 25th. Figure 3-1 shows the number of events by month since 2014.

The following sections describe two event types, consecutive and partial-dispatch, and provide information about 2017's participants. The results of the 2017 impact analysis are presented in Section 6.2 and 6.3, ex post and ex ante impacts, and include a visual representation of the sequencing and impacts of consecutive and partial-dispatch events.

[3] All of the results in this appendix are based on analyses conducted on 29 events, to include the July 3rd and 7th events. When those two July events are excluded, the 2017 evaluated impacts are 0.70 kW per participant at Dominion Energy's summer peak.

3.2 Consecutive Events

When events occur on consecutive days in the same week they are called consecutive events. There were three four-day consecutive events and three three-day consecutive events in 2017 representing 72% of all events. Two of the three, four-day events occurred in consecutive weeks on the hottest days of the season and returned some of the highest impacts. Figure 3-2 shows that 2017 had the highest number of three- and four-day consecutive events.

Figure 3-1. Number of Events by Month, 2014–2017

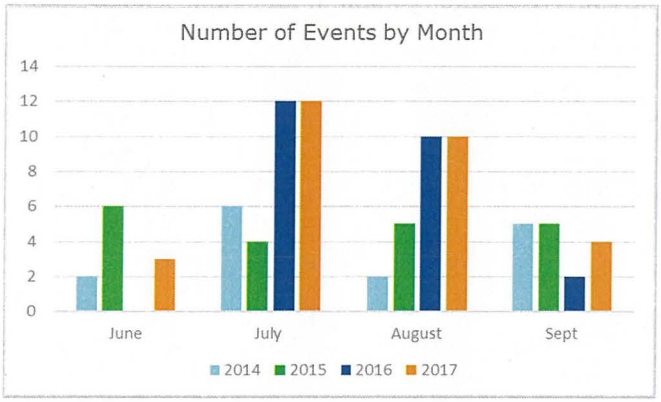
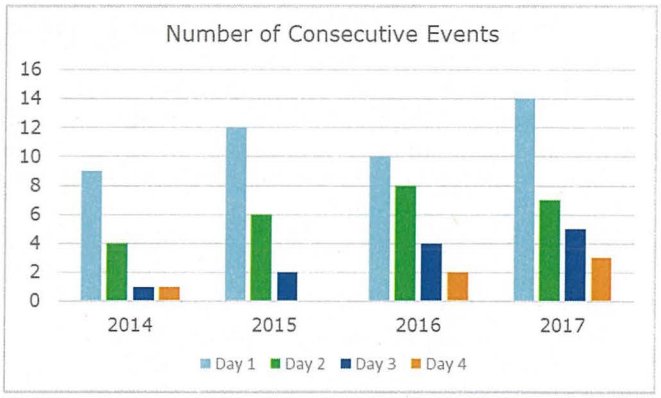


Figure 3-2. Number of Consecutive Events, 2014–2017



4 2017 AC CYCLING PARTICIPANTS

At the request of the Commission in 2016, Dominion Energy calculated AC Cycling impacts using 100% of the AMI-enabled participants, rather than a random sample of AMI-enabled participants as in prior years. AMI meters are installed not to directly support the AC Cycling Program but rather for multiple operational purposes and are therefore not randomly distributed across program participants.

Table 4-1 shows the number of participants by division, the number of participants with AMI meters, and the percent of AMI participants by division relative to total AMI and total participants for accounts that participated in the first event on June 12, 2017. Although the number of program participants is lower than 2016, the number of AMI meters has increased. This is due to the addition of AMI meters in North Carolina and to the relative proportion of new participants with AMI meters.

Of the 8,152 AMI-enabled participants that participated in the June 12 event, 93% reside in the Northwest division, and across all 27,511 participants in the Northwest, 27% have AMI meters. This is the highest relative percentage of AMI-enabled participants across all divisions. The Eastern, Central, and North Carolina divisions make up approximately 67% of program participants, but a combined total of approximately 5% of all enabled AMI participants.

Table 4-1. Number of Total and AMI Participants by Division for the June 12, 2017 Event

Division	# Participants by Division	% Participants to Total Participants by Division	# AMI Participants by Division	% AMI Participants to Total AMI Participants by Division	% AMI Participants to Total Participants by Division
Eastern	37,449	42%	117	1%	0.31%
Northwest	27,511	31%	7,544	93%	27%
Central	18,479	21%	222	3%	1%
North Carolina	3,519	4%	96	1%	3%
Not Available	2,068	2%	173	2%	8%
Total	89,026	100%	8,152	100%	9%

Due to the uneven distribution of AMI meters across divisions, Dominion Energy commissioned a customer load modeling analysis, a new recruit trend study, and a non-AMI comparison. In turn, both were included in the Final Order of the State Corporation Commission on April 19, 2016. The results of these studies are found in Appendix R-1: Impact Evaluation of 2016 Dispatch Events.[4]

[4] Evaluation, Measurement, and Verification Report for Virginia Electric and Power Company, May 1, 2017, Appendix R-1: Impact Evaluation of 2016 Dispatch Events, Appendices A thorugh C

5 AC CYCLING IMPACT ANALYSIS

This section describes the multiple sources of data used in the analysis, provides summary information about the program participants, and the methodology employed in the analysis.

5.1 Analysis Data

Four sources of data are used in the impact analysis:

- Half hourly AMI consumption data spanning June 1, 2017 to September 30, 2017
- Control account history logs with a complete record of participating accounts on an event-by-event basis
- Business intelligence (BI) program tracking data, the record of active participants, their connected loads and address
- Hourly temperature and humidity data[5]

5.2 Methodology

The following steps are used to calculate the kW impact estimates on the full census of AMI participants:

1. The half-hourly interval AMI consumption data for each participant is delivered to DNV GL on a monthly basis, and subjected to quality control (QC) tests upon delivery.
2. The AMI accounts are assigned weights based on the state, connected load, and division to ensure that the impact analysis is representative of all program participants. The assigned weights are included in Appendix A, Extrapolating the AMI-enabled Account Impacts to the Program Population.
3. The AMI data is merged with the control history logs, the record of customers who participated in each event (Section 5.3.2).
4. Using the AMI data, the control history logs and weather stations assigned to each account, participant-level regressions are estimated to account for opt-outs, weather conditions (in the form of THI), and time.
5. Baseline and actual load are aggregated to a program total using weights to extrapolate the AMI population to the program population.
6. An event day adjustment is applied to the event day load shape, to align the regression baseline with load at an interval just prior to the event and three hours after the event.
7. Load reduction is calculated from the aggregate baselines and load.
8. Ex ante load is derived from a regression of estimated load reductions for each event on THI and event hour. Ex ante load reduction is program performance extrapolated to a particular hour and THI level.

5.3 Data Quality Tests

Once the event participants have been identified in the event logs, the subset of AMI-enabled participants are linked to their corresponding AMI consumption data. The AMI data and the control history account logs undergo QC tests to ensure that the AMI data is complete, and that only active participants are included in the analysis. The following conditions must be met for an account to be included in the impact analysis:

[5] National Oceanic and Atmospheric Association (NOAA), National Centers for Environmental Information, Local Climatological Data.

- The consumption data must be substantially free of missing, zero, or negative intervals.
- An account must be associated with an active participant.
- An account in the control history log must be associated with corresponding consumption data.

Section 5.3.1 summarizes QC results for the AMI data. Section 5.3.2 provides information about the control history logs. The QC tests rely partially on a cross reference between the AMI consumption data, the control logs, and the BI data.

5.3.1 AMI Data

Half-hourly AMI consumption data for all active AC Cycling participants as of April 2017 was delivered monthly to DNV GL from April through October 2017. Table 5-1 shows the four stages of quality tests and results for the 2017 AMI data. Of the 9,848 AMI accounts delivered, 822 (8%) were removed from the analysis.

Table 5-1. Quality Test Results for the AMI Data

Quality Test	Number of Accounts Removed	Remaining Population
Remove duplicate accounts	7	9,841
Remove inactive participants	129	9,712
Remove accounts not identified in BI data	671	9,041
Remove accounts with a significant number of missing or negative intervals	15	9,026

5.3.2 Control History Account Log

A control history account log is created for each event. The control logs list all dispatched accounts and the length of the events. Program participants who were not dispatched in selected events are not included in the event log or the analysis for that event. An account may be absent for the account logs because the customer opted out of an event or because they were not dispatched during a partial-dispatch event. Account information for 3% of accounts listed in the control logs could not be located in the BI data. These accounts were not included in the impact analysis.

5.4 Special Circumstances

5.4.1 Partial-dispatch Events

In 2017, a fully-dispatched event included approximately 84,000 participants, varying slightly per event. During a partial-dispatch event, a subset of participants is deliberately omitted from the dispatch. Between July 27th and August 18th there were eight partial-dispatch events that excluded part of the Eastern Division for a total of 24 controlled hours. Approximately 13,000 participants (35% of Eastern, and 14% of all participants) were not signaled. As a result of potential transmission constraints in the Surry-Skiffes Creek area, Dominion Energy's Market Operations group called events that excluded those zip code areas during

certain AC Cycling events in the 2017 season. This was done in order to save events and hours within that area in case needed later in the summer to help with potential reliability issues. These potential constraints remain through 2018 and will be handled similarly. The eight partial-dispatch events constituted 25% of all controlled hours in 2017. It was the highest number of partial-dispatch events since 2013. The next highest number occurred in 2016, with three partial-dispatch events over eight controlled hours.

5.4.2 Partial-dispatch Hours

In another scenario, events are dispatched for a fraction of an hour, but impacts are calculated at "hour ending." This occurred on September 21. On this day the event was dispatched at 15:45, and the impact was calculated at hour ending 16. Because the equipment was cycled for only 15 minutes (15:45–16:00), the impact for hour ending 16 is low. Further, the event ended at 18:30 with impacts measured at hour ending 19. By this time, air conditioners had been returning to full load for 30 minutes. Impacts were also low for hour ending 19.

5.4.3 Opt-outs

The 2016 AC cycling season had an unusually high opt-out rate of 0.36%. 2017's rate returned to a more typical level of 0.03%. In 2016, it was speculated that a compressed timeframe between the first and last event likely increased "event fatigue," resulting in high opt-out rates. In 2017, events spanned from mid-June through late September; eight of 29 events were not called in portions of the Eastern Division and two events only lasted two hours. As an illustration of the low rates, during the partial-dispatch events between July 27th and August 18th, an average of nine participants (0.01%) opted out of each event. During full-dispatch events an average of 28 participants (0.03%) opted out.

6 RESULTS

The ex post analysis estimates the average kW reduction in demand achieved by day and hour for the 29 events dispatched in 2017 (Section 6.2). The ex ante analysis (Section 6.3) is the forecast of kW impacts from the AC Cycling Program for different hours, temperatures, and humidity conditions. The ex post impacts form the inputs to the ex ante analysis.

The presentation of results begins with three event-day plots illustrating average, high, and no impacts (Figure 6-1–Figure 6-3). Detailed data for each event is then presented in a timeline (Figure 6-4), and by day and hour (Table 6-1). The ex ante impacts are presented in Table 6-2.

6.1 Event-day plots

In Figure 6-1 through Figure 6-3, results are presented for events with average, high, and no impacts. Results are illustrated in time-series representations of:

- ***Event-day load profile for the AC Cycling Program participant population (solid purple line).*** This series has a generally consistent load shape, with a low point near the interval ending at 17:00 and a peak near 19:00, if not considering the load reduction during the event. There is generally a post-event load spike (snapback or rebound) following each event before load resumes to normal levels.
- ***Baseline during the event (solid red line)***. The solid red line plots the baseline for the event-day load curve during the intervals impacted by the AC Cycling event. The baseline modeled from the non-event days is adjusted to match the event-day load curve at the time of dispatch and at three hours after load restoration. This line plots the modeled baseline during the event. Baseline estimates for every AMI customer, which use a regression model based on non-event day load, temperature, and humidity, are generated for the ex post analysis. The customer-level hourly event-day AMI consumption is then aggregated using the weights shown in Table 6-3 to produce program-level baseline estimates for all participants.
- ***Pre- and post-event true-ups.*** True-ups align the aggregated baseline load shape before and after the event. True-ups accounts for differences between the event-day load and the baseline load that are close to, but not exactly equal to, the AMI participants' load profile. The pre-event true-up point is chosen as the last interval reading unaffected by the curtailment event, and the post-event alignment point occurs three hours after the event. This takes into account the assumption that snapback (or rebound) at the household level will diminish within three hours of the end of the event. For example, an event dispatched between 16:00 and 17:00 is trued-up at the 16:00 and 20:00 intervals.
- ***Reference load outside the event (dashed red line).*** This line plots the baseline load profile before and after the event.
- ***Event-day temperature* (green line)**. Hourly temperatures are extracted from the National Oceanic and Atmospheric Association (NOAA) National Centers for Environmental Information, and mapped to the addresses of AMI-enabled participants. The average temperatures are plotted to give context for the load curves and event impacts.

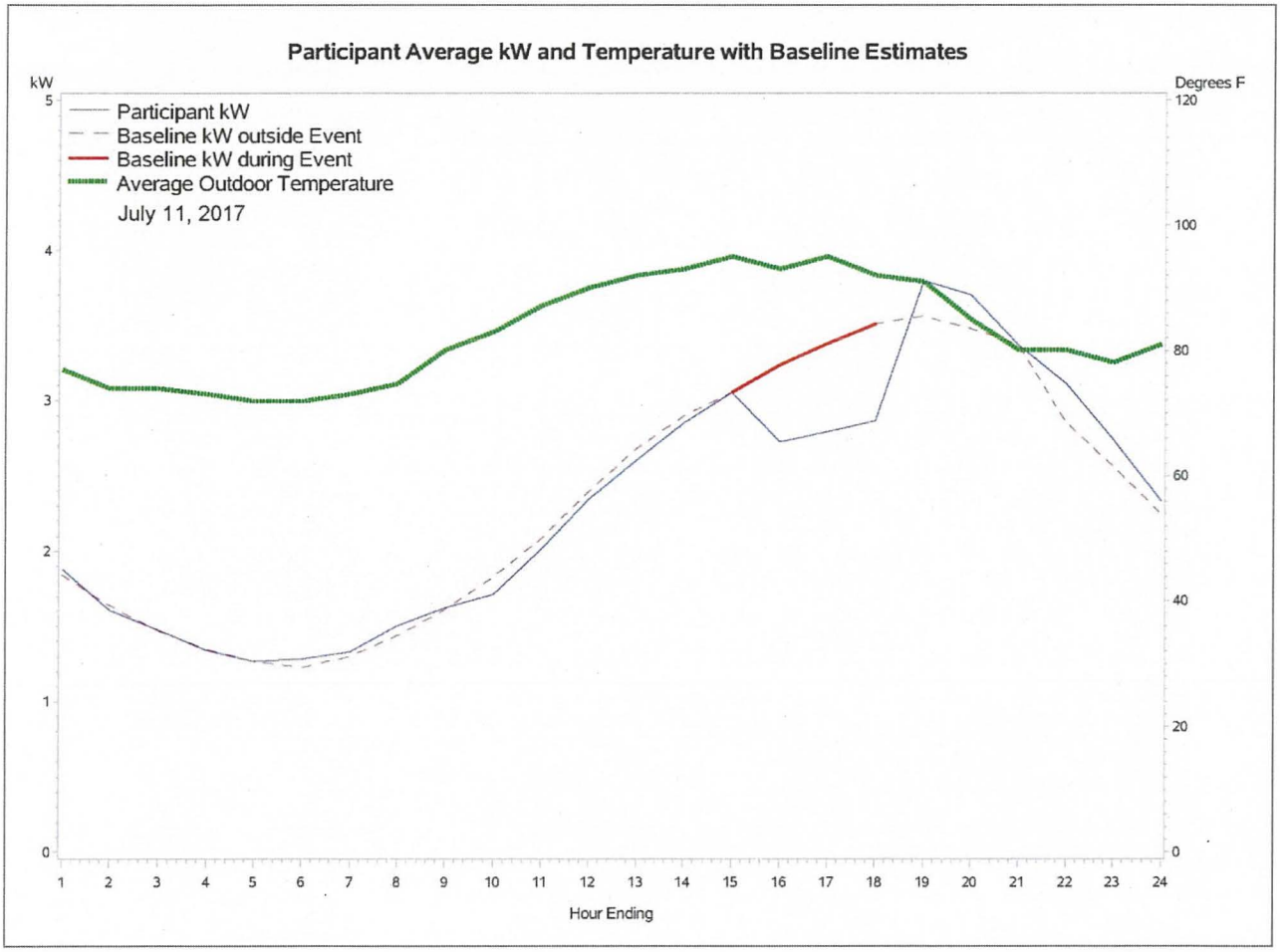
The impact estimate in kW is the difference between the adjusted baseline (solid red line) and the actual load curve (purple line) during an event interval. The event intervals represent the end of each event hour (hour ending). The start time of the 2017 events ranges from 14:00–19:00, depending on the event.

6.1.1 Load Profile with Average Impacts

Figure 6-1 illustrates the event called on July 11, 2017 that yielded an average impact. The maximum temperature on July 11 was 95°F and the estimated kW impact was 0.58 kW. The estimated impact is the difference between the load profile (purple solid line) of all cycled participants, and the baseline (red solid line) of all cycled participants. The period of load reduction for July 11, 2017 is clearly visible at hours ending 16, 17 and 18 (between 15:00 and 18:00).

July 11 was the first of four consecutive events (July 11–July 14), and yielded the highest impact of the three four-day consecutive events. The fourth event-day (July 14) shown on the next page in Figure 6-2 is an example of an event with relatively high impacts.

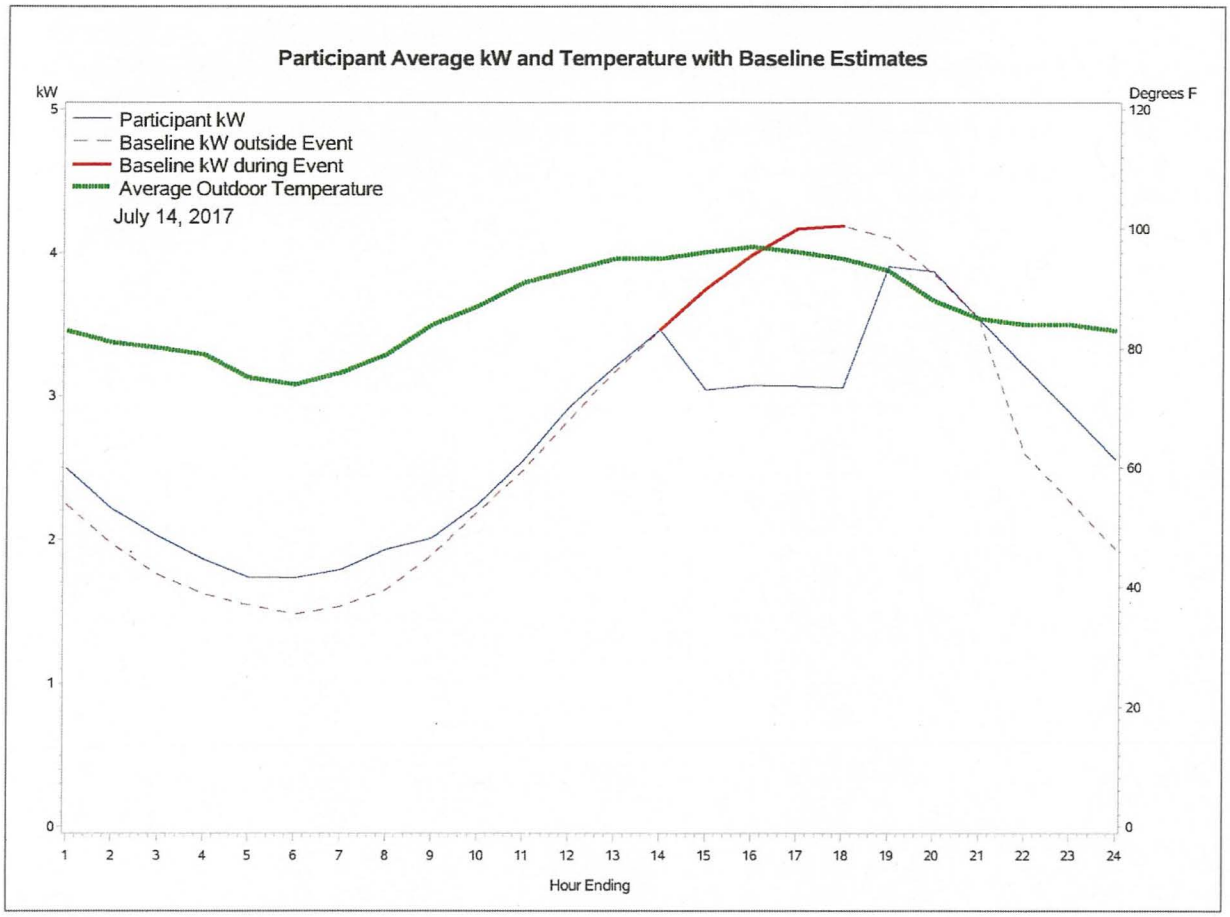
Figure 6-1. Load Profile for an Event-Day with Average Impacts (July 11, 2017).



6.1.2 Load Profile with High Impacts

Figure 6-2 shows the relatively high impact achieved on July 14, 2017. It was the last day of four consecutive events days (July 11–July 14). Together, the four consecutive events yielded the highest average impact over all three four-day consecutive events. The temperature reached its daily high of 97°F at 13:00 and the load reduction during the event is clearly visible at hours ending 15, 16, 17, and 18 (between 14:00 and 18:00). The estimated average peak shaved during this event was 0.96 kW per participant. The maximum impact per participant for a single interval also occurred on this day (1.13 kW) at hour ending 18.

Figure 6-2. Load Profile for an Event with High Impacts (July 14, 2017)

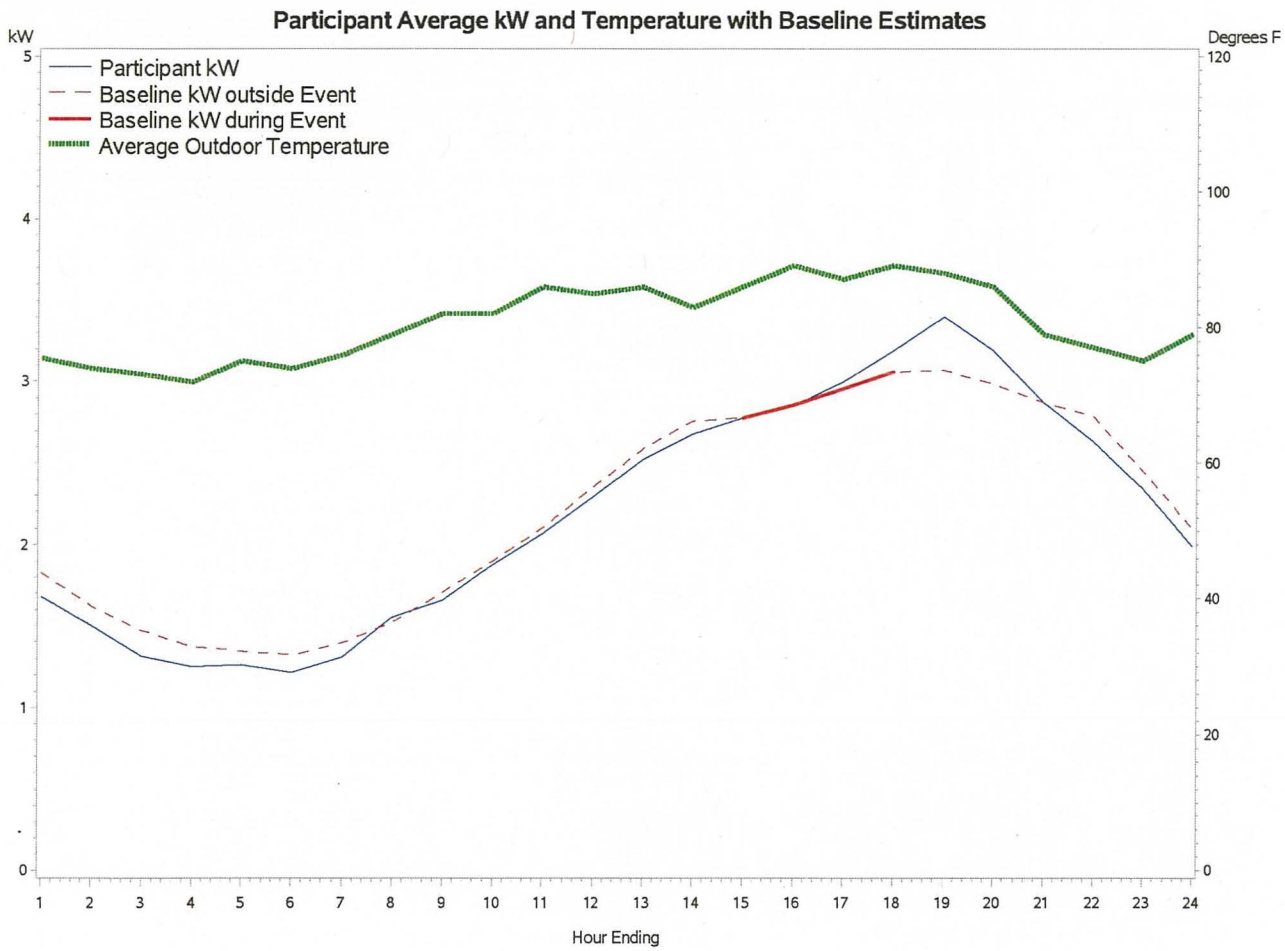


6.1.3 Load Profile with No Impact

Figure 6-3 shows an event with no impact that occurred on July 7, 2017. Dominion Energy replaced a server on the paging system that sends control messages to the AC control units. Although the pages were going out immediately after the server replacement, and were being received by a test pager, they were not in the correct format to be decoded by the control units. July 7, 2017 is one of two events (the other occurring on July 3rd) that the page signal was not decoded by the control units.[6]

The temperature reached its daily high of 93°F just before 15:00. The estimated average peak shaved during the July 7, 2017 event shown below was -0.06 kW per participant, a slight increase in load.

Figure 6-3. Load Profile for an Event Day with No Impacts (July 7, 2017).



[6] All of the results in this appendix are based on analyses conducted on 29 events, to include the July 3rd and 7th events. When those two July events are excluded, the 2017 evaluated impacts are 0.70 kW per participant at Dominion Energy's summer peak.

6.2 Ex post Impacts

Figure 6-4 is a timeline of the 2017 season and depicts each event as it relates to time, temperature, and impact (load reduction). It includes annotations noting the three instances of four-day consecutive events, and the beginning and end of the eight partial-dispatch events.

Average ex post impacts by day and hour are presented in Table 6-1. Also shown is the maximum daily temperature, opt-out percent, whether there was a full or partial-dispatch, and a day number indicating an event order in consecutive events.

The maximum impact per participant for a single interval in 2017 was 1.13 kW occurring at hour ending 18 on July 14. It was the fourth consecutive event-day and the maximum temperature reached 97°F. The event plot for July 14 is shown above in Figure 6-2.

The 2017 average maximum daily temperature for event-days was 91°F (down 1°F from 2016). The maximum temperature for a single event-day in 2017 was 98°F. Five event-days in 2017 exceeded 95°F, whereas only one event-day in 2016 exceeded 95°F.

Figure 6-4. 2017 Timeline, Events (Circle), Daily High Temperature (Left Axis), and Impacts in kW (Right Axis).

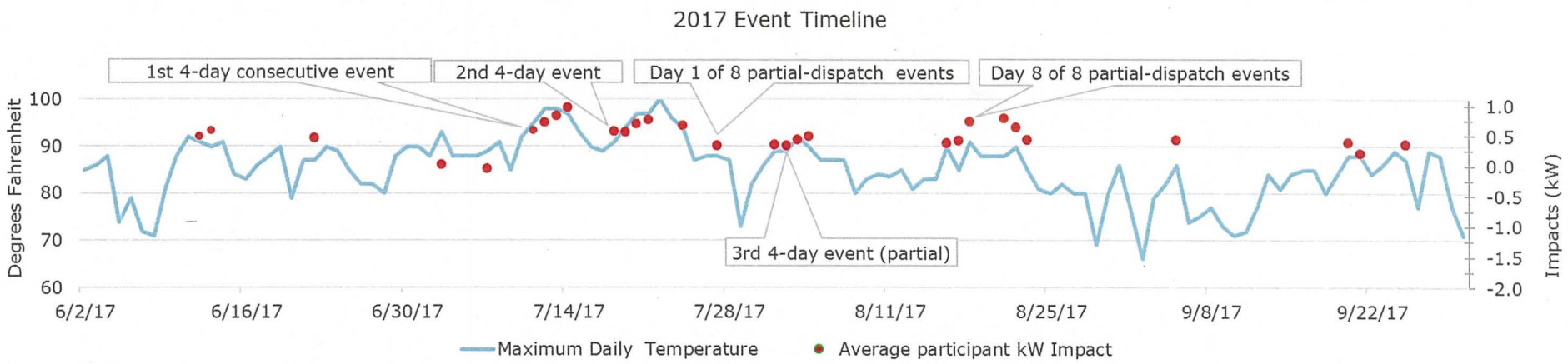


Table 6-1. 2017 AC Cycling Impacts by Event-Day and Hour

Event Date	12-Jun	13-Jun	22-Jun	03-Jul	07-Jul	11-Jul	12-Jul	13-Jul	14-Jul	18-Jul	19-Jul
Consecutive Event-days	1	2	1	1	1	1	2	3	4	1	2
Dispatch Type	Full-dispatch	Full-dispatch	Full-dispatch	Full-dispatch	Full-dispatch	Full-dispatch	Full-dispatch	Full-dispatch	Full-dispatch	Full-dispatch	Full-dispatch
Opt Out Percent	0.100%	0.075%	0.024%	0.00%	0.01%	0.037%	0.087%	0.124%	0.123%	0.045%	0.070%
Daily High Temperature	91	90	87	93	89	95	98	98	97	91	94
15:00:00								0.74	0.71		
16:00:00	0.45	0.49	0.38	0.03	0.01	0.51	0.68	0.85	0.91	0.51	0.46
17:00:00	0.50	0.62	0.49	0.00	-0.04	0.59	0.71	0.82	1.10	0.62	0.56
18:00:00	0.50	0.62	0.48	0.02	-0.13	0.64	0.78	0.87	1.13	0.60	0.59
19:00:00	0.49						0.71			0.51	0.60
Average Kw Impact	0.48	0.57	0.45	0.02	-0.06	0.58	0.72	0.82	0.96	0.56	0.55

Table 6–1 Continued

Event Date	20-Jul	21-Jul	24-Jul	27-Jul	1-Aug	2-Aug	3-Aug	4-Aug	16-Aug	17-Aug	18-Aug
Consecutive Event Days	3	4	1	1	1	2	3	4	1	2	3
Dispatch Type	Full-dispatch	Full-dispatch	Full-dispatch	Partial-dispatch	Partial-dispatch	Partial-dispatch	Partial-dispatch	Partial-dispatch	Partial-dispatch	Partial-dispatch	Partial-dispatch
Opt Out Percent	0.043%	0.053%	0.029%	0.015%	0.001%	0.007%	0.009%	0.014%	0.010%	0.000%	0.019%
Daily High Temperature	97	97	94	88	89	89	92	90	90	85	91
15:00:00								0.41			
16:00:00	0.63	0.65	0.56	0.34	0.32	0.34	0.41	0.54	0.38	0.40	0.63
17:00:00	0.69	0.76	0.70	0.34	0.37	0.35	0.46	0.50	0.37	0.42	0.75
18:00:00	0.73	0.83	0.72	0.32	0.36	0.31	0.42		0.36	0.41	0.80
19:00:00											
Average Kw Impact	0.68	0.75	0.66	0.33	0.35	0.33	0.43	0.49	0.37	0.41	0.73

Table 6–1 Continued

Event Date	21-Aug	22-Aug	23-Aug	5-Sep	20-Sep	21-Sep	25-Sep
Consecutive Event-days	1	2	3	1	1	2	1
Dispatch Type	Full-dispatch	Full-dispatch	Full-dispatch	Full-dispatch	Full-dispatch	Partial-dispatch	Full-dispatch
Opt Out Percent	0.016%	0.032%	0.014%	0.004%	0.003%	0.004%	0.008%
Daily High Temperature	88	90	85	86	88	88	87
15:00:00	0.72	0.55					0.29
16:00:00	0.89	0.61	0.47	0.38		0.05	0.36
17:00:00	0.82	0.65	0.47	0.46	0.35	0.42	0.39
18:00:00	0.71	0.71	0.35	0.45	0.41	0.38	0.40
19:00:00						0.01	
Average Kw Impact	0.78	0.63	0.43	0.43	0.38	0.21	0.36

6.3 Ex ante Impacts

The second objective of this analysis is to calculate ex ante impact estimates for the program year. The ex ante analysis models each hour to obtain the impacts for a range of temperature humidity index (THI) values. This is achieved by fitting linear regression models to predict impacts using weather data specific to each event hour. Similar to the 2016 model, the 2017 ex ante model is based solely on 2017 ex post impacts.

The ex ante analysis models impacts for a range of THI values for each event interval. A regression model was fit for the ex post impacts for each of the event hours (15:00, 16:00, 17:00, 18:00, and 19:00), with THI as a predictor variable.

Table 6-2 shows the predicted values from the regression models aggregated by whole-hour intervals and tabulated by hour and THI. The Dominion Energy peak condition for planning purposes is 83.4 THI at hour ending 17. This corresponds with a temperature of 95°F at 43% relative humidity (RH). Interpolating between 83°F and 84°F (bolded) at 17:00, the expected peak load reduction is 0.68 kW per customer.

There was not a sufficient number of event observations to model impacts for hours ending 13, 14, 20, or 21. In these cases, ex ante estimates were assumed to be equivalent to closest hour (15 or 19).

Table 6-2. 2017 Ex Ante Impacts by THI and Hour Ending Per Participant

Per participant Ex Ante Impacts in kW by THI and Event Hour Ending									
	Event Hour Ending								
THI	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
79	0.42	0.42	0.42	0.37	0.43	0.46	0.38	0.38	0.38
80	0.47	0.47	0.47	0.42	0.49	0.51	0.47	0.47	0.47
81	0.53	0.53	0.53	0.48	0.54	0.57	0.56	0.56	0.56
82	0.58	0.58	0.58	0.53	0.60	0.63	0.65	0.65	0.65
83	0.64	0.64	0.64	0.59	**0.66**	0.69	0.74	0.74	0.74
84	0.69	0.69	0.69	0.64	**0.71**	0.75	0.83	0.83	0.83
85	0.75	0.75	0.75	0.70	0.77	0.81	0.92	0.92	0.92
86	0.80	0.80	0.80	0.75	0.82	0.86	1.01	1.01	1.01
87	0.86	0.86	0.86	0.81	0.88	0.92	1.10	1.10	1.10
88	0.91	0.91	0.91	0.86	0.93	0.98	1.19	1.19	1.19

APPENDIX A. EXTRAPOLATING THE AMI-ENABLED ACCOUNT IMPACTS TO THE PROGRAM POPULATION

Using the BI data and the control history account logs, participants are categorized by division, connected load and whether the account is AMI-enabled (Table 6-3). To extrapolate the AMI account impacts to the AC Cycling Program population, the AMI-enabled accounts are assigned weights based on their division and connected load relative to all participants. The weights assigned to the AMI enabled group for the June 12 event are listed in the "Weight" column in Table 6-3 and weights for each event are adjusted according to event participation, which varies slightly from event to event, and may vary significantly during a partial-dispatch event (see Section 5.4.1). The weight can be understood as the number of program customers represented by each meter in the AMI group. The following steps were taken to build the 2017 weights, which are specific to each event depending on the mix of controlled participants.

1. Construct a list of all event participants by address, division, and connected load. The list of participants is event-specific and reported in the control history logs. The program tracking data, or BI data, is the source of the addresses and connected loads.
2. Stratify the participants based on state, division and connected load.
3. Calculate weights based on the number of AMI participants for each event relative to all participants within each stratum.[7]

Table 6-3. 2017 Weights by State, Division and Connected Load for June 12, 2017

State	Division	Load (kW)	# AMI meters	Population	Weight
VA	Northwest	Not Available	2,604	10,887	4
VA	Northwest	< 4kW	2,632	8,069	3
VA	Northwest	⩾4kW	2,308	8,555	4
NC	NC	Not Available	0	10	0
NC	NC	< 4kW	2	305	153
NC	NC	⩾4kW	94	3,204	34
VA	Not Available	Not Available	162	1,590	10
VA	Not Available	< 4kW	8	261	33
VA	Not Available	⩾4kW	3	217	72
VA	Central	Not Available	51	5,293	104
VA	Central	< 4kW	89	7,516	84
VA	Central	⩾4kW	82	5,670	69
VA	Eastern	Not Available	33	11,312	343
VA	Eastern	< 4kW	44	15,571	354
VA	Eastern	⩾4kW	40	10,566	264
		Total	**8,152**	**89,026**	

[7] The weight within each stratum is the population divided by the total number of AMI meters in the study group.

About DNV GL

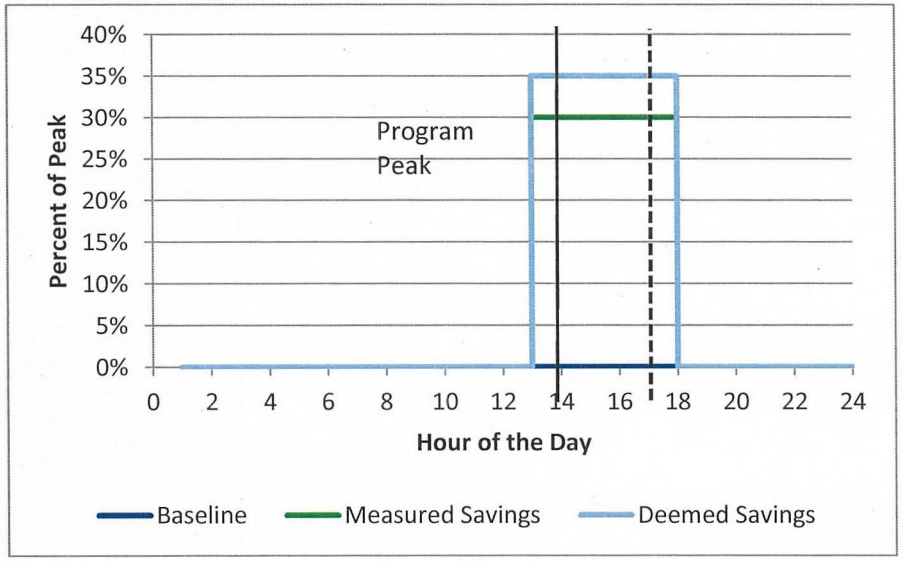
Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter, and greener.

APPENDIX P. NON-RESIDENTIAL DISTRIBUTED GENERATION PROGRAM EM&V PLAN (VERSION 8.0)

Program Summary	The Non-residential Distributed Generation Program provides qualifying customers with an incentive to curtail load by operating backup generation when called upon, up to a limited number of hours per year. The program is implemented by a contractor who is responsible for: installing equipment to enable remote operation, monitoring of the customer's backup generation equipment, and dispatching load curtailment events under the direction of the Company. Participants must have at least 200 kW demand to be eligible for this program. The program implementation contractor will be provided notice of each event 30 minutes in advance either by e-mail or phone. Total monthly average load curtailment must be at least 95% of enrolled kW for curtailment capability payments; total monthly average load curtailment must be at least 50% of enrolled kW for continued program participation.
Measures	Load curtailment using remotely-controlled backup generation equipment at customer sites.

EM&V Method	International Performance Measurement and Verification Protocol (IPMVP - Option B): Because this program focuses on specifically metered equipment, IPMVP Option B is the appropriate EM&V method to apply. Program participants are known and the load curtailment will be metered directly.

Illustrative Load Shape: Non-Residential Distributed Generation



1. Baseline Estimation Approach (Dark blue line): The baseline for this program is zero during the event period, because these units are generally not operating in the absence of the program.

2. Deemed Savings Approach (Light blue line): Deemed savings values will be developed and incorporated into the DNV GL Energy STEP Manual.

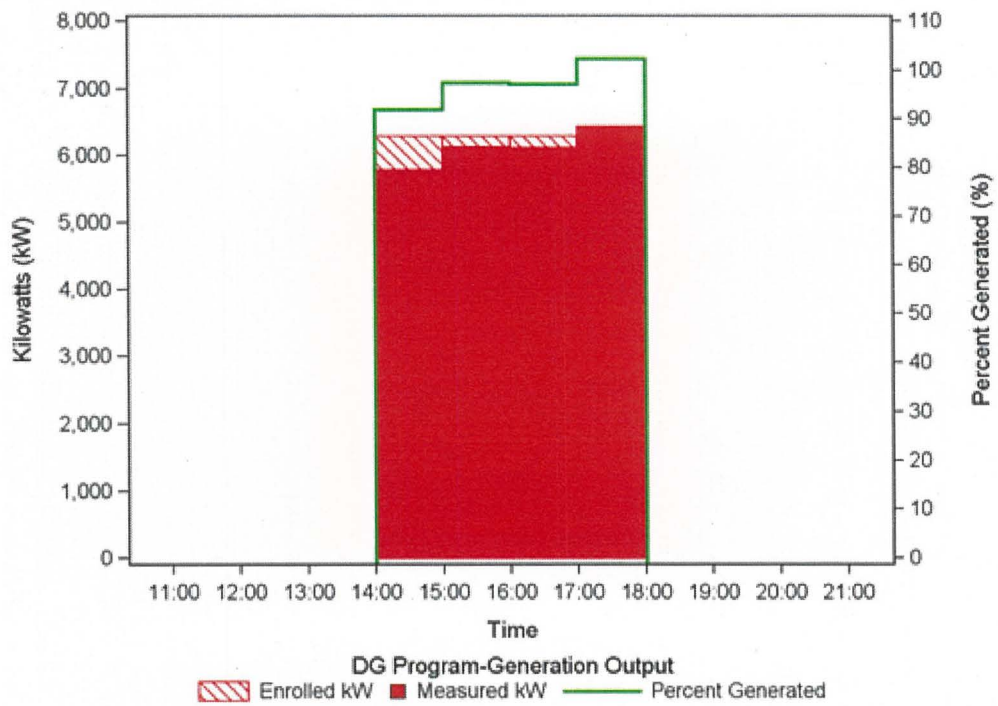
3. Measured Savings Approach (Green line): The program participants are known and the load and runtime hours will be metered directly through the program.

EM&V Summary and Sampling Strategy	Customer data regarding backup generation equipment will be collected prior to enrollment and will be used to determine customer eligibility. Direct electrical metering data will be collected and archived for all enrolled generators during load curtailment events. Data will be collected from vendor-owned metering and from Company-owned metering.

Sampling Strategy:

- Census: Electrical output from 100% of enrolled generators will be metered.

Sample Plot:



EM&V Measurement, Timeline, and Scope of Work	• Analysis of program tracking and metered data: Annual Report (May 1 of each year following program launch). • Semi-annual program tracking summary table (ending July 2015). 2015 will be final year of semi-annual reporting, as North Carolina submissions will be changing next year to line up with Virginia. Semi-annual program tracking summary table (July of each year). • Annual event season report (November of each year). • Annual updates to STEP Manual for updates that occurred to its referenced sources. • Develop baseline, measure savings, and efficient load shapes. • Provide regulatory support as necessary.
EM&V Summary and Sampling Strategy	• A census of participant data will be evaluated since electrical output from 100% of enrolled generators will be metered, the event times are known, and the load and run time hours will be directly metered and reported. • Missing meter data will be replaced to the extent possible with redundant meter data. Analysis of program tracking and metered data: Annual Report (May 1 of each year following program launch). • Semi-annual program tracking summary table (ending July 2015). 2015 will be final year of semi-annual reporting, as North Carolina submissions will be changing next year to line up with Virginia. Semi-annual program tracking summary table (July of each year). • Annual event season report (November of each year). • Annual updates to STEP Manual for updates that occurred to its referenced sources. • Develop baseline, measure savings, and efficient load shapes. • Provide regulatory support as necessary.
Sampling Confidence Level, Relative Precision, and Assumed Error Ratio	• A census of participant data will be evaluated since electrical output from 100% of enrolled generators will be metered, the event times are known, and the load and run time hours will be directly metered and reported. • Missing meter data will be replaced to the extent possible with redundant meter data.
Lost Revenue Methodology	• Not applicable
Document Revision History	Version 1.0 • Added semi-annual program tracking summary table in the "Frequency of EM&V Measurement & Timeline" section. Not applicable
	Version 2.0 • No material changes to the content. • Added semi-annual program tracking summary table in the "Frequency of EM&V Measurement & Timeline"

	section.
	Version 3.0 • No material changes to the content. • No material changes to the content.

	Version 4.0
	• Updated program requirements with more details, as shown below:
	  ○ Added minimum kW demand requirement of 200 kW to be eligible for this program to the "Program Summary" section.
	  ○ Added customer notification process of each DG event through e-mail or phone 30 minutes in advance.
	  ○ Added compliance requirement that participants must be within +/- 5% of committed peak shaving enrolled kW.
	• Changed "KEMA" to "DNV KEMA."
	• Changed "Program Penetration & Initial Baseline Assumptions" section title to "Program Penetration" and removed initial baseline assumptions.
	• Updated program penetrations and added "Source" column to the "Program Penetration" table.
	• Changed "Revision History" section title to "Document Revision History."
	Updated planned penetration table based on 2013 IRP.
	• No material changes to the content.

	Version 5.0
	• Removed 2013 planned customer penetration numbers.
	Added sentence on PJM requirements to end of "EM&V Method."
	• Updated program requirements with more details, as shown below:
	  ○ Added minimum kW demand requirement of 200 kW to be eligible for this program to the "Program Summary" section.
	  ○ Added customer notification process of each DG event through e-mail or phone 30 minutes in advance.
	  ○ Added compliance requirement that participants must be within +/- 5% of committed peak shaving enrolled kW.
	• Changed "KEMA" to "DNV KEMA."
	• Changed "Program Penetration & Initial Baseline Assumptions" section title to "Program Penetration" and removed initial baseline assumptions.
	• Updated program penetrations and added "Source" column to the "Program Penetration" table.
	• Changed "Revision History" section title to "Document Revision History."
	• Updated planned penetration table based on 2013 IRP.

	Version 6.0 • Updated DNV KEMA to DNV GL Energy. • Clarified that compliance is defined by total monthly average load curtailment that is at least 95% of committed peak shaving enrolled kW (rather than +/- 5% of enrolled kW). • Renamed "Frequency of EM&V Measurement and Timeline" section title to "EM&V Measurement, Timeline and Scope of Work" to more accurately reflect the content in that section • Added on-going scope that was not explicitly mentioned to "EM&V Measurement, Timeline and Scope of Work" section. • Deleted program penetrations section • Removed 2013 planned customer penetration numbers. • Added sentence on PJM requirements to end of "EM&V Method."
	Version 7.0 • Clarified that compliance for program participation is 50% of enrolled, but compliance for payments is 95% of enrolled kW. Updated bullet "Semi-annual program tracking summary table (as required)." to "Semi-annual program tracking summary table (ending July 2015). 2015 will be final year of semi-annual reporting, as North Carolina submissions will be changing next year to line up with Virginia. • Updated DNV KEMA to DNV GL Energy. • Clarified that compliance is defined by total monthly average load curtailment that is at least 95% of committed peak shaving enrolled kW (rather than +/- 5% of enrolled kW). • Renamed "Frequency of EM&V Measurement and Timeline" section title to "EM&V Measurement, Timeline and Scope of Work" to more accurately reflect the content in that section • Added on-going scope that was not explicitly mentioned to "EM&V Measurement, Timeline and Scope of Work" section. • Deleted program penetrations section • Updated bullet "Semi-annual program tracking summary table (as required)." to "Semi-annual program tracking summary table (ending July 2015). 2015 will be final year of semi-annual reporting, as North Carolina submissions will be changing next year to line up with Virginia." • Clarified difference between payment compliance (95% of enrolled load) and program participation compliance (50% of enrolled load)
	Version 8.0 • Updated "April 1" report date to "May 1" in "EM&V Measurement, Timeline, and Scope of Work" section

DNV·GL

DISTRIBUTED GENERATION PROGRAM

Appendix P-1: Impact Evaluation of 2017 Dispatch Events

Dominion Energy

Date: May 1, 2018

Table of contents

List of tables

1 EXECUTIVE SUMMARY

This report presents the results of the annual impact analysis of Dominion Energy's (hereafter referred to as "the Company") Non-residential Distributed Generation (DG) Program for 2017.

The program began in June 2012 with the objective of curtailing peak load. During periods when demand for electricity is particularly high, the Company calls upon participating large non-residential customers to provide a supply resource to the company by operating backup power to curtail load on the Company's grid. Customers must meet specific eligibility requirements to participate in the program and receive an incentive from the Company in exchange for their participation.

The three objectives of the impact analysis are to:

- Compute the aggregate load curtailed, in kW, by participating customers at one-hour intervals during each 2017 event day
- Compute program realization rates annually, seasonally and for each event interval by comparing measured generation to the requested dispatched generation
- Describe trends across event intervals that may influence program performance

Table 1 shows DG Program monthly impacts for 2017. The table provides the planned and actual participants in MW and the average dispatched and measured generation in kW. The "average dispatched" is the average amount of load curtailment, in kW, requested by the Company per event-hour interval aggregated to the monthly level, while "average generation" is average metered generation, also in kW, delivered by the participants per event-hour interval and aggregated to the monthly level. The realization rate is calculated by dividing the average monthly measured generation by the average monthly dispatched generation for participating sites.

Table 1. 2017 DG Program Performance Against Planned

2017	Planned Participants (MW)	Enrolled Participants (MW)	Net kW Planned	Net kW Enrolled	Event Days	Average Dispatched (kW)	Average Generation (kW)	Average Realization Rate
Jan	7.4	6.1	7,394	6,130	1	6,130	5,157	84%
Feb	No events							
Mar	No events							
Apr	No events							
May	7.4	6.1	7,394	6,130	2	6,030	5,517	91%
Jun	7.4	5.9	7,394	5,940	3	5,832	6,163	106%
Jul	7.4	5.9	7,394	5,940	13	5,509	6,151	112%
Aug	7.4	5.5	7,394	5,450	4	5,386	6,401	119%
Sep	7.4	5.6	7,394	5,640	2	5,563	5,658	102%
Oct	No events							
Nov	No events							
Dec	7.4	6.1	7,394	6,130	2	6,130	5,273	86%

The average dispatched generation per event interval per month over the 27 total event days in 2017 varied from 5,386 kW to 6,130 kW. The winter season spans October–March, while the summer season spans April–September. In 2017, 13 events were called in July, which was the greatest number for both the year and the summer season. The highest average monthly realization rate for the year occurred in August, achieving 119%. January had the lowest realization rate for the year, at 84%. The average realization rate for the year was 108%. Summer events averaged 110%, and winter events averaged 85%.

2 INTRODUCTION AND BACKGROUND

The Virginia State Corporation Commission approved the Non-Residential DG Pilot on January 17, 2008 and subsequently achieved program status on April 30, 2012. The pilot ran through the end of 2014. In June 2017, the program was extended for an additional 5 years through May 31, 2022.[1] As of December 31, 2017, there are 21 enrolled sites representing a potential 6.1 MW of resources to the Company. Large non-residential customers with at least 200 kW of demand and backup generation capacity are eligible to participate in the program. Details of the DG Program are as follows:

- One customer can qualify as multiple participants. One participant is equal to 1,000 kW of enrolled onsite generation, and the level of incentive corresponds with the kW of enrolled generation capacity.2
- Participating customers are in compliance with the program compensation rules if the average measured on-site generation is at least 95% of the dispatched target for each event day.
- The Company has the right to adjust the incentive paid to customers based on historical performance if the average realization rate is below the 95% target.

DG Pilot participants were reported in the tracking data through the conclusion of the pilot at the end of 2014. Unlike participants in the DG Program, the 8 pilot program sites were eligible for the incentive based on participation alone, and were not required to meet the 95% realization target. Therefore, the results from this report are not directly comparable to the results of combined pilot and program impact analyses reported in 2013 and 2014.

[1] Case No. PUE-2016-00111. Commonwealth of Virginia, State Corporation Commission, "Final Order" on the subject "For approval to implement new, and to extend existing, demand-side management programs and for approval of two updated rate adjustment clauses pursuant to § 56-585.1 A 5 of the Code of Virginia." June 1, 2017.

[2] Customers who do not have exact multiples of 1,000 kW of onsite generation are credited with fractional levels of participation and incentive, e.g., 1,500 kW would be counted as 1.5 participants.

3 IMPACT ANALYSIS METHODOLOGY

The key performance metric used to measure program performance for the DG Program is the realization rate. For an individual site, the realization rate for a given event interval is the measured generation for that interval divided by the dispatched generation for the site during the interval. The realization rate for the program during an event interval is the total measured generation divided by the total dispatched generation. For participants indexed by i, and for an event interval j,

$$Realization\ Rate_j = \frac{\sum_i Measured\ Generation\ (kW_{i,j})}{\sum_i Dispatched\ Generation\ (kW_{i,j})}$$

The aggregate dispatched and measured generation across the program is tabulated by event interval and day to track performance.

An event interval is an hour occurring during a generator dispatch event that the Company calls. The start and end times vary by event day. The number of dispatched sites on a given event day also varies. If there is measured generation prior to or following a dispatched event, the on-site power generation is not attributed to the DG Program.

Event days for the 2017 analysis were separated into winter and summer seasons. The winter season spans October–March, while the summer season spans April–September.

4 RESULTS

This section describes the event impacts from 2013 to 2017, but focuses on the 2017 DG events. There were 27 event days in 2017, of which three were called in January and December while all other events were called in May, June, July, August, and September.

Table 2 presents a yearly summary of the number of event days, average dispatched generation in kW, average generation in kW, and realization rate. The 2017 overall realization rate was the highest in the past five years and exceeded the program's 95% target by 13%.

Table 2. Program Participant Impacts and Realization Rates per Year

Year	Event Days	Average Dispatched (kW)	Average Generation (kW)	Realization Rate
2013	12	6,239	6,306	102%
2014	23	5,862	5,978	101%
2015	26	5,899	5,457	93%
2016	37	5,215	5,524	106%
2017	**27**	**5,603**	**6,054**	**108%**

Table 3 presents an overview of DG Program participant impacts by year and season. The 2017 realization rates for winter and summer were the highest seasonal realization rates for comparable program years 2015 and 2016. Current year results in Table 2 are highlighted and bold.

Table 3. Program Participant Impacts and Realization Rates per Year and Season

Year/Season	Event Days	Average Dispatched (kW)	Average Generation (kW)	Realization Rate
2014 Winter	9	6,060	3,954	65%
2015 Winter	6	5,846	4,515	78%
2016 Winter	3	5,911	4,281	72%
2017 Winter	**3**	**6,130**	**5,234**	**85%**
2014 Summer	14	5,798	6,305	109%
2015 Summer	20	5,958	5,903	99%
2016 Summer	34	5,171	5,602	108%
2017 Summer	**24**	**5,564**	**6,114**	**110%**

Sections 4.1 and 4.2 discuss dispatched generation, measured generation, and realization rates per event day and hour, by season. Section 4.3 provides site-level realization rate details per event day.

4.1 Overall Program Event Impacts

The total dispatched generation for all DG Program participants during the 2017 winter and summer event intervals are shown in Table 4 and Table 5 below, respectively. The total and average dispatched generation is summarized by event day. The total hourly dispatched capacity ranged from 4,980 kW to the full enrolled amount of 6,130 kW across the 27 events called in 2017.

The dispatched kW is a reflection of the Company's needs for the individual event or deviations in the level of participant commitment, rather than a reflection of performance.

Table 4. Overall Dispatched Generation During Winter Events

Overall Dispatched Generation (kW) by Event Day and Time							
Event Day	Hour Ending						
	8:00	9:00	...	19:00	20:00	Total	Average
Jan 9	6,130	6,130				12,260	6,130
Dec 28				6,130	6,130	12,260	6,130
Dec 29	6,130	6,130				12,260	6,130

Table 5. Overall Dispatched Generation During Summer Events

Overall Dispatched Generation (kW) by Event Day and Time							
Event Day	Hour Ending						
	15:00	16:00	17:00	18:00	19:00	Total	Average
May 17			5,880	5,880		11,760	5,880
May 18		6,130	6,130	6,130		18,390	6,130
Jun 12		5,940	5,940	5,940	5,940	23,760	5,940
Jun 13		5,760	5,760	5,760		17,208	5,760
Jun 22		5,760	5,760	5,760		17,208	5,760
Jul 3		5,940	5,940	5,940		17,820	5,940
Jul 7		5,940	5,940	5,940		17,820	5,940
Jul 10		5,790	5,790	5,790	5,790	23,160	5,790
Jul 11		5,940	5,940	5,940		17,820	5,940
Jul 12		5,790	5,790	5,790	5,790	23,160	5,790
Jul 13	5,440	5,620	5,620	5,620		22,300	5,575
Jul 14	5,440	5,440	5,440	5,440		21,760	5,440
Jul 18		5,220	5,220	5,220	5,220	20,880	5,220
Jul 19		5,250	5,250	5,250	5,250	21,000	5,250
Jul 20		5,250	5,250	5,250		15,750	5,250
Jul 21		5,250	5,250	5,250		15,750	5,250
Jul 22		5,250	5,250	5,250		15,750	5,250
Jul 24		4,980	4,980	4,980		14,940	4,980
Aug 17		5,300	5,300	5,300		15,900	5,300
Aug 18		5,300	5,300	5,300		15,900	5,300
Aug 21	5,450	5,450	5,450	5,450		21,800	5,450
Aug 22	5,450	5,450	5,450	5,450		21,800	5,450
Sep 21			5,460	5,460	5,460	16,380	5,460
Sep 25	5,640	5,640	5,640	5,640		22,560	5,640

Table 6 and Table 7 below provide the total measured generation by all program participants for each event interval during winter and summer events, respectively.

The total and average generation in kW are summarized by event day. The greatest average measured power produced by the participants per event day was greater in the summer (6,953 kW) than in the winter (5,324 kW). This is consistent with program expectations for winter events, since the dispatched kW per site reflects the summer peak load. In the winter, space heating for large commercial sites is typically fueled by natural gas, not electricity.

Table 6. Overall Measured Generation During Winter Events

Overall Generation (kW) by Event Day and Time							
Event Day	Hour Ending						
	8:00	9:00	...	19:00	20:00	Total	Average
Jan 9	4,942	5,373				10,314	5,157
Dec 28				5,255	5,889	10,444	5,222
Dec 29	5,279	5,370				10,649	5,324

Table 7. Overall Measured Generation During Summer Events

Overall Generation (kW) by Event Day and Time							
Event Day	Hour Ending						
	15:00	16:00	17:00	18:00	19:00	Total	Average
May 17			4,735	5,817		10,552	5,276
May 18		5,429	5,719	5,886		17,034	5,678
Jun 12		5,592	6,441	6,478	6,352	24,863	6,216
Jun 13		5,870	6,365	6,209		18,444	6,148
Jun 22		5,902	6,189	6,230		18,321	6,107
Jul 3		6,219	6,639	6,597		19,455	6,485
Jul 7		5,272	6,629	6,416		18,318	6,106
Jul 10		6,222	6,477	6,553	6,474	25,726	6,431
Jul 11		6,572	6,836	6,782		20,190	6,730
Jul 12		6,781	7,043	7,002	6,985	27,811	6,953
Jul 13	6,670	7,120	7,001	6,774		27,565	6,891
Jul 14	6,073	6,479	6,365	6,320		25,237	6,309
Jul 18		4,920	5,064	4,996	2,518	17,499	4,375
Jul 19		5,557	5,836	5,814	5,806	23,013	5,753
Jul 20		5,888	6,078	5,912		17,878	5,959
Jul 21		5,985	6,405	6,347		18,738	6,398
Jul 22		5,869	6,274	6,366		18,509	6,170
Jul 24		5,229	5,873	5,771		16,872	5,642
Aug 17		5,649	6,085	6,108		17,842	5,947
Aug 18		6,413	6,676	6,620		19,708	6,569
Aug 21	6,179	6,374	6,514	6,526		25,593	6,398
Aug 22	6,210	6,835	6,718	6,710		26,474	6,619
Sep 21			5,570	5,763	5,436	16,769	5,590
Sep 25	5,361	5,884	5,811	5,784		22,840	5,710

4.2 Realization Rates

The average realization rates in Table 8 and Table 9 show the DG Program total measured generation as a percentage of the corresponding dispatched generation for each event interval.

Average realization rates for event intervals that met or exceeded the DG Program target of 95% of dispatched generation are highlighted green in both Table 8 and Table 9, where applicable.

The realization rates per event-hour for the three winter events did not meet the 95% realization rate target, nor did the average daily performance (see Table 8). In contrast, 21 out of 24 summer event days, met or exceeded the 95% target (see Table 9). The highest performing summer event days were achieved on July 13 and August 18, generating 124% of the requested load curtailment on both event days. The lowest performing summer event day occurred July 18, 2017, generating 84% of the requested load curtailment.

Table 8. Overall Realization Rates During Winter Events

Overall Realization Rate by Event Day and Time						
Event Day	Hour Ending					
	8:00	9:00	...	19:00	20:00	Average Realization Rate
Jan 09	81%	88%				84%
Dec 28				86%	85%	85%
Dec 29				86%	88%	87%

Table 9. Overall Realization Rates During Summer Events

Overall Realization Rate by Event Day and Time						
Event Day	Hour Ending					
	15:00	16:00	17:00	18:00	19:00	Average Realization Rate
May 17			81%	99%		90%
May 18		89%	93%	96%		93%
Jun 12		94%	108%	109%	107%	105%
Jun 13		102%	111%	108%		107%
Jun 22		102%	107%	108%		106%
Jul 3		105%	112%	111%		109%
Jul 7		89%	112%	108%		103%
Jul 10		107%	112%	113%	112%	111%
Jul 11		111%	115%	114%		113%
Jul 12		117%	122%	121%	121%	120%
Jul 13	123%	127%	125%	121%		124%
Jul 14	112%	119%	117%	116%		116%
Jul 18		94%	97%	96%	48%	84%
Jul 19		106%	111%	111%	111%	110%
Jul 20		112%	116%	113%		114%
Jul 21		114%	122%	121%		119%
Jul 22		112%	120%	121%		118%
Jul 24		105%	118%	116%		113%
Aug 17		107%	115%	115%		112%
Aug 18		121%	126%	125%		124%
Aug 21	113%	117%	120%	120%		117%
Aug 22	114%	125%	123%	123%		121%
Sep 21			102%	106%	100%	102%
Sep 25	95%	104%	103%	103%		101%

4.3 Site-Level Detail

Table 10 shows the average realization rates by participant site for each event day. Each site is listed by a randomly assigned unique identifier. If a participant site was not dispatched during an event, the cell appears blank. Realization rates greater than or equal to 95% are highlighted green, less than 95% and greater than 50% are purple and rates less than or equal to 50% are highlighted blue.

For the single event day in January, 10 sites met or exceeded the 95% target and two sites realized less than 50% of the target generation. The performance of the two December events showed similar results. 10 sites met or exceeded the 95% target on December 28, and 11 sites met the 95% target on December 29. Both December events had a minimum of one site that generated less than 50% of the target generation. Site IDs 9, 11 and 13 met or exceeded the target in each 2017 event which they participated, as seen in Table 10. With the exception of Site ID 14, which achieved low realization rates for events days July 14–24, most participants in 2017 met or exceeded the 95% realization performance target. This is shown in Table 10 where the majority of the cells are highlighted green.

Table 11 highlights the monthly average event realization rate for each site, again illustrating that most sites achieved or exceeded the program target of 95%. Lower realization rates, highlighted in blue, spanned both seasons. Site ID 1 was the only site with two instances of average winter monthly realization rates that were less than or equal to 50%, while many sites did not have any instances. Six sites (Site IDs 8, 9, 10, 11, 13 and 20) met or exceeded the target 95% realization rate for each event month in 2017.

Table 10. Average Realization Rates by Site and Event-day

	Jan	May		Jun			Jul													Aug				Sep		Dec	
ID	9	17	18	12	13	22	3	7	10	11	12	13	14	18	19	20	21	22	24	17	18	21	22	21	25	28	29
1	49%	77%	84%	82%	93%	96%	86%	93%	88%	96%	101%	105%	105%	87%	92%	100%	105%	99%	91%	95%	107%	99%	101%	88%	82%	50%	50%
2	38%	85%	95%	89%	89%	97%	97%	93%	99%	105%	112%	119%	113%													71%	83%
3	74%	60%	85%	89%	89%	93%	102%	104%	113%	114%	116%	117%	117%	91%	110%	116%	117%	116%	114%	110%	114%	115%	117%	100%	104%	88%	84%
4	70%	99%	97%	91%	94%	99%	89%	87%	99%	99%	101%	105%	103%	83%	99%	60%	106%	103%	100%	95%	104%	97%	103%	100%	101%	66%	66%
5	63%	85%	89%	93%	91%	90%	91%	82%	94%	96%	97%									90%	101%	92%	101%	88%	81%	57%	50%
6	65%	78%	85%	89%	87%	86%	85%	74%	89%	90%	92%	95%	94%	76%	87%	94%	98%	93%	89%	80%	97%	88%	94%	88%	0%	64%	63%
7	60%	75%	81%	88%	91%	92%	88%	75%	89%	89%	92%	100%	107%	78%	96%	99%	96%	98%	92%	79%	94%	95%	94%	87%	87%	85%	86%
8	139%	92%	103%	96%	85%	104%	117%	113%	128%	137%	134%	138%	136%	102%	121%	129%	134%	136%	123%	121%	148%	128%	143%	123%	105%	130%	132%
9	165%	133%	145%	153%	153%	143%	141%	131%	137%	143%	141%	151%	154%	117%	146%	149%	149%	153%	148%	141%	150%	144%	151%	128%	140%	133%	142%
10	157%	99%	109%	90%	94%	117%	117%	108%	116%	118%	121%	132%	131%	102%	126%	130%	129%	131%	125%	118%	130%	123%	129%	113%	116%	145%	147%
11	195%	181%	188%	182%	186%	183%	178%	174%	191%	200%	206%	207%	208%	157%	196%	189%	199%	197%	193%	188%	200%	189%	196%	185%	181%	192%	211%
12	90%	36%	37%	97%	105%	102%	106%	98%	101%	105%	110%	110%	100%	82%	104%	106%	107%	110%								71%	73%
13	157%	130%	143%	114%	119%	127%	122%	120%	146%	125%	157%	157%	131%	108%	128%	134%	132%	135%	127%	129%	136%	135%	137%	111%	113%	106%	116%
14	124%	96%	107%	106%	106%	101%	104%	86%	99%	107%	106%	67%	0%	1%	1%	1%	42%	2%	41%	93%	108%	95%	106%	95%	100%	113%	118%
15	135%	115%	128%	134%	101%	0%	135%	1%		64%		152%	84%	114%								145%	151%	133%	132%	93%	109%
16	109%		97%	97%	116%	111%	104%	105%	109%	113%	122%	123%	122%	88%	108%	108%	108%	122%	117%	116%	128%	116%	126%	73%	77%	82%	85%
17	54%	93%	86%	101%	97%	95%	101%	91%	96%	103%	108%	116%	117%	79%	101%	104%	104%	116%	111%	104%	114%	111%	114%	99%	98%	70%	65%
18	153%	0%	0%																					143%	141%	140%	145%
19	70%	39%	98%	244%	251%	246%	251%	175%	247%	199%	257%	262%	267%	28%	244%	255%	227%	256%	247%	245%	263%	249%	250%	115%	220%	168%	162%
20	156%	238%	228%	233%	235%	233%	236%	235%	232%	239%	244%	240%	246%	25%	230%	236%	237%	245%	233%	205%	218%	207%	213%	195%	179%	132%	135%
21	72%	186%	39%	177%			196%	196%	196%	196%	196%	196%			186%	202%	199%	204%	191%	196%	196%	196%	196%		196%	196%	196%

Table 11. Average Realization Rates by Site and Event-month

	Jan	May		Jun			Jul												Aug				Sep		Dec	
ID	9	17	18	12	13	22	3	7	10	11	12	13	14	18	19	20	21	22	24	17	18	21	22	21	25	28	29
1	49%	80%		90%			96%													101%				85%		50%	
2	38%	90%		91%			105%																			77%	
3	74%	73%		91%			111%													114%				102%		86%	
4	70%	98%		95%			95%													100%				100%		66%	
5	63%	87%		92%			92%													96%				84%		54%	
6	65%	81%		87%			89%													90%				44%		63%	
7	60%	78%		90%			92%													91%				87%		85%	
8	139%	98%		95%			127%													135%				114%		131%	
9	165%	139%		150%			143%													147%				134%		138%	
10	157%	104%		101%			122%													125%				114%		146%	
11	195%	184%		184%			192%													193%				183%		202%	
12	90%	37%		101%			103%																			72%	
13	157%	136%		120%			132%													134%				112%		111%	
14	124%	102%		105%			51%													100%				98%		115%	
15	135%	121%		78%			92%													148%				133%		101%	
16	109%	97%		108%			112%													121%				75%		84%	
17	54%	89%		98%			104%													111%				98%		67%	
18	153%	0%																						142%		143%	
19	70%	68%		247%			224%													252%				168%		165%	
20	156%	233%		234%			221%													211%				187%		134%	
21	72%	113%		177%			196%													196%				196%		196%	

5 CONCLUSIONS

The objective of each DG event is to provide the Company with a supply resource and for on-site power generation to meet or exceed at least 95% of the dispatched curtailment requested. In 2017, DG Program participants exceeded program goals by 13%, achieving an average realization rate of 108% across all events. As in prior years, summer events exceeded the 95% program target, averaging 110%. The 2017 winter events averaged 85%, falling short of the program target; however, 2017's winter performance was higher than the previous three winter realization rates.

6 RECOMMENDATIONS

The purpose of the Company's annual DG evaluation of dispatch events is to assess program progress towards planned goals, while providing actionable information for program managers to calibrate program operation to align with these goals.

DNV GL recommends that enrolled and dispatched load be reviewed and updated seasonally to account for changes in site-level demand for electricity and its corresponding on-site generation capacity. Since participants are only generating electricity for their own use and not returning excess capacity to the electric grid, commitments based on maximum generation capacity corresponding with summer peak demand are not attainable in the winter months. The Company would need to establish site-level estimates of the monthly peak kW based on historical and/or in-season site-level measured demand to make this change. The benefits of doing so would be:

- Improved ability to predict the peak shaving capability of the program in aggregate throughout the year
- Improved ability to track site-level performance with realization rates comparable across all months

About DNV GL

Driven by our purpose of safeguarding life, property and the environment, DNV GL enables organizations to advance the safety and sustainability of their business. We provide classification and technical assurance along with software and independent expert advisory services to the maritime, oil and gas, and energy industries. We also provide certification services to customers across a wide range of industries. Operating in more than 100 countries, our 16,000 professionals are dedicated to helping our customers make the world safer, smarter, and greener.