AEP OHIO
A unit of American Electric Power

INTERIM TECHNOLOGY PERFORMANCE REPORT (TPR)

AEP OHIO

gridSMART® Demonstration Project

A Community- Based Approach to Leading the Nation in Smart Energy Use

Department of Energy (DOE) Smart Grid Demonstration Project (SGDP)

Contract Award Number DE-OE0000193

March 29, 2013

Use or disclosure of data appearing in this document is subject to the restrictions set forth on the notification page of this document.

This material is based upon work supported by the Department of Energy under Award Number DE-OE0000193

This material is based upon work supported by the Department of Energy under Award Number DE-OE0000193

NOTIFICATIONS

Acknowledgment

This material is based upon work supported by the Department of Energy under Award Number DE-OE0000193.

Disclaimer Of Warranties And Limitation Of Liabilities

Confidentiality Notice

Table of Contents

Table of Figures

List of Tables

1 INTRODUCTION

In 2009, the United States Department of Energy (DOE) awarded a Smart Grid Demonstration Project to Ohio Power Company (the surviving company of a merger with Columbus Southern Power Company), doing business as AEP Ohio. This project, the AEP Ohio gridSMART® Demonstration Project (Project), award number DE-OE0000193, integrates and evaluates commercially available products, innovative technologies, and new consumer products to understand the economic, environmental, and reliability benefits that can be achieved with scaling such technology to the electrical grid nationwide.

This Interim Report provides insight into the implementation, operation and analytical progression of demonstrated technologies. Many of the observations in this Report are preliminary while AEP Ohio continues to refine impact trends and conclusions. Since AEP Ohio undertook numerous smart technologies simultaneously, data and interpretation adjustments are anticipated as the technologies evolve.

1.1 GLOSSARY OF TERMS

Word/Phrase	Meaning
American Electric Power	American Electric Power Service Corporation is an investor owned utility holding company that is engaged in the generation, transmission, and distribution of electric power to retail and wholesale customers. The company also supplies and markets electric power
AEP Ohio	Ohio Power Company is a unit of the American Electric Power System and does business as AEP Ohio. It is the surviving entity of the merger with Columbus Southern Power Company. It is the electric utility distributing electricity to portions of Ohio and West Virginia and is the award recipient.
AEP Ohio gridSMART Demonstration Project	One of the sixteen (16) ARRA- funded Smart Grid Demonstration Projects (SGDP) awarded by DOE to AEP Ohio.
CAIDI	The average outage duration that any given customer would experience in a sustained outage. This figure is calculated by dividing the total customer minutes of interruption by the number customers interrupted.
Circuit	The wired power grid infrastructure distributing electricity from an electric utility
Check Read	An on-demand meter reading
Columbus Southern Power (CSP)	Columbus Southern Power is the original award recipient, and was merged out of existence with Ohio Power Company.
Distribution Automation Circuit Reconfiguration (DA-CR)	Automatic circuit configuration for recovery from electric faults.

Word/Phrase	Meaning
Distribution Automation Volt VAR Control (DA-VVC)	Voltage control and optimization where volt-ampere reactive (VAR) is a unit of reactive power in a system.
Direct Load Control (DLC) Event	To respond to a period of high energy demand, the utility sends signals to Home Area Network (HAN) devices in the consumer residence to reduce usage.
Direct Load Control (DLC) Rider	The mechanism by which participation in the DLC program is reimbursed for participation. A credit is applied to the monthly bill.
Double Auction	A process of buying and selling where competitive buyer bids (consumer bids) are matched with competitive seller offers (supply bids). Potential consumers submit their bids for energy based on the smart appliances' needs and the electric utility simultaneously compiles an asking price related to the quantity of energy supplied. The system combines the received consumer bids for energy and compares this cumulative bid curve with the electric utility's cumulative generation and purchase cost curve to determine the market cost for energy to be consumed. The intersection of the cumulative demand bid curve with the energy supply cost curve is the resulting market value or the clearing price of energy for the present time increment. The clearing price is the actual price paid for energy by the consumer but limits and adjustments, such as cost correction factors, may be applied before the clearing price is determined.
eView^{SM}	One of the two Consumer Programs that give visibility of energy use to residential electricity customers.
Feeder	See Circuit
Grid	The wired infrastructure, above and below ground, which distributes electricity from the electric utility to the customer.
gridSMART®	The AEP Registered Trademark for their implementation of smart grid technology.
"Last Gasp" [outage] message	When an AMI meter senses that power has gone out, a capacitor in the meter discharges to send a signal over the communications network prior to itself losing power.
MAIFI	The average number of momentary interruptions that a customer would experience. This is calculated as the total number of customer momentary (<=five minutes) interruptions divided by the total number of customers served.
Ohio Power Company	The unit of the American Electric Power System that distributes and sells electricity in Ohio and West Virginia , the surviving company of the merger with Columbus Southern Power Company. It is also known as AEP Ohio, the name used throughout this report.

Word/Phrase	Meaning
Outage Response Time	In this report, the time between notification by some system (AMI last gasp, customer call, etc.) and when the utility declares an outage and dispatches a crew.
Peak Load	The maximum amount of power used by a customer over a period of time: peak by day, peak by month, peak by season.
Peak Load and Mix	A name given to the analysis of peak load at a point in time and the different sets of customers who contribute to that peak: residential, commercial, and industrial; those on different tariffs; those in different demographics; etc.
Project	AEP Ohio gridSMART Demonstration Project, awarded to Ohio Power Company by U.S. DOE (award number DE-OE0000193).
Project area	The Project area is located in northeast quadrant of Central Ohio.
Rate	The cost of electricity per unit of measure.
Residential Peak Day	The peak load consumed by residential customers over a season: summer, autumn, winter, spring.
Rebate	A credit applied to customers' electricity bill for their participation in certain types of programs.
Rider	A debit applied to customers' electricity bill for their participation in certain types of programs.
SAIDI	The average outage duration that any given customer would experience in a sustained outage. This figure is calculated by dividing the total customer minutes of interruption by the number of customers served.
SAIFI	The average number of sustained interruptions that a customer would experience. This is calculated as the total number of customer sustained (>five minutes) interruptions divided by the total number of customers served.
Selection Bias	A statistical term used to describe a result that may not be truly representative of the answer to a question.
Smart Grid	The set of new technologies being introduced to improve the efficiency, reliability, safety, and environmental impact of electricity consumption.
Smart Grid Demonstration Project	The set of 16 DOE managed, ARRA funded smart grid projects. See www.smartgrid.gov.
SMART Shift^{SM} SMART Shift Plus^{SM} SMART Cooling^{SM} SMART Cooling Plus^{SM} SMART Choice^{SM}	The AEP Ohio branded Consumer Programs covered by this Project. See Table 11.
Smart Meter	A utility meter capable of two-way communication with the utility company.

Word/Phrase	Meaning
System area	The System area is the area served by Columbus Southern Power in 2009; approximately 750,000 electricity customers. This was established at the beginning of the Project. CSP has become Ohio Power Company which is also known as AEP Ohio.
System Peak Day	The peak load of a combination of circuits and feeders that constitute the utility company footprint.
Tariff	A Public Utilities Commission of Ohio (PUCO) approved algorithm for the electricity utility to use in charging and billing customers for the use of electricity. See Rider. See Rate. See Rebate.
Time-of-Day Tariff	A customer tariff where electricity costs a different rate depending on the time of day. Typically electricity during peak load periods is more expensive than during non-peak periods.
Transmission Congestion Cost	The incremental cost to the Transmission utility providing power to a distribution utility caused by peak load events, congestion, imposed on the grid.
Unity	Refers to a power factor of 1.0 that is obtained when current and voltage are in phase.
VAR	Volt-ampere reactive, a component of electricity on the grid.
Volt VAR Control	A type of control applied to a power grid circuit to more efficiently distribute electricity through the grid.

1.2 LIST OF ACRONYMS

Acronym	Definition
6loPAN	Low Power Wireless Personal Area Networks
AC	Alternating Current
ACE	AEP Cost Engine
AEP	American Electric Power
AEPSC	American Electric Power Service Corporation
AES	Advanced Encryption Standard
AMI	Advanced Metering Infrastructure
ANSI	American National Standards Institute
API	Application Programming Interface
ARRA	American Recovery and Reinvestment Act of 2009
BDRS	Battelle Demand Response System
BEV	Battery Electric Vehicle
BIDS	Business Intelligence Development Studio 2008
BMI	Battelle Memorial Institute
CAIDI	Customer Average Interruption Duration Index
CAIFI	Customer Average Interruption Frequency Index
CEMI	Customer Experiencing Multiple Interruption
CEP	Computing Environment Profile

Acronym	Definition
CES	Community Energy Storage
CIM	Common Information Model
CIS	Customer Information System
CKMP	Certificate & Key Management Policy
CMI	Customer Minutes Interrupted
CMMI	Capability Maturity Model Integration
CO_2	Carbon Dioxide
CP	Consumer Programs
CPP	Critical Peak Pricing/Price
CRC	Circuit Reconfiguration Controller
CSP	Columbus Southern Power Company
CSV	Comma Separated Values
CVVC	Coordinated Volt VAR Control
DA	Distribution Automation
DAC	Distribution Automation Controller
DA-CR	Distribution Automation and Circuit Reconfiguration
DA-VVC	Distribution Automation – Volt VAR Control
DBA	Doing Business As
DDC	Distribution Data Center
DEM	Distributed Energy Management
DES	Data Exchange Specification
DLC	Direct Load Control
DMS	Distribution Management System
DNP	Distributed Network Protocol/Disconnection for Nonpayment
DNP3	Distributed Network Protocol 3
DNS	Domain Name Server
DOE	Department of Energy
DOMA	Distribution Operations Model and Analysis
DR	Demand Response
DSA	Digital Signature Algorithm
DSL	Digital Subscriber Line
DW	Data Warehouse
DWMS	Distribution Work Order Management System
ECC	Elliptical Curve Cryptography
EHAN	Enhanced Home Area Network
EI	Enterprise Integration
EMS	Energy Management System
ENMAC™	Energy Management and Control from General Electric
EPA	Environmental Protection Agency
ePCT	Enhanced Programmable Communicating Thermostat
EPRI	Electric Power Research Institute
ES	Electric Storage
ESI	Energy Services Interface
ET	Electric Transportation

Acronym	Definition
ETL	Extract, Transform, and Load
EUMD	End Use Measurement Device
EVDO	Evolution-Data Optimized
EVSE	Electric Vehicle Supply Equipment
F	Fahrenheit
FIPS	Federal Information Processing Standard
FLIR	Fault Location, Isolation, Restoration
FRO	Field Revenue Operations
FTP	File Transfer Protocol
g	Gram(s)
GE	General Electric
GFA	Grid Friendly Appliance™
GIS	Geographical Information System
GQM	Goals, Questions, and Metrics
GridLAB-D	Smart Grid Simulator Utility
GWAC	GridWise® Architecture Council
HAN	Home Area Network
HEM	Home Energy Manager
HOIS	Historical Outage Information System
HTTP	Hypertext Transfer Protocol
ICD	Interface Control Document
ID	Identifier
IDC	Input Data Category
IEC	International Electrotechnical Commission
IENS	Integrated Event Notification System
IG	Internet Gateway
IHD	In-home Display
IL	Interruptible Load
IM	Impact Metrics
IO	Investigative Order
IP	Internet Protocol
IPD	In-Premise Display
IPS	Intrusion Prevention System
IPv6	Internet Protocol version 6
ISO	Independent System Operator
IT	Information Technology
IVVC	Integrated Volt VAR Control
J2EE	Java 2 Platform, Enterprise Edition
JMS	Java Messaging System
JNDI	Java Naming Directory Interface
kg	Kilogram
kVARh	kiloVolt-Amp-reactive-hour
kV	Kilovolt
kW	Kilowatt

Acronym	Definition
LCS	Load Control Switch
LMP	Locational Marginal Price
LMS	Load Management System
MAC	Message Authentication Code
MACSS	Marketing and Customer Service System
MAIFI	Momentary Average Interruption Frequency Index
MBRP	Metrics and Benefits Reporting Plan
MDM	Meter Data Management
MDMS	Meter Data Management System
MFR	Multi-Feeder Reconnection
MRO	Meter Revenue Operations
mW	Milliwatt
MW	Megawatt
MWh	Megawatt Hour
NA, N/A	Not Applicable
NETL	National Energy Technology Laboratory
NIC	Network Interface Card
NIST	National Institute of Standards and Technology
NOC	Network Operations Center
NO_X	Nitrogen Oxides
ODBC	Open Database Connectivity
OLAP	Off-Line Analysis Processing
OlyPen	Olympic Peninsula Project
OMS	Outage Management System
OPKG	Open PacKaGe
OTA	Over the air
PCT	Programmable Communicating Thermostat
PEM	Patrol Enterprise Manager
PEV	Plug-in Electric Vehicle
PFC	Pay for Curtailment
PGP	Pretty Good Privacy
PHEV	Plug-in Hybrid Electric Vehicle
PI	Process Information
PII	Personally Identifiable Information
PJM	Pennsylvania, New Jersey and Maryland RTO
$PM_{2.5}$	Particulate Matter under 2.5 Microns
PNNL	Pacific Northwest National Laboratory
PRIZM	XML Runner based browser
PUCO	Public Utilities Commission of Ohio
RF	Radio Frequency
RFP	Request For Proposal
RI IS	Reverse Invoke, Integration Server
RSA	Rivest-Shamir-Adleman
RTA	Radio Thermostat of America

Acronym	Definition
RTO	Regional Transmission Operator
RTP	Real Time Pricing
RTPda	Real Time Pricing with Double Auction
RTPi	Real Time Pricing Integration Layer
S&C	S&C Electric Company
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SAN	Storage Area Network
SCADA	Supervisory Control and Data Acquisition
SEL	Schweitzer Engineering Laboratories
SEM/SM	Smart Electric Meter/Smart Meter
SEP	Smart Energy Profile
SGD	Smart Grid Dispatch
SME	Subject Matter Expert
SNMP	Simple Network Management Protocol
SO_2	Sulfur Dioxide
SOAP	Simple Object Access Protocol
SOPO	Statement of Project Objectives
SO_X	Sulfur Oxides
SQL	Structured Query Language
SRD	Software Requirements Document
SSIS	SQL Server Integration Services
SSL	Secure Sockets Layer
SSN	Silver Spring Networks
TBD	To Be Determined
TCP/IP	Transmission Control Protocol/Internet Protocol
TLS	Transport Layer Security
TOD	Time-of-Day
TOD/CPP	Time-of-Day with Critical Peak Price
TPR	Technology Performance Report
UIQ	Utility IQ
URL	Uniform Resource Locator
UTF	Unicode Transformation Format
V	Volt (SI derived unit for electric potential)
VAR	Volt-Ampere Reactive
VM	Virtual Machine
VOT	Virtual Operations Test
VPN	Virtual Private Network
VVC	Volt VAR Control
VVO	Volt VAR Optimization (same as Volt VAR control)
Wi-Fi	Wireless
WPA	Wi-Fi Protected Access
XML	Extensible Markup Language
XSD	XML Schema Definition

Acronym	Definition
ZCL	ZigBee Cluster Library
ZigBee SEP	ZigBee Smart Energy Profile

1.3 References

Table 1 provides a list of references cited in this report. Supporting appendices appear at the end of the document.

No.	Document	Date
1	AEP Ohio gridSMART Demonstration Project Metrics and Benefits Reporting Plan	October 13, 2010
2	Instructions For Preparation of Deliverables for Cooperative Agreements Under the Smart Grid Demonstration Program	April 27, 2010
3	Smart Grid Demonstration Program Guidance for Technology Performance Reports	June 17, 2011
4	Guidebook for ARRA Smart Grid Program Metrics and Benefits—Smart Grid Demonstration Project	June, 2010
5	AEP Ohio gridSMART Demonstration Project Management Plan (Revision 1)	June 25, 2010
6	AEP Ohio gridSMART Demonstration Project Quarterly Build Metrics Report	January 31, 2013
7	AEP 2011 Fact Book	November 8, 2011

Table 1. List of Document References

1.4 Contacts

Table 2 provides a list of contacts for the Project.

Name	Role	Telephone
Paula Igo	AEP Ohio—gridSMART Project Manager	614-883-7895
Karen Sloneker	AEP Ohio—Director, Customer Service and Marketing	614-883-6677
Scott Osterholt	AEP Ohio—gridSMART Project Lead	614-883-6872
Rick Gampp	AEP Ohio—gridSMART Project Comptroller	614-883-6771
Frank Jakob	Battelle—Project Manager	614-424-4130

Table 2. List of Contacts

2 AEP OHIO DEMONSTRATION

Ohio Power Company is a unit of the American Electric Power System ("AEP"), one of the largest electric utilities in the country. AEP Ohio was selected for the demonstration area because its service area reflects the region and much of the nation in terms of demographic and economic strata, energy consumption patterns, distribution infrastructure, and climate characteristics.

The AEP Ohio territory allows for small-scale and controlled testing of various new technologies and consumer programs in such an environment. The Project intends to integrate these technologies and programs, which include utility-operating distribution system improvements, consumer-managed technology, two-way communications technology, demand management and dispatch technology, and utility-to-customer interfaces.

2.1 AREA

AEP Ohio's infrastructure includes generation, transmission, and distribution assets throughout the state of Ohio and a portion of northern West Virginia, as shown in Figure 1. Table 3 provides estimates for the entire AEP Ohio territory's customer, distribution, transmission, generation, and asset attributes.

Customers	
Customers	1.5 million
Communities	890
Counties	61
Distribution	
Distribution Lines	47,000 miles
Transmission	
Transmission Lines	9,200 miles
Generation	
Total Capacity	11,736 MW
Assets	
Total	**$8.3 billion**

Table 3. AEP Ohio Territory Attribute Estimates

Figure 1. AEP Ohio Territory

The Project is located within northeast central Ohio and in the territory formerly Columbus Southern Power Company (CSP). This area demonstrates ideal characteristics for implementation and evaluation of grid-enhancing technology. It includes a significant number of 13 kV and 34.5 kV circuits; has distribution stations; includes diverse customer income levels; has a good blend of industrial, commercial, and residential accounts; and receives a large number of customer service orders.

In this report, the term "System area" refers to former CSP's entire territory, as shown in Figure 2. The term "Project area" refers to the area where Project assets, functionality, or programs are implemented, as shown in Figure 3.

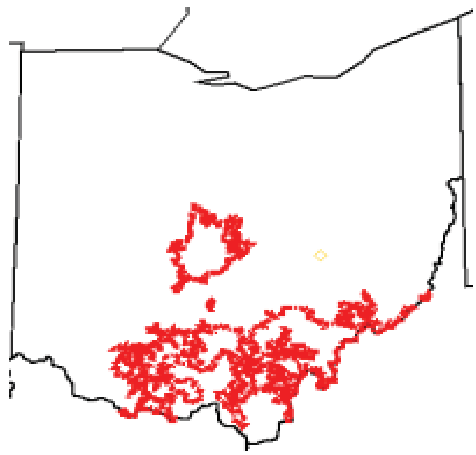


Figure 2. CSP Territory

Figure 3. Project Area Scope

Table 4 summarizes the high-level characteristics of both the System and Project areas discussed in this report.

Metric	System Area (2009)	Project Area
Total number of customers:		
Residential	667,018	100,000
Commercial	81, 866	10,000
Industrial		
Peak load:		
Summer	4,209 MW	800 MW

Metric	System Area (2009)	Project Area
Winter	3,934 MW	650 MW
Total MWh sales:	**20,623,813 MWh**	**3,500,000 MWh**
Residential	7,303,192 MWh	1,200,000 MWh
Commercial	13,320,621MWh	1,000,000 MWh
Industrial		
Total number of substations	136	16
Total number of distribution feeders	673	80
Total miles of distribution line	18,876 miles	3,000 miles
Total miles of transmission line	2,274 miles	0 miles

Table 4. AEP Ohio's gridSMART System and Project Areas

2.2 Technologies

The Project introduced multiple technology enhancements to the infrastructure of the AEP Ohio Project area, including:

- **Advanced Metering Infrastructure** (**AMI**) – Two-way communication enabled meters
- **Home Area Network** (**HAN**) – Enhanced communication capability
- **Distribution Automation Volt VAR Control (DA-VVC)** – Voltage control and optimization
- **Distribution Automation Circuit Reconfiguration (DA-CR)** – Automation of distribution assets.

The addition of the above technologies served as the foundation to enable two-way communication with customers and allowed for consumer programs and products, such as plug-in electric vehicles and smart appliances. The introduction of these technologies also required comprehensive cyber security and interoperability capabilities for both new and legacy systems.

Explanations of each technology and the extent of their functionality will be outlined within the Demonstrated Technologies sections of this report.

2.3 Benefits

Each technology, or combination of technologies, is expected to produce a benefit to either the utility and/or electric consumers. Table 5 summarizes some of the anticipated benefits of these technologies.

Benefit Category	Benefit	Technologies
Economic	Reduced meter operations costs – meter reading routes	AMI
Economic	Reduced meter operations costs – avoided truck rolls	AMI, DA-CR
Economic	Reduced electricity costs to consumers	CP, DA-VVC

Benefit Category	Benefit	Technologies
Economic	Reduced peak load	CP, DA-VVC
Reliability	Improved outage response time	AMI, DA-CR
Reliability	Increased number of meters reporting daily	AMI
Reliability	Increased distribution system reliability	DA-CR
Environmental	Reduced number of truck rolls	AMI, DA-CR
Environmental	Reduced meter operations vehicle miles	AMI, DA-CR
Environmental	Reduced CO_2 emissions	AMI, CP, DA-VVC
Environmental	Reduced pollutant emissions	AMI, CP, DA-VVC

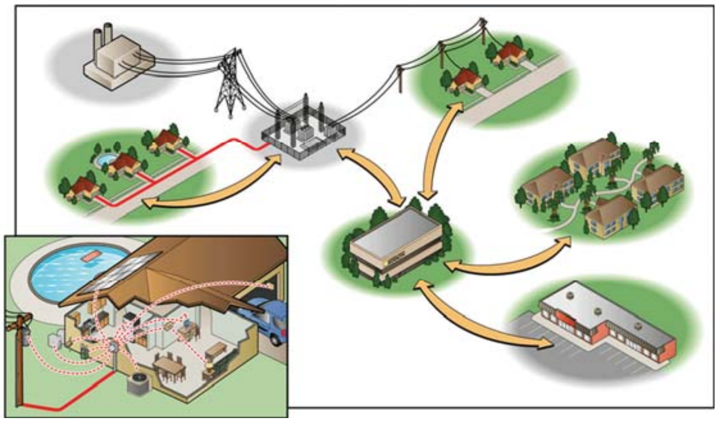
Table 5. Expected Benefits of Technologies

2.4 PLAN/SCHEDULE

AEP Ohio began installing smart grid technologies in the Project area in 2009. Complete schedules for planning, deployment and operation of the Project are provided in AEP Ohio's gridSMART Project Management Plan [Ref. 5]. Detailed schedules regarding metrics and benefits reporting are provided in the Metrics and Benefits Report Plan [Ref 1].

3 TECHNICAL APPROACH

Adopting smart grid technology and integrating it with an aging infrastructure poses many challenges and uncertainty about its performance and benefits. The electrical grid is dynamic in design and when the mechanics, weather, people and systems involved are added, its complexity increases two-fold.



Components of this smart grid technology add functionality to communicate and respond with utility customers effectively from remote locations, even further modernizing capability and information at the premise level. As with the addition of any new technology with enhanced capability, installation, testing, monitoring and evaluating, and adjusting are necessary to ensure learning, growth and effectiveness.

Figure 4. Smart Technology Integration

3.1 EXPERIMENTAL DESIGN

AEP Ohio developed an innovative approach to maximize the amount of information obtainable from the Project. This approach included an experimental design consisting of a careful, multi-level segmentation of the demonstration grid and participants, as discussed in Section 2.1 of the Project Management Plan, DE-OE0000193 [Ref. 5]. The initial design produced more than 100 unique combinations of consumer engagement, distribution configuration, and smart grid technologies for analysis, enabling a deeper understanding of consumer behavior and grid performance. Additionally, use of appropriate controls, filters, and statistics, provides a greater understanding of the interaction of the various components and behaviors involved in electricity usage. This understanding is critical to capturing lessons learned, evaluating different business models, and developing best practices for deployment of smart grid technologies at the regional and national levels.

3.2 DATA COLLECTION AND STORAGE

The introduction of multiple new technologies and its accompanying volume of data into AEP Ohio's territory warranted a single repository for the collection and analysis of data. This process included combining legacy systems with new systems, adding and updating integrations, and challenging the architecture of these legacy systems, as shown in Figure 5.

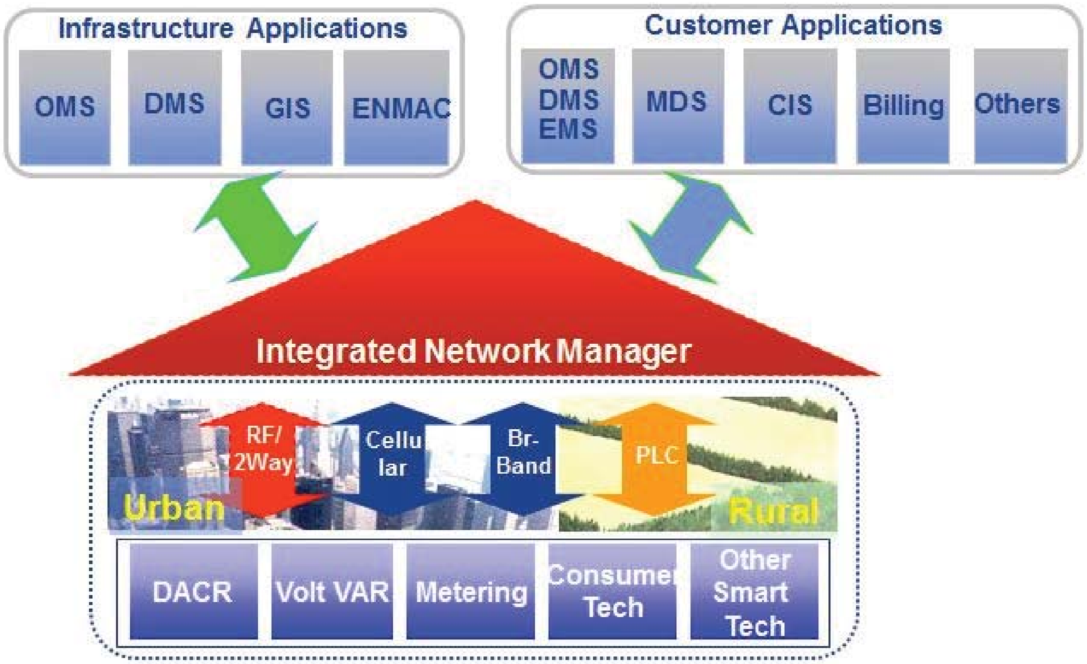


Figure 5. System Integration

A Data Warehouse (DW) was built to collect relevant data necessary to analyze the new technology and quantify overall impacts, all while adjusting necessary data points as the technology and understanding of the technology evolved over the course of the Project. A System Requirements Document (SRD) was created to identify and organize data points for collection and analysis. Because of the magnitude of data, multiple iterations were necessary in data identification and collection to gauge and adjust as technology evolved to make tactical and strategic decisions involving smart grid technologies.

3.3 Data Analysis

AEP Ohio utilized impact metrics from the Metrics and Benefits Reporting Plan (MBRP) as the foundational basis for analysis and added the analysis of several other technologies (not mentioned in the MBRP, e.g. Smart Appliances) to provide the DOE and other stakeholders a holistic understanding of impacts, benefits and challenges experienced within the Project. An analytical front was added to the DW to aid in the collection and presentation of data for interpretation.

3.4 Impact Metrics

Below is a listing of impact metrics identified within the MBRP and an outline of impacts that cross reference amongst multiple technologies. This format is referenced throughout this report to provide both analytical details and high-level conclusions to all technology areas.

Impact Metric Cross Reference

ID	Scope	Description	Applicable to			
			AMI	CP	DA-CR	DA-VVC
MBRP impact metrics for AMI and Consumer Programs						
M01	Project	Hourly Customer Electricity Usage		☐		
M02	Project	Monthly Customer Electricity Usage		☐		
M03	Project	Peak Load and Mix		☐		☐
M04	Project	Meter Operations Cost	☐			
M05	Project	Truck Rolls Avoided	☐			
M06	Project	Meter Operations Vehicle Miles	☐			
M07	Project	CO_2 Emissions	☐	☐		
M08	Project	Pollutant Emissions (SO_X, NO_X, $PM_{2.5}$)	☐	☐		
M09	System	CO_2 Emissions	☐	☐		
M10	System	Pollutant Emissions (SO_X, NO_X, $PM_{2.5}$)	☐	☐		
M11	Project	Meter Data Completeness	☐			
M12	Project	Meters Reporting Daily	☐			
MBRP impact metrics for Distribution Automation						
M13	Project	Distribution Feeder Load			☐	☐
M14	Project	Distribution Feeder/ Equipment Overload			☐	
M15	Project	Deferred Distribution Capacity Investments			☐	☐
M16	Project	Equipment Failure Incidents			☐	☐
M17	Project	Distribution Equipment Maintenance Cost			☐	☐
M18	Project	Distribution Operations Cost			☐	
M19	Project	Distribution Feeder Switching Operations			☐	
M20	Project	Distribution Capacitor Switching Operations				☐
M21	Project	Distribution Restoration Cost			☐	
M22	Project	Distribution Losses (%)				☐
M23	Project	Distribution Power Factor				☐
M24	System	Reduced Transmission Congestion Cost	**Data Unavailable**			
M25	Project	Truck Rolls Avoided			☐	
M26	Project	SAIFI			☐	
M27	Project	SAIDI/CAIDI			☐	
M28	Project	MAIFI			☐	
M29	Project	Outage Response Time	☐		☐	
M30	Project	Major Event Information			☐	
M31	Project	Distribution Operations Vehicle Miles			☐	
M32	Project	CO_2 Emissions			☐	☐
M33	Project	Pollutant Emissions (SO_X, NO_X, $PM_{2.5}$)			☐	☐
M34	System	CO_2 Emissions			☐	☐
M35	System	Pollutant Emissions (SO_X, NO_X, $PM_{2.5}$)			☐	☐
MBRP impact metrics for CES; *CES has been suspended*						

Table 6. Project Impact Metrics

4 DEMONSTRATED TECHNOLOGIES – ADVANCED METERING INFRASTRUCTURE

4.1 PURPOSE

Prior to the Project, AEP Ohio operated largely with electromechanical meters that registered usage and readings at the customer premise and required that meter readers physically review and collect meter data. While a few other meter types exist in the Project area, there were no AMI meters. AMI meters enable two-way communication between AEP Ohio and the customer premise with the ability to provide detailed, near real-time information using network capability and interact with other external devices controlled by the customer. AEP Ohio's demonstration of these meters is intended to:

- Prove that the Silver Spring Networks technology would function properly in urban, suburban, and rural applications;
- Show efficiencies associated with automated meter reading on a large-scale basis, including real-time meter reading and daily meter reads;
- Demonstrate the effect of AMI meters on meter operations costs;
- Demonstrate remote reconnect/disconnect capabilities, along with advantages and disadvantages of the program;
- Leverage the two-way communication between meters in the field and the network and back office;
- Study the demographic groups, including multi-unit, residential, commercial, and industrial, with a complete mixture of socioeconomic classes, and their response to different aspects of the AMI meters;
- Determine the amount of data generated by the AMI meters and how to best utilize the information, including meter alarms and alerts, power quality information, energy usage and outage/restoration notification;
- Enable the use of two-way Home Area Networks (HAN) in the overall energy efficiency and demand response programs;
- Exhibit the benefits of receiving real-time information from different operational areas, such as billing, customer service, engineering, dispatch, meter reading, credit, etc.; and
- Reduce or shift electricity demand and consumption through consumer programs.

4.2 TECHNOLOGY

AEP Ohio elected to deploy 110,000 General Electric kV2c and I210+c model meters, including 4-channel recording capability, voltage detection, and ZigBee communication in the Project area. These meters include two-way communication abilities and utilize a Radio Frequency (RF) mesh network with wireless carrier backhaul communications. In addition to the meters, the network includes a network interface card for each meter, relays, access points, and eBridges. The single-phase residential and commercial meters also included a remote connect/disconnect switch. In addition to standard meter functions, AEP Ohio utilized the AMI system for remote connect/disconnect capabilities, outage reporting, interval data collection, calculation of bill determinants (kWh, kW, kVArh, on-peak, off-peak), power quality monitoring, and consumer programs facilitation.

AMI Asset Summary
• 100,000 residential meters
• 10,000 non-residential meters
• 31 access points
• 133 relays

Table 7. AMI Asset Summary

Refer to the AEP Ohio Quarterly Build Metrics Report [Ref. 6] for an up-to-date status report on AEP Ohio's deployment of AMI system assets.

The meter infrastructure interfaces with back-office systems to collect, measure, and manage meter, customer, and utility activities. The meter infrastructure includes the following integrations:

- Utility IQ software (UIQ)
- Silver Spring Networks (SSN)
- Marketing and Customer Service System (MACSS) for customer-associated data management
- Meter Data Management (MDM)
- Distribution Management System (DMS).

Figure 6 illustrates the AMI system implementation within AEP Ohio.

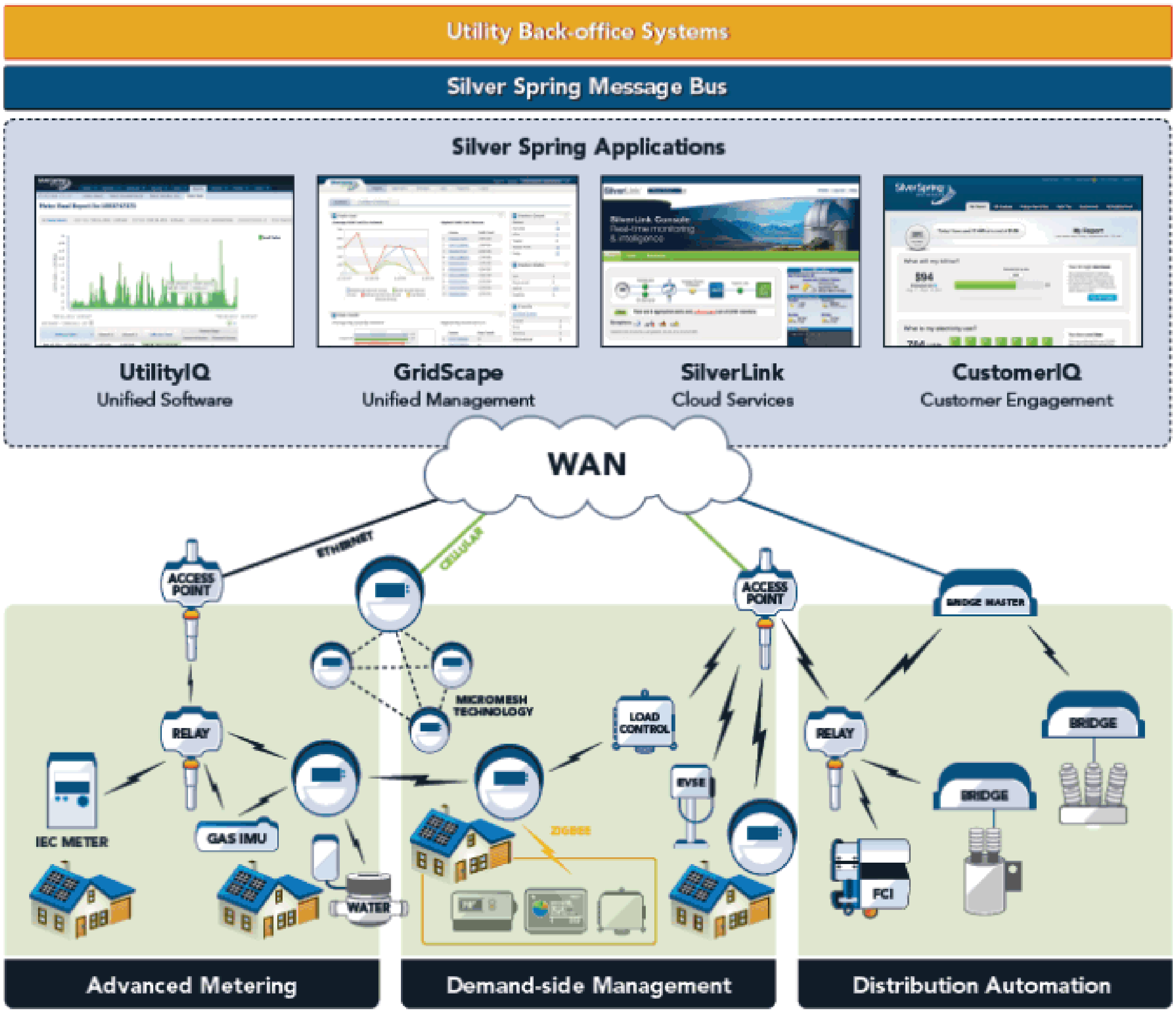


Figure 6. AMI System Illustration

4.3 IMPLEMENTATION & APPROACH

When initially selecting the area in which AMI meters would be installed, AEP Ohio made a conscious decision to install the meters in an area of Central Ohio that had one of the highest delinquency rates. The intention was to leverage this technology to reduce truck rolls required to perform disconnections for non-payment (DNP), and subsequent reconnections. However, additional savings could be realized if the current Public Utilities Commission of Ohio (PUCO) requirement for physical notification prior to DNP was reversed. This will be discussed in the Impact Metric Details section.

The installation of the meters was dependent on the completion of the supporting network. Before AEP Ohio could begin installing AMI meters, the installation of the access points and relays for the meters had to be completed. In addition, meter blackout dates influenced the installation schedule.

To install the meters as quickly as possible, AEP Ohio retained contract resources to install the wireless network and all single-phase meters. AEP Ohio employees installed all poly-phase and instrument-rated meters while contractors were completing the single-phase installations.

As installations were completed, a parallel reading period ensued. The manual reads were compared with the over-the-air reads to ensure that the meter was installed at the correct premise and that the meter was reading with 100% accuracy. Meter installations were complete by April 1, 2010. AEP Ohio found these meters to be accurate in their “out-of-box” state, and no major manual intervention was required. As a result, the parallel reading process ended before July 1, 2010.

4.4 Presumed Benefits

The introduction of AMI technology has the potential to impact the electrical grid and operations of the grid. Theoretical impacts of AMI technology include some level of benefit to the utility, customers and society as a whole. The proceeding sections describe foreseeable AMI benefits to the economy, reliability of our nation's grid and the environment.

4.4.1 Economic Benefits

Economic benefits are anticipated by the installation and use of AMI meters in several ways. First, two-way communication meters no longer require individual meter readers to walk routes and manually collect meter readings. This can now be conducted by back-office personnel. Savings can be obtained through the elimination of both labor associated to manual meter reading and vehicles driven to reach these meter reading routes. The two-way flow of information between the meter and the back office allow the utility to troubleshoot meter issues remotely, minimizing truck rolls to individual premises. The added functionality and insight provided by AMI meters, such as connect, disconnects, meter theft, and check reads, are anticipated to result in a net savings to operation costs. In addition, the utility can expect to see a reduction in credit collection activities as a result of timely meter readings and operations.

4.4.2 Reliability Benefits

AMI enhanced communication abilities, such as near real-time data flow, provides the utility the opportunity to react to meter data that did not exist with electromechanical meters of the past. This messaging provides the utility the opportunity to leverage meter information to enhance system reliability by receiving and responding to outage, tampering, or voltage notifications sooner than customer notification.

4.4.3 Environmental Benefits

As described above, two-way communication from AMI meters has the potential to reduce the amount of traveling to customer premises. Fewer company trucks in operation can result in less fuel burned and less pollutants released into the atmosphere. While AMI meters alone did not directly affect demand, their functionality allows for the introduction of consumer programs and other technologies that can result in reduced demand. This level of demand reduction may result in a reduction in environmental pollutants from generation facilities.

In an effort to evaluate economic, reliability and environmental impacts by AMI metering, AEP Ohio provides detailed analysis of MBRP impact metrics provided by the DOE.

4.5 MBRP Impact Metric Details (AMI)

Of the 43 total impact metrics enumerated in the MBRP for the Project, the ten impact metrics shown in Table 8 are associated with the AMI suite of technologies; eight relate to the Project area and two relate to the System area.

Metric ID	Metric Scope	Metric Description	AMI
M04	Project	Meter Operations Cost	M04-AMI
M05	Project	Truck Rolls Avoided	M05-AMI
M06	Project	Meter Operations Vehicle Miles	M06-AMI
M07	Project	CO_2 Emissions	M07-AMI
M08	Project	Pollutant Emissions (SO_X, NO_X, $PM_{2.5}$)	M08-AMI
M09	System	CO_2 Emissions	M09-AMI
M10	System	Pollutant Emissions (SO_X, NO_X, $PM_{2.5}$)	M10-AMI
M11	Project	Meter Data Completeness	M11-AMI
M12	Project	Meters Reporting Daily	M12-AMI
M29	Project	Outage Response Time	M29-AMI

Table 8. Impact Metrics Addressing AMI Technology Performance

4.5.1 Meter Operations Cost (M04-AMI)

4.5.1.1 Objective

The purpose of this metric is to understand the impact of AMI on the overall cost of AEP Ohio's meter operations. This metric analyzes presumed savings, incremental and ongoing, achieved due to avoiding customer service truck rolls, eliminating meter reading routes, and reducing meter theft. Also included are the increased costs associated with equipment failure, software licensing, and network maintenance in order to calculate a net savings value.

4.5.1.2 Organization of Results

The following sections describe the total net-dollar savings due to AMI from the following sources. The first two sources are provided in this Interim report. All will be provided in the Final Report.

- Service-related truck rolls avoided

  This section contains monthly graphs showing savings and additional costs incurred for both vehicle and labor costs. Graphs are then presented for net-labor savings and net vehicle savings. Finally, a graph is presented showing the total dollar value of monthly savings due to truck rolls avoided.

- Elimination of meter reading routes

  This section contains the analysis of savings due to the elimination of meter reading routes by reading meters remotely through the AMI network.

- Reduction in meter theft

  This section contains the analysis of the difference in meter theft rates between AMI and non-AMI meters. This will be provided in the Final Report.

- Changes in meter failure rate

This section contains the analysis of the difference in meter failure rates between AMI and non-AMI meters. This will be provided in the Final Report.

- Software and network maintenance costs

  This section contains the analysis of the ongoing maintenance costs associated with operating the AMI network. This will be provided in the Final Report.

4.5.1.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

- AEP Ohio meter readers typically read one route per day, so for calculation purposes, it is assumed that eliminating a route equals 8 hours of labor.
- Cost reduction was determined based on conversion factors for vehicle and labor rates.

4.5.1.4 Results of Data Collected to Date

Subsection 1 shows savings results related to customer service-related truck rolls. This section contains nine figures.

Subsection 2 shows results for eliminated meter routes.

Results for Customer Service Related Truck Rolls Avoided:

The average monthly net savings due to customer service truck rolls avoided during 2012 was $33,900, with an annual total of $407,000. The population of meters was approximately 132,000 meters. The average savings is $3.08/meter/month.

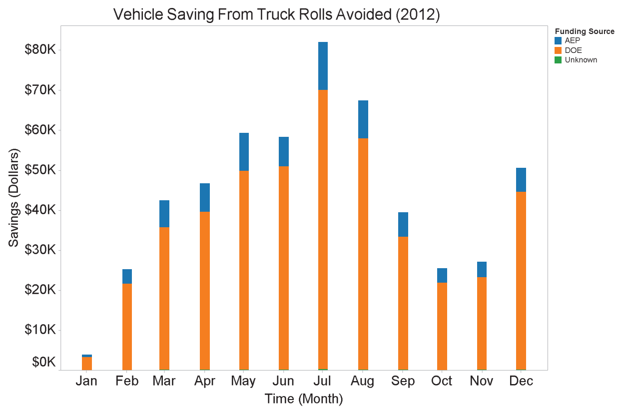


Figure 7. Savings from reduced vehicle costs

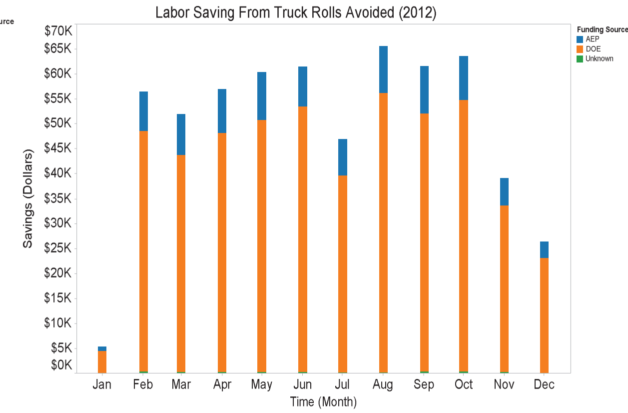


Figure 8. Savings from reduced labor costs

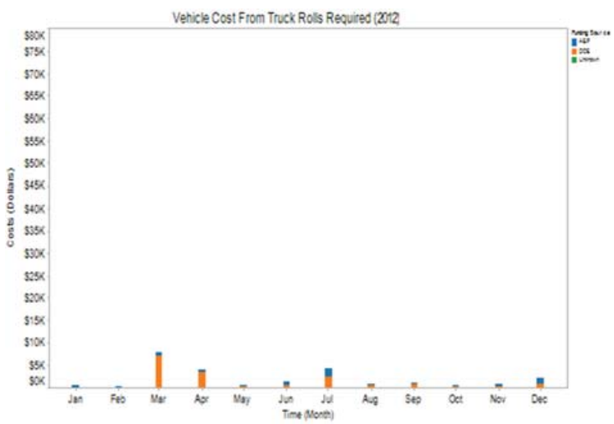


Figure 9. Additional vehicle costs due to AMI

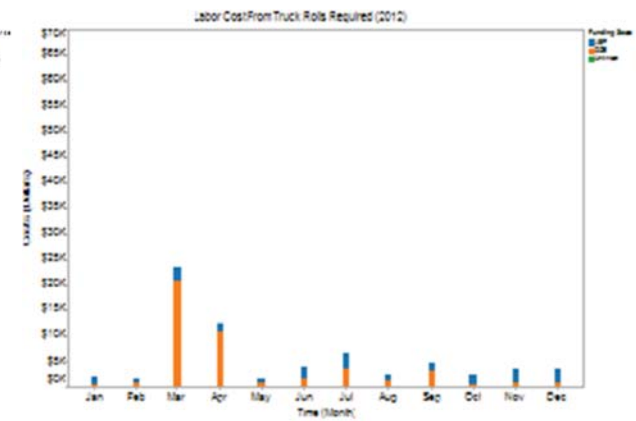


Figure 10. Additional labor costs due to AMI

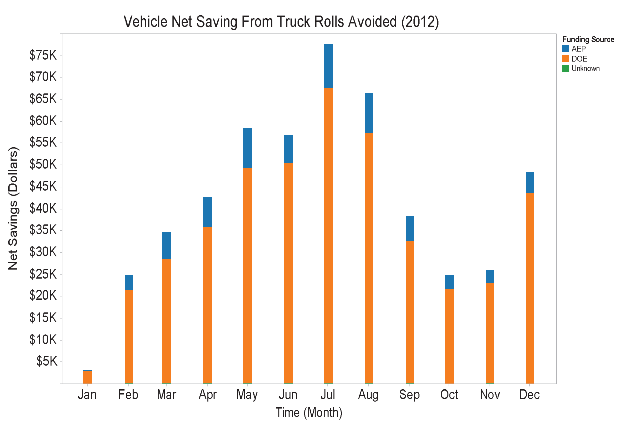


Figure 11. Net vehicle savings due to truck rolls avoided

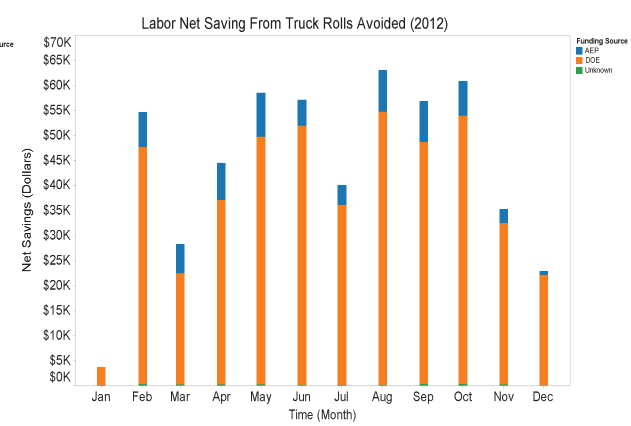


Figure 12. Net labor savings due to truck rolls avoided

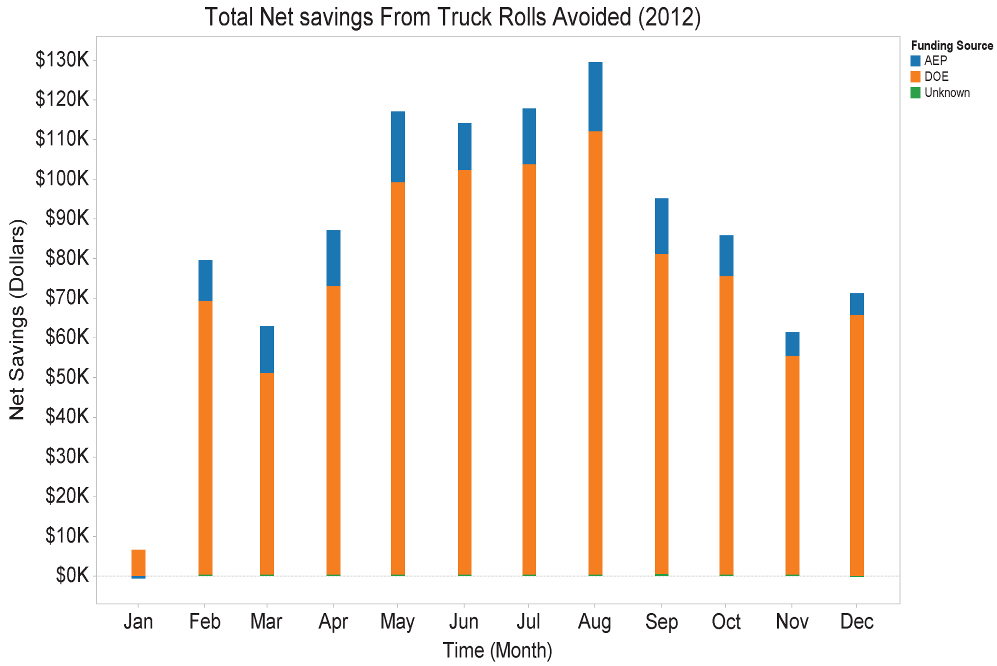


Figure 13. Total net savings associated with AMI service truck rolls avoided

Results for Eliminated Meter Reading Routes:

Prior to the installation of AMI meters, AEP Ohio had 994 meter reading routes in the Columbus metropolitan area. Through the use of AMI, AEP Ohio was able to eliminate 187 meter reading routes in the Project area. AEP Ohio meter readers typically read one route per day, so for calculation purposes, it is assumed that eliminating a route equals 8 hours of labor. On average, AEP Ohio reads 87 percent of the meter reading routes each month in the Columbus area. As a result of installing AMI and eliminating 187 meter reading routes, AEP Ohio has saved 1,301.5 hours in labor and eliminated 10 meter reading positions.

Table 9 outlines the savings due to the elimination of meter reading routes.

Item	Hourly Cost	Total Hours	Total Savings
Meter Reader Salary (2012) - loaded	21.45	1,301.50	$27,917
Vehicle Operations (2012)	7.50	1,301.50	$9,761
Grand Total – Monthly			$ 37,676
Grand Total – Yearly			**$452,112**

Table 9. Meter Reading Route Elimination Savings

For the Final Report, a forecast will be provided for the projected savings if the technology were expanded to the entire System area.

Calculation Approach

Certain types of customer events, such as check read requests, can be handled remotely by the use of the AMI system, thereby avoiding a truck roll. A list was compiled of all customer event order types that lead to an avoided truck roll. The number of truck rolls avoided due to AMI was then calculated based on the number of customer events with matching order type codes.

Average mileage per truck roll was calculated by month for each AEP Ohio service center in the Project and System areas. These average mileage values were applied to the count of truck rolls avoided to calculate mileage avoided due to AMI.

The following queries and methods were used to generate presentation items:

- Labor savings from AMI truck rolls avoided per service center, month, and meter funding source were calculated by multiplying the number of truck rolls avoided by [CF-AEP-01] $20 per truck roll.
- Vehicle savings from AMI truck rolls avoided per service center, month, and meter funding source were calculated by multiplying the number of truck rolls avoided by the average vehicle cost per work order completed by each service center and month.
- Labor costs from AMI truck rolls required per service center, month, and meter funding source were calculated by multiplying the number of truck rolls required by [CF-AEP-02] $50 per truck roll.
- Vehicle costs from AMI truck rolls required per service center, month, and meter funding source were calculated by multiplying the number of truck rolls required by the average vehicle cost per work order completed by each service center and month.

4.5.2 Truck Rolls Avoided (M05-AMI)

4.5.2.1 Objective

The AMI system has the potential to reduce the number of truck rolls required by meter operations through the elimination of meter reading routes and the ability to remotely perform services such as check reads, connections, and disconnections. This impact metric quantifies the number of truck rolls avoided and/or added due to features of AMI technology. This metric also takes into account the number of truck rolls added due to increased information such as tamper detection provided by the AMI meters.

4.5.2.2 Organization of Results

The following section describes the number of truck rolls avoided due to AMI from the following sources:

- Service-related truck rolls avoided

  This section contains monthly graphs showing the number of truck rolls avoided, as well as the number of new truck rolls required due to AMI. A final graph is then presented showing the net number of truck rolls avoided.

- Elimination of meter reading routes

  This section contains analysis of savings due to the elimination of meter reading routes by reading meters remotely through the AMI network.

4.5.2.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

- Disconnections for non-payment are not included in this analysis because AEP Ohio is required by the PUCO to send a representative to the customer premise prior to disconnection.

4.5.2.4 Results of Data Collected to Date

Subsection 1 shows savings results related to customer service-related truck rolls. This section contains nine figures.

Subsection 2 shows results for eliminated meter reading routes.

Results for Service Related Truck Rolls Avoided:

The average monthly net count of truck rolls avoided during 2012 was 2,366 truck rolls/month. The annual total of this would be 28,392 net truck rolls avoided.

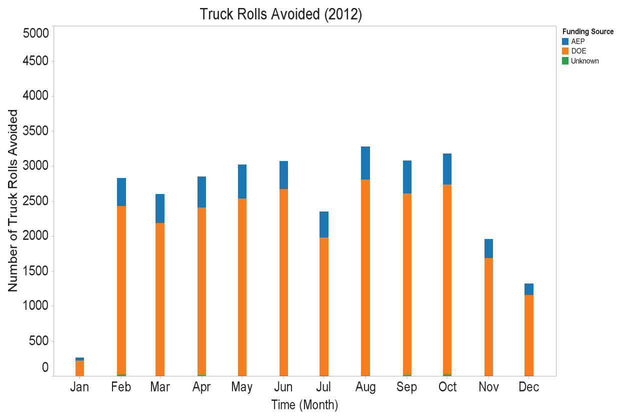


Figure 14. Truck rolls avoided due to AMI

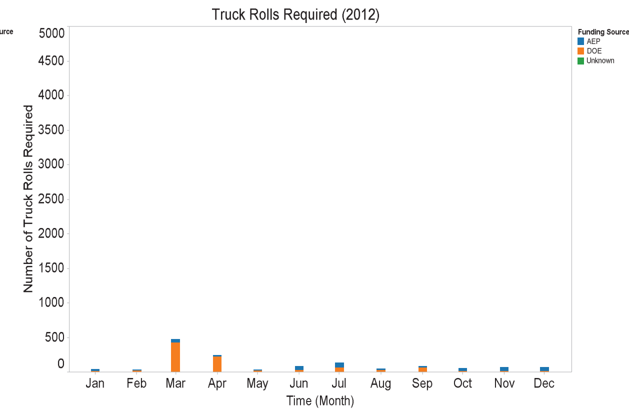


Figure 15. Additional truck rolls required due to AMI

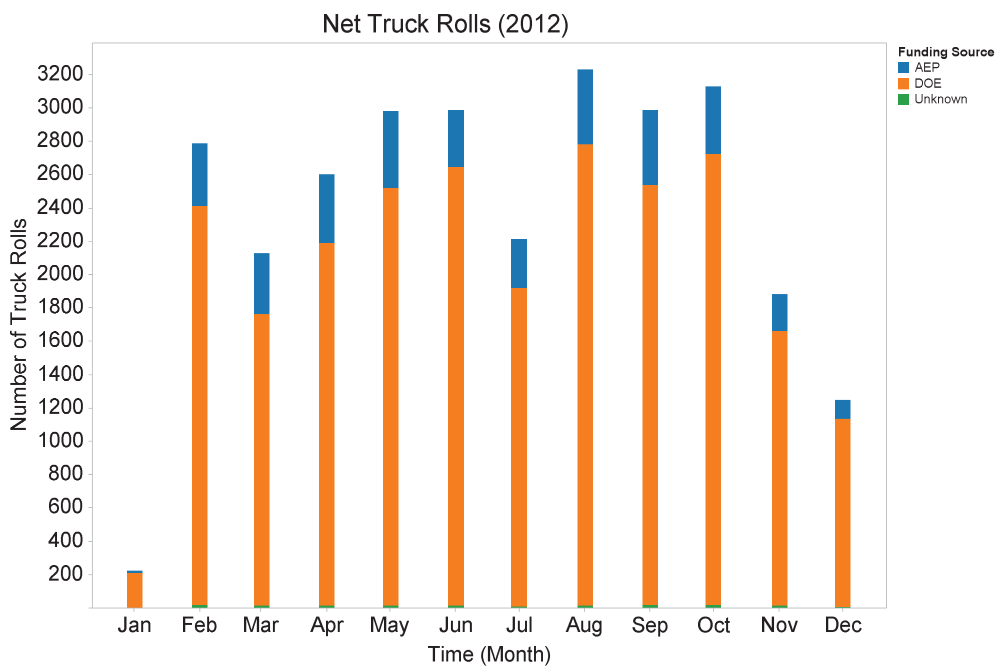


Figure 16. Net truck rolls avoided due to AMI

Results for Eliminated Meter Reading Routes:

Prior to the installation of AMI meters, AEP Ohio had 994 meter reading routes in the Columbus metropolitan area. Through the use of AMI, AEP Ohio was able to eliminate 187 meter reading routes in the Project area. On average, AEP Ohio reads 87 percent of the meter reading routes each month in the Columbus area. This results in 163 avoided truck rolls per month, or 1,952 truck rolls avoided per year.

Due to the reporting location for meter readers in proximity of the Project area, the average meter reader travels 35 miles per route. Therefore, meter reading truck rolls avoided represent a much larger mileage savings compared with meter service-related truck rolls.

Calculation Approach

Certain types of customer events, such as check read requests, can be handled remotely by the use of the AMI system thereby avoiding a truck roll. A list was compiled of all customer event order types that led to an avoided truck roll. The number of truck rolls avoided due to AMI was then calculated based on the number of customer events with matching order type codes.

The following queries and methods used to generate presentation items:

- AMI truck rolls avoided per service center, month, and meter funding source were calculated by multiplying the ratio of miles for a circuit in a service center to total miles for a circuit multiplied by the number of customer events for customers with AMI meters where the order type that generated the customer event was any order type except "Excess use on an inactive account" and the meter response to a meter request was something other than "Error" and the customer event type was one of the following:

  •Connect Request
  •Disconnect Request
  •Estimated Bill Complaint
  •High Bill Complaint
- AMI truck rolls required per service center, month, and meter funding source were calculated by adding the number of truck rolls required from meter events for AMI meters where the event type was "Tamper" to the number of meter requests for AMI meters where the order type for the meter request was "Read/Solve Access".
- AMI net truck rolls per service center, month, and meter funding source were calculated subtracting the AMI truck rolls required from the AMI truck rolls avoided.

4.5.3 Meter Operations Vehicle Miles (M06-AMI)

4.5.3.1 Objective

The AMI system has the potential to reduce the number of truck rolls required by AEP Ohio meter operations staff through the elimination of meter reading routes and the ability to remotely perform services such as meter reading, connection, and disconnection. This impact metric provides an estimate of the number of vehicle miles avoided and/or added due to changes resulting from AMI technology.

4.5.3.2 Organization of Results

The following section describes the number of vehicle miles avoided due to AMI from the following sources:

- Service-related truck rolls avoided

  This section contains monthly graphs showing the number of vehicle miles avoided due to the net number of truck rolls avoided.

- Elimination of meter reading routes

  This section contains analysis of vehicle miles avoided due to the elimination of meter reading routes by reading meters remotely through the AMI network.

4.5.3.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

4.5.3.4 Results of Data Collected to Date

Subsection 1 shows savings results related to customer service-related truck rolls. This section contains three figures.

Subsection 2 shows results for eliminated meter routes.

Results for Customer Service-Related Truck Rolls Avoided:

The average monthly net mileage avoided during 2012 was 11,066 miles/month. The annual total of this would be 132,792 miles avoided.

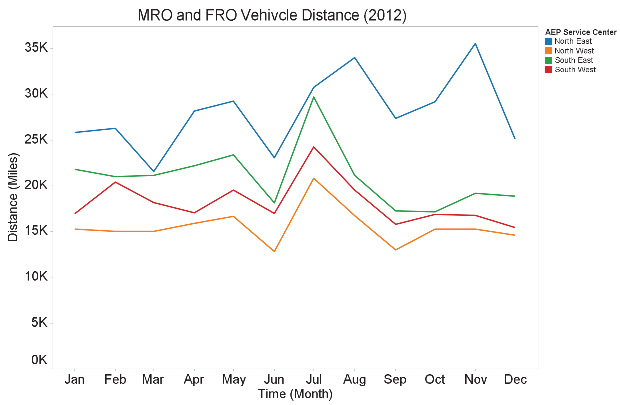


Figure 17. Total vehicle distance by service center

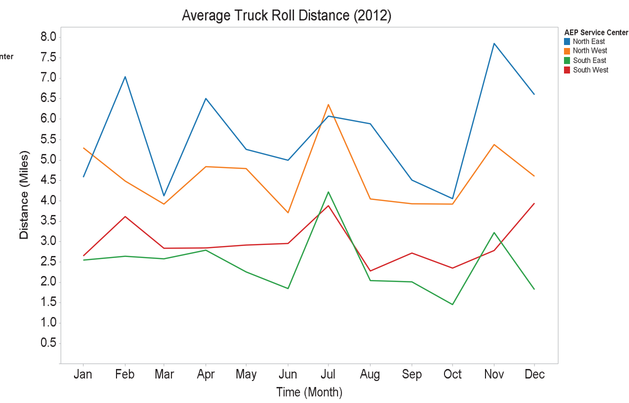


Figure 18. Average truck roll distance by service center

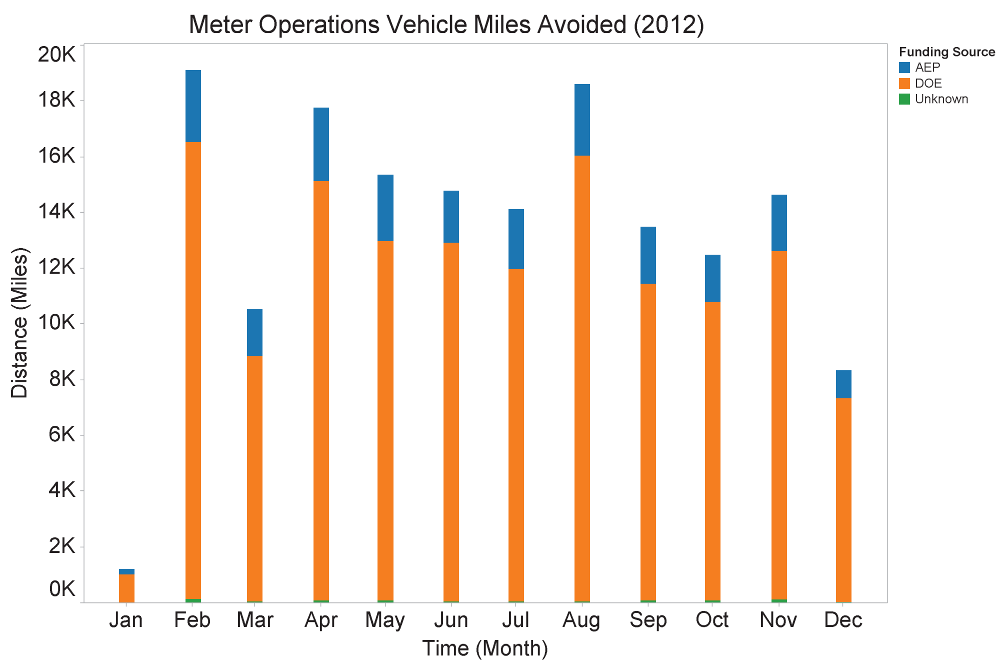


Figure 19. Net mileage avoided due to AMI

Results for Eliminated Meter Reading Routes:

Through the use of AMI, AEP Ohio was able to eliminate 187 meter reading routes in the Project area. AEP Ohio reads on average 87 percent of the meter reading routes each month, and the average meter route is 35 miles long. This results in a vehicle mileage avoidance of 5,694 miles/month or 68,328 miles per year.

Calculation Approach

Certain types of customer events, such as check read requests, can be handled remotely by the use of the AMI system, thereby avoiding a truck roll. A list was compiled of all customer event order types that led to an avoided truck roll. The number of truck rolls avoided due to AMI was then calculated based on the number of customer events with matching order type codes.

Average mileage per truck roll was calculated by month for each AEP Ohio service center in the Project and System areas. These average mileage values were applied to the count of truck rolls avoided to calculate mileage avoided due to AMI.

The following queries and methods were used to generate presentation items:

- Vehicle distances per service center and month for the Meter Revenue Operations (MRO) and Field Revenue Operations (FRO) business units were calculated by summing the vehicle use mileage quantities.
- Average truck roll distances per service center and month for the MRO and FRO business units were calculated by taking the average of the vehicle distances by service center and month for the MRO and FRO business units divided by the number of completed work orders per service center and month.
- The meter operations vehicle miles avoided per service center, month, and meter funding source were calculated by multiplying the AMI truck rolls avoided per service center, month, and meter funding source by the average truck roll distances by service center and month for the MRO and FRO business units.

4.5.4 CO_2 Emissions – Project (M07-AMI)

4.5.4.1 Objective

The AMI system has the potential to reduce the number of truck rolls required by AEP Ohio meter operations staff through the elimination of meter reading routes and the ability to remotely perform services such as meter reading, connection, and disconnection. This impact metric provides an estimate of the CO_2 emissions saved by avoiding truck rolls due to AMI functionality.

4.5.4.2 Organization of Results

The following section describes the amount of CO_2 avoided due to AMI from the following sources:

- Customer service-related truck rolls avoided

  This section contains monthly graphs showing the amount of CO_2 avoided due to the net number of truck rolls avoided.

- Elimination of meter reading routes

  This section contains the results from analysis of CO_2 avoided due to the elimination of meter reading routes by reading meters remotely through the AMI network.

4.5.4.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

4.5.4.4 Results of Data Collected to Date

Subsection 1 shows savings results related to customer service-related truck rolls. This section contains one figure.

Subsection 2 shows results for eliminated meter reading routes.

Results for Service-Related Truck Rolls Avoided:

The average monthly net CO_2 avoided during 2012 was 19.3 tons/month, with an annual total of 232 tons.

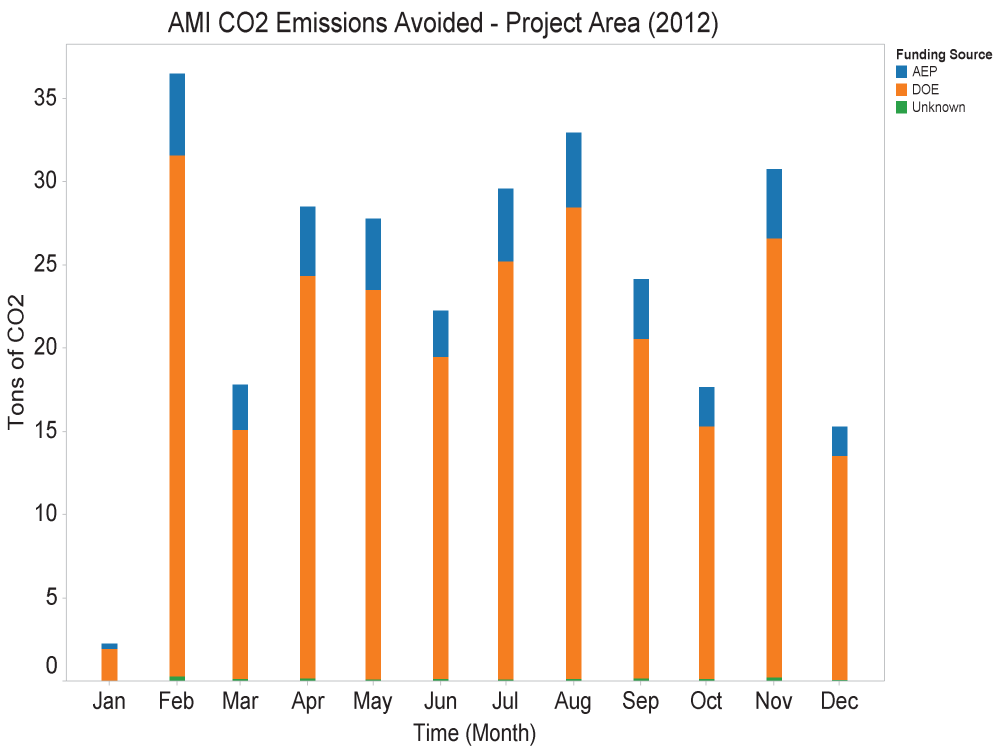


Figure 20. CO_2 avoided due to AMI truck rolls avoided

Results for Eliminated Meter Reading Routes:

Through the use of AMI, AEP Ohio was able to eliminate 187 meter reading routes in the Project area. AEP Ohio reads on average 87 percent of the meter reading routes each month, and the average meter route is 35 miles long. This results in a vehicle mileage avoidance of 5,694 miles/month or 68,328 miles per year. Using an EPA average value of 423 grams of CO_2 per mile (EPA-420-F-11-041) results in 2.408 metric tons of CO_2 avoided per month or 28.903 metric tons avoided per year.

Calculation Approach

Certain types of customer events, such as check read requests, can be handled remotely by the use of the AMI system, thereby avoiding a truck roll. A list was compiled of all customer event order types that lead to an avoided truck roll. The number of truck rolls avoided due to AMI was then calculated based on the number of customer events with matching order type codes.

Average mileage per truck roll and average vehicle fuel efficiency was calculated by month for each AEP Ohio service center in the Project and System areas. CO_2 emission avoidance was calculated using fuel efficiency and mileage avoided.

The following queries and methods used to generate presentation items:

- AEP Ohio provided an average fuel economy value for each vehicle. Corrected average monthly fuel efficiencies in miles per gallon per service center, month, and fuel type for vehicles used by the AEP Ohio MRO and FRO business units were calculated by calculating the average of monthly vehicle mileages divided by monthly quantity of fuel for each vehicle. Because some suspect monthly vehicle mileages (i.e. 703,281 miles) were received, if the average of monthly vehicle mileages divided by monthly quantity of fuel divided by the average monthly average fuel economy value was not between .5 and 2, average monthly average fuel economies were substituted for the average of monthly vehicle mileages divided by monthly quantity of fuel to calculate the corrected average monthly fuel efficiencies.
- Tons of CO_2 avoided per service center, month, meter funding source, and fuel type due to truck rolls avoided due to AMI technology were calculated by multiplying the number or truck rolls avoided multiplied by the average truck roll distance divided by the corrected average monthly fuel efficiency multiplied (8.8 kg CO_2 emissions/gallon for gas engines, 10.1 kg CO_2 emissions/gallon for diesel engines) by 0.00110231131092 (kg to tons conversion factor).

4.5.5 Pollutant Emissions - Project (SO_X, NO_X, $PM_{2.5}$) (M08-AMI)

4.5.5.1 Objective

The AMI system has the potential to reduce the number of truck rolls required by AEP Ohio meter operations staff through the elimination of meter reading routes and the ability to remotely perform services such as meter reading, connection, and disconnection. This impact metric provides an estimate of the amount of pollutants that would have been emitted by trucks to perform services that were avoided and/ or added due to AMI technology.

4.5.5.2 Organization of Results

The following section describes the amount of pollutants avoided due to AMI from the following sources:

- Customer service-related truck rolls avoided

  This section contains monthly graphs showing the amount of pollutants avoided due to the net number of truck rolls avoided.

- Elimination of meter reading routes

  This section contains the results from analysis of pollutants avoided due to the elimination of meter reading routes by reading meters remotely through the AMI network.

4.5.5.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

- Using a CARB limit value of 0.05 grams of NO_X per mile
- 0.01 g $PM_{2.5}$ emissions/mi conversion factor
- .165 g SO_X emissions/gallon for gas engines, .0963 g SO_X emissions/gallon for diesel engines conversion factor

4.5.5.4 Results of Data Collected to Date

Subsection 1 shows savings results related to customer service-related truck rolls. This section contains one figure with three sections.

Subsection 2 shows results for eliminated meter routes.

Results for Service-Related Truck Rolls Avoided:

The average monthly net NO_X avoided during 2012 was1.08 kg/month, with an annual total of 13.0 kg.

The average monthly net SO_X avoided during 2012 was 0.235 kg/month, with an annual total of 2.82 kg.

The average monthly net $PM_{2.5}$ matter avoided during 2012 was 0.216 kg/month, with an annual total of 2.59 kg.

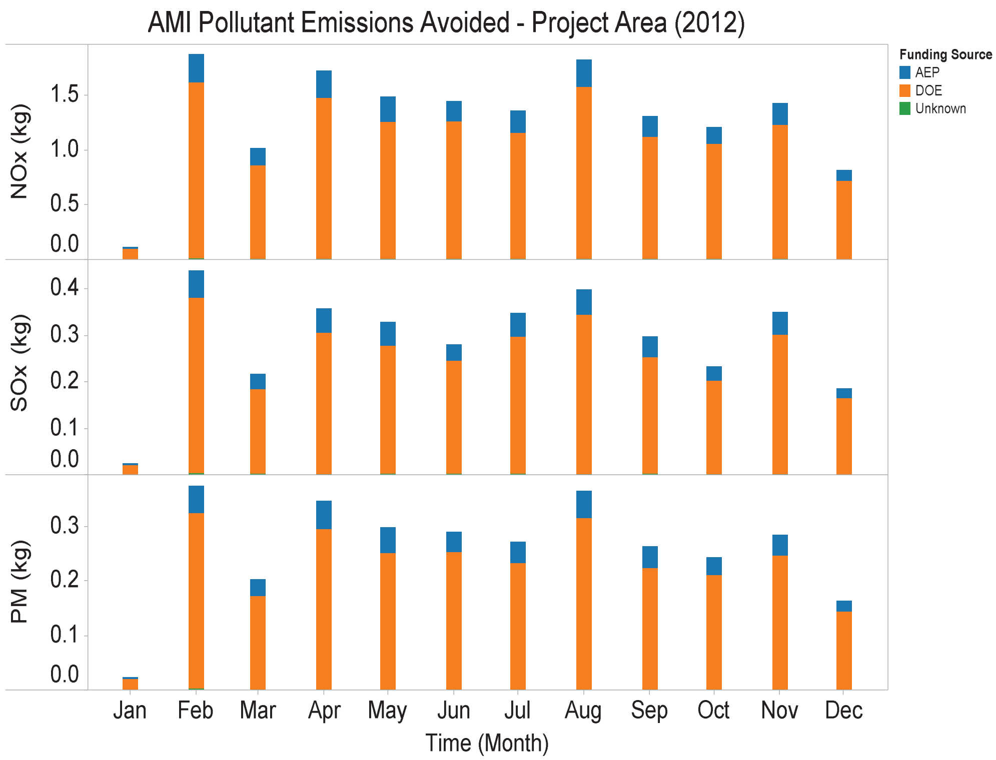


Figure 21. Pollutants avoided due to AMI truck rolls avoided

Results for Eliminated Meter Reading Routes:

Through the use of AMI, AEP Ohio was able to eliminate 187 meter reading routes in the Project area. AEP Ohio reads on average 87 percent of the meter reading routes each month, and the average meter route is 35 miles long. This results in a vehicle mileage avoidance of 5,694 miles/month or 68,328 miles per year.

Using a CARB limit value of 0.05 grams of NO_X per mile, results in 284.7 g of NO_X avoided per month or 3,416 g avoided per year.

SO_X and $PM_{2.5}$ emissions from light duty gasoline vehicles, which are typically used for meter reading routes, are negligible.

Calculation Approach

Certain types of customer events, such as check read requests, can be handled remotely by the use of the AMI system, thereby avoiding a truck roll. A list was compiled of all customer event order types that lead to an avoided truck roll. The number of truck rolls avoided due to AMI was then calculated based on the number of customer events with matching order type codes.

Average mileage per truck roll and average vehicle fuel efficiency were calculated by month for the Project area. Pollutant emission avoidance was calculated using fuel efficiency and mileage avoided.

The following queries and methods were used to generate presentation items:

- Average monthly fuel efficiencies in miles per gallon per month and fuel type for vehicles used by the AEP Ohio MRO and FRO business units were calculated by calculating the average of monthly vehicle mileages divided by monthly quantity of fuel for each vehicle.
- Kilograms of NO_X avoided per service center, month, meter funding source, and fuel type due to truck rolls avoided due to AMI technology were calculated by multiplying the number or truck rolls avoided by the average truck roll distance multiplied by 0.05 g NO_X emissions/mi multiplied by 0.001 (g to kg conversion factor).
- Kilograms of $PM_{2.5}$ avoided per service center, month, meter funding source, and fuel type due to truck rolls avoided due to AMI technology were calculated by multiplying the number or truck rolls avoided by the average truck roll distance multiplied by 0.01 g $PM_{2.5}$ emissions/mi multiplied by 0.001 (g to kg conversion factor).
- Kilograms of SO_X avoided per service center, month, meter funding source, and fuel type due to truck rolls avoided due to AMI technology were calculated by multiplying the number or truck rolls avoided by the average truck roll distance divided by the corrected average monthly fuel efficiency multiplied by (.165 g SO_X emissions/gallon for gas engines, .0963 g SO_X emissions/gallon for diesel engines) 0.001 (g to kg conversion factor).

4.5.6 CO_2 Emissions—System (M09-AMI)

4.5.6.1 Objective

The AMI system has the potential to reduce the number of truck rolls required by AEP Ohio meter operations staff through the elimination of meter reading routes and the ability to remotely perform services such as meter reading, connection, and disconnection. This impact metric provides an estimate of the amount of CO_2 that would have been emitted by trucks to perform services that could be avoided if AMI technology were extended to the entire System area.

4.5.6.2 Organization of Results

The following section describes the amount of CO_2 that could be avoided by AMI if it were deployed to the entire System area from the following sources:

- Service-related truck rolls avoided

  This section contains monthly graphs showing the amount of potential CO_2 avoided due to truck rolls avoided.

- Elimination of meter reading routes

  This section contains the results from analysis of potential CO_2 avoided due to the elimination of meter reading routes by reading meters remotely through the AMI network. This information will be included in the Final Report.

4.5.6.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

- 8.8 kg CO_2 emissions/gallon for gas engines, 10.1 kg CO_2 emissions/gallon for diesel engines conversion factor
- Forecasts for the System area may change in the Final Report because AMI may not be practical for rural areas. The future System area projections may include only urban areas of the System.

4.5.6.4 Results of Data Collected to Date

This section contains one subsection that has one figure.

Results for Service-Related Truck Rolls Avoided:

The average potential monthly CO_2 avoided during 2012 was 157 tons/month, with an annual total of 1,884 tons.

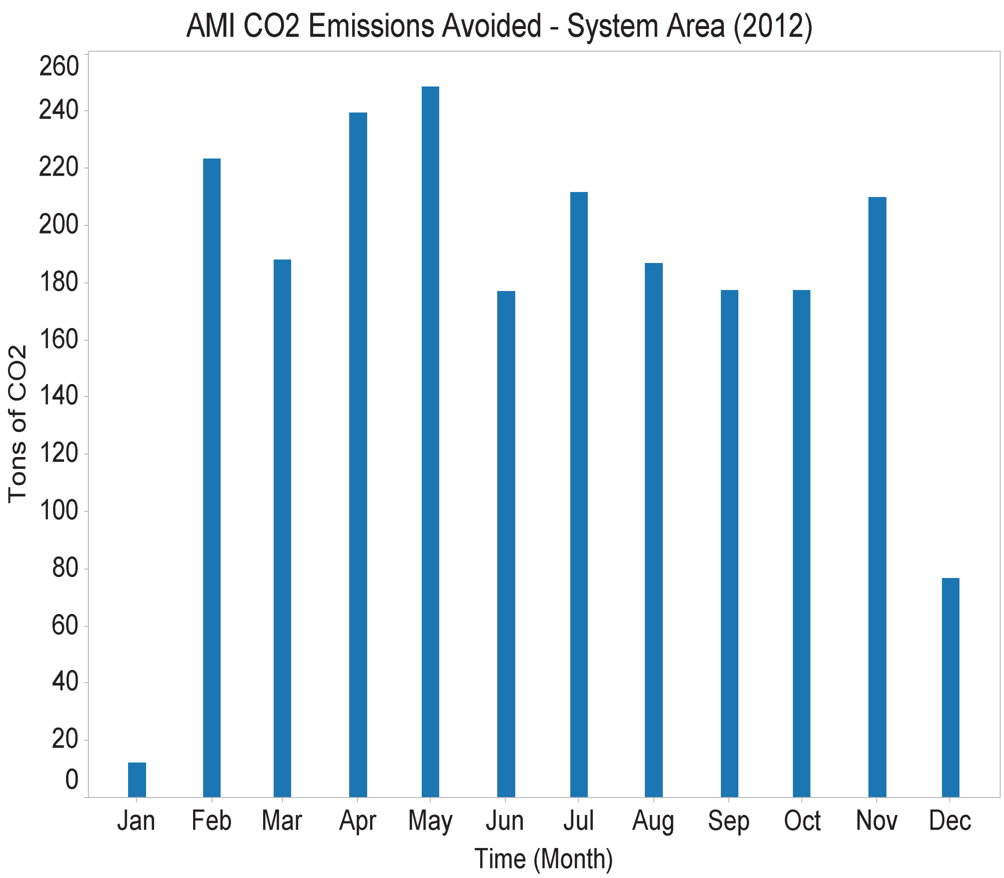


Figure 22. Potential CO_2 avoided in System area due to AMI truck rolls avoided

Calculation Approach

Certain types of customer events, such as check read requests, can be handled remotely by the use of the AMI system, thereby avoiding a truck roll. A list was compiled of all customer event order types that lead to an avoided truck roll. The number of truck rolls avoided due to AMI was then calculated based on the number of customer events with matching order type codes.

Average mileage per truck roll and average vehicle fuel efficiency were calculated by month for each AEP Ohio service center in the Project and System areas. Project area CO_2 emission avoidance was calculated using fuel efficiency and mileage avoided. This emission avoidance was then extrapolated to the System area based on number of customers and average truck roll distances for each non-Project service center.

The following queries and methods used to generate presentation items:

- Tons of CO_2 per service center and month that would be avoided if AMI technology were deployed throughout the AEP Ohio System area due to truck rolls avoided were calculated by multiplying the truck rolls avoided per customer in the Northeast Service Center multiplied by the number of customers without AMI technology per month multiplied by the average truck roll distance divided by the corrected average monthly fuel efficiency times (8.8 kg CO_2 emissions/gallon for gas engines, 10.1 kg CO_2 emissions/gallon for diesel engines) multiplied by 0.00110231131092 (kg to tons conversion factor).

4.5.7 Pollutant Emissions – System (SO_X, NO_X, $PM_{2.5}$) (M10-AMI)

4.5.7.1 Objective

The AMI system has the potential to reduce the number of truck rolls required by AEP Ohio meter operations staff through the elimination of meter reading routes and the ability to remotely perform services such as meter reading, connection, and disconnection. This impact metric provides an estimate of the amount of pollutants that would have been emitted by trucks to perform services that could be avoided if AMI technology were extended to the entire System area.

4.5.7.2 Organization of Results

The following section describes the amount of pollutants that could be avoided if AMI were deployed to the entire System area from the following sources:

- Service-related truck rolls avoided

  This section contains monthly graphs showing the amount of potential pollutants avoided due to truck rolls avoided.

- Elimination of meter reading routes

  This section contains the analysis of potential pollutants avoided due to the elimination of meter reading routes if AMI were extended to the entire System area. This information will be included in the Final Report.

4.5.7.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

4.5.7.4 Results of Data Collected to Date

This section contains one subsection that has one figure.

Results for Service-Related Truck Rolls Avoided:

The average potential monthly net NO_X avoided during 2012 was 8.75 kg/month, with an annual total of 105 kg.

The average potential monthly net SO_X avoided during 2012 was 1.91 kg/month, with an annual total of 22.9 kg.

The average potential monthly net $PM_{2.5}$ avoided during 2012 was 1.75 kg/month, with an annual total of 21.0 kg.

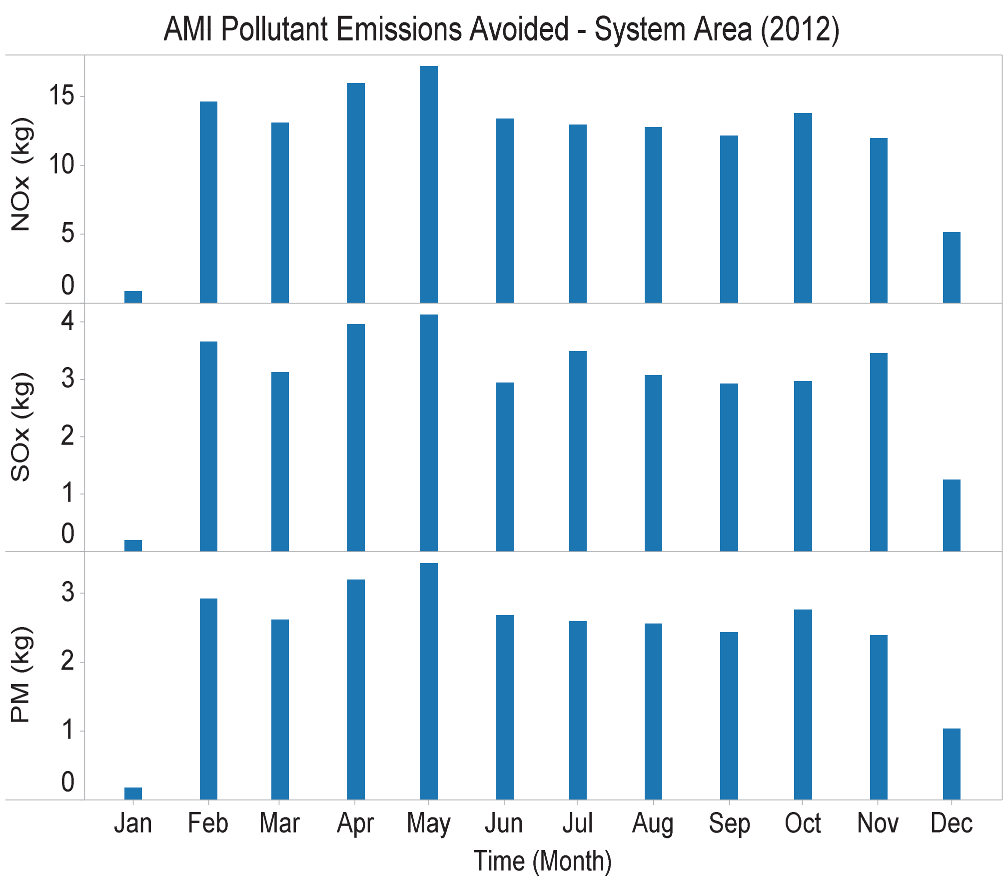


Figure 23. Potential pollutants avoided in System area due to AMI truck rolls avoided

Calculation Approach

Certain types of customer events, such as check read requests, can be handled remotely by the use of the AMI system thereby, avoiding a truck roll. A list was compiled of all customer event order types that lead to an avoided truck roll. The number of truck rolls avoided due to AMI was then calculated based on the number of customer events with matching order type codes.

Average mileage per truck roll and average vehicle fuel efficiency was calculated by month for each AEP Ohio service center in the Project and System areas. Project area pollutant emission avoidance was calculated using fuel efficiency and mileage avoided. This emission avoidance was then extrapolated to the System area based on number of customers and average truck roll distances for each non-Project service center.

The following queries and methods were used to generate presentation items:

- Kilograms of NO_X per service center and month that would be avoided if AMI technology were deployed throughout the AEP Ohio System area due to truck rolls avoided were calculated by multiplying the truck rolls avoided per customer in the Northeast Service Center by the number of customers without AMI technology per month multiplied by the average truck roll distance multiplied by 0.05 g NO_X emissions/mi multiplied by 0.001 (g to kg conversion factor).
- Kilograms of $PM_{2.5}$ per service center and month that would be avoided if AMI technology were deployed throughout the AEP Ohio System area due to truck rolls avoided were calculated by multiplying the truck rolls avoided per customer in the Northeast Service Center by the number of customers without AMI technology per month multiplied by the average truck roll distance multiplied by 0.01 g $PM_{2.5}$ emissions/mi multiplied by 0.001 (g to kg conversion factor).
- Kilograms of SO_2 per service center and month that would be avoided if AMI technology were deployed throughout the AEP Ohio System area due to truck rolls avoided were calculated by multiplying the truck rolls avoided per customer in the Northeast Service Center by the number of customers without AMI technology per month multiplied by the average truck roll distance multiplied by (0.165 g SO_2 emissions/gallon for gas engines, 0.0963 g SO_2 emissions/gallon for diesel engines) multiplied by 0.001 (g to kg conversion factor).

4.5.8 Meter Data Completeness (M11-AMI)

4.5.8.1 Objective

AMI technology has the potential to provide near real-time meter data to the utility. This impact metric reports the percentage of successfully received meter readings through the AMI system and the accuracy of data received from the meters.

4.5.8.2 Organization of Results

The following section describes the completeness of data reported through the AMI system.

- Interval readings successfully reported through the AMI network

  This section contains graphs showing the number of meter readings expected vs. the number received each day.

- Accuracy of reported meter data

  This section contains AEP Ohio's results from analysis of meter data accuracy including their procedure for spot checking meters in the field. This will be included in the Final Report.

4.5.8.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

4.5.8.4 Results of Data Collected to Date

This section contains one subsection that has two figures and one table.

Results for Interval Readings Reported Through the AMI Network:

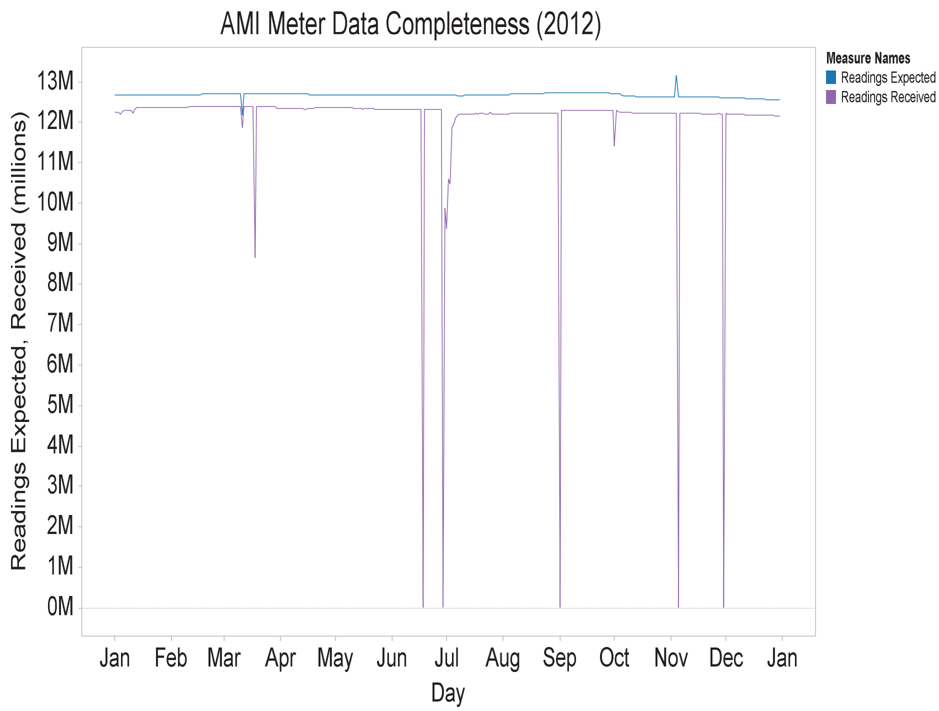


Figure 24. AMI interval readings expected and received by day

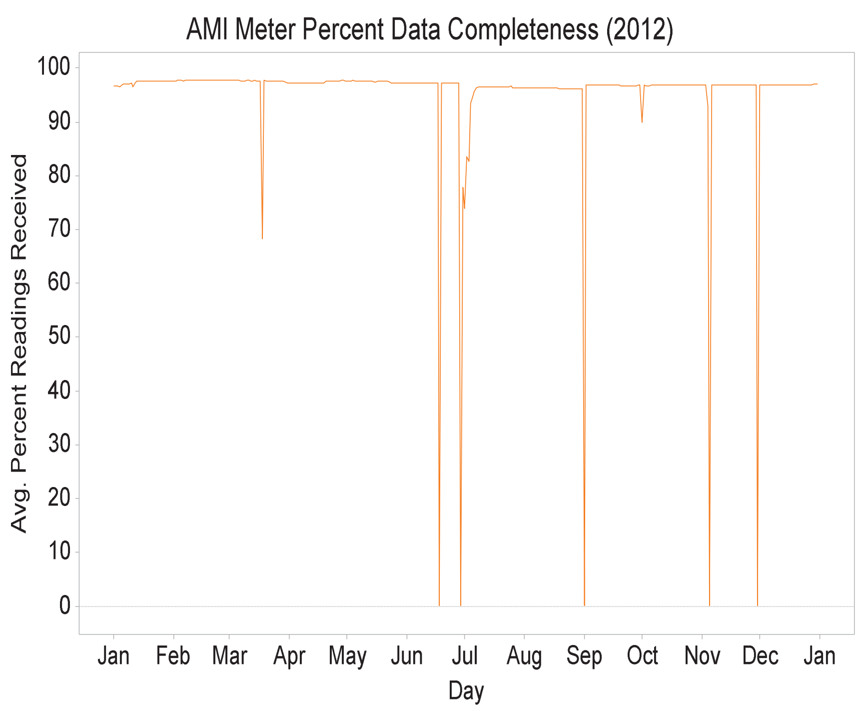


Figure 25. Percentage of expected AMI interval readings received daily

AEP Circuit Number	Avg. % Received	Readings Expected	AEP Circuit Number	Avg % Received	Readings Expected
Gahanna - 0004532	96.51	160307812	Mifflin - 0004201	93.37	26264752
Blendon - 0005632	96.74	125752964	Huntley - 0001204	96.04	24997496
Blendon - 0005631	95.74	118371132	Clinton - 0002902	94.27	24832964
Blacklick - 0026032	96.85	109458168	East Broad - 0001403	96.61	24125004
Karl - 0000913	95.01	109032968	Kirk - 0008031	93.23	23998664
Mifflin - 0004203	93.95	109007484	Karl - 0000907	94.83	23964680
Clinton - 0002908	95.76	106349324	St. Clair - 0006402	92.92	22814748
Clinton - 0002901	95.33	98478548	Columbia - 0007902	94.50	22756348
Karl - 0000910	95.81	94922264	Taylor - 0009732	87.79	21312972
Clinton - 0002906	92.84	92860684	Blacklick - 0026005	95.95	20558416
Karl - 0000921	96.09	92221592	Corridor - 0000531	94.92	17043472
Huntley - 0001206	97.53	88218132	Huntley - 0001202	97.38	16257152
Karl - 0000915	95.90	82736652	St. Clair - 0006408	92.84	13150560
Mifflin - 0004204	94.54	82615244	Bexley - 0001004	96.57	12955092
Mifflin - 0004209	96.78	80168364	Taylor - 0009733	95.21	10754692
Blendon - 0005602	96.04	79667988	St. Clair - 0006403	91.55	10289332
Westerville - 0005502	95.18	75873672	Bexley - 0001006	92.08	8891712
Clinton - 0002914	92.81	75469856	New Albany - 0003301	94.94	7827744
Karl - 0000917	95.58	74918444	Clinton - 0002913	96.04	7487232
Karl - 0000902	96.54	73983956	St. Clair - 0006404	93.19	6302316
Morse - 0005803	95.44	72319352	East Broad - 0001405	97.36	4921536
Karl - 0000919	95.91	71837360	Blacklick - 0026001	92.37	4437892
Karl - 0000911	95.56	71626264	Huntley - 0001203	89.90	3180300
Karl - 0000905	94.44	70283164	Blacklick - 0026004	91.67	3104556
Karl - 0000901	96.15	68283668	Genoa - 0003902	88.50	3078248
Westerville - 0005501	96.15	68089236	Jug Street - 0036532	87.90	2758648
Mifflin - 0004210	96.04	65250588	Morse - 0005804	94.63	2301112
Morse - 0005801	94.38	64391136	Huntley - 0001205	96.18	2297668
Gahanna - 0004502	96.68	61191296	Huntley - 0001212	95.49	2200996
Blendon - 0005633	96.29	61125928	Blacklick - 0026003	93.51	2086064
Karl - 0000918	95.88	60807796	Bexley - 0001005	94.53	1501632
Karl - 0000903	95.22	60559844	Morse - 0005812	83.89	1339584
Clinton - 0002911	95.69	56130648	East Broad - 0001406	93.68	1037764
Karl - 0000912	95.71	55136476	Morse - 0005811	80.85	936572
Morse - 0005815	96.82	54580276	Kirk - 0008032	29.58	816788
Mifflin - 0004205	96.70	53936132	Morse - 0005816	87.40	655108
Gahanna - 0004506	94.09	53383364	Bexley - 0001010	75.65	497096
Karl - 0000908	94.18	52339440	Morse - 0005814	92.62	421632
Morse - 0005802	96.40	51485688	Columbia - 0007901	1.37	400988
Huntley - 0001210	96.18	51485024	Clinton - 0002910	95.87	386496
Karl - 0000904	94.88	51330944	Morse - 0005813	76.67	275712
Morse - 0005805	96.61	51267536	Centerburg - 0027232	79.92	245952
Gahanna - 0004505	94.98	50399856	Mifflin - 0004206	98.16	228856
Karl - 0000906	95.41	50360180	Huntley - 0001207	81.99	210816
Morse - 0005806	95.50	50020240	St. Clair - 0006407	91.57	208220
Karl - 0000914	96.16	49066792	St. Clair - 0006406	83.33	205536
St. Clair - 0006405	92.14	48225056	Bixby - 0007105	0.00	175680
Morse - 0005809	94.36	47123548	Genoa - 0003901	98.36	175680
Blacklick - 0026031	96.67	46003400	Bixby - 0007101	0.00	140544
Corridor - 0000532	96.52	45897640	Huntley - 0001208	98.25	140544
Gahanna - 0004501	95.21	44721932	St. Clair - 0006409	82.88	124896
St. Clair - 0006410	93.48	42579920	Astor - 0004610	0.38	119032
Bexley - 0001009	95.30	41979984	Genoa - 0003933	97.67	106368
Gahanna - 0004503	89.65	41575508	East Broad - 0001408	98.56	105408
Blendon - 0005601	91.28	40679364	St. Clair - 0006413	0.30	84484
Karl - 0000920	94.36	39392920	Gay Street - 0000220	98.62	70272
Clinton - 0002904	95.65	36921612	St. Clair - 0006412	98.51	70272
Morse - 0005807	95.17	35244984	Etna Road - 0007004	96.10	39560
Blacklick - 0026002	96.54	34976664	Johnstown - 0006701	98.44	35136
Mifflin - 0004202	94.88	33827548	Marion - 0000714	98.44	35136
Gahanna - 0004504	95.90	33691680	St. Clair - 0006401	90.79	35136
Karl - 0000916	96.53	32015148	Astor - 0004602	0.36	26588
Karl - 0000922	93.14	30129200	Genoa - 0003931	0.76	21116
Mifflin - 0004207	97.11	30087640	Bethel Road - 0002601	94.38	5764
Mifflin - 0004208	95.93	29015412	Johnstown - 0006702	22.43	4992
Gahanna - 0004531	97.01	28391912	Shannon - 0008902	0.00	3264
Bexley - 0001003	96.35	27535120			

Table 10. Meter data completeness by circuit

***Note**: Table 10 contains both the circuits with full AMI installation, as well as a number of circuits with partial/test installations. Many of the test circuits have low completeness percentages since they were selected to test the limits of the communications system.*

Calculation Approach

This metric presents the percentage of AMI 15-minute interval readings that are successfully received from the AMI system. Any estimated readings are not counted as successful. Total expected readings are based on the number of active AMI customers.

The following queries and methods are used to generate presentation items:

- AMI readings received per meter and date were calculated by counting the number of non-estimated readings in the Input Data Category (IDC) database.
- AMI readings expected per meter, date, meter type, meter funding source, circuit, and substation were calculated by counting the number of intervals per day for normal and daylight savings on/off days multiplied by the number of AMI customers.
- AMI readings missed per meter, date, meter type, meter funding source, circuit, and substation were calculated by subtracting the number of AMI readings received from the number of AMI readings expected.

4.5.9 Meters Reporting Daily (M12-AMI)

4.5.9.1 Objective

AMI technology has the potential to provide near real-time meter data to the utility. This impact metric reports the number of AMI meters from which meter data are successfully received at least once per day through the AMI system.

4.5.9.2 Organization of Results

The following section describes the completeness of data reported through the AMI system. The specific aspect of data completeness analyzed under this metric is:

- Number of meters successfully reporting at least once per day

  This section contains a graph showing the percentage of active AMI meters that successfully report at least one reading per day. This is a significant diagnostic tool to ensure full functionality of the AMI meter.

4.5.9.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

4.5.9.4 Results of Data Collected to Date

This section contains one subsection that has one figure.

Results for Interval Readings Reported Through the AMI Network:

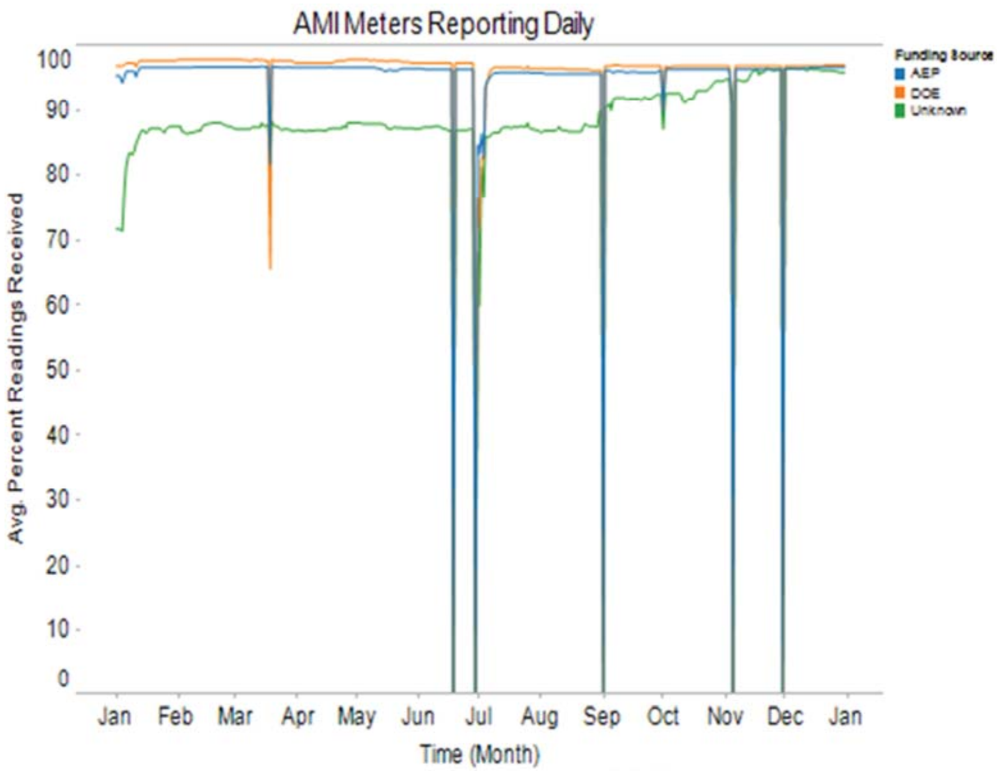


Figure 26. Percent of AMI meters reporting each day

Calculation Approach

This metric presents the number of AMI meters that successfully report at least one 15-minute interval reading per day. Any estimated readings are not counted as successful. Total expected readings are based on the number of active AMI customers.

The following queries and methods are used to generate presentation items:

- AMI readings missed per meter, date, meter type, meter funding source, circuit, and substation were calculated by subtracting the number of AMI readings received from the number of AMI readings expected.

4.5.10 Outage Response Time (M29-AMI)

4.5.10.1 Objective

The AMI system has the ability to notify AEP Ohio of customer power outages in near real-time. This notification is expected to precede the first customer reported outage. The purpose of this impact metric is to quantify the time difference between AMI outage reports and the first customer report of the same outage.

4.5.10.2 Organization of Results

This metric is intended to present the improvement in outage response time that occurs as a result of AMI technology. In this context, outage response time means the time it takes for AEP Ohio to become aware that an outage has occurred. This metric does not include the time it takes to correct the outage. The data are shown as a histogram of time differences between AMI last gasp messages and customer outage report calls for the same outage.

4.5.10.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

4.5.10.4 Results of Data Collected to Date

This section contains one subsection that has one figure.

Results for AMI notification time before customer notification time of outage:

This analysis is based on 202 customer reported outages occurring between 01/01/2012 and 02/29/2012. Of these outage reports, 57 were associated with AMI last-gasp messages.

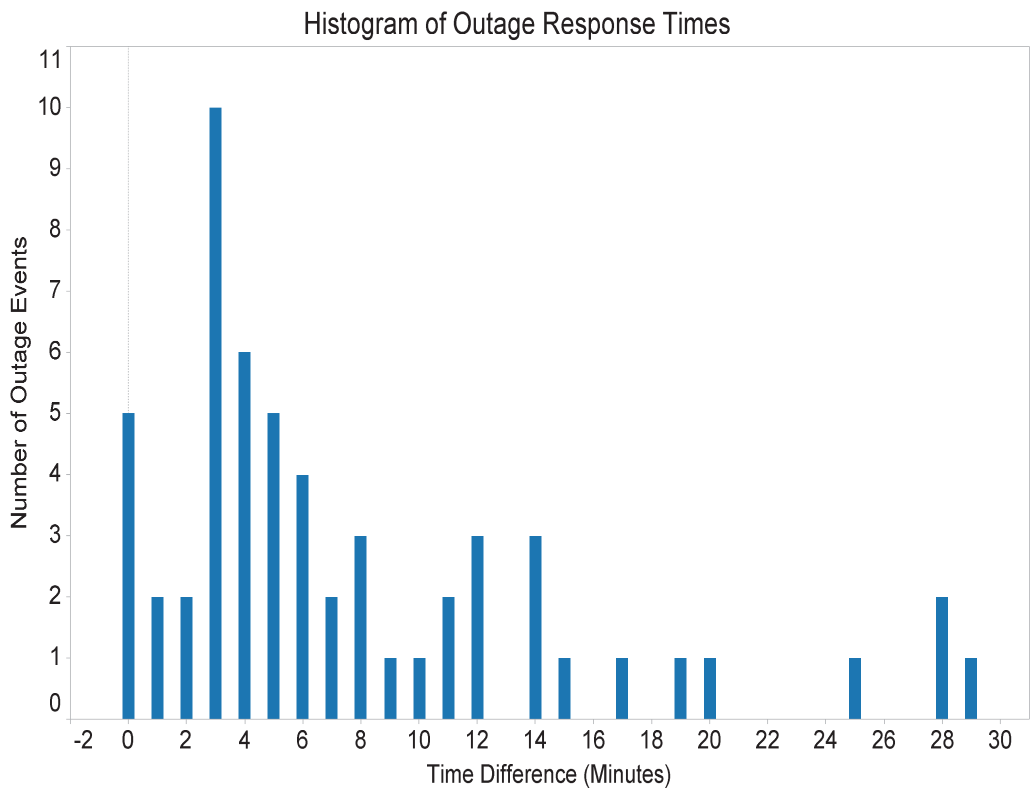


Figure 27. Histogram of outage notification time differences

Calculation Approach

For each customer reported outage event, a 30-minute window was defined preceding the customer report. The latest AMI last-gasp message from the meter was then selected as being associated with the customer event. The histogram that results is a plot of the frequency of occurrence versus customer report to last-gasp time difference.

The following queries and methods are used to generate presentation items:

- The number of last-gasp meter events per meter, date, circuit, and substation were calculated by counting the number of last-gasp meter events for AMI customers.
- The number of customer events reporting outages per meter, date, circuit, and substation were calculated by counting the number of AMI customers reporting an outage.
- The number of outages per date, circuit, and substation were calculated by counting the number of outages reported by the Historical Outage Information System (HOIS).

4.6 AMI Observations

This section contains observations of the technology to date. Conclusions will be provided in the Final Report.

There are two major sources of reductions in meter operations costs associated with the installation of AMI. The first is the elimination of truck rolls associated with customer service-related calls. Initial observations suggest that the remote connect/disconnect capabilities, the ability to access all meters, and retrieve on-demand check reads eliminate approximately 0.2 field visits per meter and provide net savings of $3.08 per meter for the year. Further analysis is needed to validate this claim. The second is the elimination of manual meter reading routes, including both the labor and vehicle costs. As a result of installing approximately 132,000 AMI meters in the Project area, AEP Ohio eliminated 187 meter reading routes and 10 meter readers, which equates to yearly savings $3.40 per meter.

- Additional financial benefits resulting from the AMI meter capabilities, such as reductions in write-offs, theft due to quicker notifications, and excessive use on inactive accounts, are still being analyzed.
- These net savings in meter operations cost are offset by ongoing maintenance costs, which are still being evaluated, but are in excess of $5.00 per meter.

A full analysis of the impact to customer service-related orders that result in a truck roll will be provided in the Final Report, but a few observations of the impacted areas are:

- Meter access issues that require a field visit to get a check read or resolve the issue dropped from 600 orders per year in 2009 to 33 orders in 2012.
- In NE Columbus, check read orders dropped from an average of 6,600 per year prior to AMI installation to 1,500 in 2012.
- Approximately 2,500 back-office disconnects for non-payment occurred in 2012. However, each disconnection still required a truck roll due to notification regulations.
- There were over 14,000 remote reconnects in 2012, but not all can result in a truck roll avoided.

CO_2 and pollutant emissions are a direct multiple of truck roll miles avoided. As a result of the vehicle mileage avoided in the Project area, approximately 232 tons CO_2, 13.0 kg of NO_X, 2.82 kg of SO_X, 2.59 kg of $PM_{2.5}$ was avoided in the Project area.

On average, AEP Ohio is receiving 95 percent of all 15-minute interval reads and at least one reading a day 97 percent of the time. The average numbers of meters reporting 15-minute intervals appear lower than the 99 percent expected with AMI meters. AEP Ohio is currently investigating these numbers and will provide an update in the Final Report.

Initially, the last-gasp notification features of the AMI meters were not used by AEP Ohio due to the incredible volume and unreliable meter communications accuracy. Significant effort has been made to understand and reduce the number of false outage notifications. Results of the accuracy of last-gasp notifications in predicting outages and the improved notification compared to traditional methods are still being analyzed and will be provided in the Final Report.

5 DEMONSTRATED TECHNOLOGIES – CONSUMER PROGRAMS, EDUCATION & RECRUITMENT

5.1 PURPOSE

As part of the Project, several experimental time-of-day tariffs and DLC riders are being tested. The purpose of this test is to determine to what level these tariffs and riders, either directly or indirectly, reduce a customer's electricity usage during weekday on-peak hours and to shift some of that usage to off-peak hours.

Whereas the current standard tariff is based on the average cost of electricity generation and distribution, these experimental time-of-day tariffs and riders are designed to more accurately reflect the actual underlying variability in the cost of electricity.

The introduction of these new consumer programs provides participants with the opportunity to better monitor their electric use and to have greater control over their monthly electric costs by potentially shifting usage from higher price periods to lower price periods or by reducing the demand on the electrical system during peak periods. From a utility perspective, a major goal of these consumer programs is to lower costs and peak demand during peak periods of high-cost generation by altering residential customer class load shapes through consumer behavior changes (demand reduction and load shifting) without negatively impacting customer satisfaction.

As approved by the PUCO, AEP Ohio offered consumers incentive programs based on time-of-day usage, critical peak pricing signals, real-time pricing signals, and utility direct load control capability. In total, AEP Ohio offered five different consumer programs, with three pricing and two DLC programs. In order to analyze new smart grid technologies effectively, AEP Ohio had to educate and recruit customers to participate in the different consumer programs.

5.2 TECHNOLOGY

Upon consumer subscription, AEP Ohio equipped residences in the Project area with auxiliary devices designed to provide usage, pricing, and event information, as well as capabilities to respond to information. These devices played a critical role in the consumer programs. Following are the devices used in the consumer programs:

- **PCT** - Programmable Communicating Thermostat, made by RTA (Radio Thermostat of America) and used with the SMART Cooling program;
- **LCS** – Load Control Switch, made by Energate and used with the SMART Cooling Plus program;
- **IHD** – Low-cost In-Home Display, made by Computime and used with the eVIEW program;
- **IHD/PCT** – High-cost In-Home Display and Programmable Communicating Thermostat, made by Control4 and used with the SMART Shift Plus program; and

- **HEM** – Home Energy Manager, made by Itron, furnished by Battelle, and used in the SMART Choice (RTP_{da}) program.

AEP Ohio also installed smart appliances in 18 homes and provided a web portal for all pilot customers with query and customer notification capabilities. Further analysis on these areas will be provided in the Final Report.

5.3 Program Overview

The following Consumer Programs were created for the Project. Refer to Appendix A – gridSMART Program Overview contains an example of consumer marketing materials for these programs.

Table 11 provides a quick reference from a program's "market" name to the AEP Ohio Tariff. Detailed descriptions of each program follow this table.

Marketed Name	AEP Ohio Tariff	Attributes
SMART Shift	040	two-tier time-of-day
SMART Shift Plus	043	three-tier time-of-day with critical peak pricing events
SMART Cooling	Rider for 013, 040	Direct load control – thermostat only
SMART Cooling Plus	Rider for 013, 040	Direct load control with load control switch
SMART Choice	045	Real-time pricing with double auction
Standard Residential	013	Flat tariff with declining block rate, average cost

Table 11. Consumer Programs and Associated Tariffs

SMART Shift^{SM}

This two-tiered pricing program requires no additional equipment. Consumers have an incentive to shift their usage to off-peak times by being charged a lower rate for power consumed before 1 p.m. and after 7 p.m. on weekdays during the summer months (June to September) only. Usage between 1 p.m. and 7 p.m. is charged at the higher peak rate.

SMART Shift Plus^{SM}

This three-tiered pricing program offers consumer incentives to modify their usage patterns during peak load times in summer months. Consumers receive an IHD and a Programmable Communicating Thermostat (PCT). This program allows AEP Ohio to declare up to 15 Critical Peak Pricing (CPP) events per calendar year and not to exceed 5 hours per day. Energy consumed during these events is assigned a substantially higher rate, thus encouraging customers to reduce their demand. Pricing for non-CPP times, during summer months only, has several tiers with just a few cents between tiers. The low tier is in effect from 9 p.m. to 7 a.m. The medium tier is effective between 7 a.m. and 1 p.m., and then again from 7 p.m. to 9 p.m.. The high tier is effective from 1 p.m. to 7 p.m. each weekday. The consumer can configure the IHD to automatically adjust the thermostat's temperature settings a few degrees during critical peak pricing events.

- **HEM** – Home Energy Manager, made by Itron, furnished by Battelle, and used in the SMART Choice (RTP_{da}) program.

AEP Ohio also installed smart appliances in 18 homes and provided a web portal for all pilot customers with query and customer notification capabilities. Further analysis on these areas will be provided in the Final Report.

5.3 Program Overview

The following Consumer Programs were created for the Project. Refer to Appendix A – gridSMART Program Overview contains an example of consumer marketing materials for these programs.

Table 11 provides a quick reference from a program's "market" name to the AEP Ohio Tariff. Detailed descriptions of each program follow this table.

Marketed Name	AEP Ohio Tariff	Attributes
SMART Shift	040	two-tier time-of-day
SMART Shift Plus	043	three-tier time-of-day with critical peak pricing events
SMART Cooling	Rider for 013, 040	Direct load control – thermostat only
SMART Cooling Plus	Rider for 013, 040	Direct load control with load control switch
SMART Choice	045	Real-time pricing with double auction
Standard Residential	013	Flat tariff with declining block rate, average cost

Table 11. Consumer Programs and Associated Tariffs

SMART Shift^{SM}

This two-tiered pricing program requires no additional equipment. Consumers have an incentive to shift their usage to off-peak times by being charged a lower rate for power consumed before 1 p.m. and after 7 p.m. on weekdays during the summer months (June to September) only. Usage between 1 p.m. and 7 p.m. is charged at the higher peak rate.

SMART Shift Plus^{SM}

This three-tiered pricing program offers consumer incentives to modify their usage patterns during peak load times in summer months. Consumers receive an IHD and a Programmable Communicating Thermostat (PCT). This program allows AEP Ohio to declare up to 15 Critical Peak Pricing (CPP) events per calendar year and not to exceed 5 hours per day. Energy consumed during these events is assigned a substantially higher rate, thus encouraging customers to reduce their demand. Pricing for non-CPP times, during summer months only, has several tiers with just a few cents between tiers. The low tier is in effect from 9 p.m. to 7 a.m. The medium tier is effective between 7 a.m. and 1 p.m., and then again from 7 p.m. to 9 p.m.. The high tier is effective from 1 p.m. to 7 p.m. each weekday. The consumer can configure the IHD to automatically adjust the thermostat's temperature settings a few degrees during critical peak pricing events.

SMART Cooling^{SM}

In the direct load control (DLC) program, the utility is able to control demand at the customer's premise by adjusting the thermostat. Customers receive a PCT. During times of peak demand, AEP Ohio can call an event. AEP Ohio is permitted to call up to 15 non-emergency events between May and September between the hours of noon and 8 p.m. During these events, AEP Ohio can adjust the PCT up to four degrees for up to five hours. An additional 10 emergency events are also available for use within all months. These emergency events are dictated by PJM. Customers who elect not to override these adjustments receive a bill credit for the months in which an event occurred.

SMART Cooling Plus^{SM}

This program is an extension of the SMART Cooling program where customers receive a load control switch (LCS). The LCS is installed on electric water heaters, pool pumps or hot tubs. Customers are offered an incentive to reduce demand by allowing the utility to control these devices during DLC events. However, problems with the LCS devices caused AEP Ohio to remove deployed devices and suspend the program. The program resumed in 2013.

SMART Choice^{SM} (Real-Time Pricing with Double Auction)

This program allows customers to participate in real-time pricing based on supply and demand for their circuit. Pricing occurs every five minutes for each circuit. Customers receive an ePCT and a HEM. Section 10 contains a full explanation of the technology.

5.4 Implementation and Approach

AEP Ohio elected to use a variety of different technologies during the Project. Once AEP Ohio selected the technology vendors, each device was tested extensively at the utility's in-house laboratory/testing facility. The equipment was tested to ensure the best customer experience during program roll-out. During the testing phase, AEP Ohio worked closely with each vendor to identify and correct issues.

Once these programs passed laboratory testing, a phased implementation was completed. The first phase involved AEP and AEP Ohio employees that lived in the Project area. Participating employees had devices installed and were placed on the appropriate program. Feedback was then gathered from these employees. Modifications to systems and/or processes were completed, and a new group of employees were recruited to go through the same process. Again, the team gathered feedback from the pilot group. The final implementation phase was to market the programs to AEP Ohio's Project area customers.

AEP Ohio selected Entertouch Inc., dba GoodCents Solutions (GoodCents) as the vendor to install the devices. GoodCents was selected primarily due to their experience and expertise. AEP Ohio worked closely with GoodCents to ensure the devices were properly installed and to create the best possible customer experience. During a standard installation, technicians would install the devices, connect the devices to the meter, and then explain the devices to the customer, answering any program-related questions posed by the customer during the process. After installation, the customer received an information packet regarding the chosen program and device(s). During the first six months of installations, AEP Ohio called customers after each installation to ensure they were satisfied and understood their new equipment and program. While processes were in place to dispatch personnel for customer issues, this was not required.

During the full customer roll-out and installation phases of the programs, AEP Ohio held weekly status calls with the call center and installation managers. These were held to review any open issues and to monitor current activities. AEP Ohio also held weekly marketing meetings to review the overall plan and upcoming marketing tactics.

Marketing/Outreach Approach

The approach taken to test the Consumer Programs and their effectiveness was to divide the 110,000 Project area residential consumers into different marketing strata. Each stratum was created to be a representation of AEP Ohio's service territory, containing all types of residential consumers. A control group, receiving no marketing material, was assigned to enable evaluation of the effectiveness of consumer outreach and the appeal of the Consumer Programs.

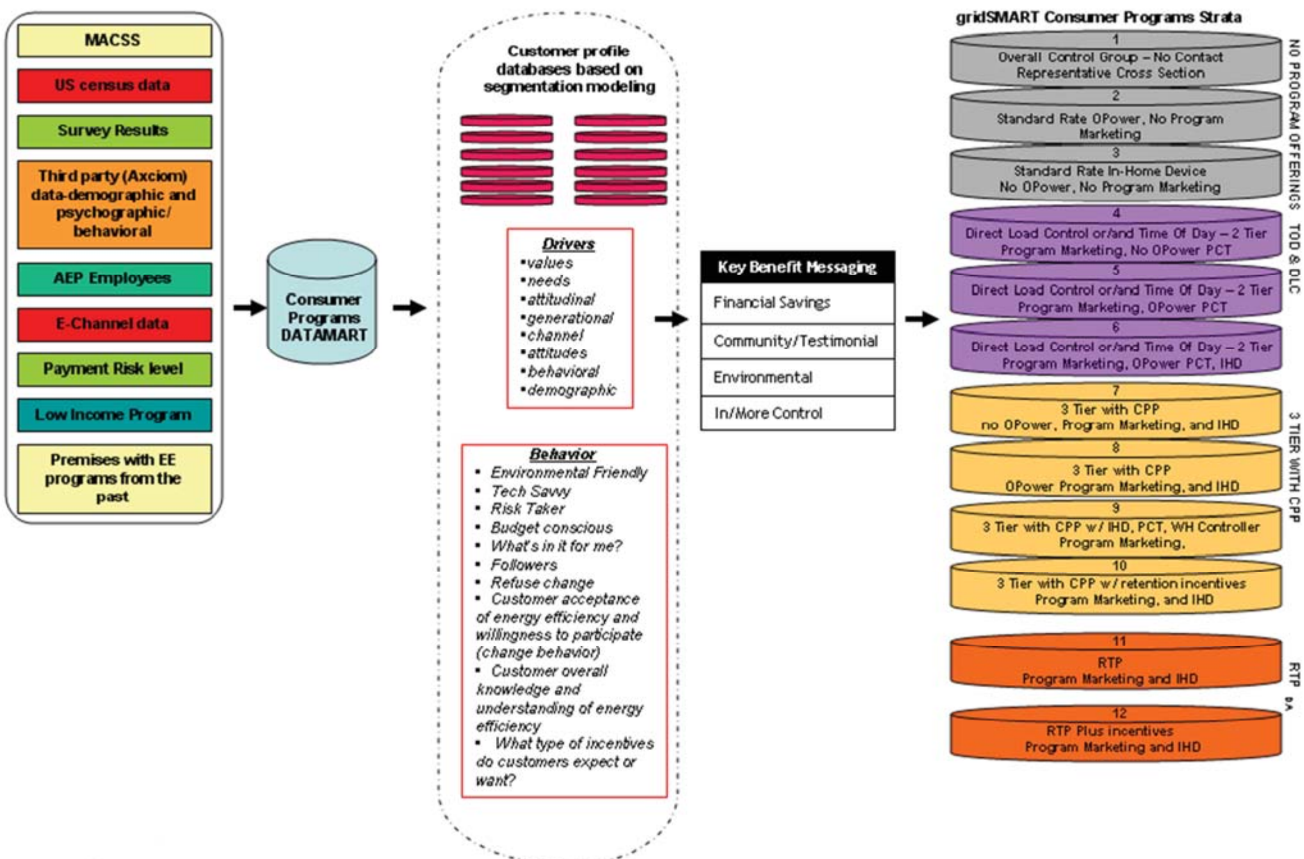


Figure 28. gridSMART Consumer Programs Profile

Several different marketing/outreach tactics were employed so that all eligible customers were aware of their options:

- Web
- Direct Mail

- Phone Blast
- E-Mail
- Door-to-door
- Community Events
- gridSMART Mobile Unit

The residential customers were divided into six different demographic groups for purposes of marketing and analysis. Following are the groups and their definitions:

Optimizers (11 clusters) – This group contains mostly affluent, middle-aged homeowners, mix of married/single, mostly without children. This group represents approximately 17.3 percent of AEP Ohio's customer base and 18.3 percent of budget billing customers. Approximately 18.5 percent are high or extremely high users of electricity. This group is generally interested in energy efficiency programs, though none of the clusters were identified as being "green."

Budget Stretchers (9 clusters) – This group consists of low and middle income, mostly young renters, single and without children. They represent approximately 12.7 percent of the customer base and roughly 3.2 percent of budget billing customers. This group is interested in energy efficiency programs, with two of the nine clusters being identified as "green."

Big Bills (8 clusters) – This group consists of wealthy, middle-aged homeowners, married with some having children. They represent approximately 13.3 percent of the customer base and around 19.1 percent of budget billing customers. 31.2 percent are high or extremely high users of electricity. Many are interested in ways to reduce their bills, but are busy with families, careers, etc. This limits the time they are willing to commit to reduced usage efforts. One of the eight clusters was identified as being "green."

Remaining Budget Billed (16 clusters) – This group consists of households with a mix of incomes, late middle-aged and senior, both married and single, and with or without children. They represent 21 percent of the customer base and 38 percent of budget billing customers. 11.8 percent are high or extremely high users of electricity. Since many are on set incomes, they are interested in ways to reduce their usage and save money. Two of the 16 clusters were identified as being "green."

Remaining with Children (9 clusters) – This group consists of mostly low to middle income families with children. They are both young and middle-aged and mostly own their homes. They represent 17.5 percent of the customer base and 10.7 percent of budget billing customers. 13.5 percent are high to extremely high users of electricity. These households are generally busy with family and are not concerned with energy efficiency. None of the clusters were identified as "green."

Remaining without Children (17 clusters) – This group is very diverse in their incomes, ages and home ownership status. It also contains both married and single homes without children. They represent 18.2 percent of the customer base and 10.7 percent of budget billing customers. Nine percent are high or extremely high users of electricity. These households are not generally concerned with energy efficiency. Two of the 17 clusters were identified as being "green."

5.4.1 Education Approach

AEP Ohio adopted a multi-channel approach to customer education. The company began contacting customers in December 2010 with mailings in the Project area. These initial mailings notified the customers of the upcoming Project. The following nine months consisted of periodic direct mailings for the same customer set. These mailings provided mainly educational materials for smart meters and included "teasers" about upcoming consumer programs and technologies.

5.4.1.1 gridSMART Website

In early 2011, information about the Project was added to the already existing gridSMARTOhio.com, as shown in Figure 29, and aepohio.com websites and was updated as technologies and consumer programs evolved.

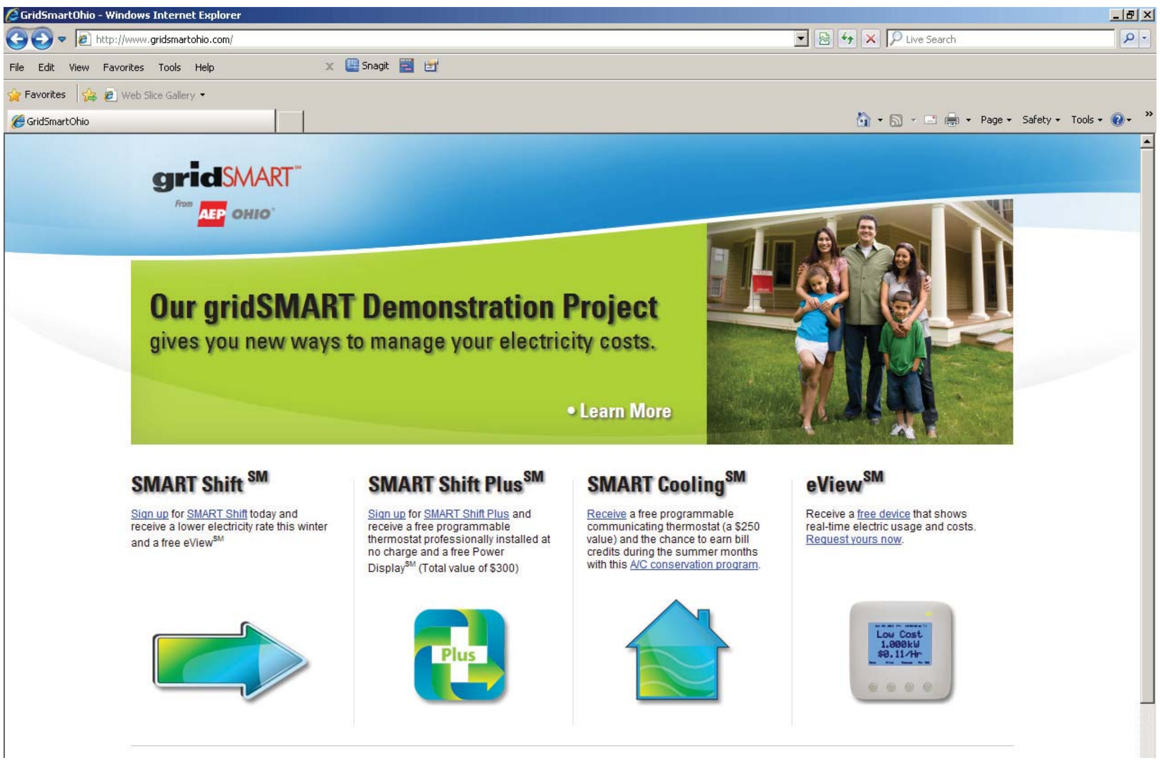


Figure 29. AEP Ohio gridSMART Website

The gridSMART website provided details about the Project and also provided links to the different consumer programs available to customers, offering the ability to enroll online.

5.4.1.2 gridSMART Mobile

In addition to the website and ongoing direct mail campaigns, AEP Ohio created the gridSMART Mobile, as shown in Figure 30.

Figure 30. gridSMART Mobile

Launched in May 2011, this converted RV contained six interactive exhibits designed to educate customers on different aspects of the Project. Upon entering the vehicle, customers were able to view a brief computer-driven, multi-media presentation. This presentation consisted of a video explaining the basics of the Project, and included a unique sound and light presentation that mimicked a realistic display of thunder and lightning.

Following the presentation, participants received an introduction to smart meters; the heart of the Project. This display provided a side-by-side comparison of the smart meter and the traditional meter and explained the benefits of using smart meters.

Other exhibits in the gridSMART mobile included a unique seven-foot-long sliding computer monitor that allowed visitors to explore a variety of new technologies that were meant to help identify power outages, restore service faster and make the distribution network more efficient. Lastly, visitors were able to test their knowledge by competing in a fun, interactive gridSMART trivia game.

The mobile's focus shifted in March 2012 from an education to a marketing channel, with much of the space designed to encourage program enrollment.

5.4.1.3 Other Education Efforts

While the gridSMART website and mobile were most visible, the team also utilized promotions to help in the education effort.

AEP Ohio worked with the Ohio Energy Project to develop and implement the gridSMART Education Program with 40 teachers and their students and families in 25 schools located throughout the Project area. Energy curriculum emphasized the new technologies and programs while correlating to Ohio's Science Content Standards.

5.5 Program Enrollment Results

Upon completion of equipment testing and completion of successful trials in AEP Ohio and AEP employee homes in the Project area, Consumer Programs were offered to consumers designated for program offerings under the stratification method discussed in section 5.4. The PUCO required that all enrollments in the first offered programs, SMART Shift and SMART Shift Plus, occur outside of the summer on-peak period effective months. This was done to alleviate concern that consumers might incur price penalties prior to their having time to adjust to the program. Enrollments in the SMART Cooling did not have time-period restrictions.

In Ohio, consumers are permitted to select their competitive generation provider. Since the gridSMART tariffs and DLC programs are primarily geared toward reduction of generation costs, experimental tariffs are not applicable for consumers who switch generation providers, As a result, participants choosing a competitive generation provider were removed from the program(s). Participants also were removed from the program(s) as they moved out of the home. Some SMART Shift participants were removed from the program(s) when their one-year hold-harmless period expired.

Enrollments in SMART Shift commenced in February 2011 and monthly enrollment and removal counts are presented in Figure 31.

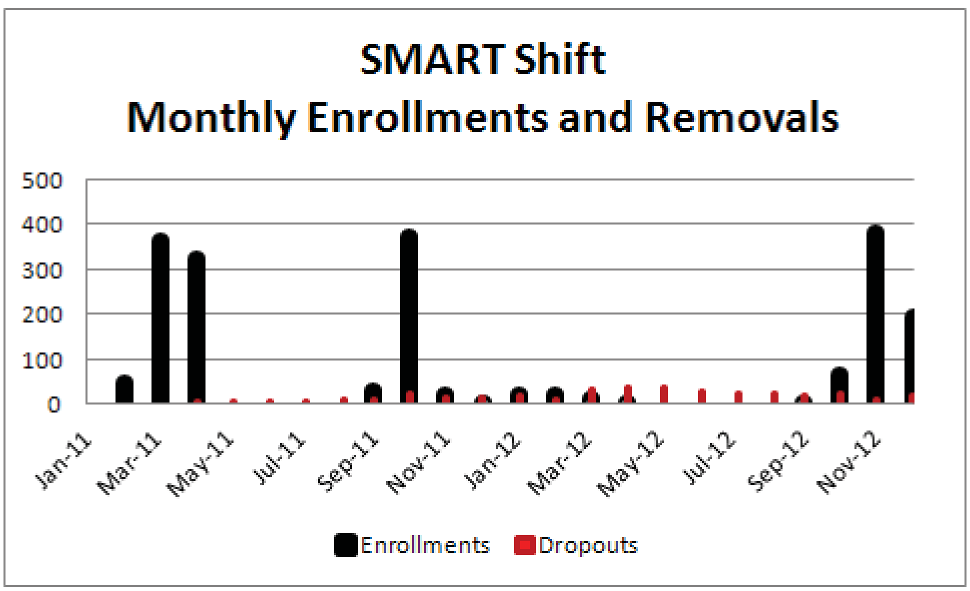


Figure 31. Monthly Enrollments – SMART Shift

Enrollments in SMART Shift Plus began in November 2011. Monthly enrollment and removal counts are presented in Figure 32.

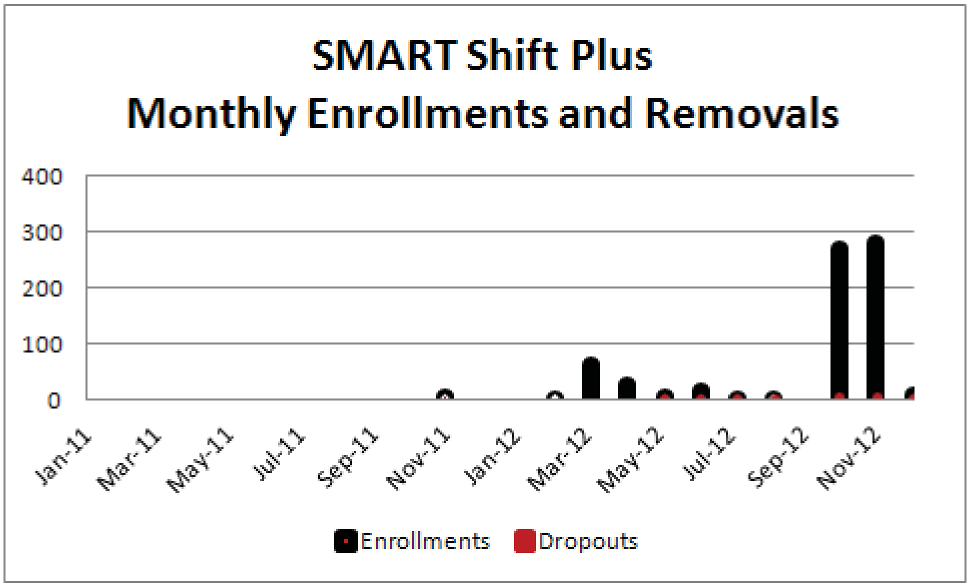


Figure 32. Monthly Enrollments - SMART Shift Plus

Enrollments in SMART Cooling began in April 2011. Monthly enrollment counts are presented in Figure 32.

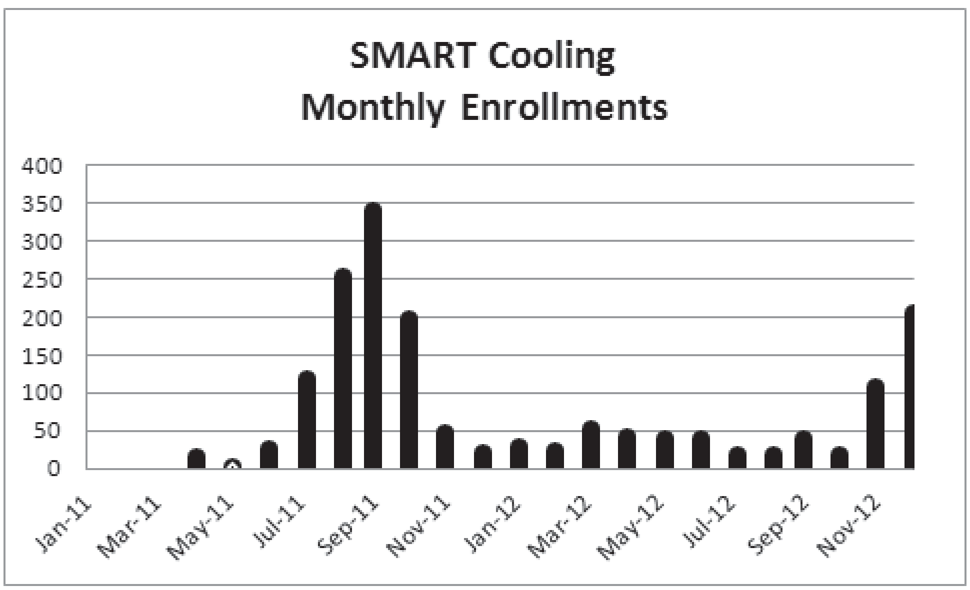


Figure 33. Monthly Enrollments - SMART Cooling

Enrollments will continue through June 1, 2013, at which time active recruitment is expected to cease.

The graphs above contain the monthly enrollment numbers. Table 12 provides the cumulative number of enrollees and installations for each of the programs.

	Program	Program To Date
Enrollments*	SMART Shift	2851
	SMART Shift Plus	1162
	SMART Cooling	3530
	SMART Cooling Plus	141
	SMART Choice	394
	eVIEW	2782
Installations*	SMART Shift Plus	712
	SMART Cooling	2248
	SMART Cooling Plus	54
	SMART Choice	161
	eVIEW	1681
Scheduled Appts (3 Wks)	SMART Shift Plus	0
	SMART Cooling	162
	SMART Cooling Plus	0
	SMART Choice	63
	eVIEW	25
Misc	Cancelled at the Door	459
	Rescheduled	1057

Table 12. Cumulative Program Enrollment Statistics

When customers contacted AEP Ohio directly regarding potential program enrollment, each customer was asked how they found out about the program and the primary motivation for pursuing program enrollment. Most customers learned about the program from the program mailers, and most participated primarily to save money. Figure 34 and Figure 35 provide the responses to those questions.

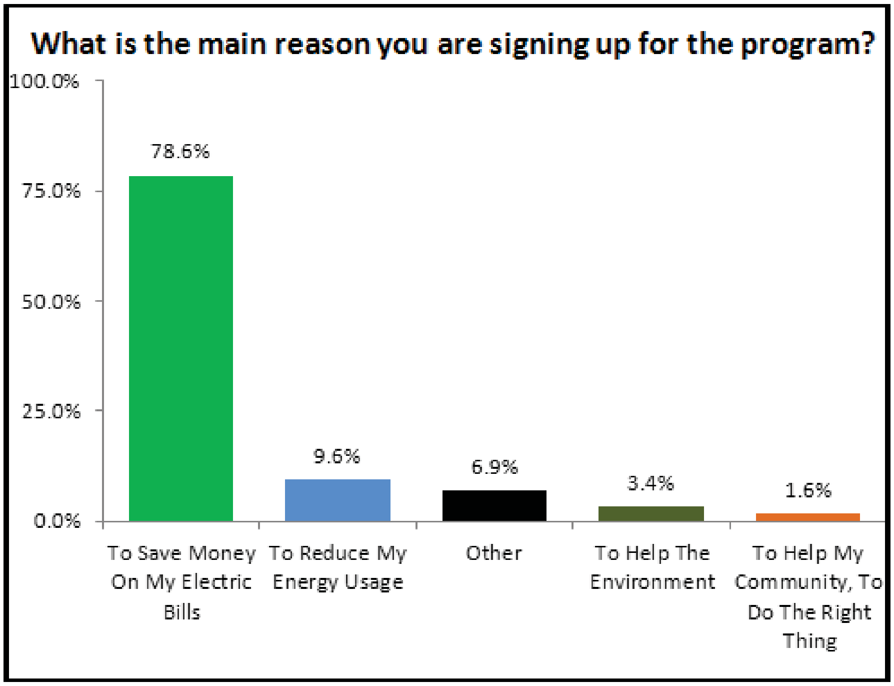


Figure 34. Program Enrollment Reasons

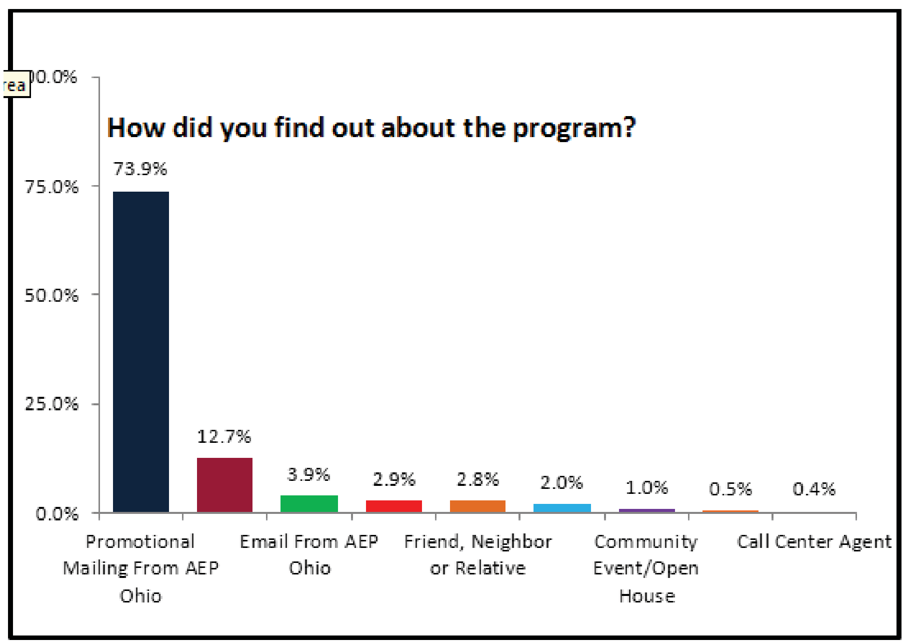


Figure 35. Consumer Notification Method

5.6 Benefits Analysis

Consumer Program technology is expected to benefit AEP Ohio's grid, operations, and customers. Below are three high-level areas of intended impacts and descriptions of how AEP Ohio anticipates that consumer programs will affect these areas.

In order to evaluate the economic, reliability, and environmental impacts created by consumer programs, detailed analysis is provided in the relative MBRP impacts metrics that follow.

5.6.1 Economic Benefits

The introduction of new consumer programs will provide economic benefits to both the consumer and the utility. Participants in several of the programs were able to reduce their bills by shifting their usage to off-peak times. This shift also provides the utility with economic benefits, as large shifts have the potential to postpone generation investments. The reduction in load through direct load control also can reduce demand.

5.6.2 Reliability Benefits

While none of the programs had direct reliability impacts, the programs that are designed to shift load to off-peak times can help to reduce the number of overload events during summer months. As these programs expand, there will be more opportunities to realize these benefits.

5.6.3 Environmental Benefits

The environmental benefits are tied directly to the load reduction achieved through the different programs. Direct load control contributes to reduced demand. While some load is shifted, which does not actually reduce emissions, the net effect of several of the programs is an overall usage reduction, which reduces generation emissions.

The practice of "pre-cooling" appears to be a factor at this time. However, complete analysis on this practice is unavailable. This information will be included in the Final Report.

5.7 MBRP Impact Metric Details (Consumer Programs)

Of the 43 total impact metrics enumerated in the MBRP for the Project, the following eight impact metrics are associated with the AMI suite of technologies- five relate to the Project area and three relate to the System area. See Table 6 for a complete list of impact metrics and each metric's relevance to a particular technology set.

Metric ID	Metric Scope	Metric Description	Consumer Programs
M01	Project	Hourly Customer Electricity Usage	M01-CP
M02	Project	Monthly Customer Electricity Usage	M02-CP
M03	Project	Peak Load and Mix	M03-CP
M07	Project	CO_2 Emissions	M07-CP
M08	Project	Pollutant Emissions (SO_X, NO_X, $PM_{2.5}$)	M08-CP
M09	System	CO_2 Emissions	M09-CP
M10	System	Pollutant Emissions (SO_X, NO_X, $PM_{2.5}$)	M10-CP
M24	System	Reduced Transmission Congestion Cost	M24-CP

Table 13. Impact Metrics Discussed in Each of the Interim Quantification Reports

5.7.1 Hourly Customer Electricity Usage (M01-CP)

5.7.1.1 Objective

Consumer Programs and supporting devices have the potential to enable and influence consumer usage patterns. Utilities can provide incentives for customers to modify their usage and behavior to reduce peak loading and enable load shifting. This impact metric examines tariff composition in relation to consumer-adopted programs and devices. These consumer programs include: time-of-use prices, critical peak price events, DLC events, and a real-time pricing tariff. This impact metric will also compare the impacts against various customer demographic categories and consumer strata. These parameters will be used to determine which programs have the most impact.

5.7.1.2 Organization of Results

All load profile data for this metric includes 2011 and 2012 information.

Various views of data were selected to quantify and visualize this impact metric, Hourly Customer Electricity Usage. The key parameters of interest include time, account class, the account's applicable tariff, and, for residential accounts, applicable demographic data.

The time varying aspect of consumer behavior is addressed by: 1) aggregating data by three seasons- Summer, Winter and Autumn/Spring combined; 2) aggregating data for different day types into three groupings- Weekday (Monday through Friday), Saturday, and Sunday; and 3) graphing usage data as a function of each hour of the day- 1 through 24.

Account class was set as the three traditional groupings of customers: Industrial, Commercial and Residential.

Residential customers were categorized by account class, tariff, and demographic. RTP_{da} analysis will be included in the Final Report.

Due to the extent of possible analysis combinations, subsets of combinations were chosen for this report, as shown in Table 14. Analysis is provided only for the areas for which a figure notation is present.

		Season:	Summer			Winter			Autumn/Spring		
		Day Type:	Weekday	Saturday	Sunday	Weekday	Saturday	Sunday	Weekday	Saturday	Sunday
Account Class	Category of Data	Dimension									
Industrial	All Customers	None	Figure 36	x	x	Figure 37	x	x	x	x	x
Commercial	All Customers	None	Figure 38	x	X	Figure 39	x	x	x	x	x
Residential	All Demographics	by Tariff	Figure 40			Figure 41			Figure 42	x	x
		“ (weekend)		Figure 43	Figure 44		Figure 45	Figure 46			
	Graphs for Each Tariff										
	All Three Tariffs (013,040,043)	by Demographic	Figure 47	x	X	Figure 51	x	x	x	x	x
	013 Standard tariff	by Demographic	Figure 48	x	X	Figure 52	x	x	x	x	x
	040 SMART Shift	by Demographic	Figure 49	x	X	Figure 53	x	x	x	x	x
	043 SMART Shift Plus	by Demographic	Figure 50	x	X	Figure 54	x	x	x	x	x
	Graphs for Each Demographic										
	Big Bills	by Tariff	Figure 55	x	x	x	x	x	x	x	x
	Optimizer	by Tariff	Figure 56	x	x	x	x	x	x	x	x
	Budget Stretcher	by Tariff	Figure 57	x	x	x	x	x	x	x	x
	Remaining with Kids	by Tariff	Figure 58	x	x	x	x	x	x	x	x
	Remaining with out Kids	by Tariff	Figure 59	x	x	x	x	x	x	x	x
	Remaining Budget Billed	by Tariff	Figure 60	x	x	x	x	x	x	x	x

Table 14. Table of Figures used for “Hourly Customer Electric Usage” Metric

5.7.1.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

5.7.1.4 Results of Data Collected to Date

The figures on the following pages quantify the impact metric for this section.

Hourly Load Profiles by Account Class: Summer/Winter, Industrial/Commercial

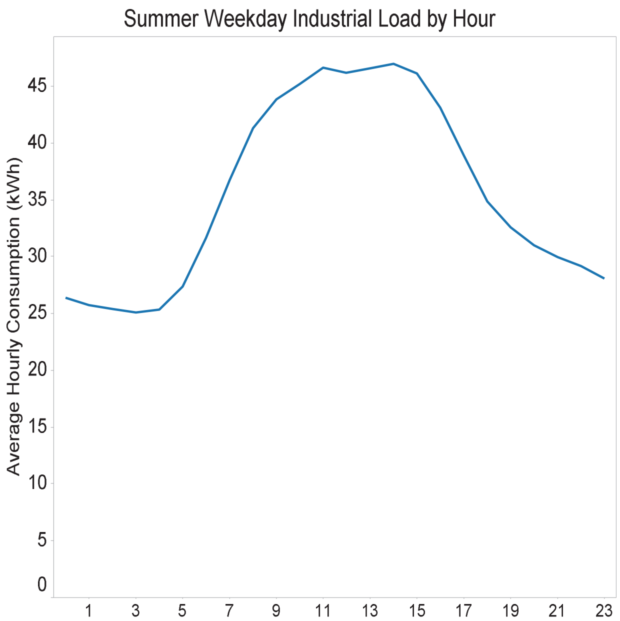


Figure 36. Summer Industrial hourly load profile (Weekday)

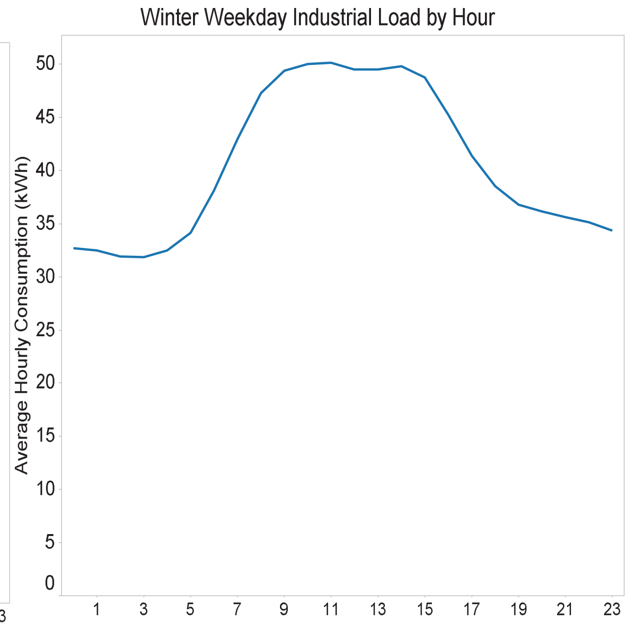


Figure 37. Winter Industrial hourly load profile (Weekday)

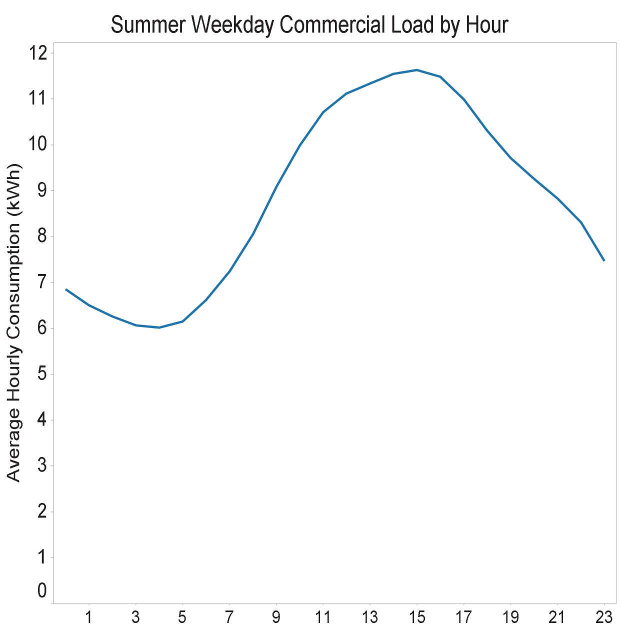


Figure 38. Summer Commercial hourly load profile (Weekday)

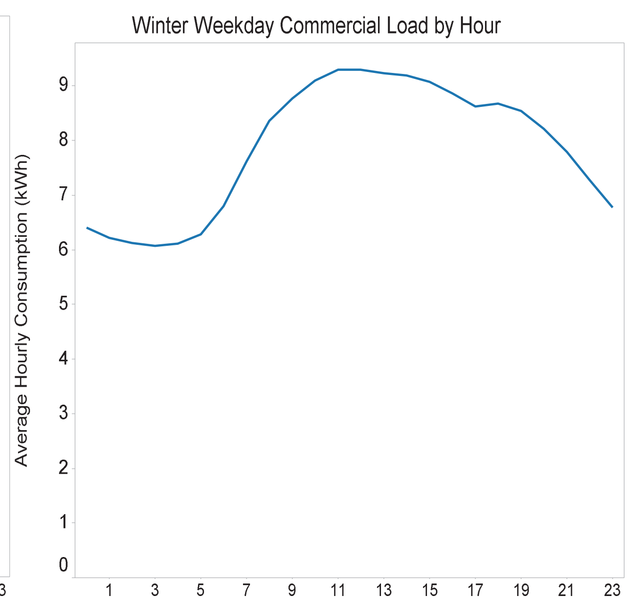


Figure 39. Winter Commercial hourly load profile (Weekday)

Hourly Residential Load Profiles by Tariff for each season: Summer, Winter, Autumn/Spring combined.

Note: *Tariff 013 is Standard Residential; Tariff 040 is SMART Shift; Tariff 043 is SMART Shift Plus*

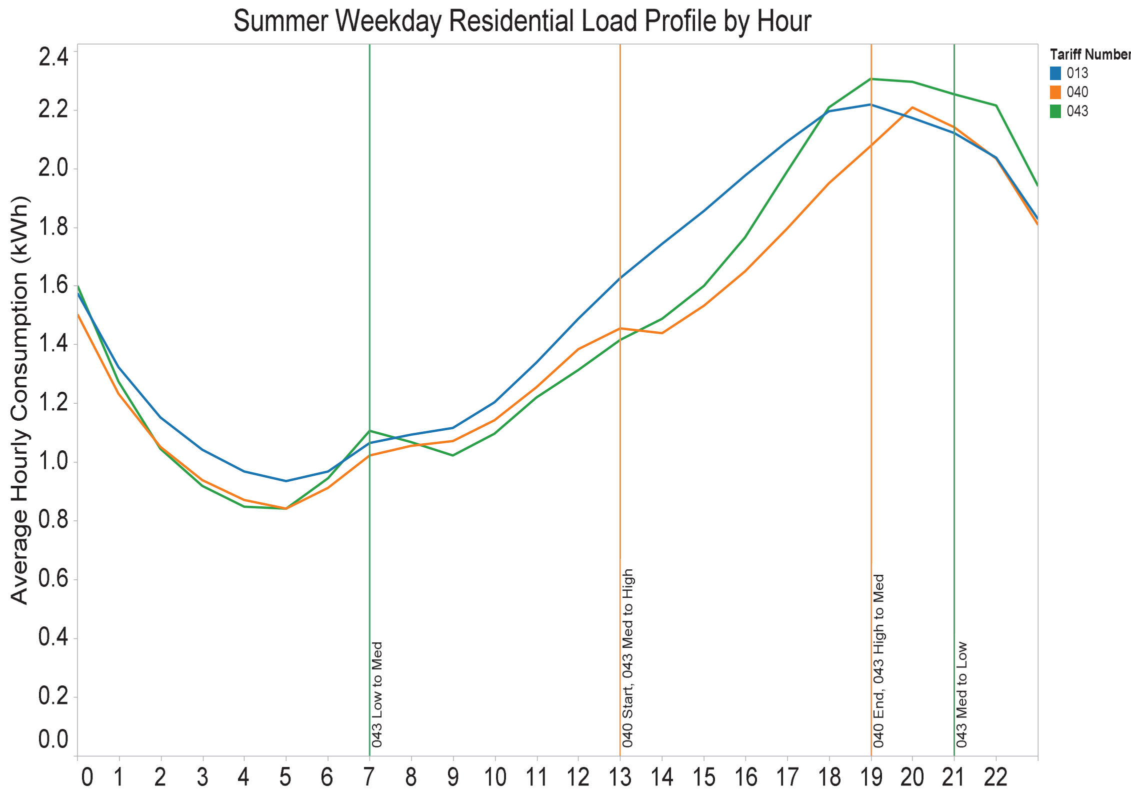


Figure 40. Summer hourly load profile by Tariff (Weekday)

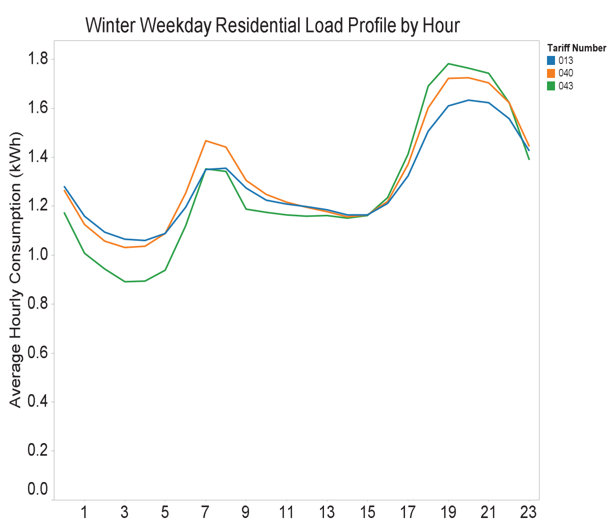


Figure 41. Winter hourly load profile by Tariff (Weekday)

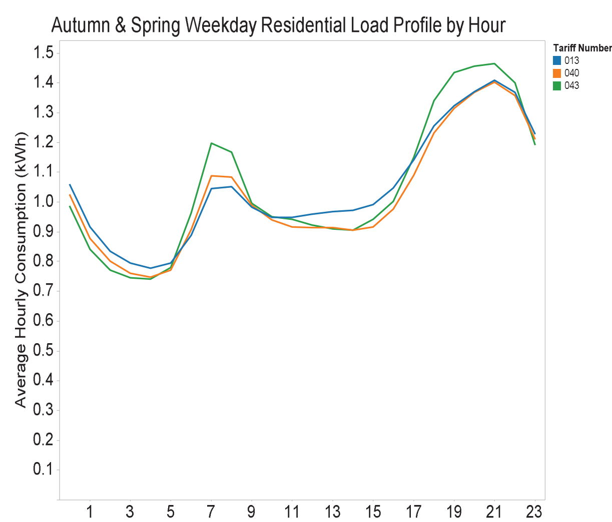


Figure 42. Autumn/Spring hourly load profile by Tariff (Weekday)

Weekend Hourly Residential load profiles by Tariff: Summer, Winter

Note*: Tariff 013 is Standard Residential; Tariff 040 is SMART Shift; Tariff 043 is SMART Shift Plus.*

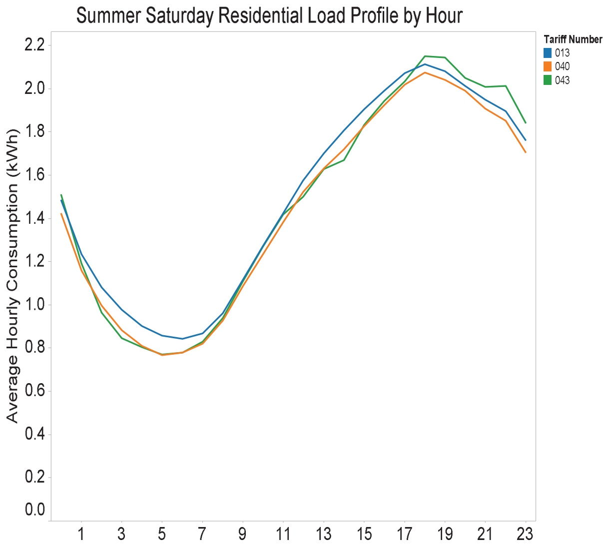


Figure 43. Summer hourly load profiles by tariff (Saturday)

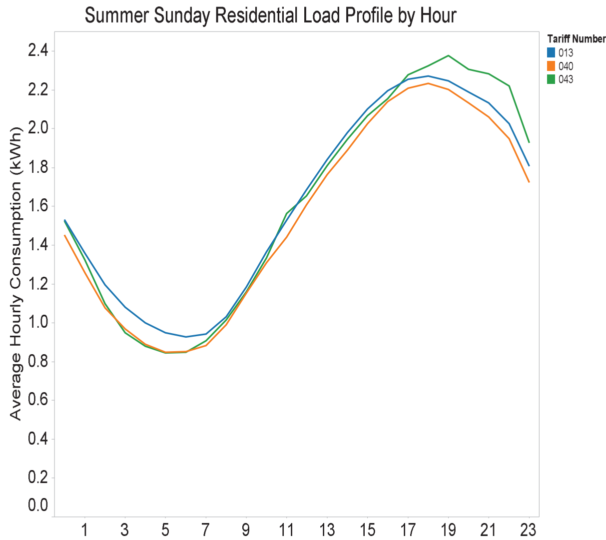


Figure 44. Summer hourly load profiles by tariff (Sunday)

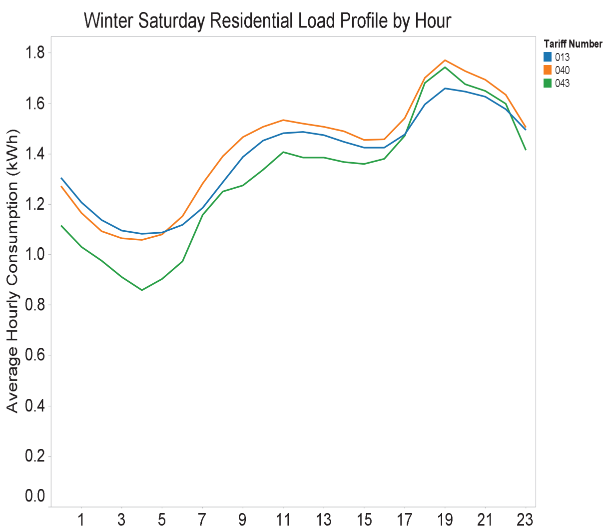


Figure 45. Winter hourly load profiles by tariff (Saturday)

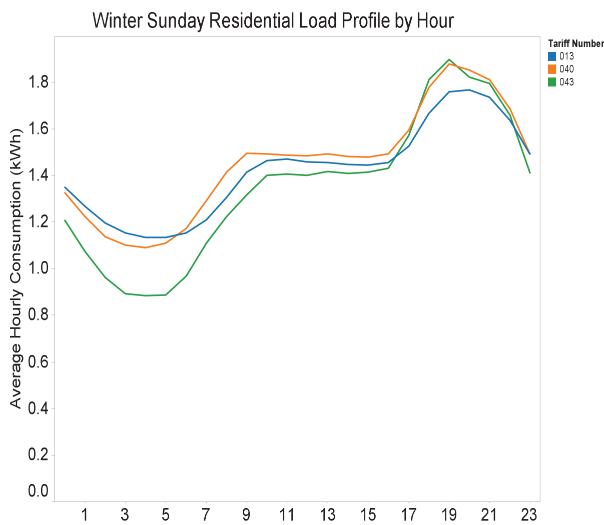


Figure 46. Winter hourly load profiles by tariff (Sunday)

Residential hourly load profiles by Demographic: Summer, Winter.

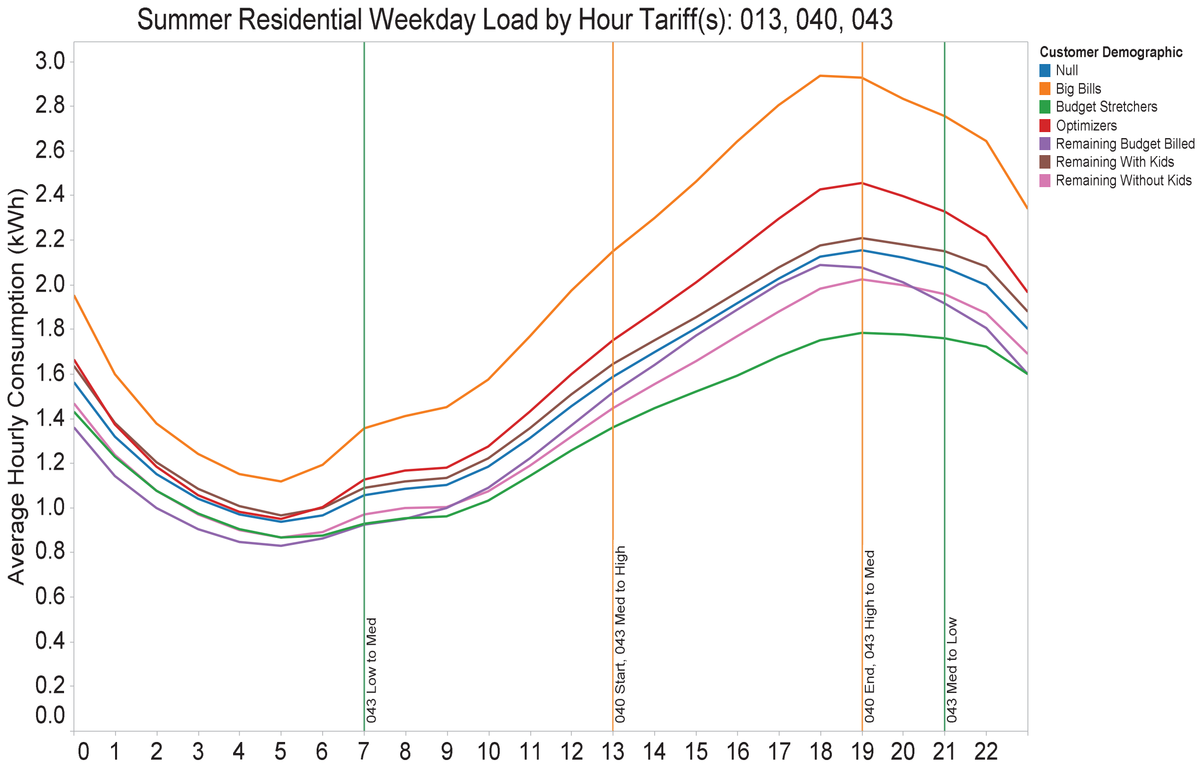


Figure 47. Summer hourly load profile by Demographic - All Tariffs (Weekday)

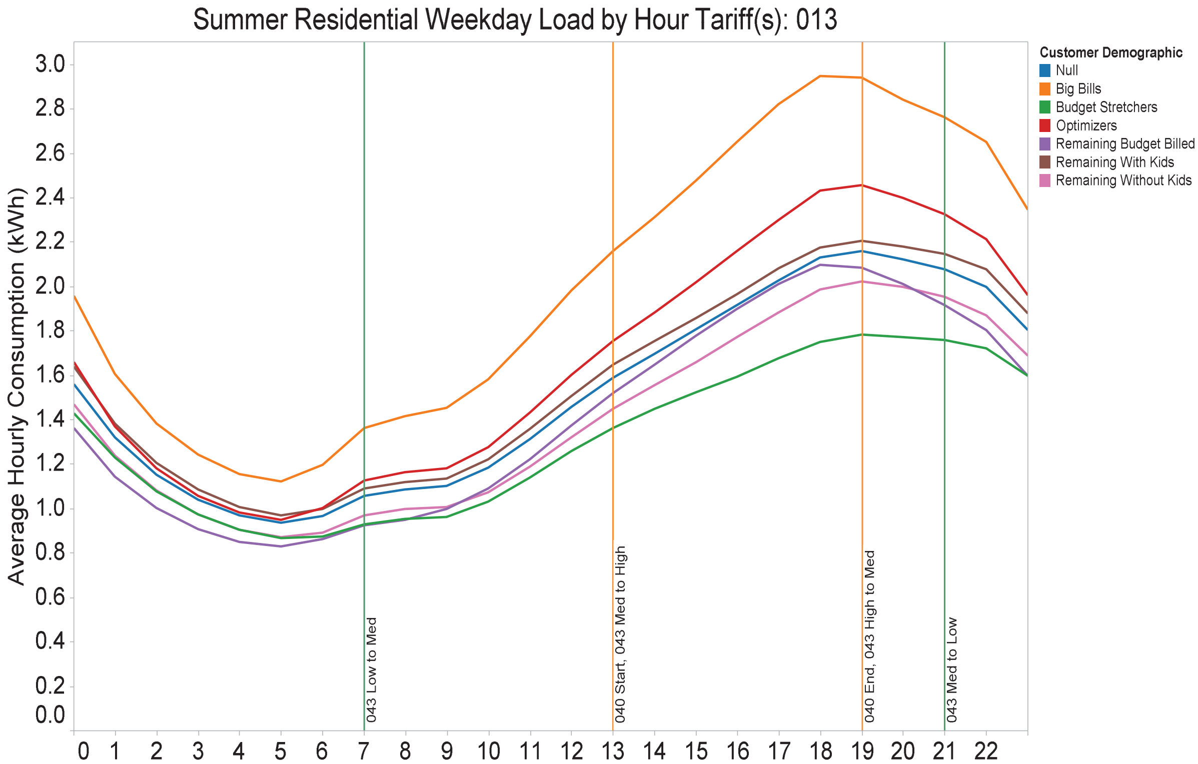


Figure 48. Summer hourly load profile by Demographic – 013 Standard Residential Tariff (Weekday)

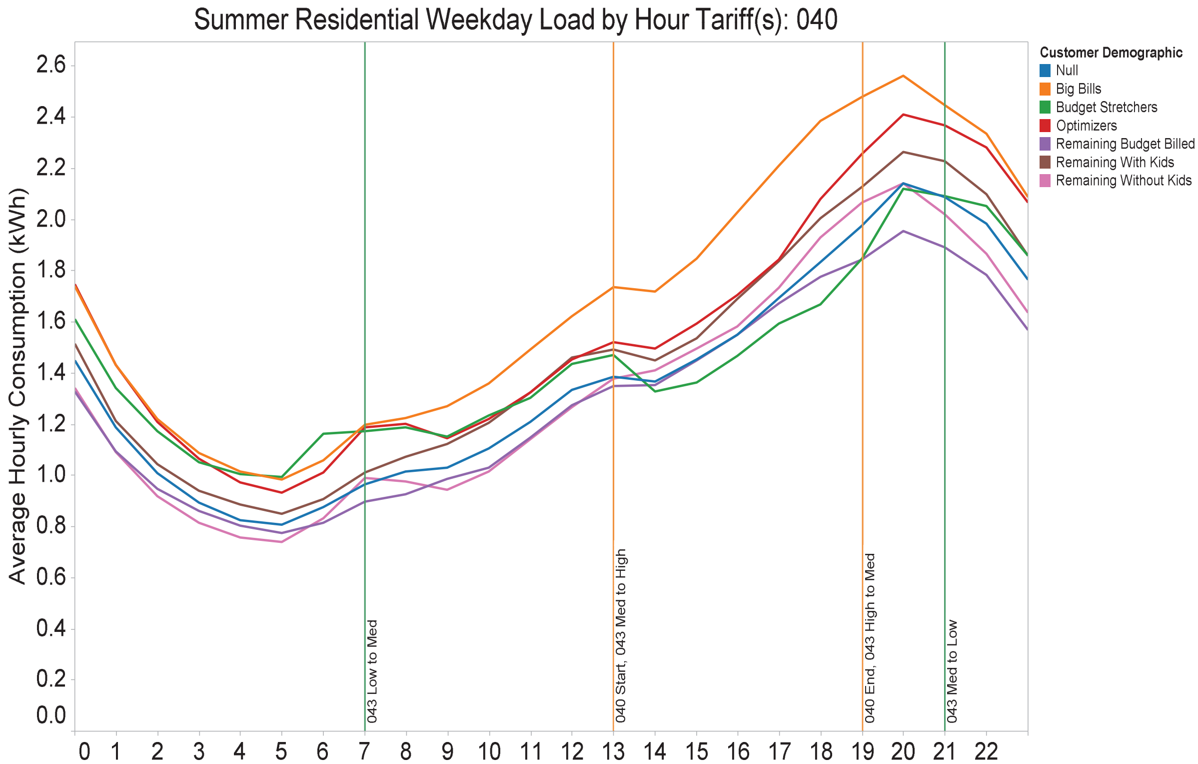


Figure 49. Summer hourly load profile by Demographic – 040 SMART Shift (Weekday)

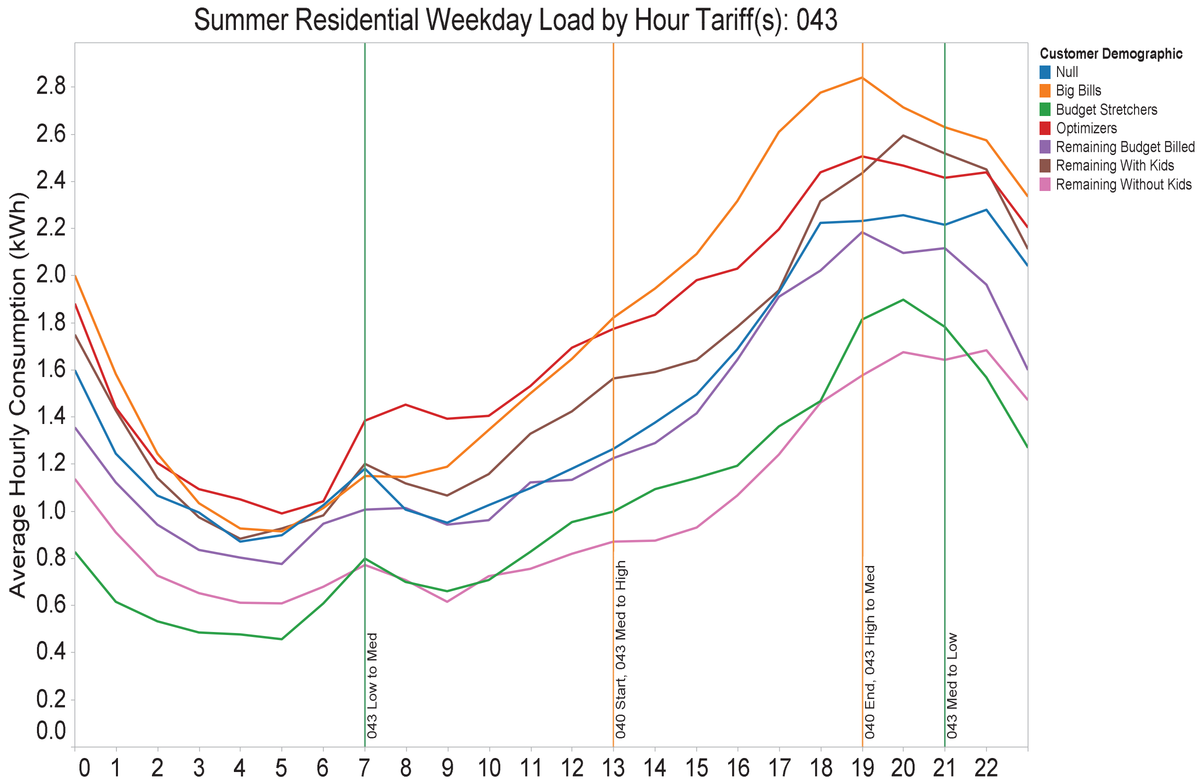


Figure 50. Summer hourly load profile by Demographic – 043 SMART Shift Plus (Weekday)

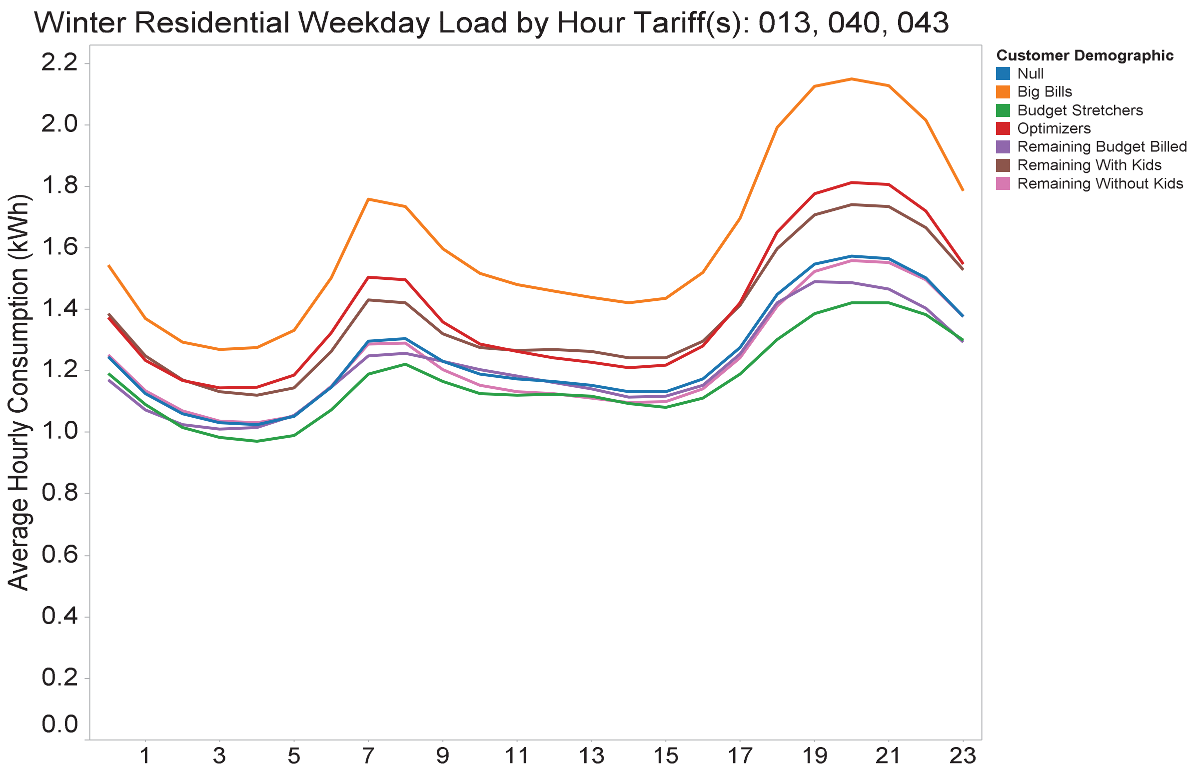


Figure 51. Winter hourly load profile by Demographic – All Tariffs (Weekday)

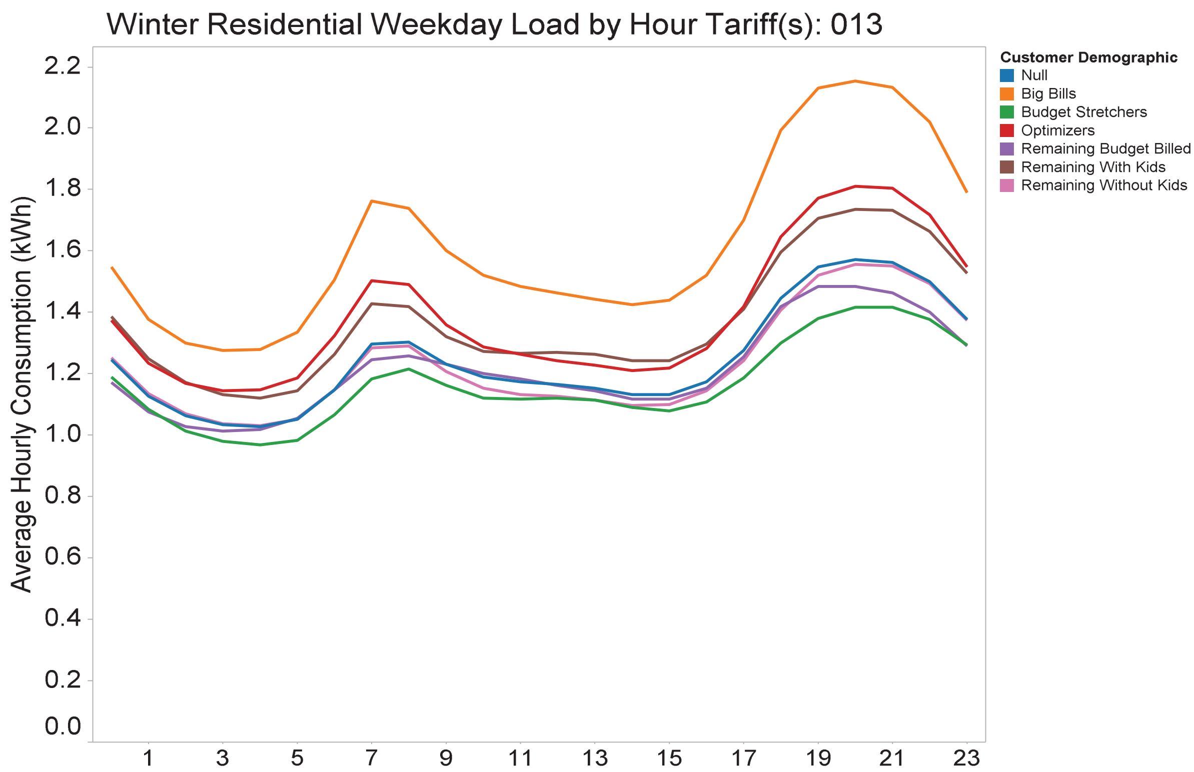


Figure 52. Winter hourly load profile by Demographic – 013 Standard Residential (Weekday)

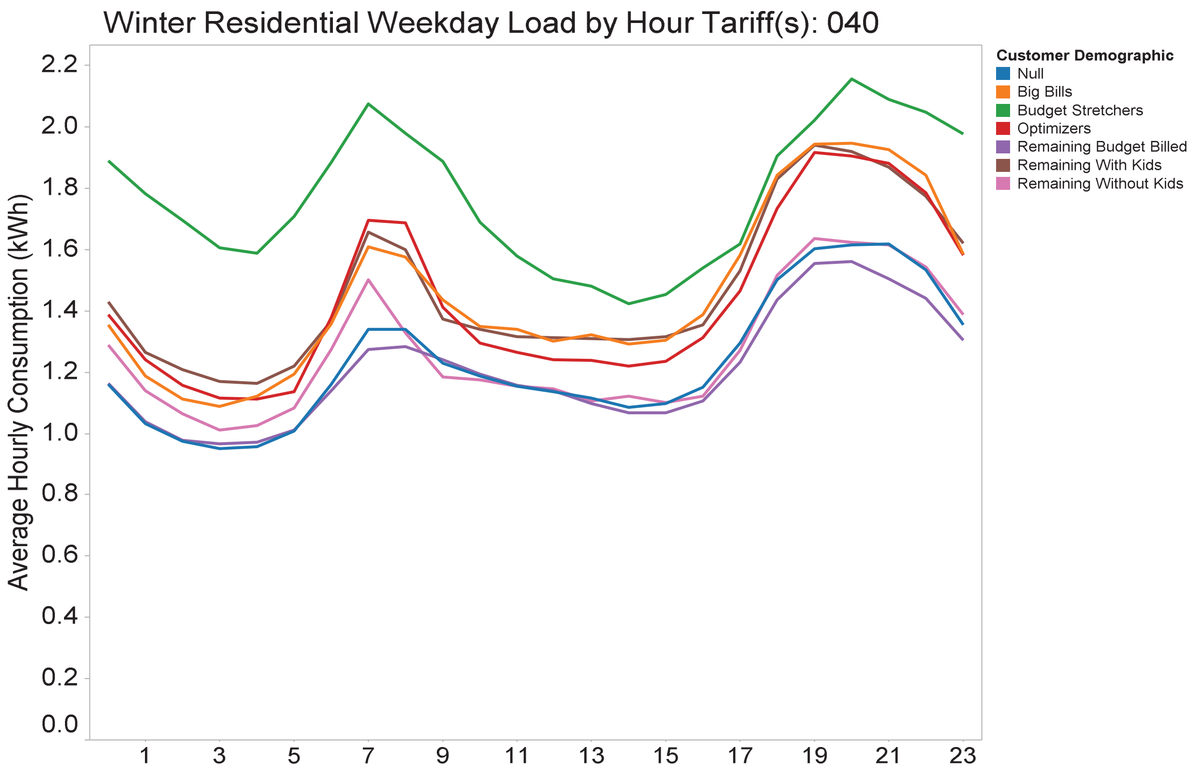


Figure 53. Winter hourly load profile by Demographic – 040 SMART Shift (Weekday)

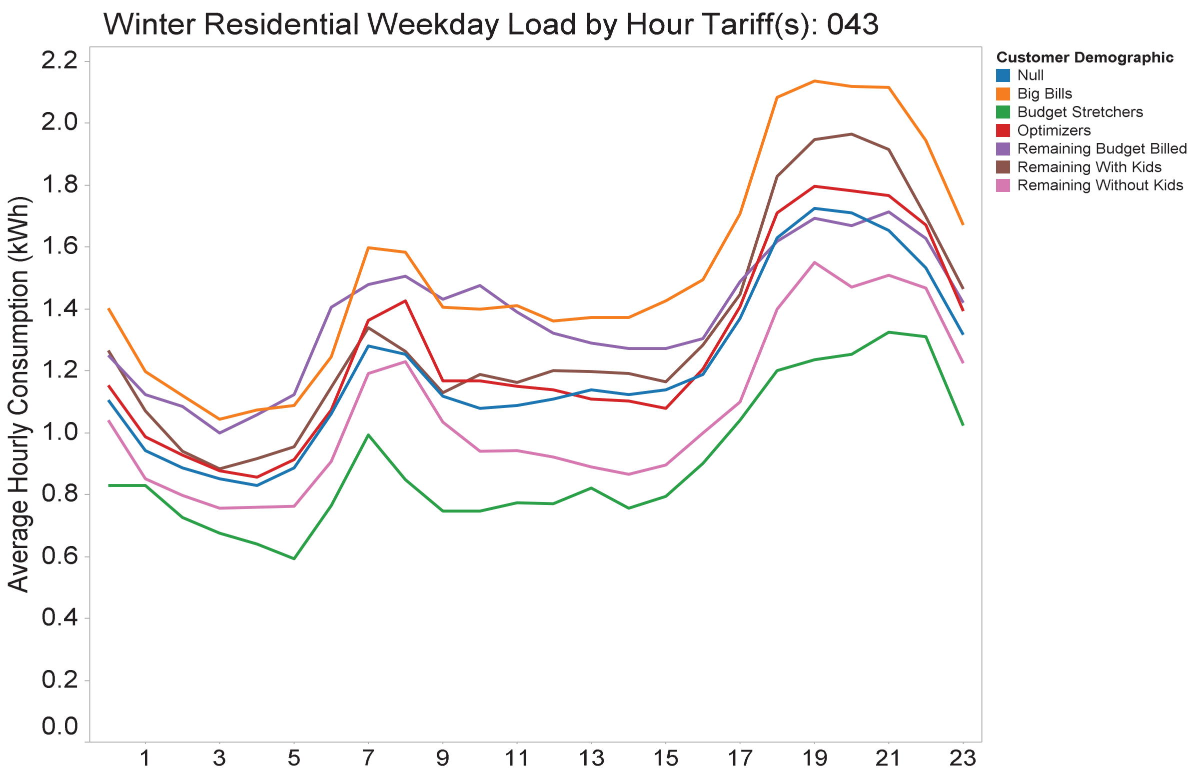


Figure 54. Winter hourly load profile by Demographic– 043 SMART Shift Plus (Weekday)

Residential Hourly Load Profiles for Each Demographic by Tariff: Summer Weekday.

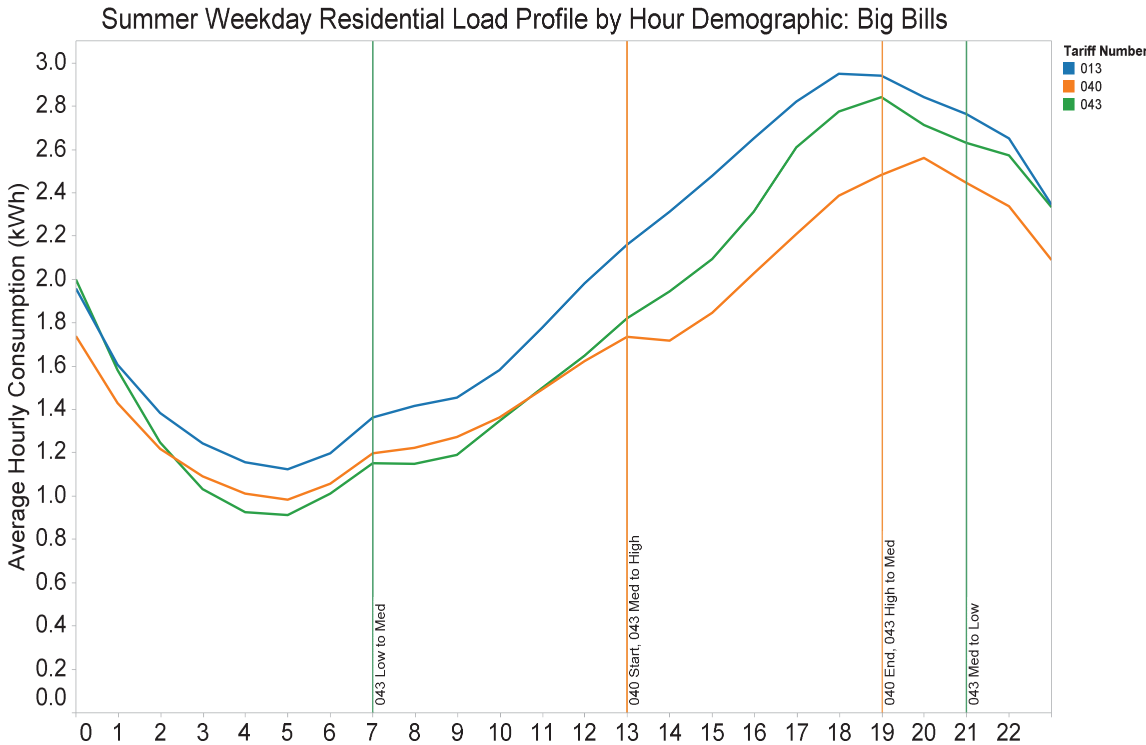


Figure 55. Summer hourly load profile for "Big Bills" by Tariff (Weekday)

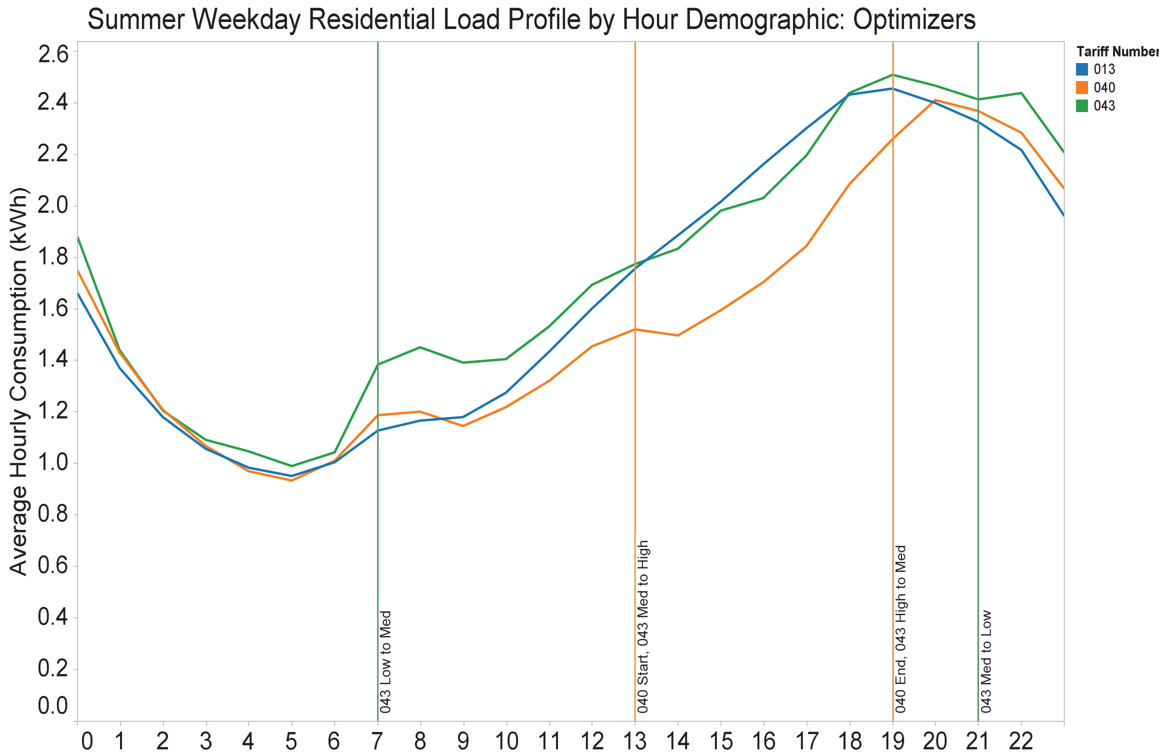


Figure 56. Summer hourly load profile for "Optimizers" by Tariff (Weekday)

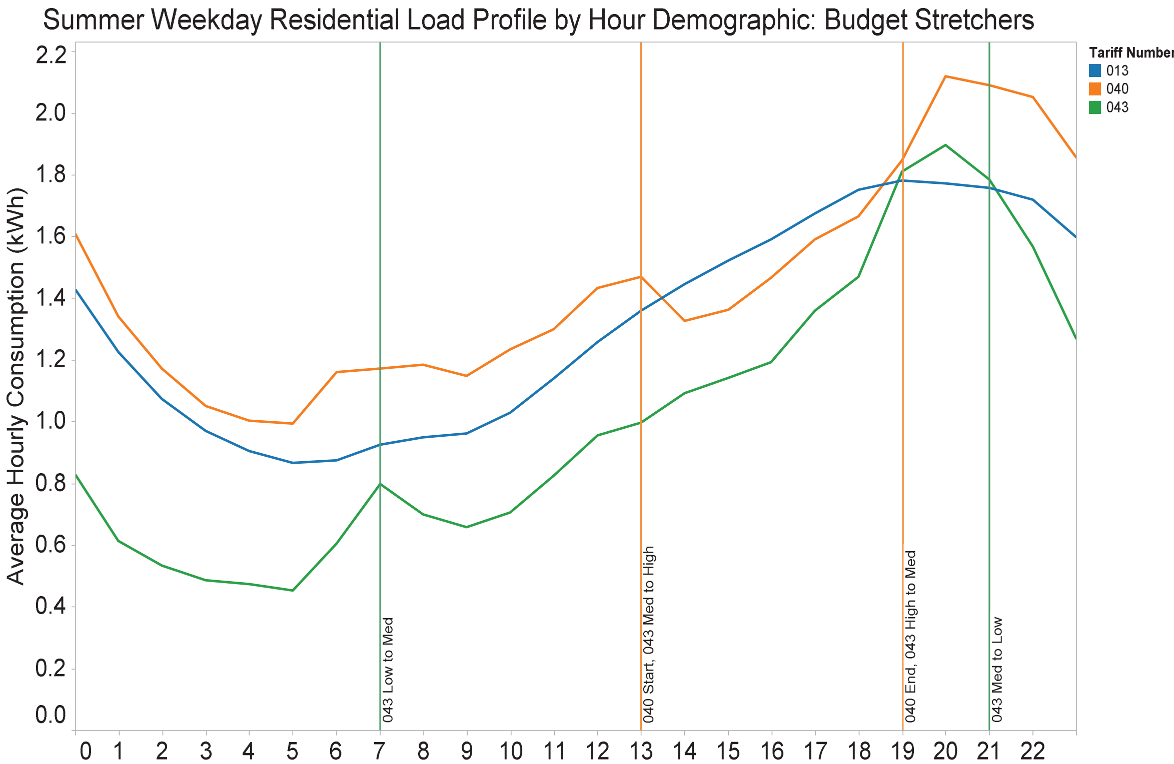


Figure 57. Summer hourly load profile for "Budget Stretcher" by Tariff (Weekday)

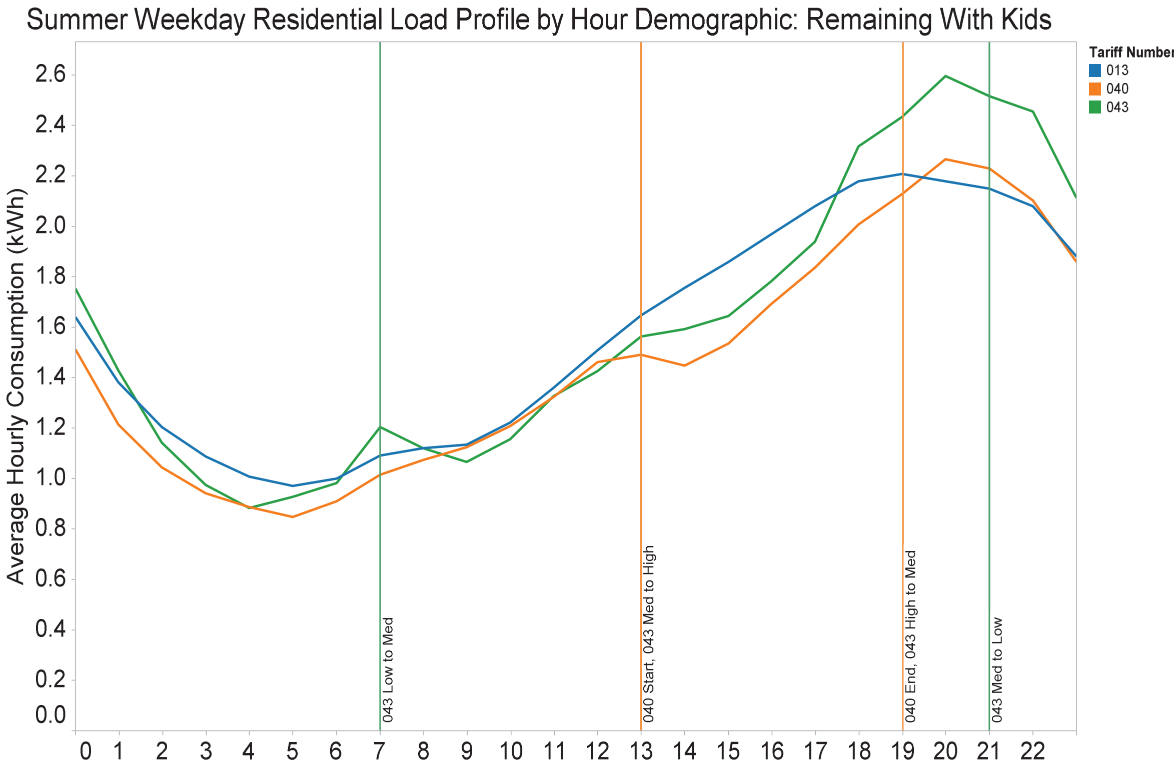


Figure 58. Summer hourly load profile for "with kids" by Tariff (Weekday)

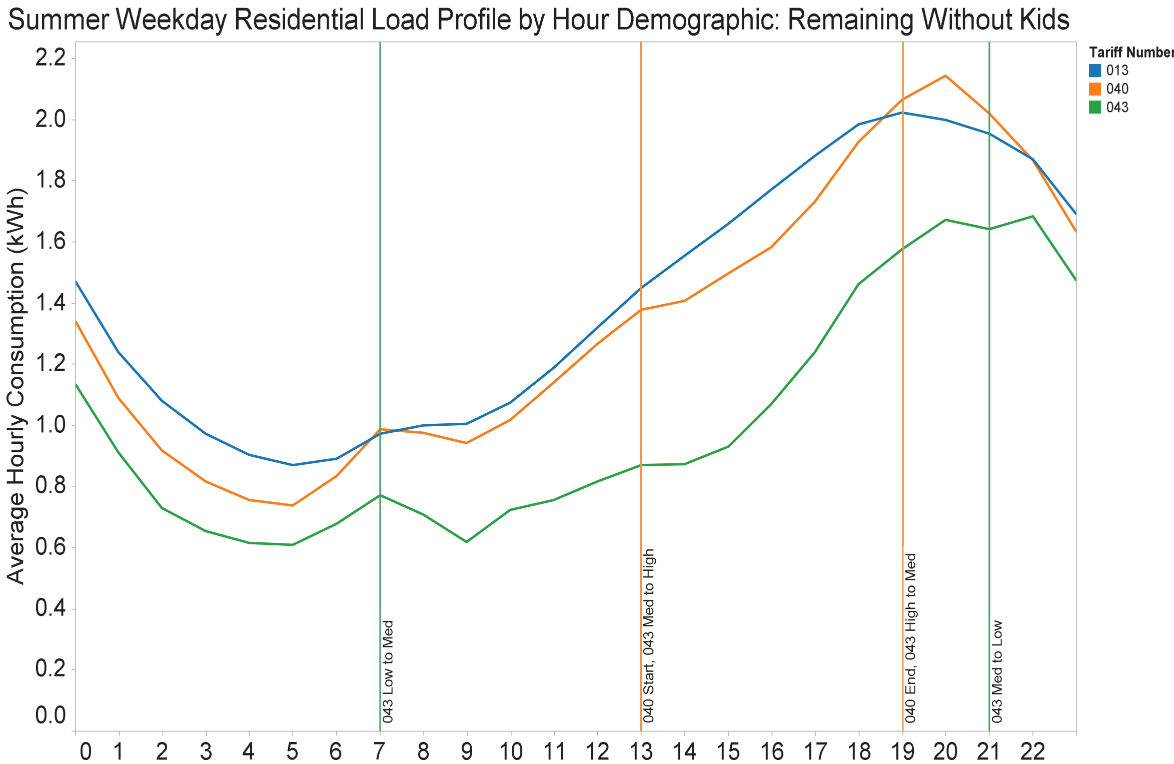


Figure 59. Summer hourly load profile for "without kids" by Tariff (Weekday)

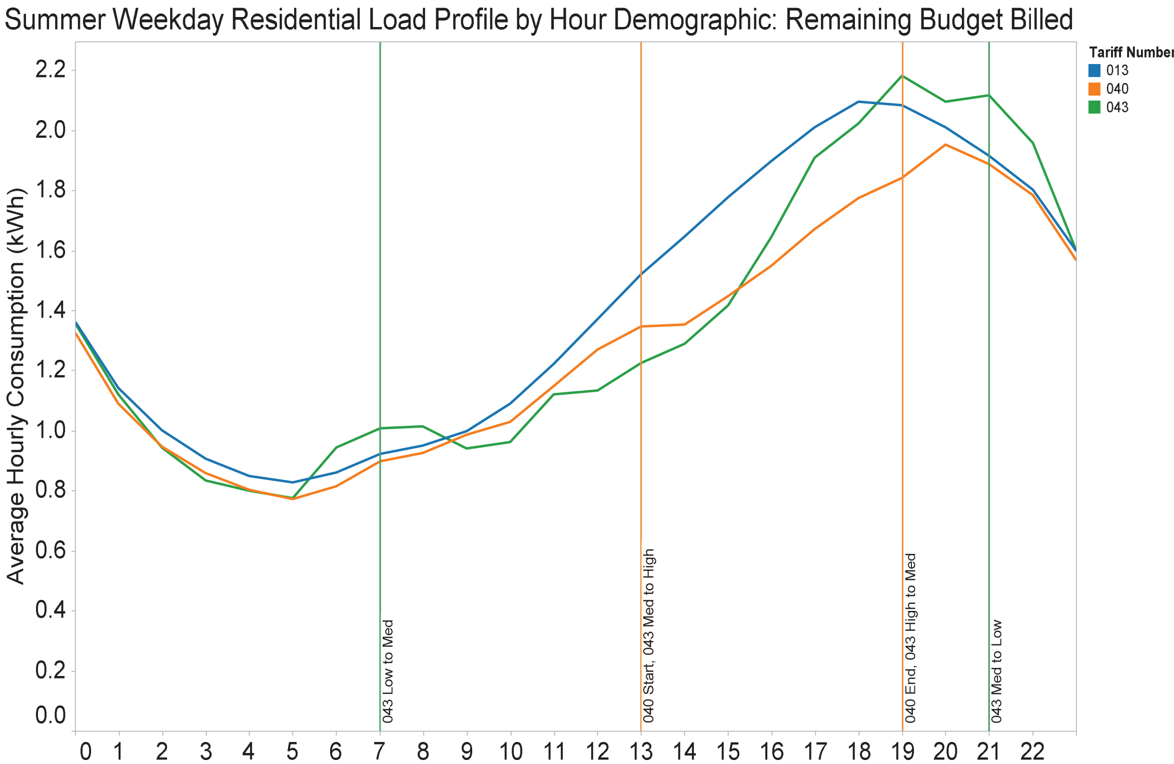


Figure 60. Summer hourly load profile for "Budget Billed" by Tariff (Weekday)

Calculation Approach

This impact metric provides an analysis of average daily usage patterns for consumers grouped by combinations of day of week, season, demographic, and tariff.

The following queries and methods were used to generate presentation items:

- Hourly customer electricity usage was calculated by averaging hourly customer electricity usage into 24 hourly bins.

5.7.2 Monthly Customer Electricity Usage (M02-CP)

5.7.2.1 Objective

Consumer Programs and supporting devices have the potential to enable and influence consumer usage patterns. Utilities can provide incentives for customers to modify their usage and behavior to reduce peak loading and enable load shifting. Customers in various account classes, demographic groups and strata are expected to modify their behaviors and consumption patterns as a result of participating in any of the consumer programs offered. This impact metric will measure the cost impact to electricity customers as a result of various consumer programs.

5.7.2.2 Organization of Results

All load profile data for this metric includes 2011 and 2012 information.

This metric presents average monthly bills for residential, commercial, and industrial customer classes for 2011 and 2012. The residential graphs are separated by tariff and demographic.

- Residential monthly average costs
  - The first residential graph shows the average monthly bill per customer by tariff code 013, 040 or 043. The second graph shows the average monthly bill per customer by demographic.
- Commercial and industrial monthly average costs
  - This section has two graphs, one for industrial and one for commercial average monthly cost.

5.7.2.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

For this metric, a month refers to a monthly billing cycle, not a calendar month.

5.7.2.4 Results of Data Collected to Date

The following Figures constitute this section

Figure 64. Average residential monthly bill by customer device

Presentation of residential monthly cost data:

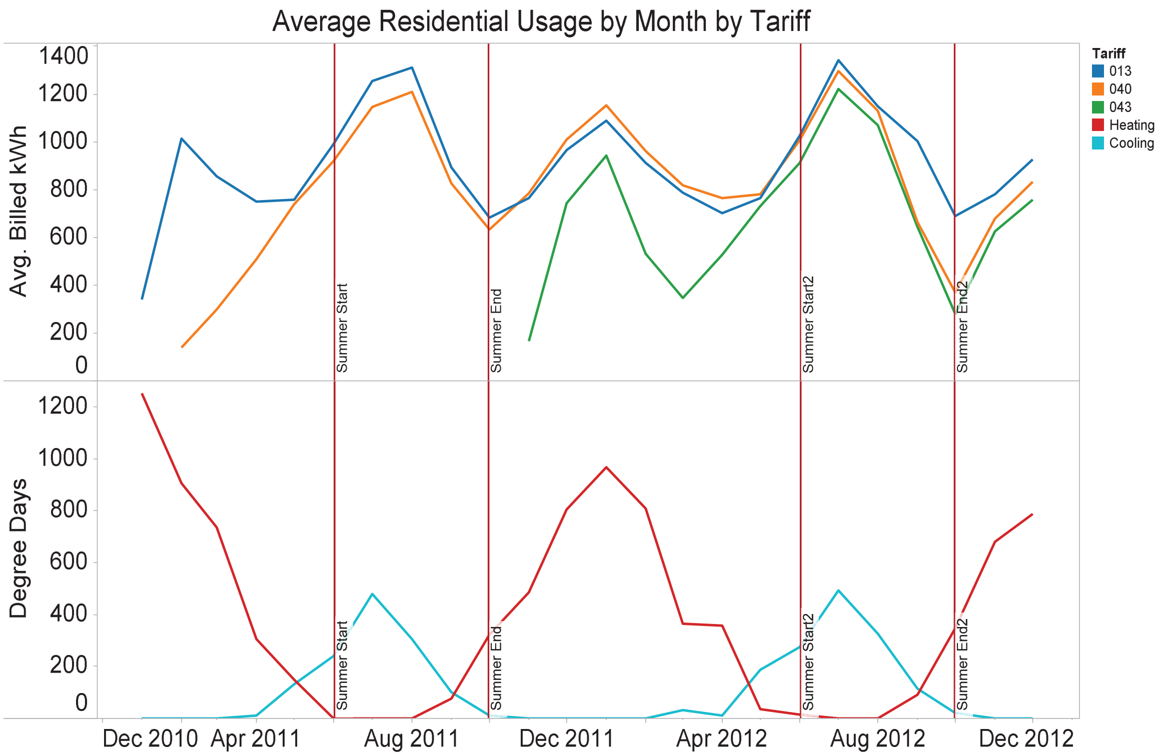


Figure 61. Average residential monthly usage for three tariffs: 013 Standard Residential, 040 SMART Shift, and 043 SMART Shift Plus

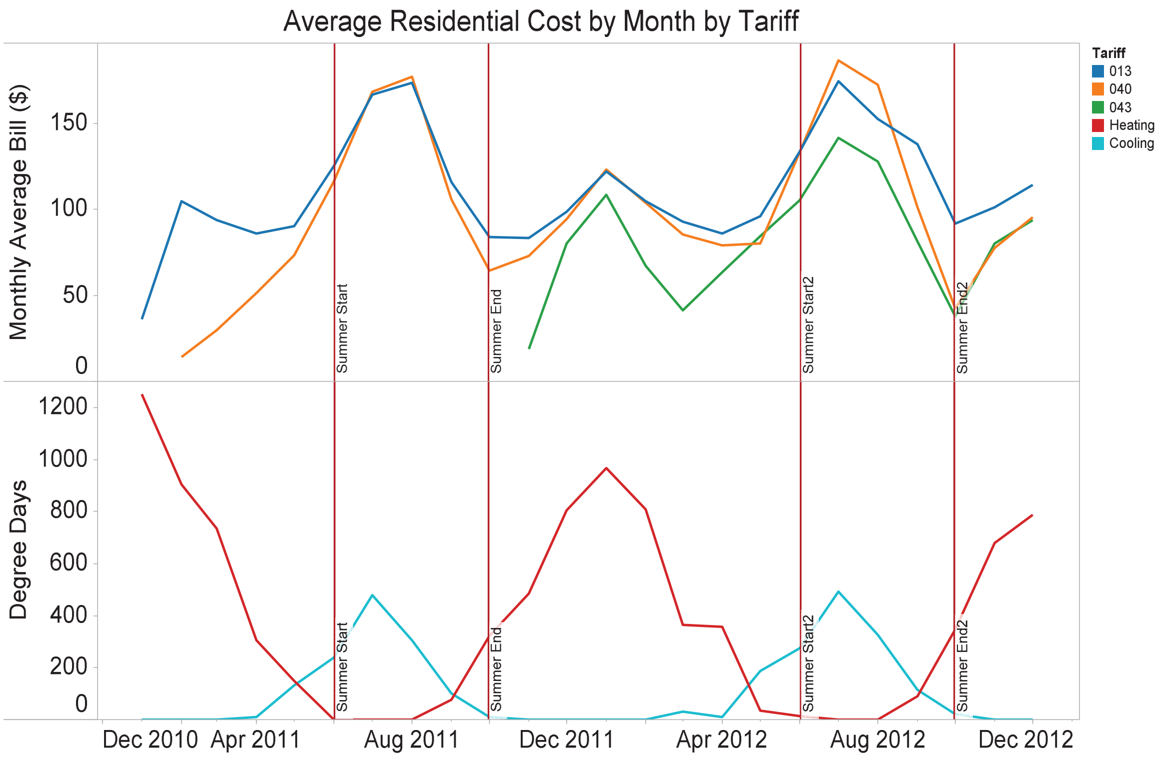


Figure 62. Average residential monthly bill for three tariffs: 013 Standard Residential, 040 SMART Shift, and 043 SMART Shift Plus

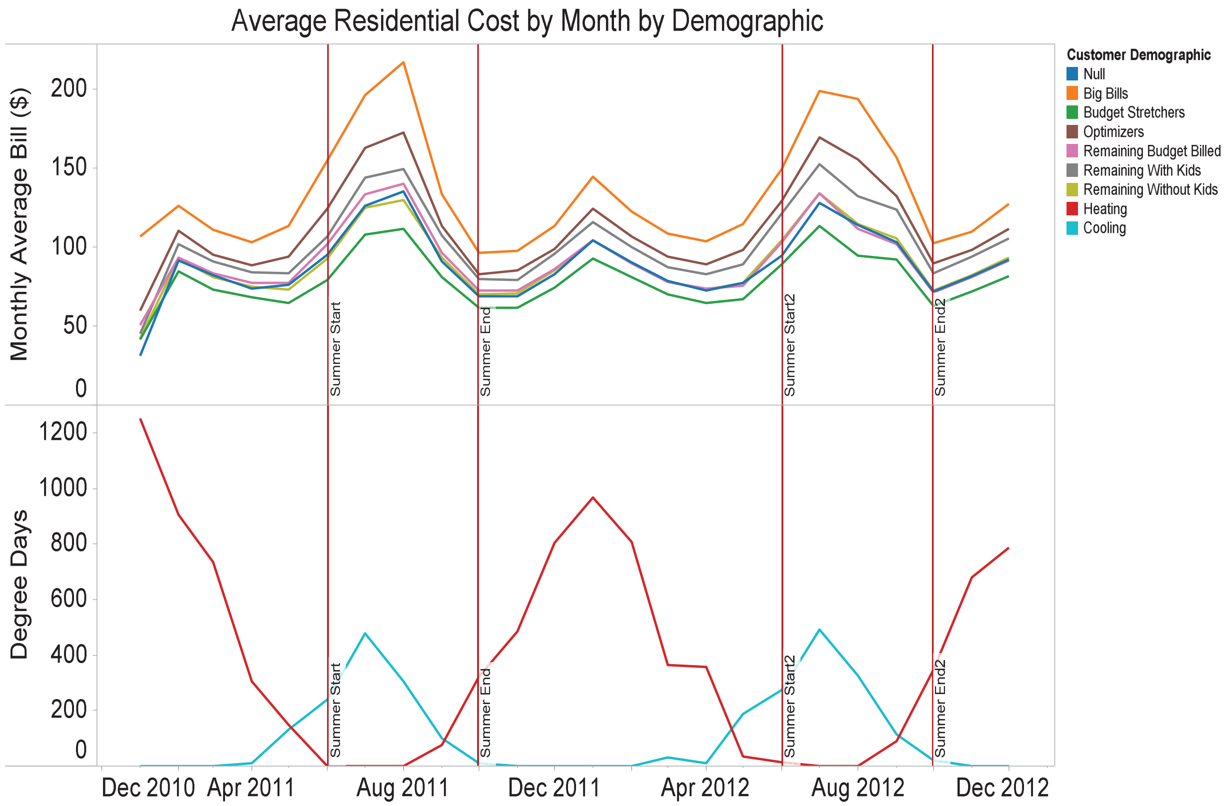


Figure 63. Average residential monthly bill for each customer demographic

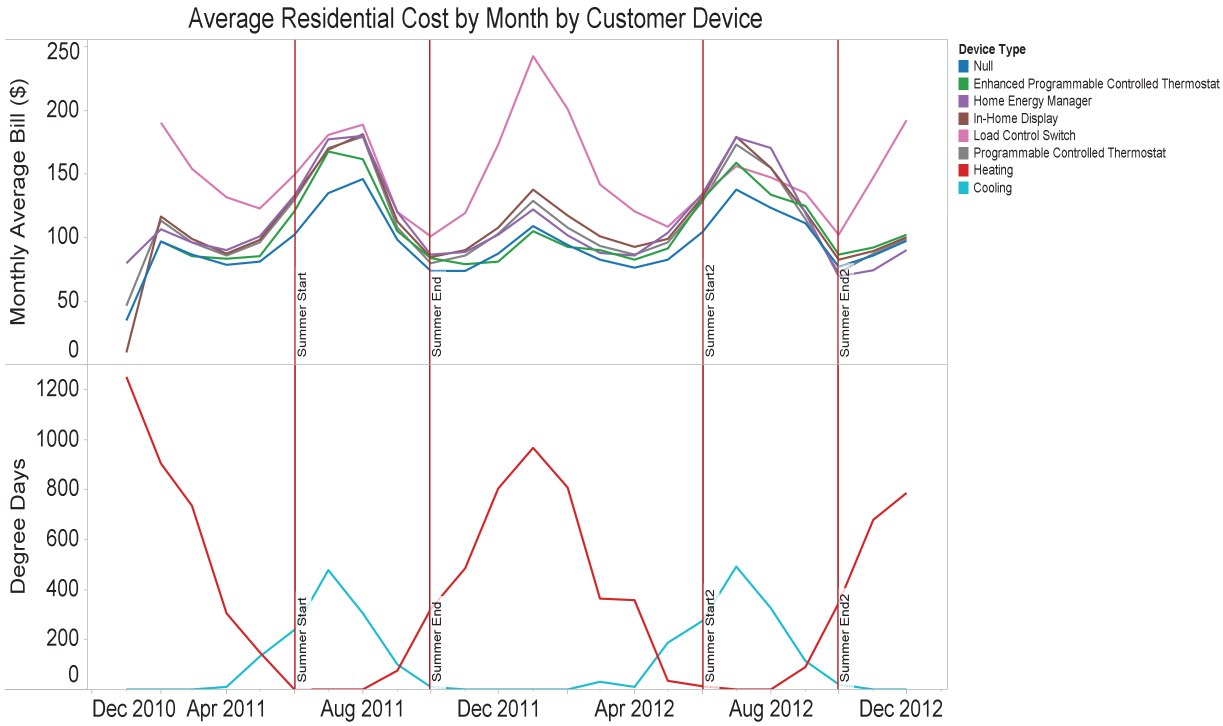


Figure 64. Average residential monthly bill by customer device

Calculation Approach

This impact metric provides an analysis of average bill amount and average energy consumption for consumers grouped by demographic and marketing stratum.

The following queries and methods were used to generate presentation items:

- Average monthly customer electricity usage was calculated by averaging the billed usage for the ending month of the billing period for all residential customers on the standard residential tariff.
- Average monthly customer electricity usage per tariff was calculated by averaging the billed usage for the ending month of the billing period for all residential customers on the standard residential, SMART Shift, and SMART Shift Plus tariffs.
- Average monthly customer cost was calculated by averaging the billed amount for the ending month of the billing period for all residential customers on the standard residential tariff. These data points are not normalized for rate changes occurring within the period.
- Average monthly customer cost per tariff was calculated by averaging the billed amount for the ending month of the billing period for all residential customers on the standard residential, two-tier TOD, and three-tier TOD with SMART Shift Plus tariffs.
- Hourly outdoor temperature in degrees Fahrenheit for Port Columbus International Airport was collected from the National Oceanic and Atmospheric Administration: http://hurricane.ncdc.noaa.gov/pls/plclimprod/poemain.accessrouter?datasetabbv=DS3505&countryabbv=&georegionabbv=

5.7.3 Peak Load and Mix (M03-CP)

5.7.3.1 Objective

Consumer Programs and supporting devices have the potential to enable and influence consumer usage patterns. Utilities can provide incentives for customers to change their usage and behavior to reduce peak loading and enable load shifting. This impact metric examines the impact of the various consumer programs on the daily usage peaks. This impact metric will compare the impacts across account classes, such as residential, commercial, and industrial. Various consumer strata and demographic data will be used to determine which programs have the most impact on peak load and mix.

5.7.3.2 Organization of Results

This impact metric assesses the ability of programs, tariffs, and technologies to influence customers to shift their load away from traditionally typical peak periods.

Various views of data were selected to quantify and visualize this impact metric, Peak Load and Mix. The key parameters of interest include time, account class, the account's applicable tariff, and, for residential accounts, applicable demographic data.

The time variant aspect of the data was handled by graphing data as a function of each hour of the day.

Account class was set as the three traditional groupings of customers: Industrial, Commercial and Residential.

Residential customers were categorized by account class, tariff, and demographic. RTP_{da} analysis will be included in the Final Report.

There were three key demographic groups identified with the remainder of the customers placed in one of three groups: those on a fixed billing program, and customers with and without children in the household, and customers without children in the household.

Due to the extent of possible analysis combinations, subsets of combinations were chosen for this report, as shown in Table 15. Analysis is provided only for the areas for which a figure notation is present.

			Peak Period	Peak Days		DLC Event
Account Class	Category of Data	Dimension	July 2 – 9, 2012 Monday to Monday	July 7, 2012 Saturday *Residential Peak*	July 17, 2012 Tuesday *System Peak*	
Industrial	All Customers	None	Figure 65	Figure 68		
Commercial	All Customers	None	Figure 66	Figure 69		
Residential	All Demographics	None	Figure 67			
	All Demographics	By Tariff		Figure 70	Figure 71	
	Graphs for Each Tariff					
	013 Standard tariff	by Demographic		Figure 72		
	040 SMART Shift	by Demographic		Figure 73		
	043 SMART Shift Plus	by Demographic		Figure 74		
	DLC Events					
	June 21, 2012, Tuesday	By DLC Rider				Figure 75
	July 17, 2012, Tuesday	By DLC Rider				Figure 76

Table 15. Table of Figures used for "Peak Load and Mix" Impact Metric

5.7.3.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

5.7.3.4 Results of Data Collected to Date

The figures referenced above follow on the subsequent pages of this section.

Presentation of usage data by Account Class and hour of the day for the peak week:

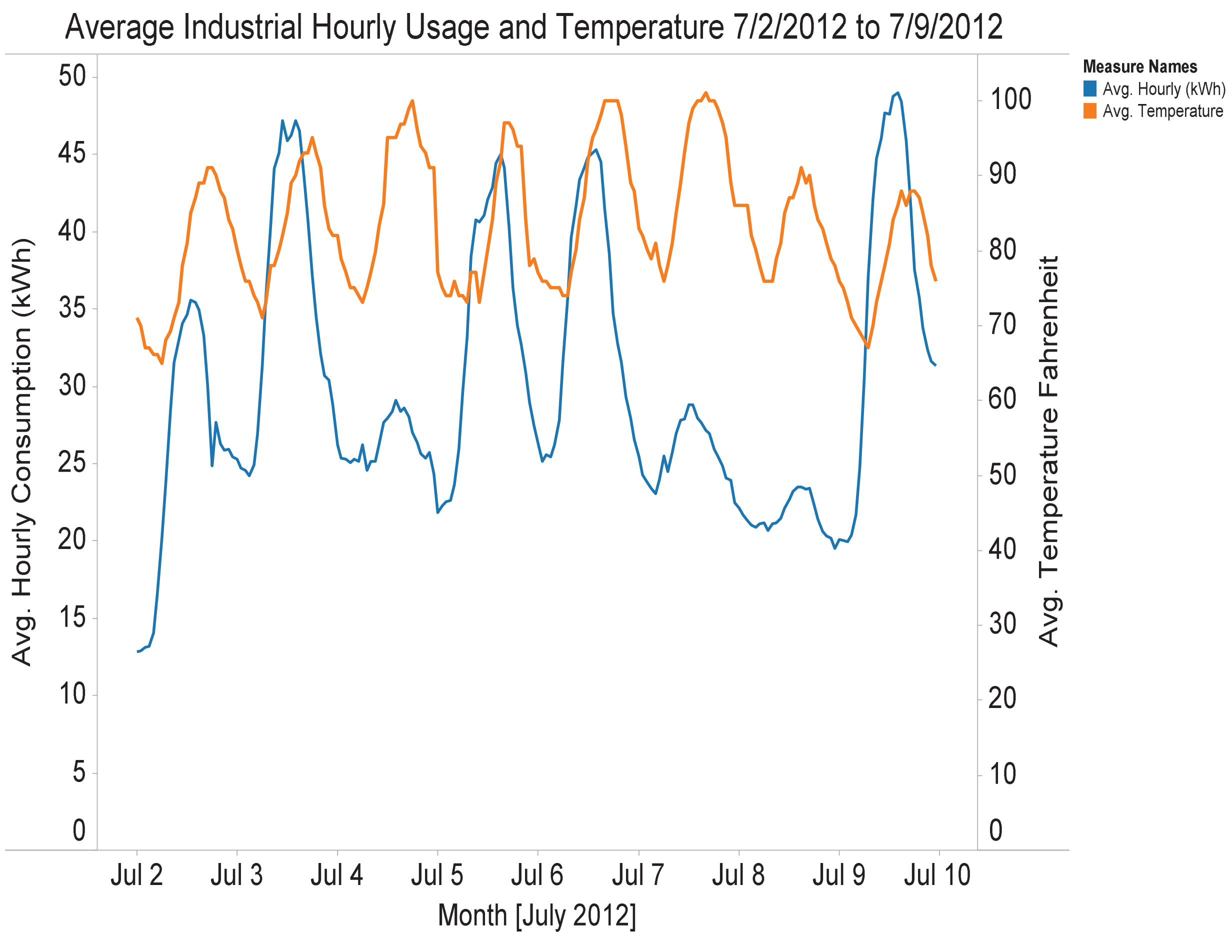


Figure 65. Industrial hourly usage and temperature for Monday July 2, 2012 through Monday July 9, 2012

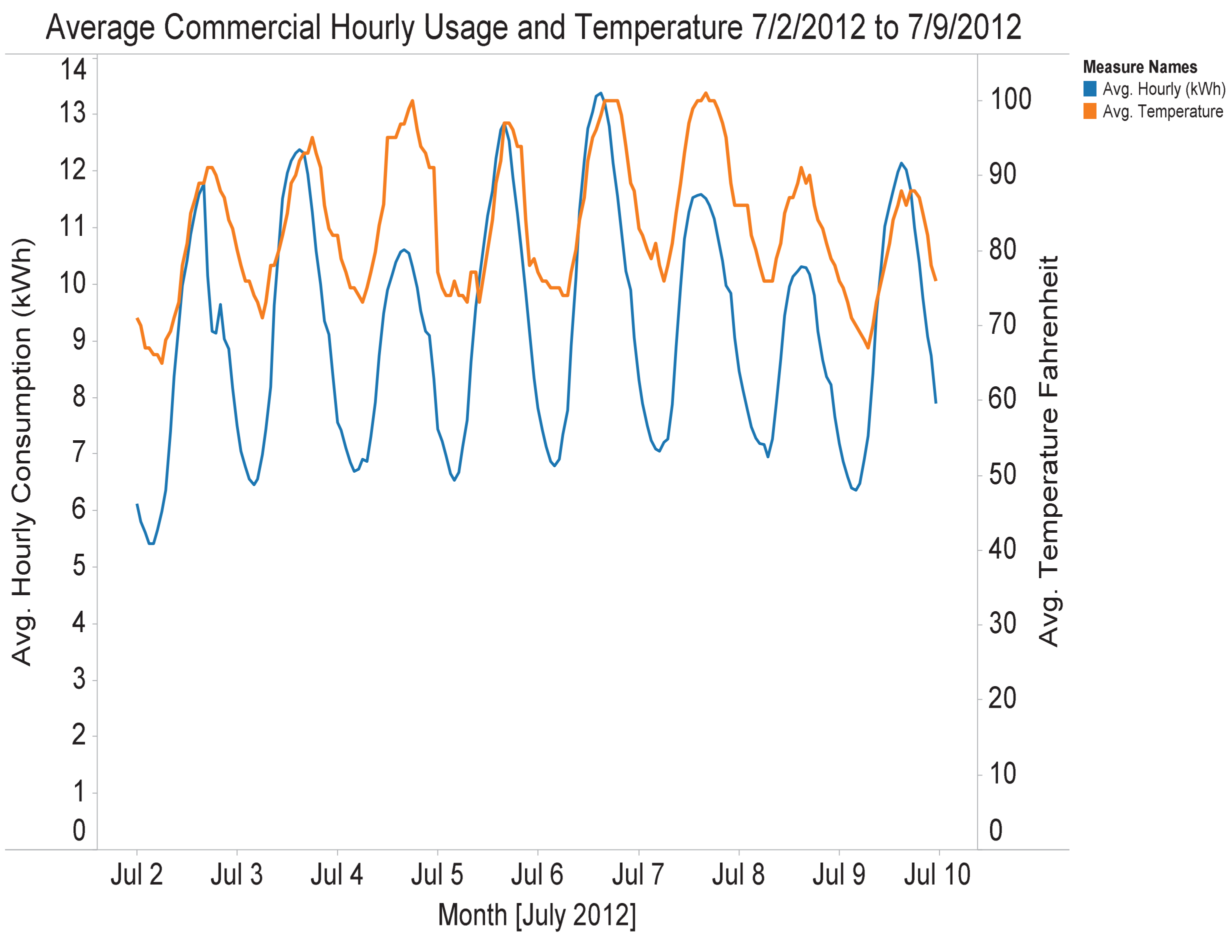


Figure 66. Commercial hourly usage and temperature for Monday July 2, 2012 through Monday July 9, 2012

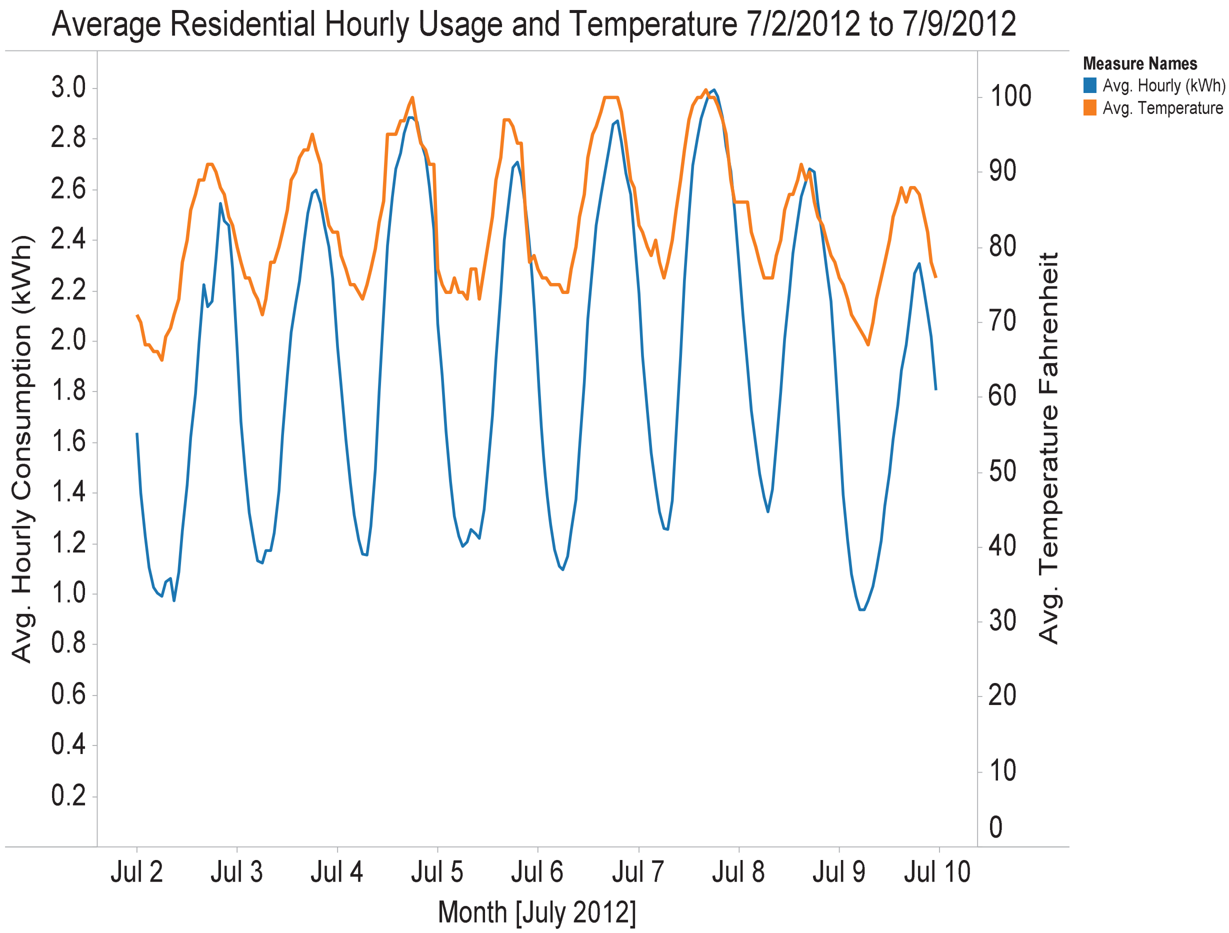


Figure 67. Residential hourly usage and temperature for Monday July 2, 2012 through Monday July 9, 2012

Presentation of load profile data by Account Class for the peak day:

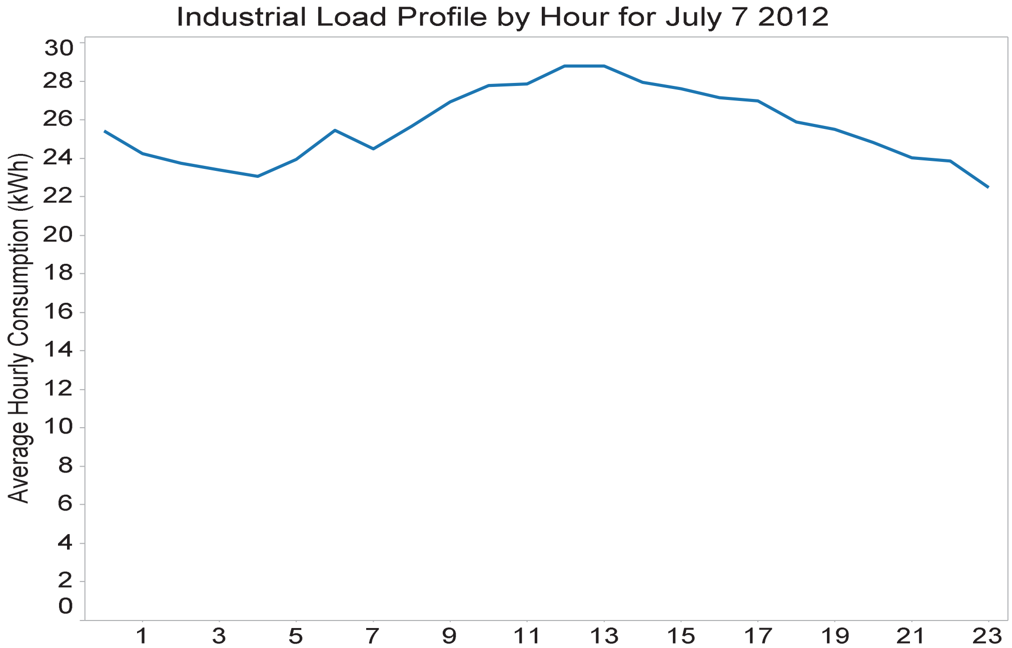


Figure 68. Average industrial hourly usage for Saturday July 7, 2012

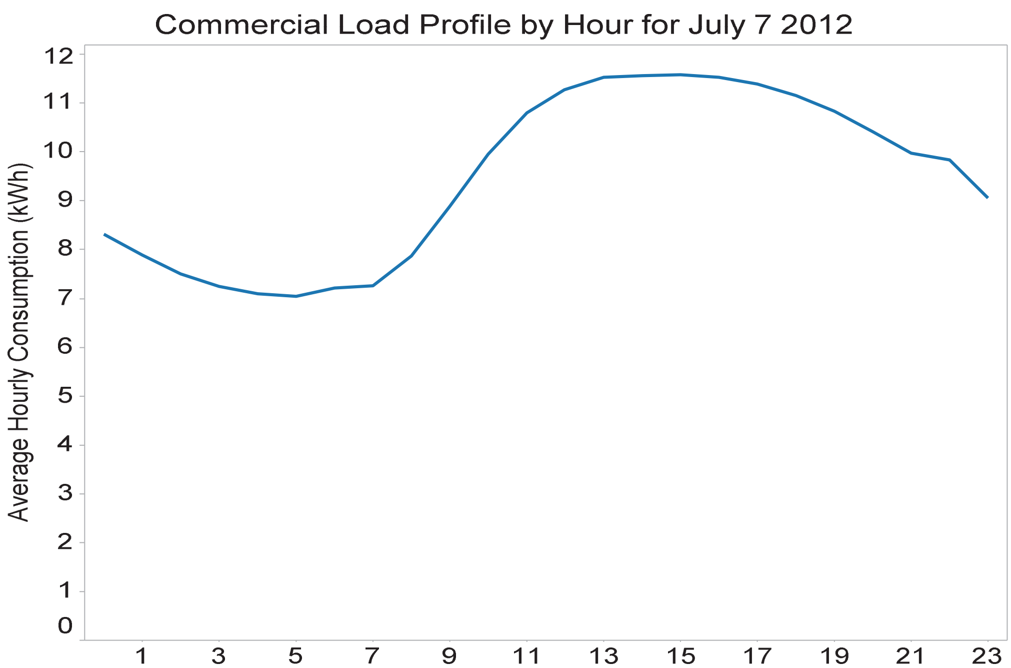


Figure 69. Average commercial hourly usage for Saturday July 7, 2012

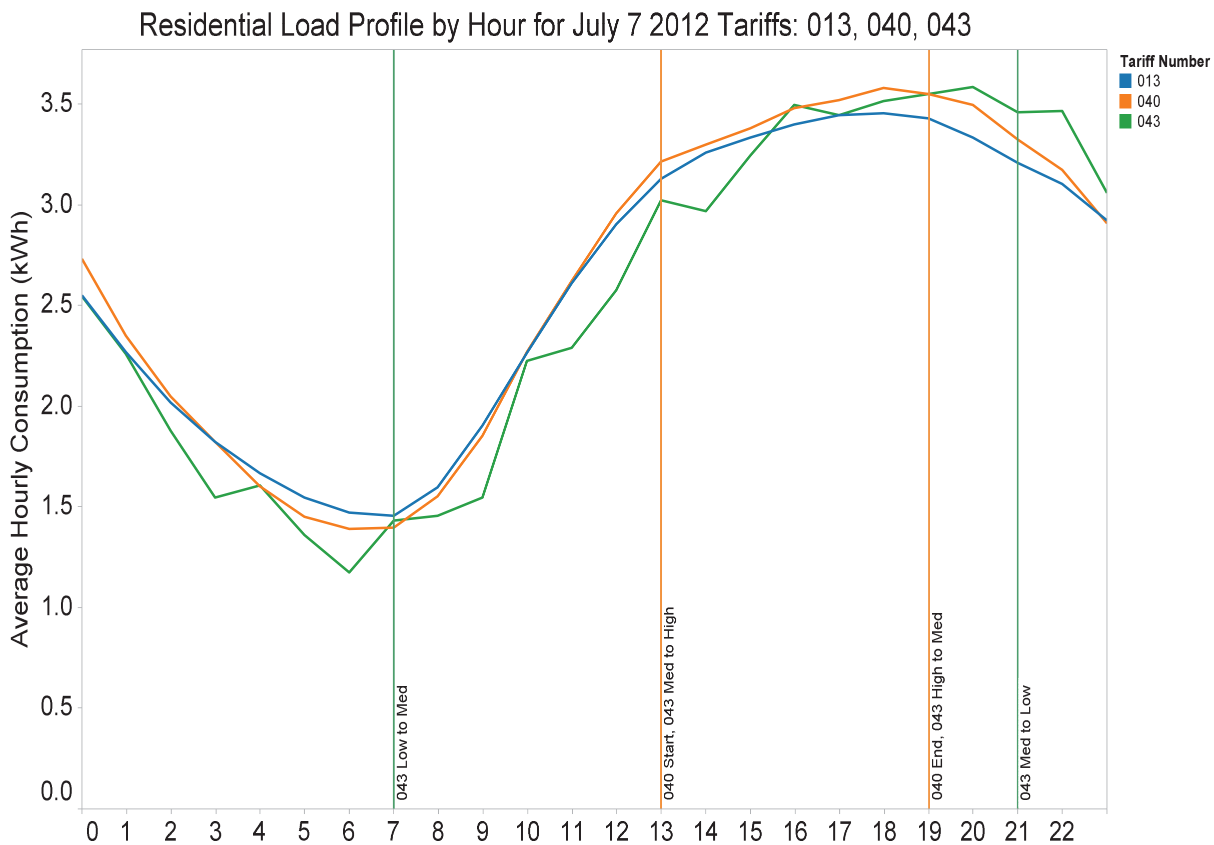


Figure 70. Average residential hourly usage for Residential Peak Day Saturday July 7, 2012; separated by tariff

***Note**: The rates for all three tariffs are flat for this weekend day. The hours marked above for price changes apply only to weekdays, but are included here to illustrate whether or not peak shifting behaviors from weekdays persist into weekends, despite the lack of price changes.*

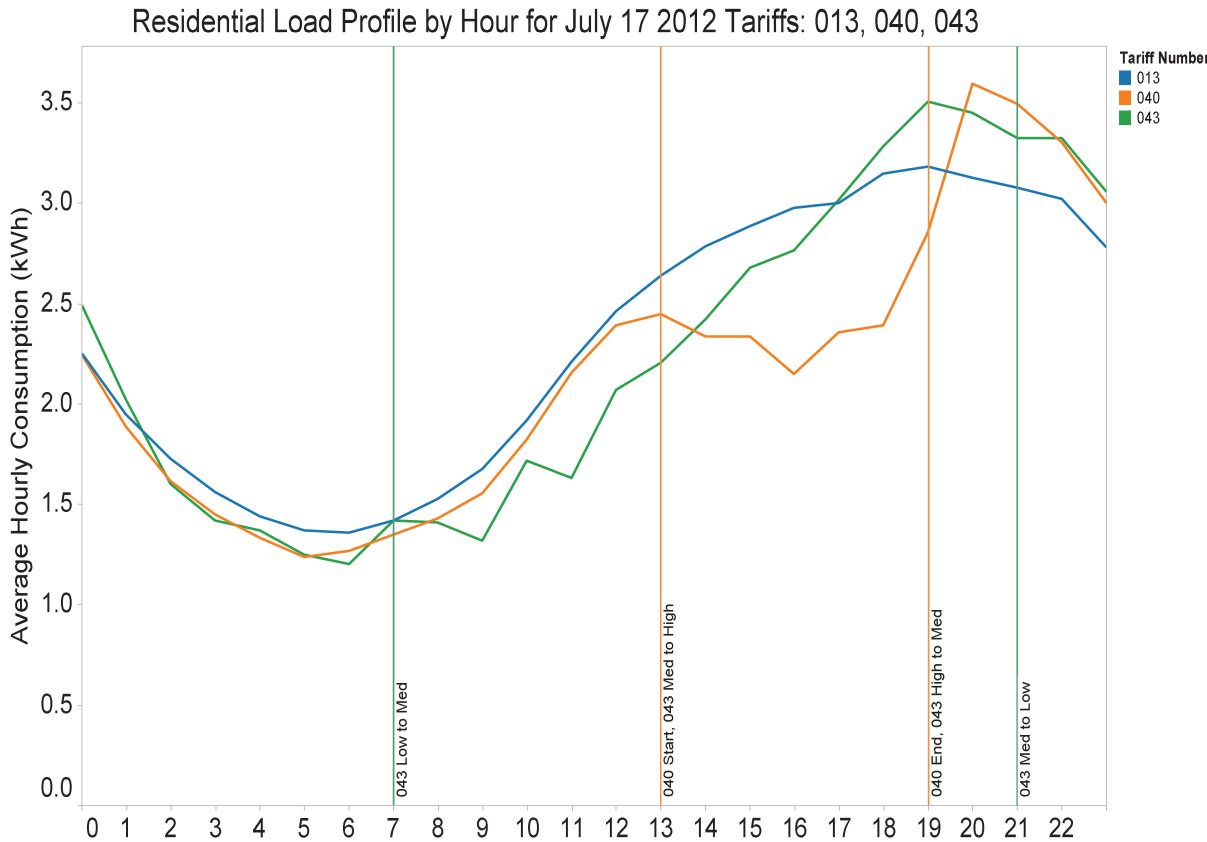


Figure 71. Average residential hourly usage for System Peak Day: Tuesday July 17, 2012; separated by tariff

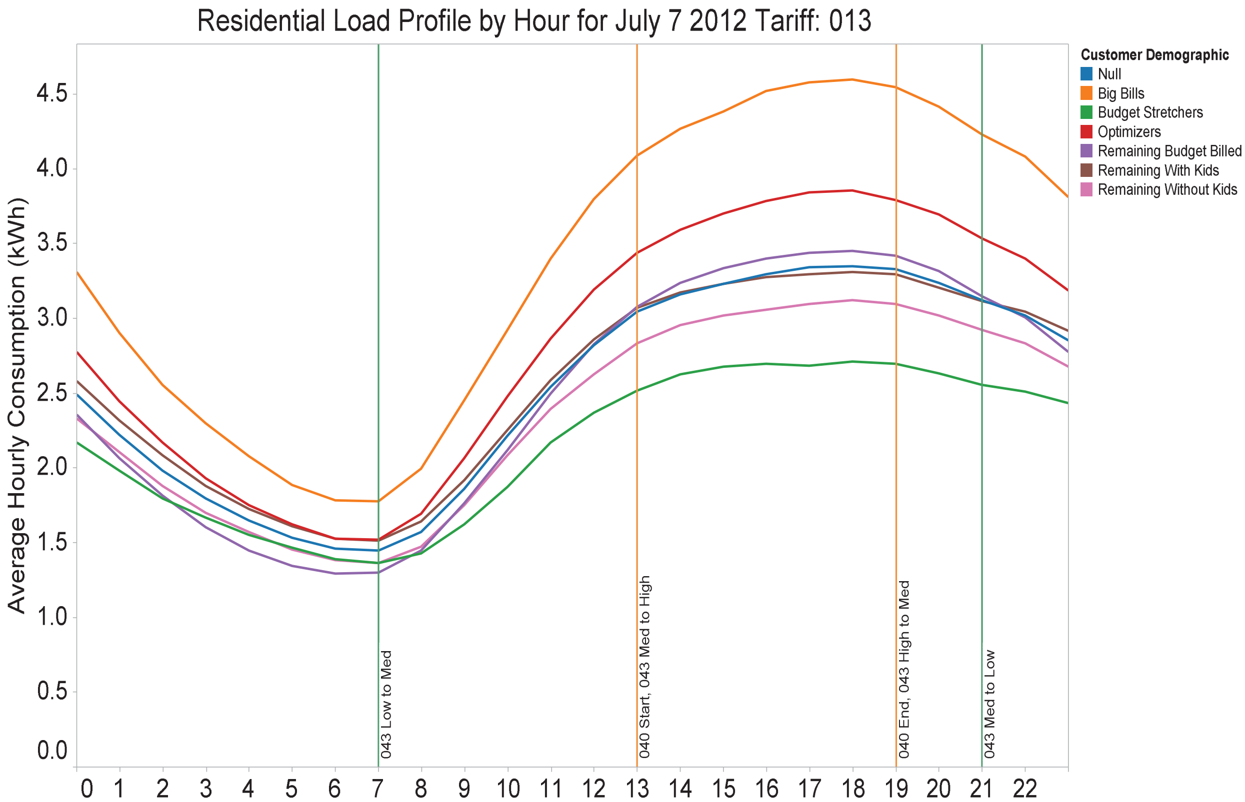


Figure 72. Average residential hourly usage on tariff 013 Standard Residential for Saturday July 7, 2012; separated by demographic

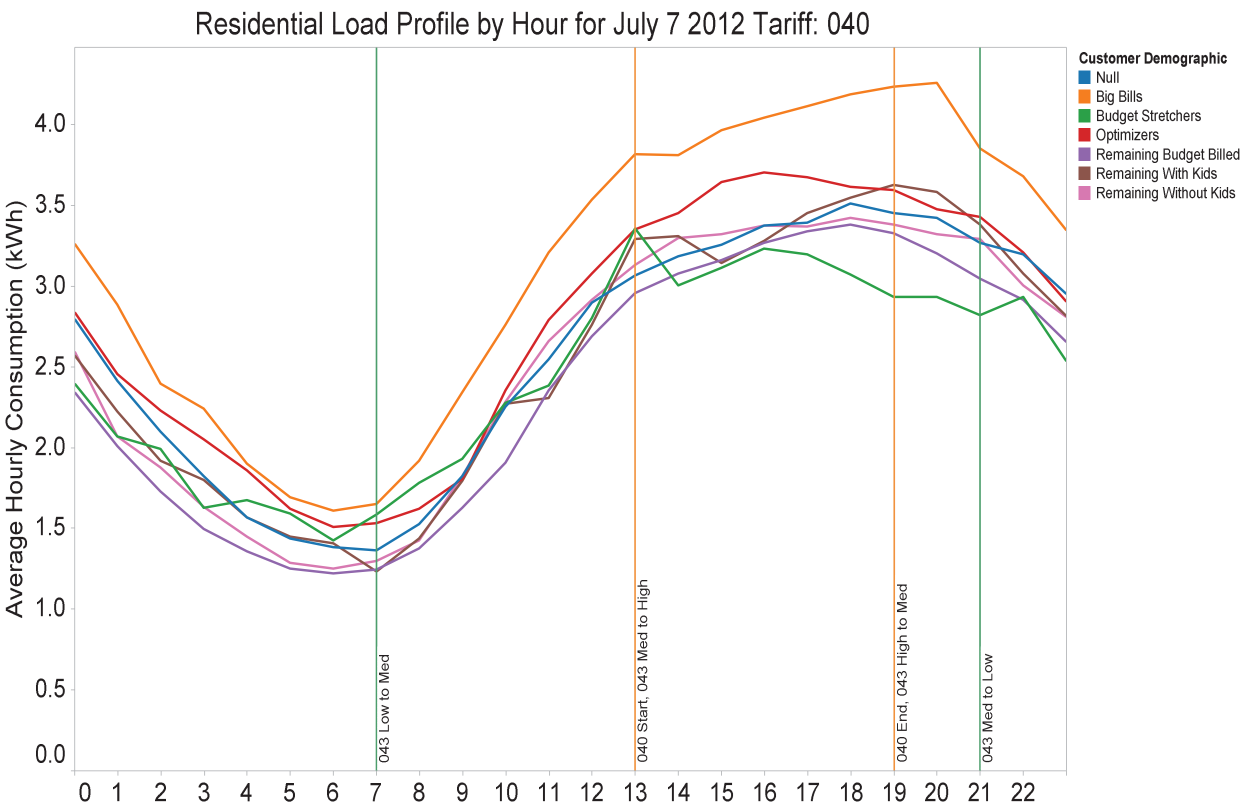


Figure 73. Average residential hourly usage on tariff 040 SMART Shift for Saturday July 7, 2012; separated by demographic

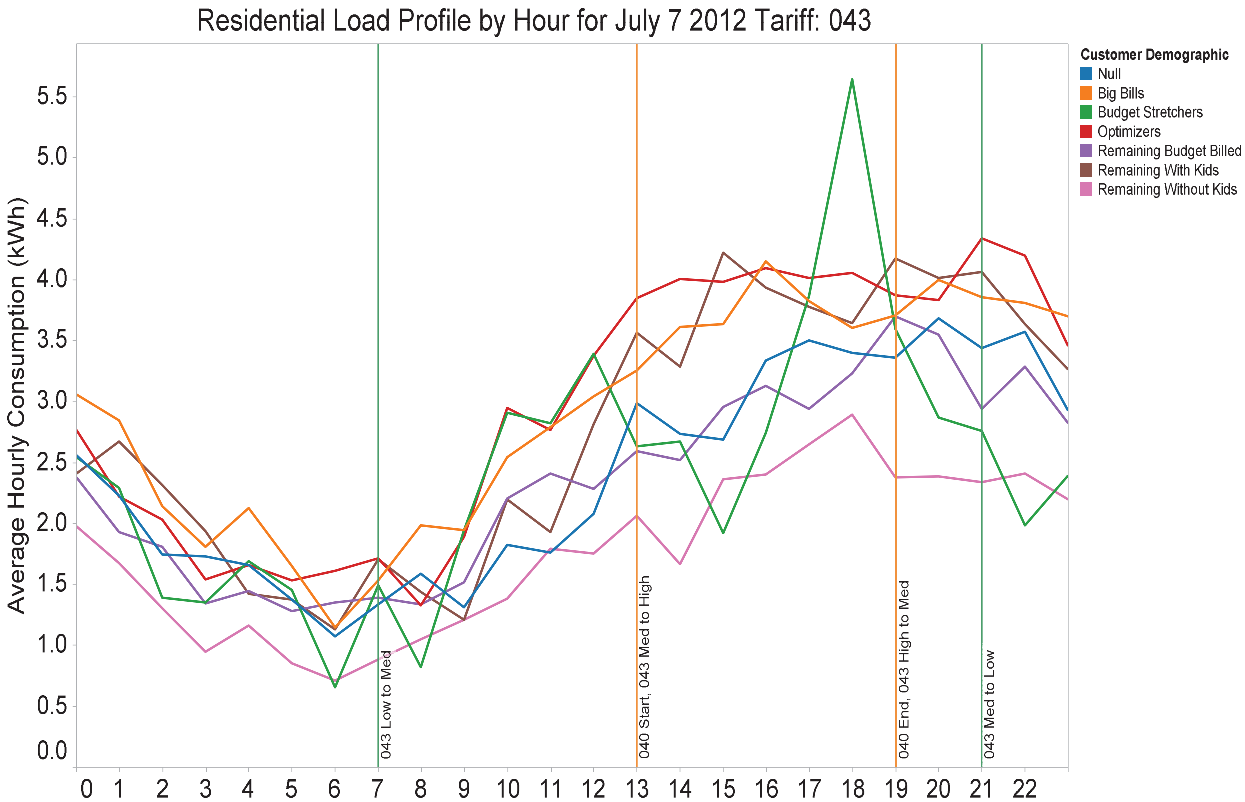


Figure 74. Average residential hourly usage on tariff 043 SMART Shift Plus for Saturday July 7, 2012; separated by demographic

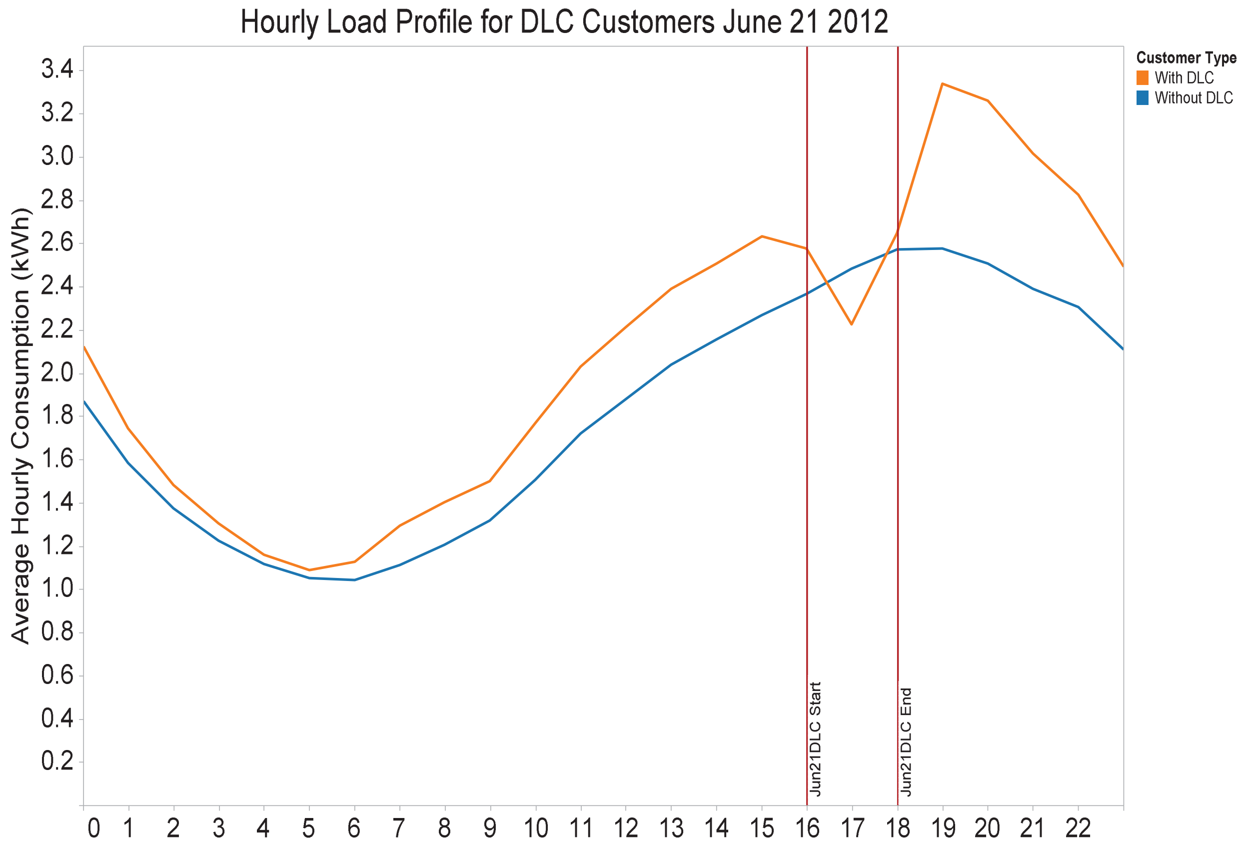


Figure 75. Average residential hourly usage for Thursday June 21, 2012; separated by the presence of DLC rider

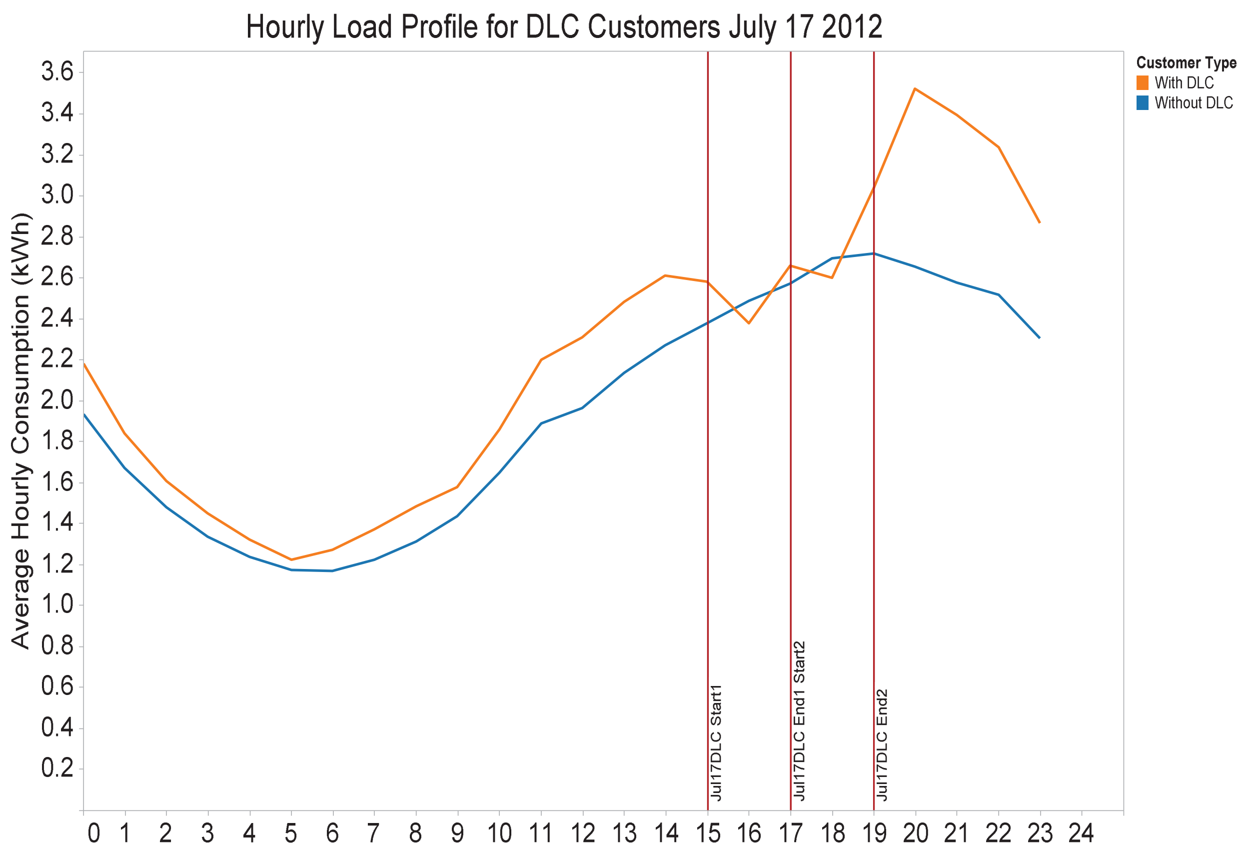


Figure 76. Average residential hourly usage for Tuesday July 17, 2012; separated by the presence of DLC rider

Calculation Approach

This impact metric provides an analysis of average daily usage patterns during selected peak days for consumers grouped by demographic and marketing stratum.

The following queries and methods are used to generate presentation items:

- Peak load and mix were calculated by averaging hourly customer electricity usage into 24 hourly bins.
- Hourly outdoor temperature in degrees Fahrenheit for Port Columbus International Airport was collected from the National Oceanic and Atmospheric Administration: http://hurricane.ncdc.noaa.gov/pls/plclimprod/poemain.accessrouter?datasetabbv=DS3505&countryabbv=&georegionabbv=
- DLC events per meter were selected based on the type of DLC device installed on a customer's premise.

5.7.4 CO_2 Emissions – Project Area (M07-CP)

5.7.4.1 Objective

Consumer Programs and supporting devices have the potential to enable and influence consumer usage patterns. Utilities can provide incentives for customers to change their usage and behavior to reduce peak loading and enable load shifting. This impact metric examines the impact to CO_2 emissions resulting from changes in consumer usage behaviors in the Project area. In principle, the reduction of energy use or shifting of energy use to different times of day will have an impact on the CO_2 emitted by the generation fleet. This impact metric will compare the impacts against account classes, such as residential, commercial, and industrial. Various consumer strata and demographic data will be used to determine which programs have the most impact to CO_2 emissions.

5.7.4.2 Organization of Results

This metric presents the impact of Consumer Programs on CO_2 emissions by quantifying the difference in energy consumption from new tariffs and technologies versus traditional flat rate electric tariffs.

- CO_2 emissions avoided by month
    - This metric is displayed as a graph that shows the CO_2 emissions avoided by the customers on the experimental tariffs: 040 SMART Shift, 043 SMART Shift Plus, and 045 SMART Choice.

5.7.4.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

5.7.4.4 Results of Data Collected to Date

The figures on the following pages quantify the impact metric for this section.

Presentation of CO_2 emissions data for the Project Area:

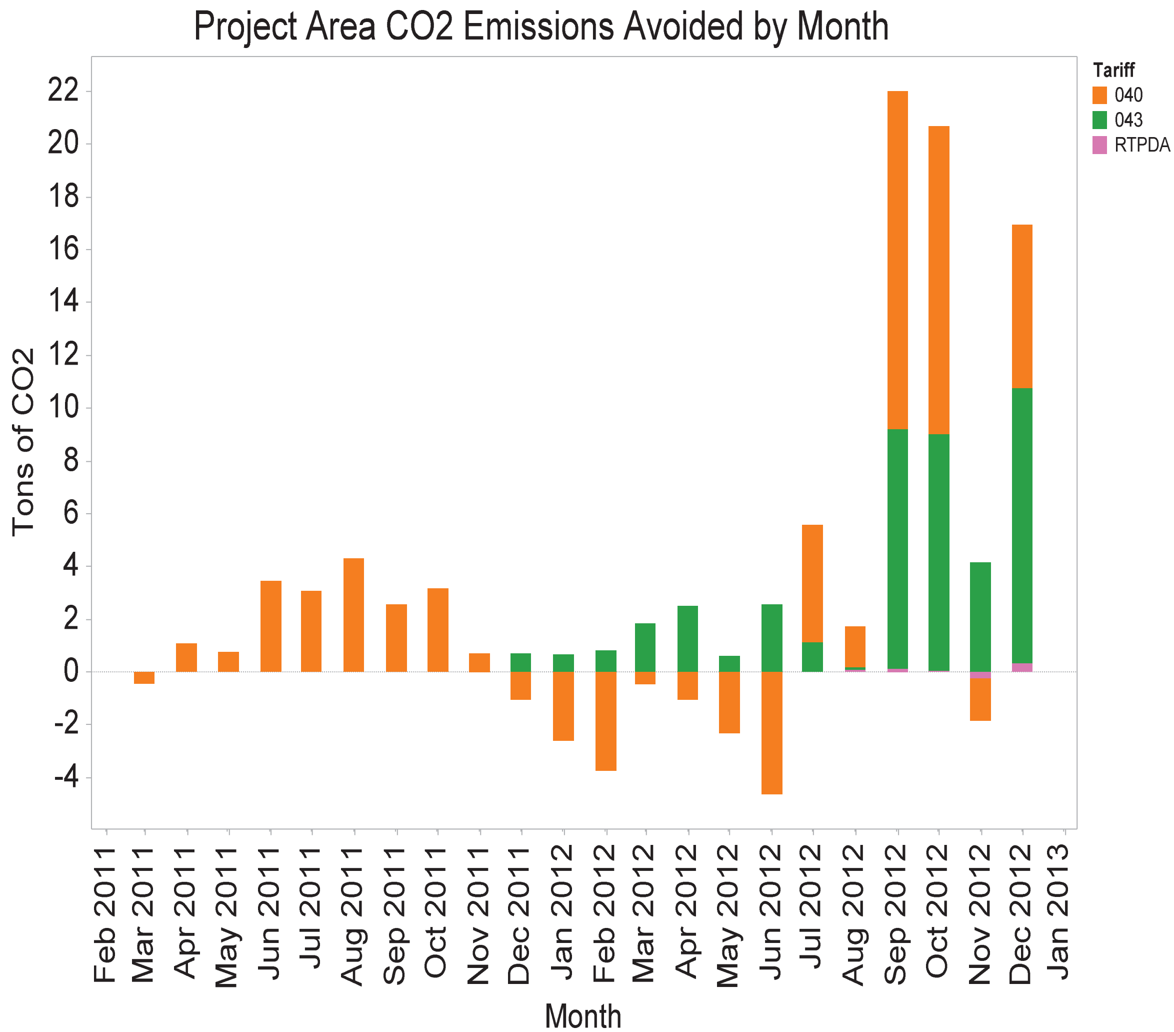


Figure 77. Monthly CO_2 emissions avoided or contributed by three tariffs -- 040 SMART Shift, 043 SMART Shift Plus, and SMART Choice -- for the Project area

Calculation Approach

Load reduction due to Consumer Programs was calculated as the difference between usage for customers on an experimental tariff versus usage of similar customers on the standard residential tariff. These results are reported for customers grouped by demographic and by stratum.

Load reduction was translated into CO_2 reduction using typical generation emissions factors.

The following queries and methods were used to generate presentation items:

- Energy consumption reductions per month, customer class, consumer stratum, customer demographic, and tariff based on Consumer Programs were calculated by subtracting the average billed hourly usage for residential consumers not on the standard residential tariff from average billed hourly usage for residential consumers on the standard residential tariff for the same month, customer class, consumer stratum, and customer demographic.

- Tons of CO_2 avoided per month, consumer stratum, customer demographic, and tariff for Consumer Programs were calculated by multiplying the energy consumption reductions by 0.00068956 (tons per kWh).

5.7.5 Pollutant Emissions – Project Area (SO_X, NO_X, $PM_{2.5}$) (M08-CP)

5.7.5.1 Objective

Consumer Programs and supporting devices have the potential to enable and influence consumer usage patterns. Utilities can provide incentives for customers to change usage and behavior to reduce peak loading and enable load shifting. This impact metric examines the impact to pollutant emissions resulting from changes in consumer usage behaviors. In principle, the reduction of energy use or shifting of energy use to different times of day will have an impact on the pollutants emitted by the generation fleet. This impact metric will compare the impacts against account classes, such as residential, commercial, and industrial in the Project area. Various consumer strata and demographic data will be used to determine which programs have the most impact to pollutant emissions.

5.7.5.2 Organization of Results

This metric presents the impact of Consumer Programs on pollutant emissions by quantifying the difference in energy consumption from new tariffs and technologies vs. traditional flat rate electric tariffs.

- Pollutant emissions avoided by month
  - This metric is displayed as a graph that shows the pollutant emissions avoided by the customers in the Project area on the experimental tariffs: 040 SMART Shift, 043 SMART Shift Plus, and 045 SMART Choice.

5.7.5.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

5.7.5.4 Results of Data Collected to Date

The figures on the following pages quantify the impact metric for this section.

Presentation of Pollutant emissions data for the Project Area

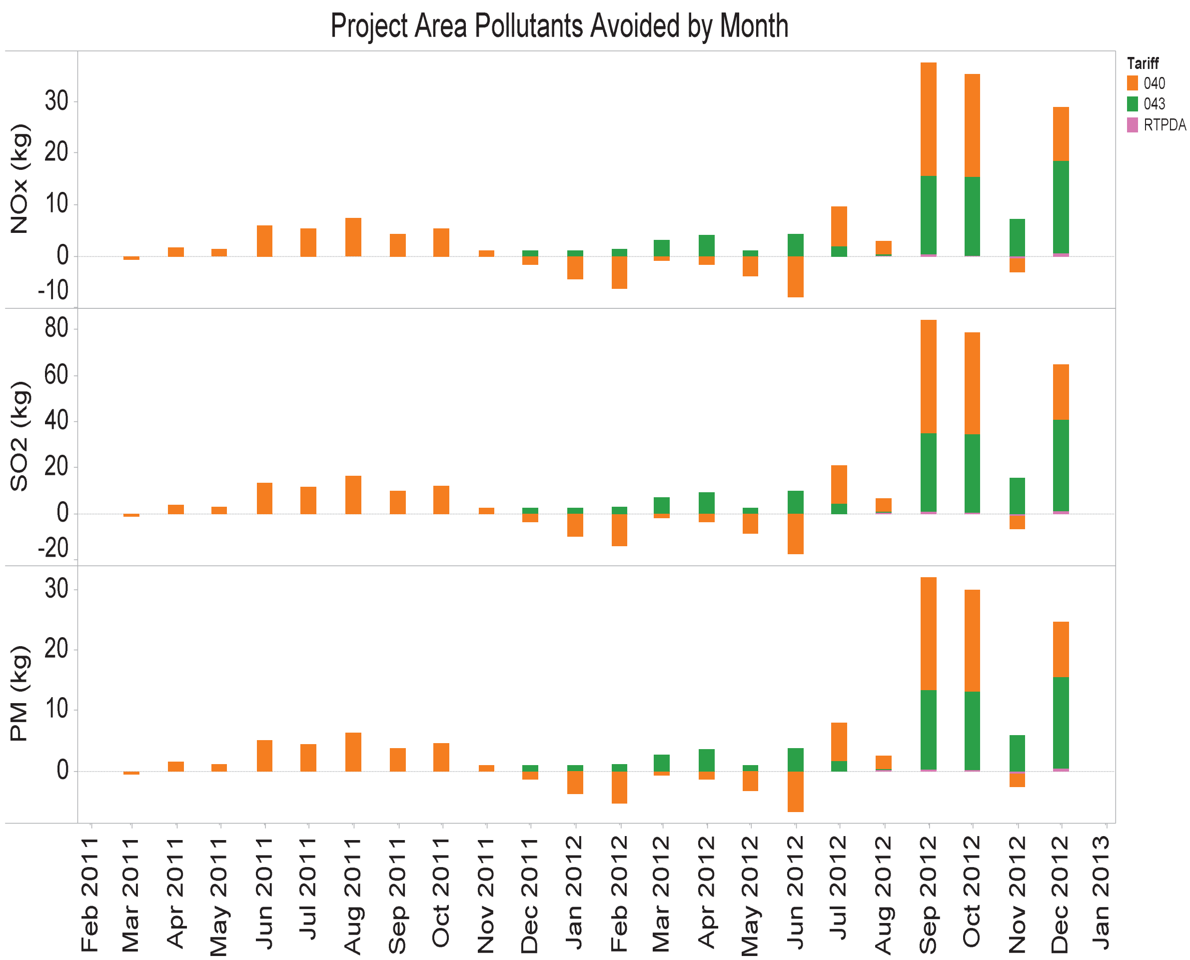


Figure 78. Monthly Pollutant emissions avoided or contributed by three tariffs -- 040 SMART Shift, 043 SMART Shift Plus, and SMART Choice -- for the Project area

Calculation Approach

Load reduction due to consumer programs was calculated as the difference between usage for customers on an experimental tariff versus usage of similar customers on the standard residential tariff. These results are reported for customers grouped by demographic and by stratum. Note that this analysis does not thoroughly account for selection bias and is under review by Battelle.

Load reduction was then translated into pollutant reduction using typical generation emissions factors.

The following queries and methods are used to generate presentation items:

- Energy consumption reductions per month, customer class, consumer stratum, customer demographic, and tariff based on consumer programs were calculated by subtracting the average billed hourly usage for residential consumers not on the standard residential tariff from average billed hourly usage for residential consumers on the standard residential tariff for the same month, customer class, consumer stratum, and customer demographic.
- Kilograms of NO_X avoided per month, consumer stratum, customer demographic, and tariff for consumer programs were calculated by multiplying the energy consumption reductions by 0.00117934 (kilograms per kWh).
- Kilograms of $PM_{2.5}$ avoided per month, consumer stratum, customer demographic, and tariff for consumer programs were calculated by multiplying the energy consumption reductions by 0.001 (kilograms per kWh).
- Kilograms of SO_X avoided per month, consumer stratum, customer demographic, and tariff for consumer programs were calculated by multiplying the energy consumption reductions by 0.00263084 (kilograms per kWh).

5.7.6 CO_2 Emissions – System Area (M09-CP)

5.7.6.1 Objective

Consumer Programs and supporting devices have the potential to enable and influence consumer usage patterns. Utilities can provide incentives for customers to change usage and behavior to reduce peak loading and enable load shifting. This impact metric examines the impact to CO_2 emissions resulting from consumer usage behaviors in the System area. In principle, the reduction of energy use or shifting of energy use to different times of day will have an impact on the CO_2 emitted by the generation fleet. This impact metric will compare the impacts against account classes, such as residential, commercial, and industrial. Various consumer strata and demographic data will be used to determine which programs have the most impact to CO_2 emissions.

5.7.6.2 Organization of Results

This metric presents the impact of Consumer Programs on CO_2 emissions by quantifying the difference in energy consumption from new tariffs and technologies versus traditional flat rate electric tariffs.

- CO_2 emissions avoided by month

- This metric is displayed as a graph that shows the CO_2 emissions avoided by the customers projected into the System area as if they were on the two time-of-use tariffs- 040 SMART Shift, 043 SMART Shift Plus, and 045 SMART Choice.

5.7.6.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

5.7.6.4 Results of Data Collected to Date

The figures on the following pages quantify the impact metric for this section.

Presentation of CO_2 emissions data for the System Area:

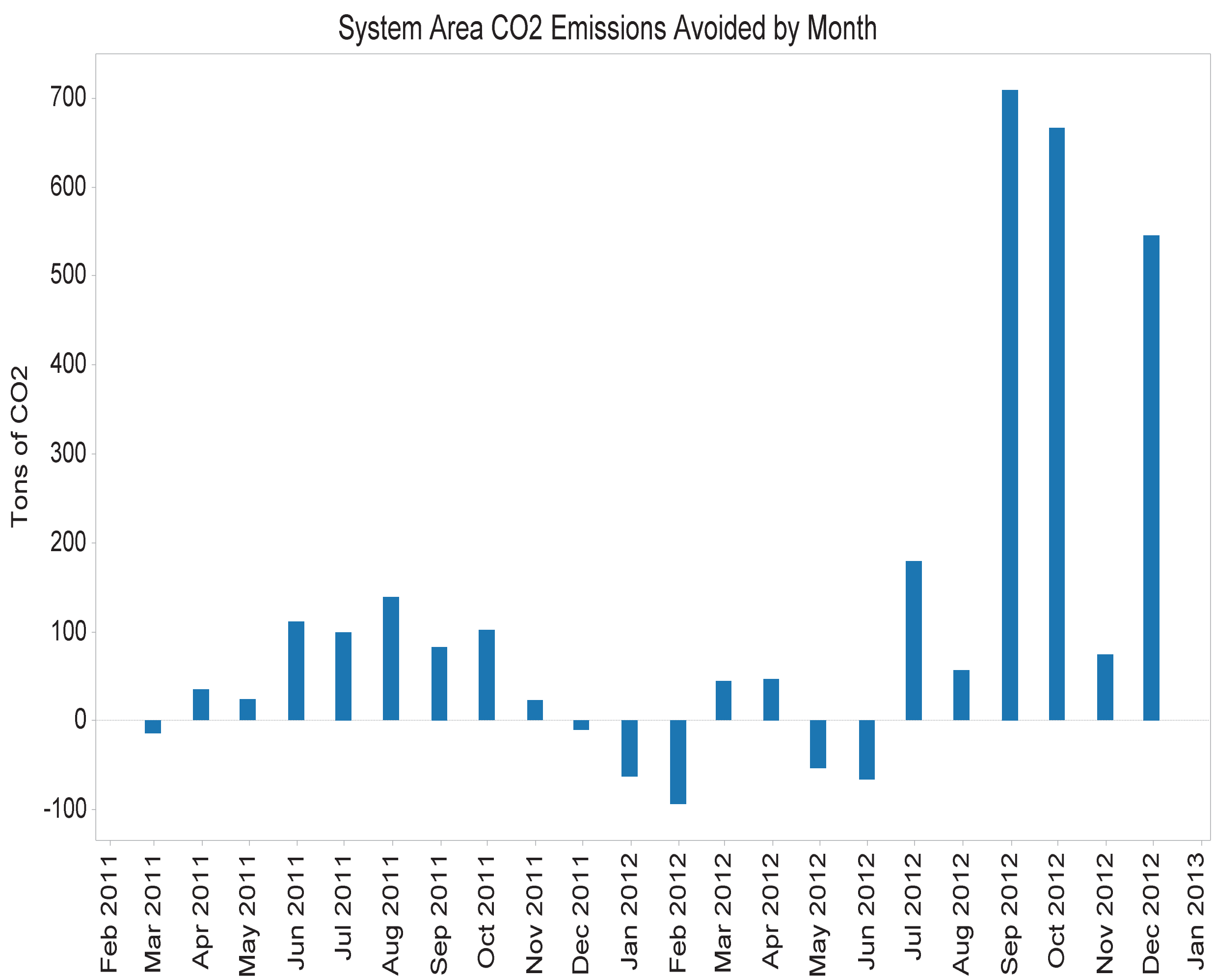


Figure 79. Monthly CO_2 emissions avoided or contributed by three tariffs -- 040 SMART Shift, 043 SMART Shift Plus, and SMART Choice -- for the System area

Calculation Approach

Load reduction due to Consumer Programs was calculated as the difference between usage for customers on an experimental tariff versus usage of similar customers on the standard residential tariff. These results are reported for customers grouped by demographic and by stratum.

Load reduction was translated into CO_2 reduction using typical generation emissions factors. This reduction was then extrapolated onto the System area based on the ratio of total circuit load.

The following queries and methods were used to generate presentation items:

- Tons of CO_2 that would be avoided if Consumer Programs were expanded to the System area. These were calculated by multiplying the tons of CO_2 emissions avoided times the ratio of all residential customers on a circuit to residential customers not on the standard residential tariff.

5.7.7 Pollutant Emissions – System Area (SO_X, NO_X, $PM_{2.5}$) (M10-CP)

5.7.7.1 Objective

Consumer Programs and supporting devices have the potential to enable and influence consumer usage patterns. Utilities can provide incentives for customers to change usage and behavior to reduce peak loading and enable load shifting. This impact metric examines the impact to pollutant emissions if Consumer Programs were extended to the System area. The reduction of energy or shifting of energy usage to different times of day may have an impact on the pollutants emitted by the generation fleet. This impact metric will compare the impacts against account classes, such as residential, commercial, and industrial in the System area. Various consumer strata and demographic data will be used to determine which programs have the most impact to pollutant emissions.

5.7.7.2 Organization of Results

This metric presents the impact of Consumer Programs on pollutant emissions by quantifying the difference in energy consumption from new tariffs and technologies versus traditional flat rate electric tariffs.

- Pollutant emissions avoided by month
    - This metric is displayed as a graph that shows the pollutant emissions avoided by the customers projected into the System area as if they were on the two time-of-use tariffs- 040 SMART Shift, 043 SMART Shift Plus, and 045 SMART Choice.

5.7.7.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

5.7.7.4 Results of Data Collected to Date

The figures on the following pages quantify the impact metric for this section.

Presentation of Pollutant emissions for the System Area:

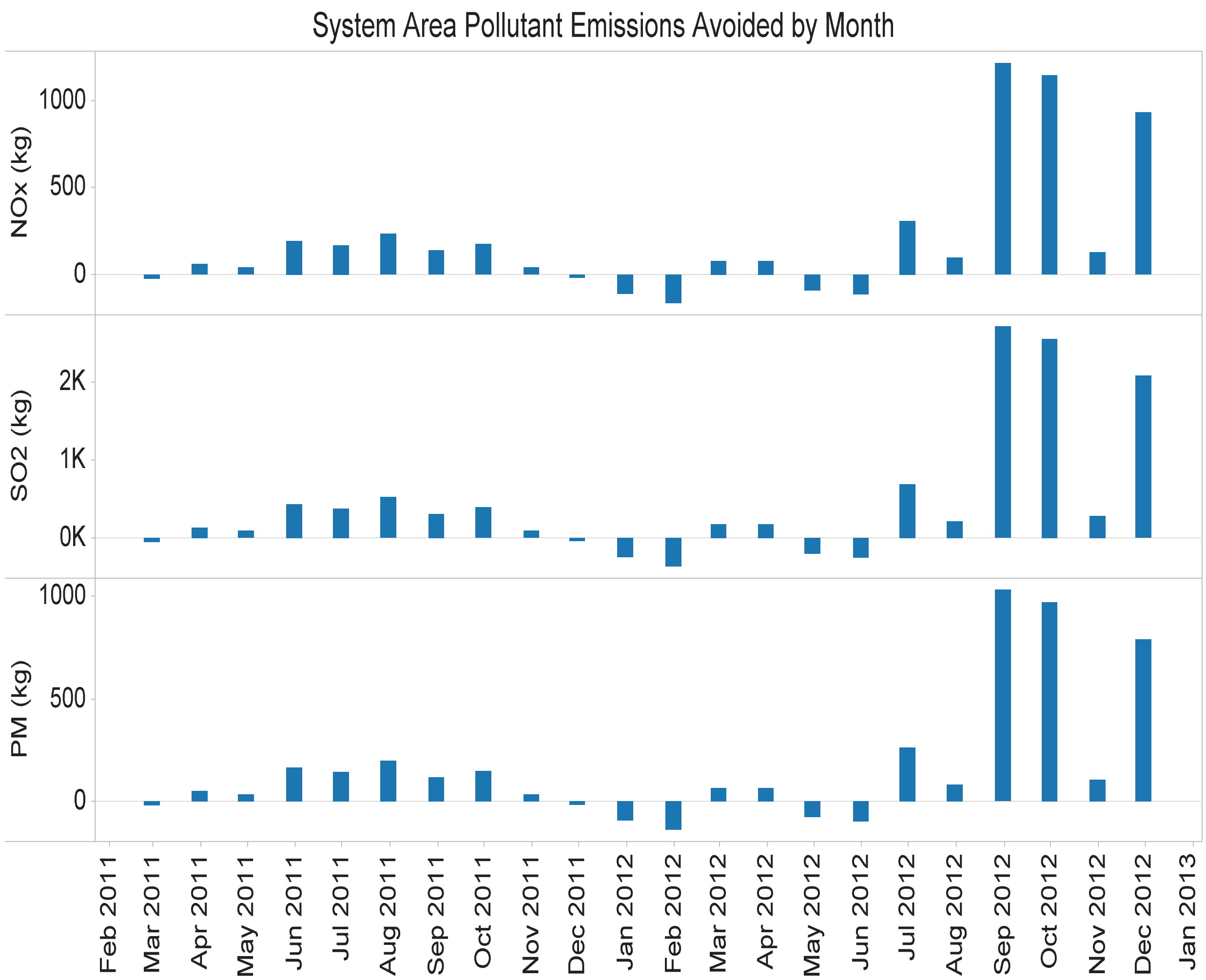


Figure 80. Monthly Pollutant emissions avoided or contributed by three tariffs -- 040 SMART Shift, 043 SMART Shift Plus, and SMART Choice -- for the System area

Calculation Approach

Load reduction due to Consumer Programs was calculated as the difference between usage for customers on an experimental tariff versus usage of similar customers on the standard residential tariff.

Load reduction was translated into pollutant reduction using typical generation emissions factors, and was extrapolated to the System area based on the ratio of total circuit load.

The following queries and methods are used to generate presentation items:

- Kilograms of NO_X per month, circuit, and customer demographic that would be avoided if Consumer Programs were deployed throughout the System area were calculated by multiplying the kilograms of NO_X emissions avoided by the ratio of all customers on a circuit to residential customers not on the standard residential tariff.

- Kilograms of $PM_{2.5}$ per month, circuit, and customer demographic that would be avoided if consumer programs were deployed throughout the System area. These were calculated by multiplying the kilograms of $PM_{2.5}$ emissions avoided by the ratio of all customers on a circuit to residential customers not on the standard residential tariff.
- Kilograms of SO_X per month, circuit, and customer demographic that would be avoided if consumer programs were deployed throughout the System area. These were calculated by multiplying the kilograms of SOx emissions avoided by the ratio of all customers on a circuit to residential customers not on the standard residential tariff.

5.7.8 Reduced Transmission Congestion Cost (M24-CP)

5.7.8.1 Objective

By shifting peak time and reducing total load, Consumer Programs have the potential to reduce the congestion component of PJM locational marginal pricing (LMP). This impact metric provides an analysis of this effect.

No additional data warehouse requirements are needed to support analysis of reduction in transmission congestion costs.

5.7.8.2 Organization of Results

No results are available for presentation in this Interim Report.

5.7.8.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

5.7.8.4 Results of Data Collected to Date

No results are available for presentation in this Interim Report.

Calculation Approach

Without knowledge of how incremental load reductions affect PJM congestion costs, AEP Ohio is unable to perform this analysis. Distribution feeder load data are provided in the *"Interim Quantification of Impact Metrics – Distribution Automation, Circuit Reconfiguration"* document Section 4.0.

5.8 Consumer Programs Observations

AEP Ohio continues to collect data from Consumer Program participants. AEP Ohio will provide more meaningful observations after the data are collected and analyzed. The observations will be provided in the Final Report. Following are the two most prominent observations regarding Consumer Programs.

AEP Ohio has found that the timing of DLC events is critical to the success of the event to impact load. With DLC events, AEP Ohio learned that there is roughly a one-hour period at the beginning of the event wherein loads fall to the maximum achievable reduction. Due to the small penetration of SMART Cooling participants on the DA-CR circuits, the DLC events have negligible impact to feeder load.

SMART Shift customers achieve significantly lower annual bills compared to the standard rate customers – nearly 10 percent overall. SMART Shift Plus customers, on the other hand, have lower bills across all months, including the summer, resulting in over 25 percent lower bills for these customers, on average, as compared with standard rate customers. Parts of these savings were due to zero CPP events being called.

6 DEMONSTRATED TECHNOLOGY – DISTRIBUTION AUTOMATION AND CIRCUIT RECONFIGURATION

6.1 PURPOSE

Distribution Automation and Circuit Reconfiguration (DA-CR) has the potential to introduce several operational advantages. AEP Ohio wanted to leverage the two-way communication and infrastructure improvements on its networks to improve reliability using DA-CR. The installation of new equipment was expected to reduce outage times for customers in the Project area by allowing these "smart" networks to automatically respond to fault conditions, including overload situations and outages.

In addition to this, DA-CR was expected to provide the following functionality:

- Two-way communication among devices with central control center visibility and automated outage recovery;
- Equipment sensors that provide near real-time condition/status;
- Integrated back office systems to provide remote and automated data collection, analysis, visualization and action;
- Preventive automated fault anticipation and location; and
- Two-way power flow support for easy integration of distributed generation.

6.2 TECHNOLOGY

AEP Ohio deployed circuit reconfiguration schemes with equipment from Schweitzer Engineering Laboratories (SEL) and G&W Electric. By replacing existing station circuit breaker relays with SEL-351S relays (the SEL-351S relays allow the Distribution Automation Controllers (DACs) to communicate with DNP3 protocol), SEL DACs are able to function as controllers on feeders included in circuit reconfiguration schemes. On these feeders, the DACs communicate with SEL-651R recloser controls, which are connected to G&W Viper reclosers. The function of the recloser is to isolate a permanent fault on any given line segment by opening on either side of a detected fault. When that is communicated to the DAC, the DAC can react to automatically restore the resulting outage by commanding other normally open reclosers to close and back feed power to customers outside of the faulted line segment.

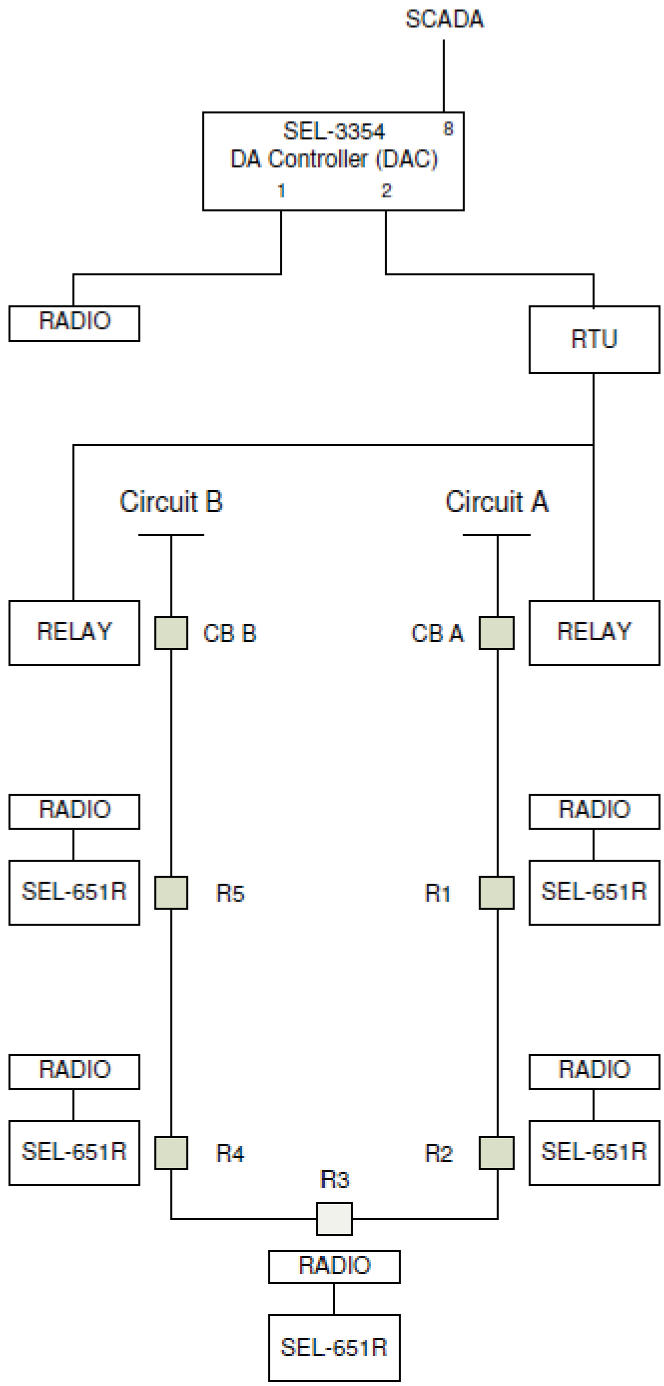


Figure 81. Example DA-CR System Architecture

NOTE: This figure represents a normally open recloser.

6.3 Implementation and Approach

Through the deployment of G&W Viper reclosers, SEL-651R recloser controllers, and SEL-3354 Distribution Automation Controller (DAC), AEP Ohio was able to automatically reconfigure circuits to isolate faulted line segments and restore power to customers affected by an outage. This system utilized the CRCs deployed in substations to communicate with all recloser controllers on circuits associated with each station. When a recloser detects a permanent fault, the recloser's controller communicates with the CRC in the substation via a wireless mesh radio frequency network so that the CRC can make decisions based on the state of the faulted circuit. It also evaluates any surrounding connected circuits in order to instruct certain reclosers to open and isolate the faulted segment of the circuit. If possible, it also instructs a normally open recloser at a tie point between another circuit to close and restore power back to the open isolating recloser.

AEP Ohio deployed DA-CR on 70 circuits in the Project area.

6.4 Benefits Analysis

DA-CR technology is believed to have impacts to AEP Ohio's grid, operations, and customers. Below are three high-level areas of intended impacts and descriptions of how AEP Ohio believes DA-CR will affect these areas.

In order to truly evaluate the economic, reliability, and environmental impacts created by DA-CR, detailed analysis is provided in the relative MBRP impacts metrics that follow.

6.4.1 Economic Benefits

The ability to remotely perform switching operations directly affects the number of truck rolls required to keep the network healthy. A reduction in truck rolls can affect distribution operations costs for the utility. While some reductions were observed, final conclusions will not be available until the Final Report.

6.4.2 Reliability Benefits

DA-CR has the ability to automate fault correction. This "intelligent" aspect of the technology can anticipate overload situations and correct them before they cause an actual outage. AEP Ohio installed automatic reclosers at strategic locations, such as at the pothead switch of an underground station exit cable, to be able to restore large amount of customers in the event of a common equipment failure issues such as underground cable and feeder regulators.

6.4.3 Environmental Benefits

The ability to remotely perform switching operations directly affects the number of truck rolls required to keep the network healthy. A reduction in truck rolls translates into reduced pollution from vehicle emissions. While some reductions were observed, final conclusions will not be available until the Final Report.

6.5 MBRP Impact Metric Details (Circuit Reconfiguration)

This supports the above benefits analysis.

Of the 43 total impact metrics enumerated in the MBRP for the Project, the following 20 impact metrics are associated with the DA-CR suite of technologies; 17 relate to the Project Area and three relate to the System Area.

Metric ID	Metric Scope	Metric Description	DA-CR
M13	Project	Distribution Feeder Load	M13-CR
M14	Project	Distribution Feeder/ Equipment Overload	M14-CR
M15	Project	Deferred Distribution Capacity Investments	M15-CR
M16	Project	Equipment Failure Incidents	M16-CR
M17	Project	Distribution Equipment Maintenance Cost	M17-CR
M18	Project	Distribution Operations Cost	M18-CR
M19	Project	Distribution Feeder Switching Operations	M19-CR
M21	Project	Distribution Restoration Cost	M21-CR
M24	System	Reduced Transmission Congestion Cost	M24-CR
M25	Project	Truck Rolls Avoided	M25-CR
M26	Project	SAIFI	M26-CR
M27	Project	SAIDI/CAIDI	M27-CR
M28	Project	MAIFI	M28-CR
M29	Project	Outage Response Time	M29-CR
M30	Project	Major Event Information	M30-CR
M31	Project	Distribution Operations Vehicle Miles	M31-CR
M32	Project	CO_2 Emissions	M32-CR
M33	Project	Pollutant Emissions (SOx, NOx, $PM_{2.5}$)	M33-CR
M34	System	CO_2 Emissions	M34-CR
M35	System	Pollutant Emissions (SOx, NOx, $PM_{2.5}$)	M35-CR

Table 16. Impact Metrics Addressing DA-CR Technology Performance

6.5.1 Distribution Feeder Load (M13-CR)

6.5.1.1 Objective

DA-CR enables equipment sensors to provide real-time condition/status of AEP Ohio's infrastructure to avoid equipment overloads, pro-actively identify potential failures, permit remote and automated equipment switching, and improve reliability. This impact metric compares feeder load and voltage data for all circuits in the DA-CR Project area to historical data for the same circuits.

6.5.1.2 Organization of Results

This metric presents circuit load graphs showing the total feeder load for each Project area feeder. Two presentations of data are conducted in this metric. The first is provided in this Interim Report. All will be provided in the Final Report.

- Circuit Load by Feeder

  Each graph shows real power, reactive power, apparent power, and feeder capacity overlaid as well as a plot of circuit voltage in 120v base.

- Overlay of DLC Events

6.5.1.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

- An assumption when planning for this metric was that noticeable penetrations of DLC would be present on circuits. From the first year of data and an examination of the recorded data shows this is not the case for circuits with less than 3 percent penetration of DLC. For a more thorough analysis of DLC load reduction, see the Consumer Programs Report.

6.5.1.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of circuit load data:

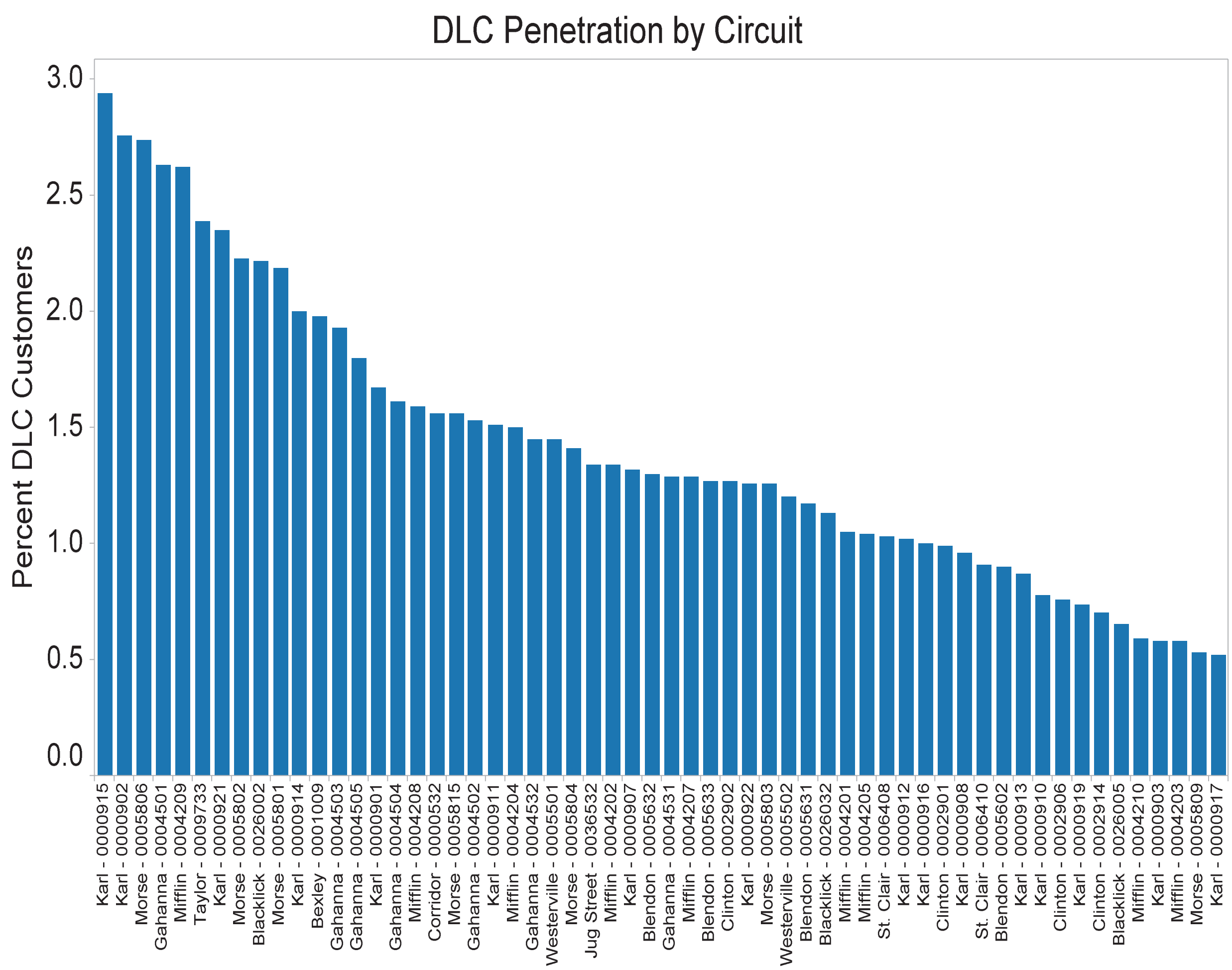


Figure 82. DLC Penetration by Circuit

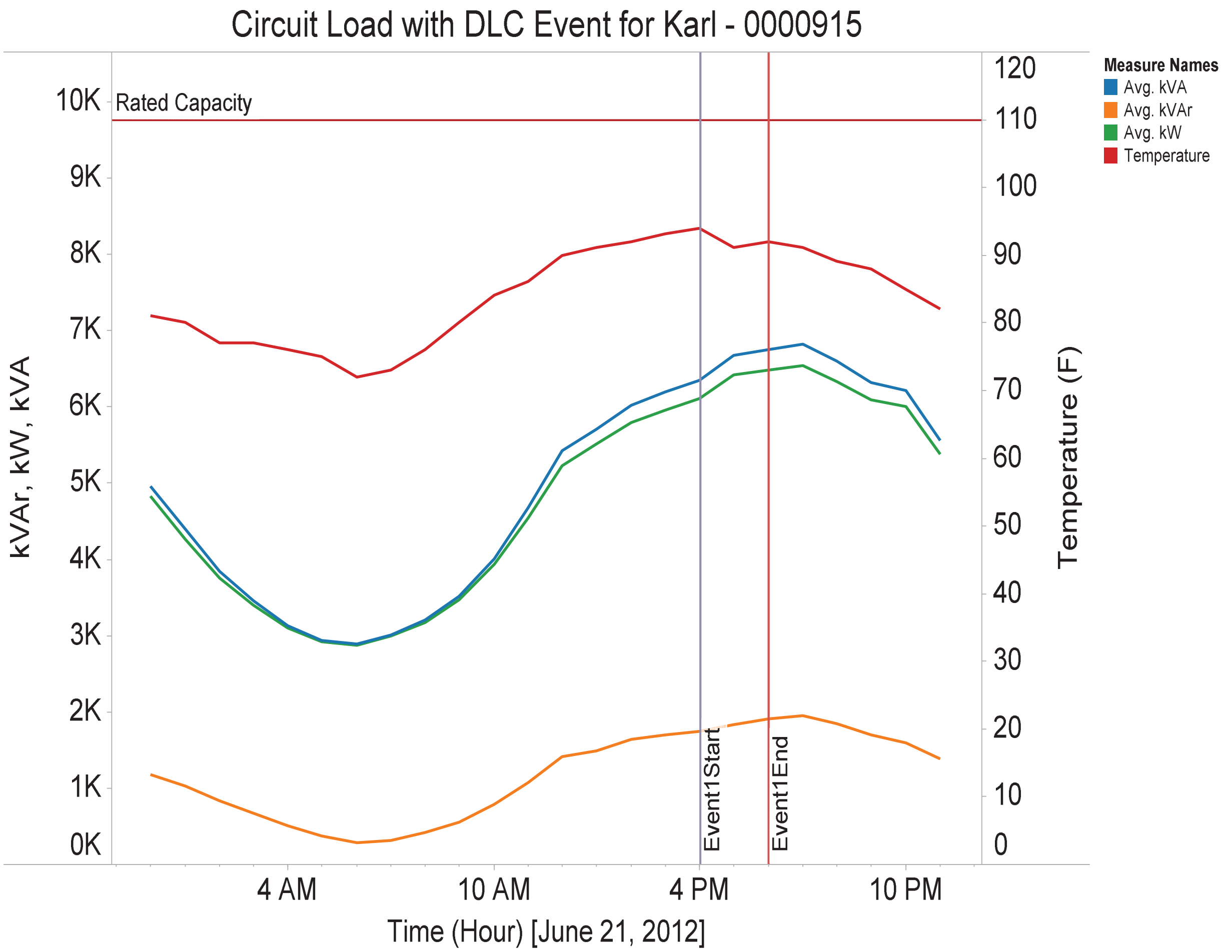


Figure 83. June 21, 2012 DLC Event - Karl Rd Feeder 0000915

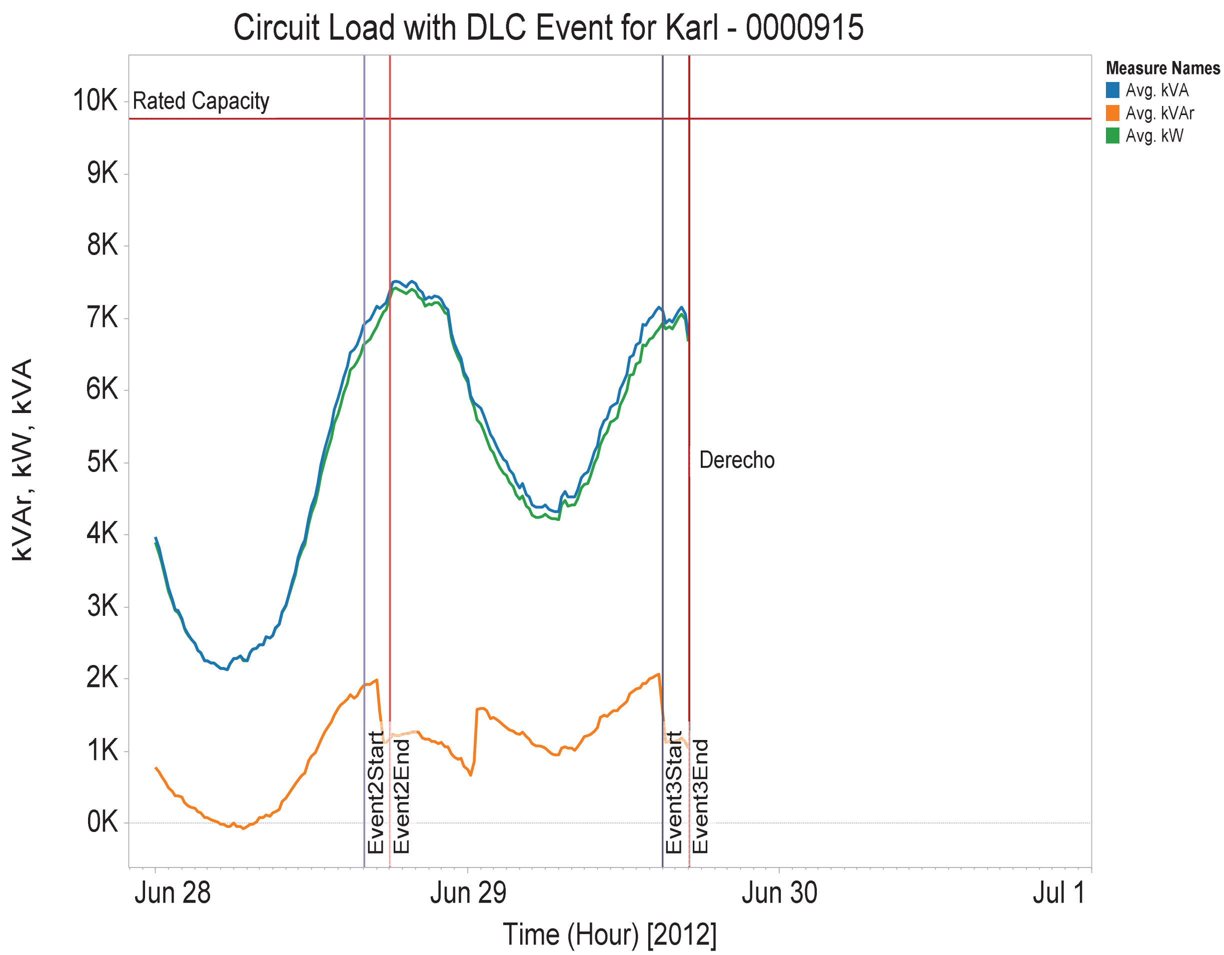


Figure 84. June 28 and 29, 2012 DLC Events - Karl Rd Feeder 0000915

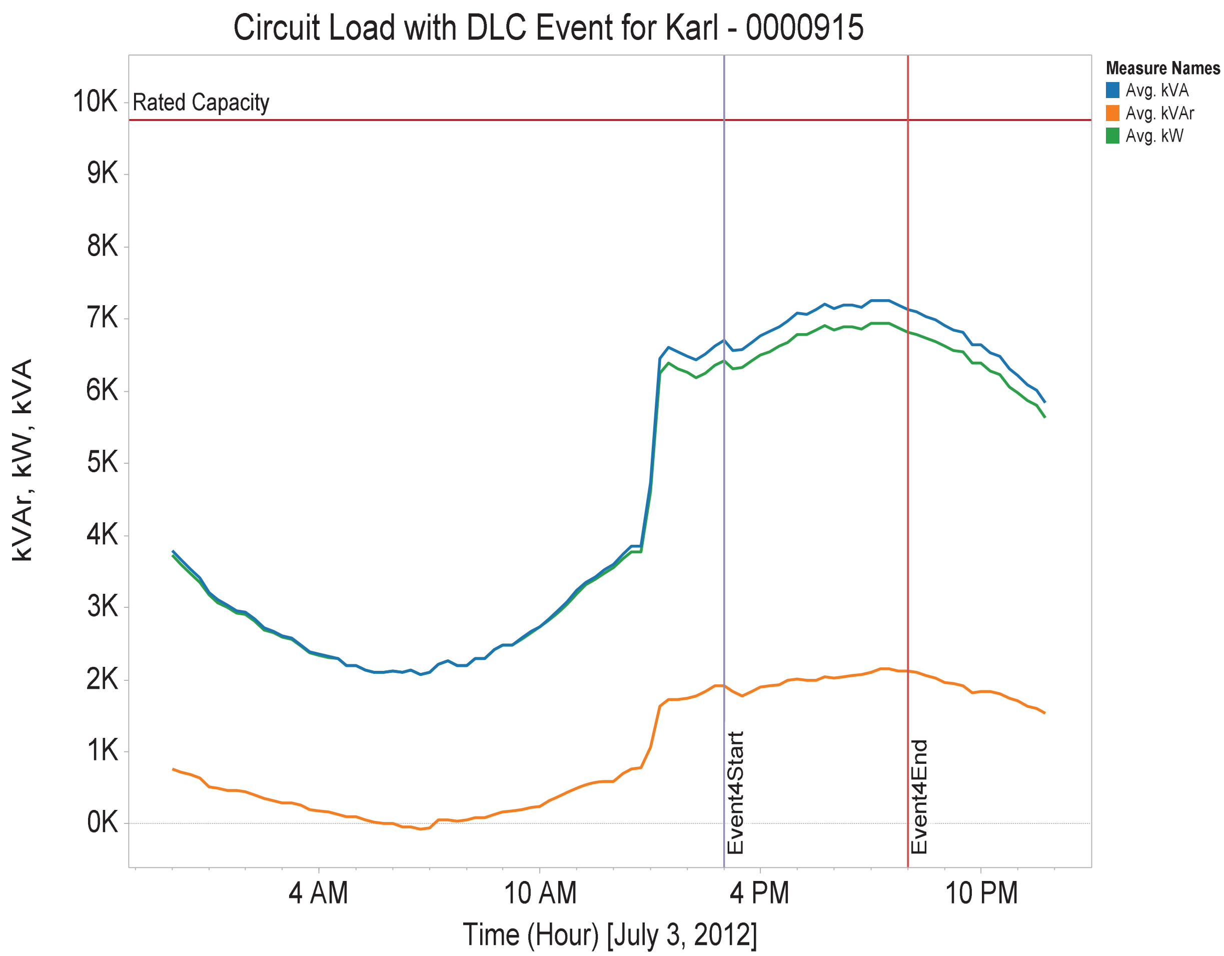


Figure 85. July 3, 2012 DLC Event - Karl Rd Feeder 0000915

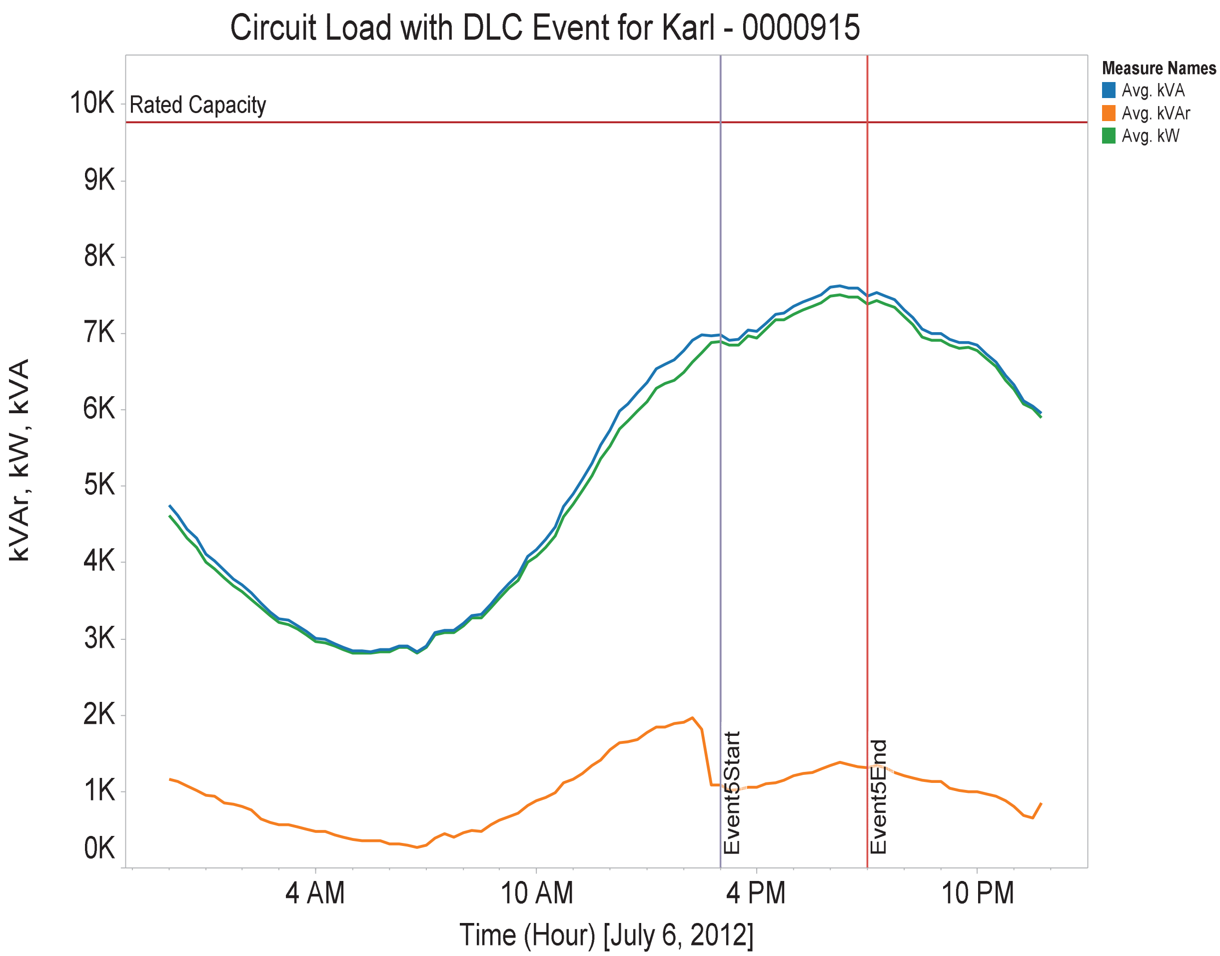


Figure 86. July 6, 2012 DLC Event - Karl Rd Feeder 0000915

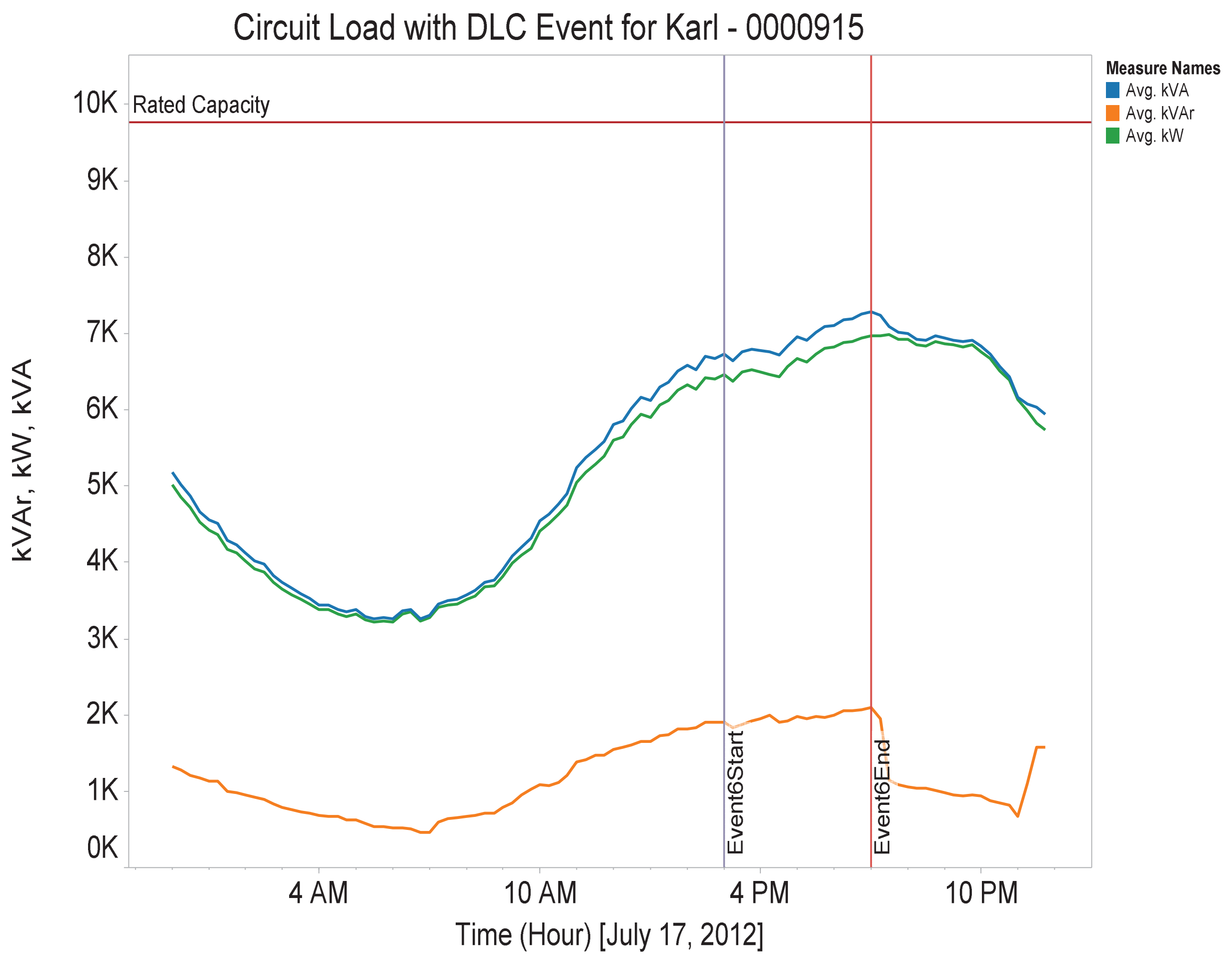


Figure 87. July 17, 2012 DLC Event - Karl Rd Feeder 0000915

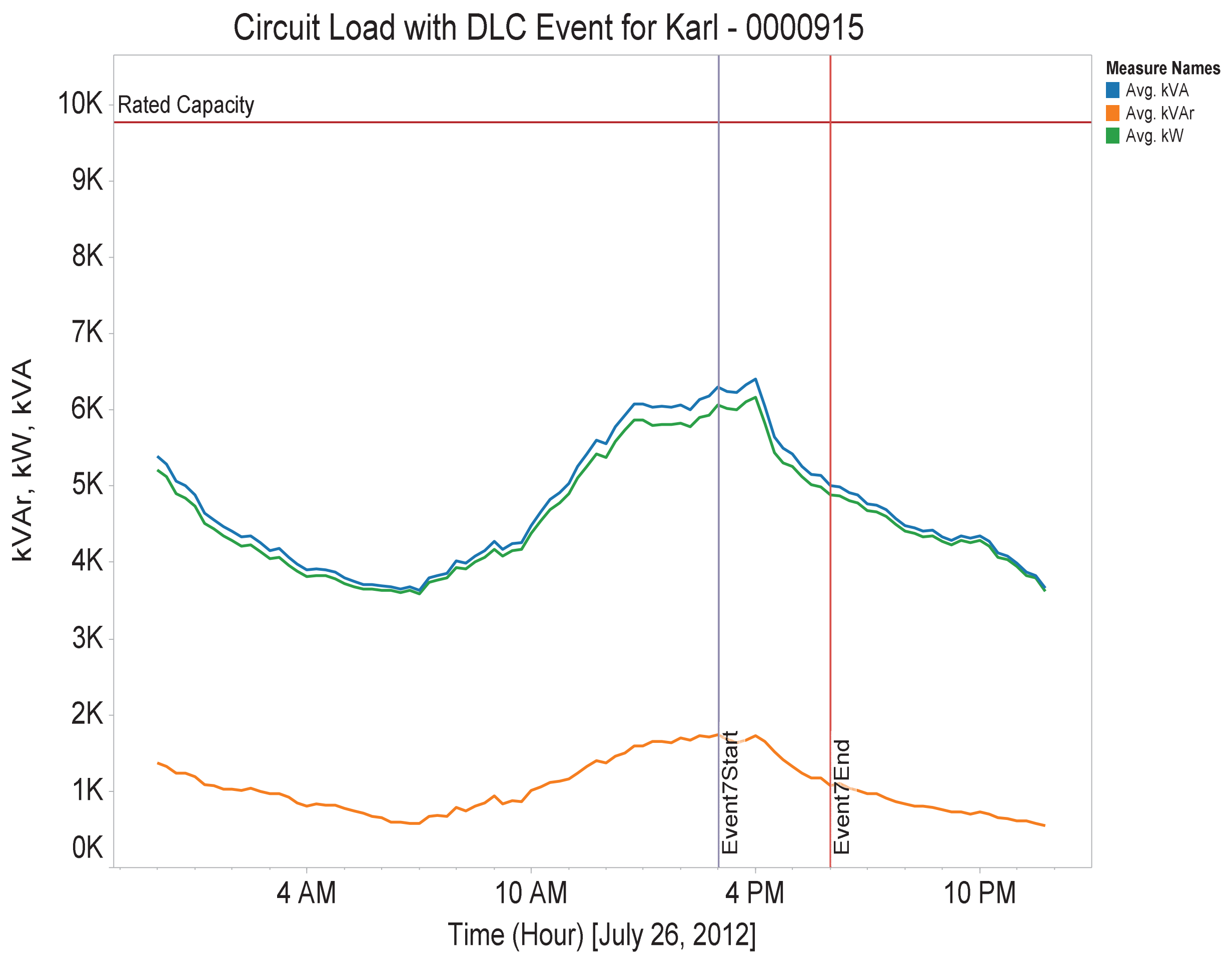


Figure 88. July 26, 2012 DLC Event - Karl Rd Feeder 0000915

Calculation Approach

The following queries and methods are used to generate presentation items:

- Circuit load per circuit, substation, time, and Volt VAR controller status were selected.
- Substation load per substation, time, and Volt VAR controller status were calculated by summing the load of circuits originating at substations.
- Hourly outdoor temperature in degrees Fahrenheit for Port Columbus International Airport was collected from the National Oceanic and Atmospheric Administration: http://hurricane.ncdc.noaa.gov/pls/plclimprod/poemain.accessrouter?datasetabbv=DS3505&countryabbv=&georegionabbv=
- DLC events per circuit were selected based on the type of DLC device installed on a customer's premise and from which circuit the premise was fed.

6.5.2 Distribution Feeder or Equipment Overload Incidents (M14-CR)

6.5.2.1 Objective

DA-CR enables equipment sensors to provide near real-time condition/status of AEP Ohio's infrastructure to avoid equipment overloads, pro-actively identify potential failures, permit remote and automated equipment switching, and improve reliability. This impact metric reports equipment overload events within and outside of the Project area in order to quantify any reduction in the number of such events. Analysis includes feeder, substation, daily weather and time conditions.

6.5.2.2 Organization of Results

This metric is intended to present a table of circuit overload events reported by the DA-CR system. Note that as of the writing of this report, no such events have occurred.

6.5.2.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.2.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of circuit overload events:

No circuit overload events have occurred as of this writing.

Calculation Approach

For each distribution feeder, overload data will be presented in a table.

The following queries and methods are used to generate presentation items:

- Equipment overload events per equipment, equipment type, circuit, substation, and time were selected. To date, no overload events have occurred.
- Hourly outdoor temperature in degrees Fahrenheit for Port Columbus International Airport was collected from the National Oceanic and Atmospheric Administration: http://hurricane.ncdc.noaa.gov/pls/plclimprod/poemain.accessrouter?datasetabbv=DS3505&countryabbv=&georegionabbv=

6.5.3 Deferred Distribution Capacity Investments (M15-CR)

6.5.3.1 Objective

DA-CR enables equipment sensors to provide near real-time condition/status of AEP Ohio's infrastructure to avoid equipment overloads, pro-actively identify potential failures, permit remote and automated equipment switching, and improve reliability. This impact metric provides a description of all distribution capacity investments that were deferred due to distribution automation.

6.5.3.2 Organization of Results

This metric a study of deferred distribution capacity investments due to circuit reconfiguration distribution automation.

6.5.3.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.3.4 Results of Data Collected to Date

N/A

Presentation of Deferred Capacity Study:

AEP Ohio has reviewed planned projects in *Distribution Load Forecasting* where VVO circuits would be involved. It did not appear that any projects were deferred as a result of VVO being installed. This matter was discussed with AEP Ohio's local planning engineer who concurs that no projects were deferred as a result of VVO being deployed. That being said, deferring capital projects by installing VVO is a potential benefit of VVO but it just didn't occur for the circuits that were involved in the Project.

AEP Ohio has also discussed with local planning engineering the subject of any projects that would have been deferred as a result of DA-CR being installed. Planning engineering feels that

DA-CR has not resulted in any project deferrals for the circuits on which they are installed in the Project area.

Calculation Approach

No planned or deferred distribution capacity investments have occurred within the DA-CR Project area.

6.5.4 Equipment Failure Incidents (M16-CR)

6.5.4.1 Objective

DA-CR enables equipment sensors to provide near real-time condition/status of AEP Ohio's infrastructure to avoid equipment overloads, pro-actively identify potential failures, permit remote and automated equipment switching, and improve reliability. A reduction in overloading could translate to a reduction in equipment failures. Conversely, DA-CR may result in increased wear on devices due to the increased frequency of operation. This impact metric provides counts of equipment failure events within the Project and System areas in order to quantify these effects.

6.5.4.2 Organization of Results

This metric presents equipment failure event information grouped by equipment type by month and equipment failures associated with substations in the Project area.

- Equipment failure events

  Each graph shows the quantity of equipment failures on the vertical axis and separates the columns by either type of equipment, month, or substation

  Failures for the following equipment types are included in this report: Capacitor Banks, Distribution Transformers, Reclosers, Switches, and Voltage Regulators. Other equipment types either had no failures or data was not available at the time of this report.

6.5.4.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.4.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of equipment failure event data:

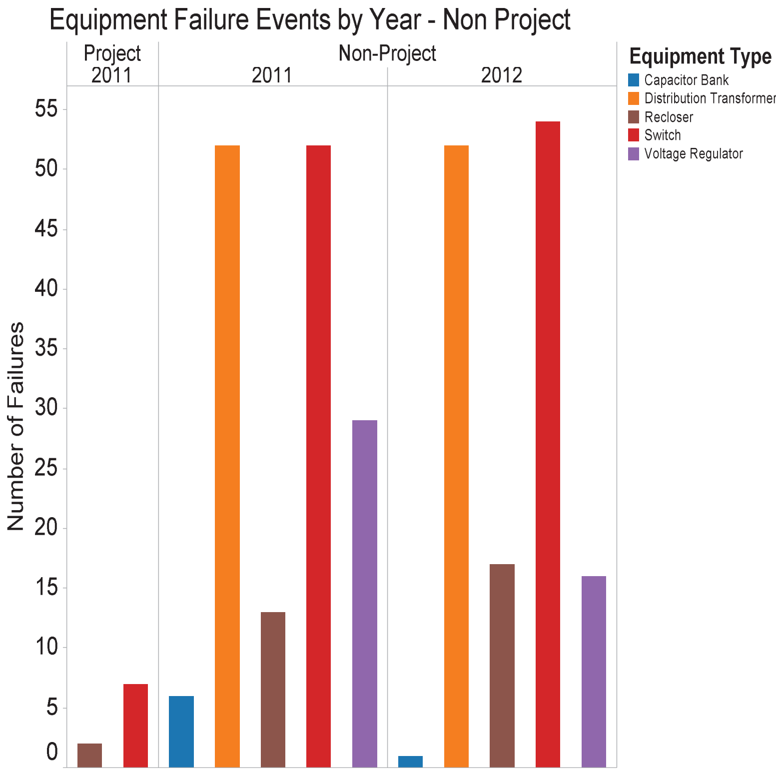


Figure 89. Equipment failure events (Project vs. non-Project area)

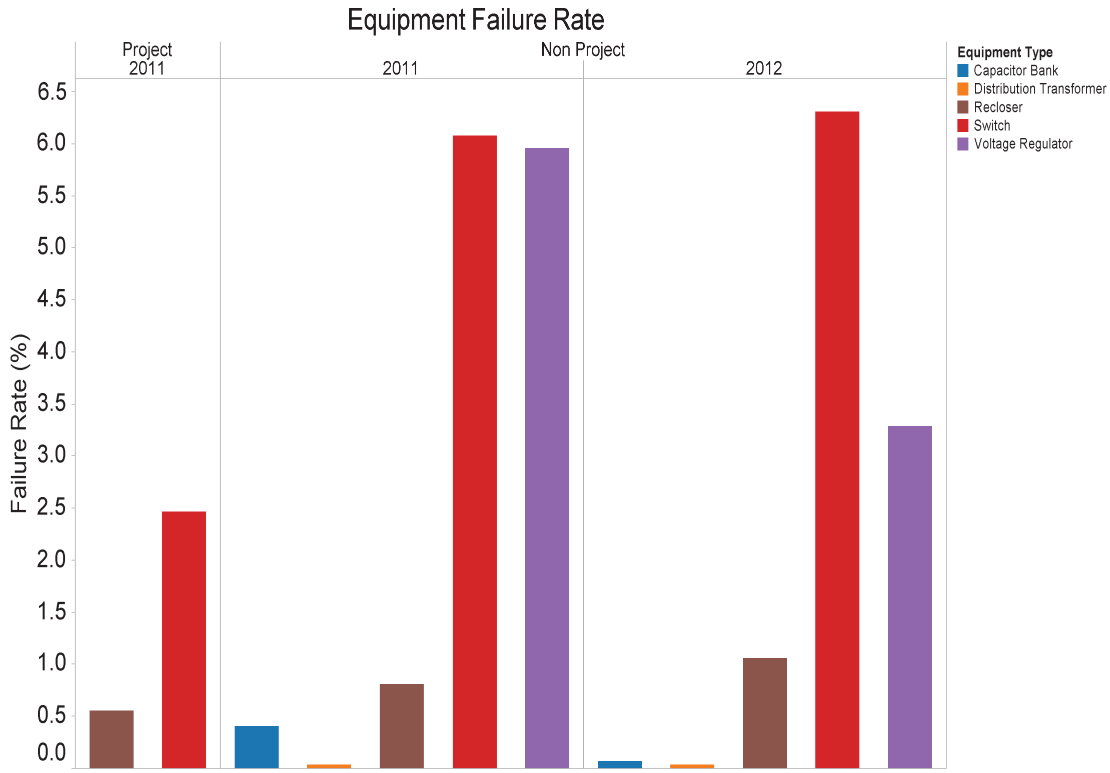


Figure 90. Equipment failure rate by year (Project vs. non-Project area)

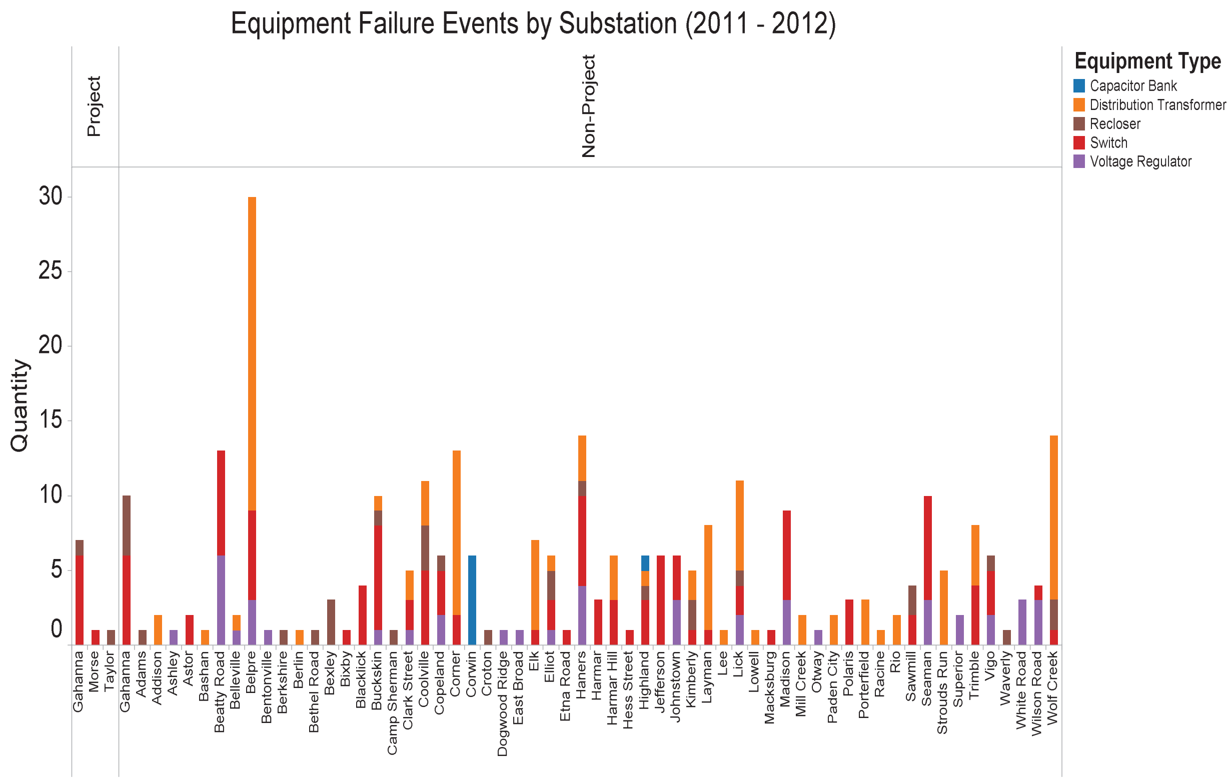


Figure 91. Equipment failure events by substation for substations with failures. Project and Non-Project Areas.

Calculation Approach

The following queries and methods are used to generate presentation items:

- Equipment failure events per date, equipment type, circuit, and substation were selected by linking equipment compatible units to circuit equipment types.
- Hourly outdoor temperature in degrees Fahrenheit for Port Columbus International Airport was collected from the National Oceanic and Atmospheric Administration http://hurricane.ncdc.noaa.gov/pls/plclimprod/poemain.accessrouter?datasetabbv=DS3505&countryabbv=&georegionabbv=

6.5.5 Distribution Equipment Maintenance Cost (M17-CR)

6.5.5.1 Objective

The DA-CR system is expected to affect distribution maintenance costs in several ways. Reduction in equipment failure may reduce maintenance costs while the introduction of new DA-CR equipment may increase costs. This impact metric provides monthly cost data for distribution maintenance activities throughout the System area.

6.5.5.2 Organization of Results

This metric presents monthly average equipment maintenance costs per feeder for both the Project and non-Project areas.

- Equipment maintenance cost

  Each graph shows average maintenance costs per feeder by month separated by components of construction overhead, labor cost, fleet cost, material costs, and the sum of all four, components. Two graphs are presented; one for the Project area and one for non-Project area.

6.5.5.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.5.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of equipment maintenance cost data:

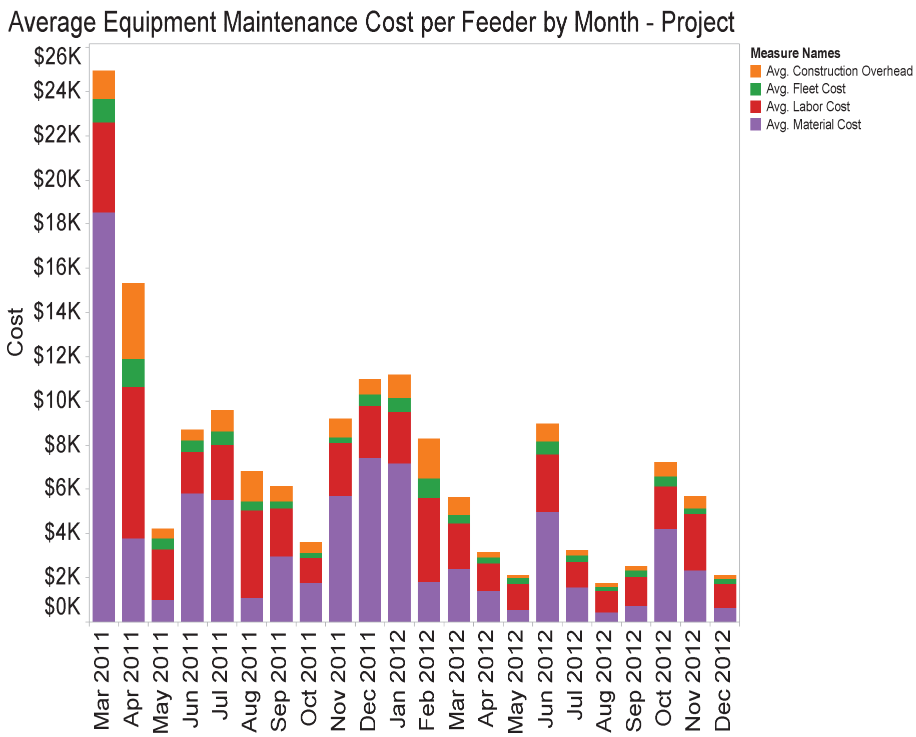


Figure 92. Average maintenance cost per feeder (Project area)

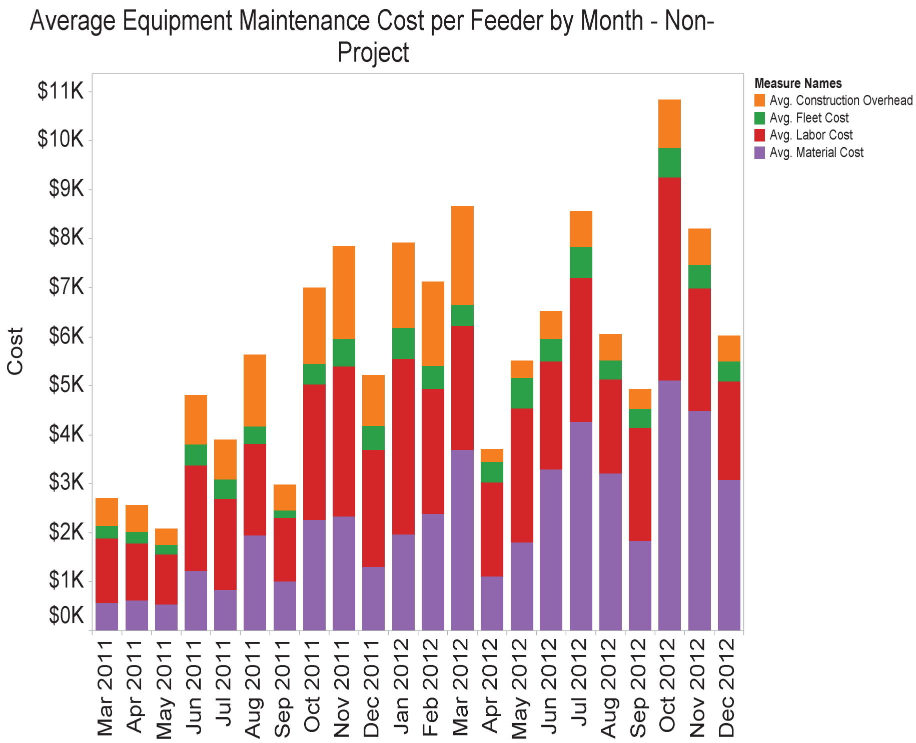


Figure 93. Average maintenance cost per feeder (non-Project area)

Calculation Approach

The following queries and methods are used to generate presentation items:

- M17 – Distribution equipment maintenance labor, material, vehicle fleet, and construction overhead costs per circuit, substation, and work order close date were calculated by summing labor, material, vehicle fleet, and construction overhead costs per work order.

6.5.6 Distribution Operations Cost (M18-CR)

6.5.6.1 Objective

The DA-CR system has the potential to reduce operations cost by eliminating inspection programs and by reducing the number of truck rolls required for actions such as switching. This metric provides an estimate of the cost reduction and/or addition achieved by these devices.

6.5.6.2 Organization of Results

This metric provides savings from avoided truck rolls per month associated with DA-CR.

- Truck rolls avoided by month

  This graph shows the net savings of truck rolls avoided, subtracting any additional truck rolls required, and computing a dollar value for these avoided costs.

6.5.6.3 Assumptions

For the purposes of this Interim Report, the assumptions required for the analysis are described in the calculation approach section following the results in this section. In the Final Report, when two full years of data are analyzed, the cross cutting assumptions will be presented here.

6.5.6.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of truck rolls avoided data:

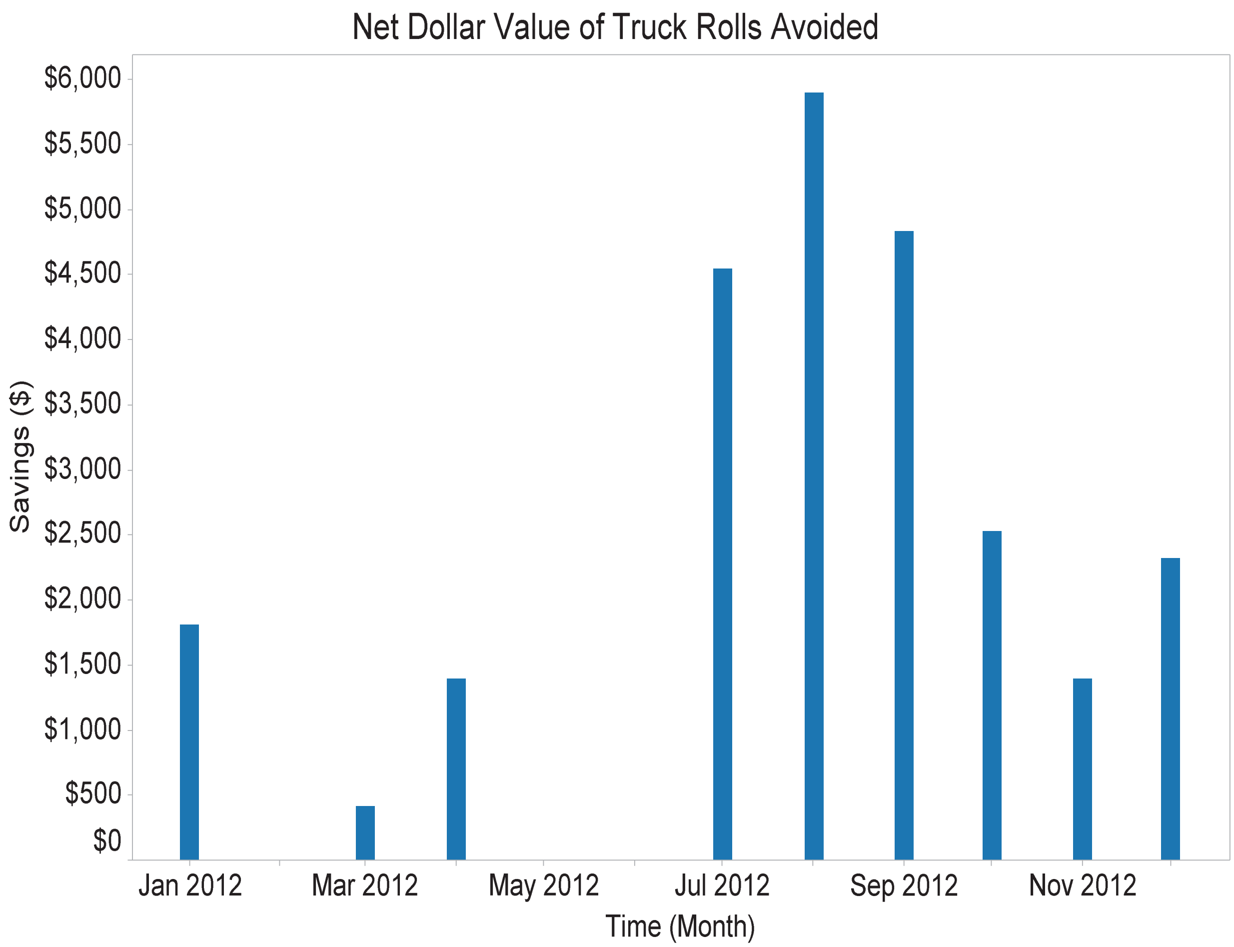


Figure 94. Net dollar savings from truck rolls avoided by month due to DA-CR

Month	Total Net Savings
Jan-12	$1,811
Mar-12	$418
Apr-12	$1,393
Jul-12	$4,550
Aug-12	$5,896
Sep-12	$4,828
Oct-12	$2,530
Nov-12	$1,393
Dec-12	$2,321

Table 17. Net dollar savings from truck rolls avoided by month due to DA-CR

Calculation Approach

Analysis was conducted by counting the number of remote switching operations and assigning these as either a short or standard truck roll avoided. Standard truck rolls are intended to represent a crew traveling from the service center to a switching location. Short truck rolls are intended to represent a crew traveling from one switching device to another nearby switching device on the same circuit or on an adjacent circuit. Cost was determined based on conversion factors for vehicle and labor rates.

The following queries and methods are used to generate presentation items:

- Short truck rolls avoided per equipment, equipment type, month, circuit, and substation due to DA-CR technology were calculated by selecting remote equipment switching events that occurred during multi-step restoration outages. These were combined with remote recloser switching events that occurred within five minutes of another remote recloser switching events on the same circuit.
- Standard truck rolls avoided per equipment, equipment type, month, circuit, and substation due to DA-CR technology were calculated by selecting remote recloser switching events which occurred more than five minutes after another remote recloser switching event on the same circuit that did not occur during an outage with a single restoration step.
- Vehicle savings from truck rolls avoided per equipment, equipment type, month, circuit, and substation due to DA-CR technology were calculated by summing short truck rolls avoided multiplied by $7.50 per truck roll with standard truck rolls avoided times $45.25 per truck roll.
- Labor savings from truck rolls avoided per equipment, equipment type, month, circuit, and substation due to DA-CR technology were calculated by summing short truck rolls avoided multiplied by $15.75 per truck roll with standard truck rolls avoided times $94.00 per truck roll.

6.5.7 Distribution Feeder Switching Operations (M19-CR)

6.5.7.1 Objective

The DA-CR system has the potential to reduce operations cost by reducing the number of truck rolls required for activities such as manual switching. This metric provides a count of the number of switching actions performed by the DA-CR system and compares these numbers to historical manual switching data to determine effects on operational costs.

6.5.7.2 Organization of Results

Switching events are presented as counts of device operations by device type over time.

Device Operations: the f graphs in this section show automated and remote switching events categorized by the type of device, such as capacitor, transformer, regulator, and volt VAR controller. The total count per day for the duration of the Project is shown in Figure 95.

6.5.7.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.7.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of switching event data:

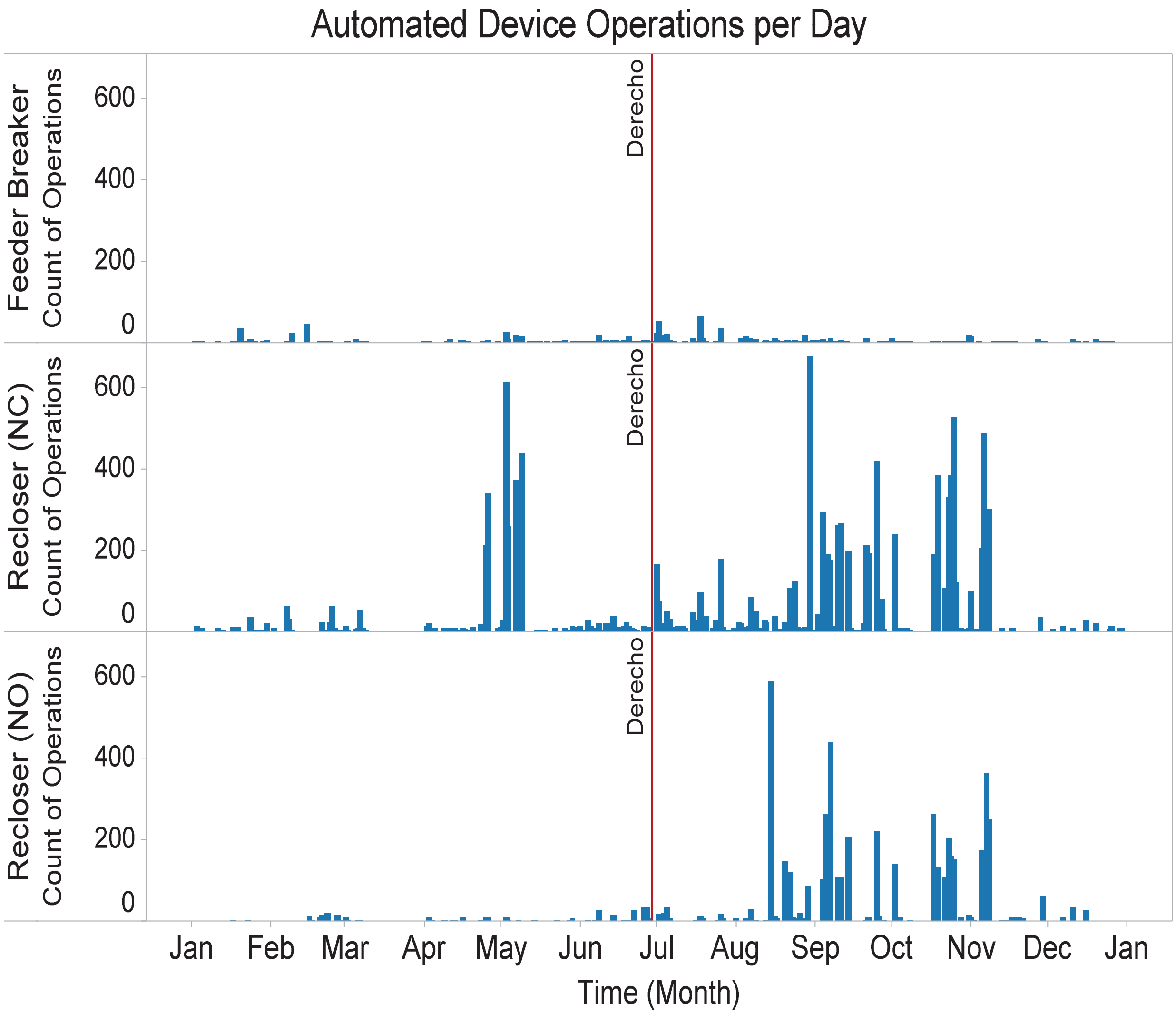


Figure 95. Recloser and Breaker Automated Switching Events 2012

NOTE: High fluctuation in on/off counts for recloser operations have been noted and require further analysis that will be included in the Final Report.

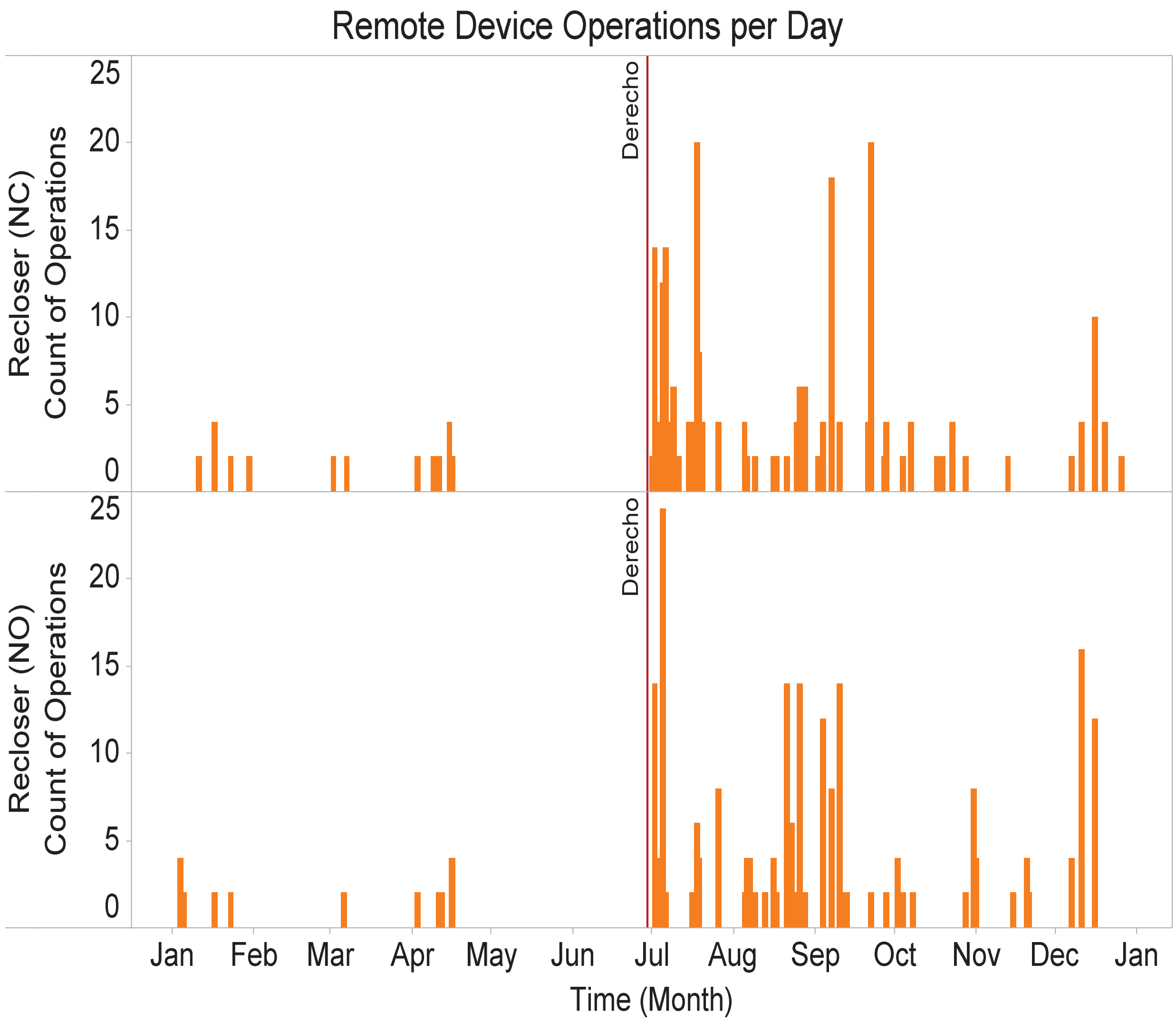


Figure 96. Recloser and Breaker Remote Switching Events 2012

Calculation Approach

The following queries and methods are used to generate presentation items:

- Equipment switching events per equipment, equipment type, date, current state, circuit, substation, and event type were calculated by counting equipment switching events.
- Short truck rolls avoided per equipment, equipment type, month, circuit, and substation due to DA-CR technology were calculated by selecting remote equipment switching events that occurred during multi-step restoration outages. These were combined with remote recloser switching events that occurred within five minutes of another remote recloser switching events on the same circuit.

6.5.8 Distribution Restoration Cost (M21-CR)

6.5.8.1 Objective

The DA-CR system has the potential to reduce restoration costs by reducing the total Customer Minutes of Interruption (CMI) associated with an outage in several ways. With automated switching, truck rolls can be avoided by performing the switching in the back office, both automatically and with user intervention. Fault location identification has the potential to reduce the number of miles driven to find a fault location on a large line segment. This impact metric compares manual switching activities, prior to DA-CR, with that of automated switching that DA-CR provides, to consider truck rolls and CMI avoided to determine cost implications.

6.5.8.2 Organization of Results

This metric presents CMI avoided by DA-CR and the associated cost savings of reducing CMI.

- CMI avoided

  Each graph shows the total minutes or equivalent cost impact of avoided CMI by month due to DA-CR.

6.5.8.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.8.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of CMI Avoided:

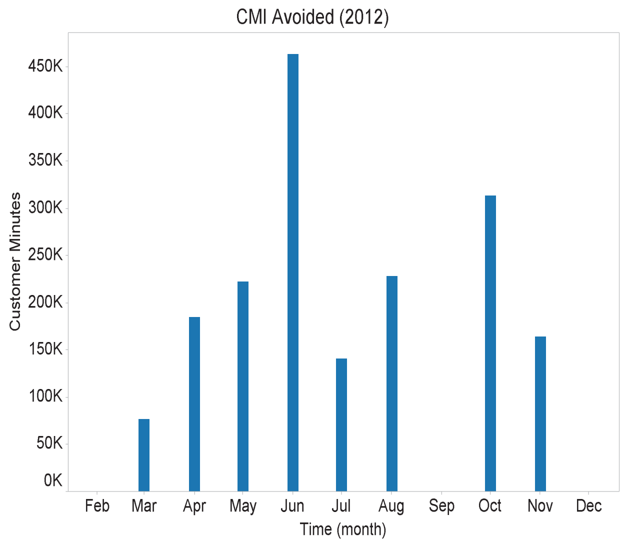


Figure 97. CMI avoided due to DA-CR

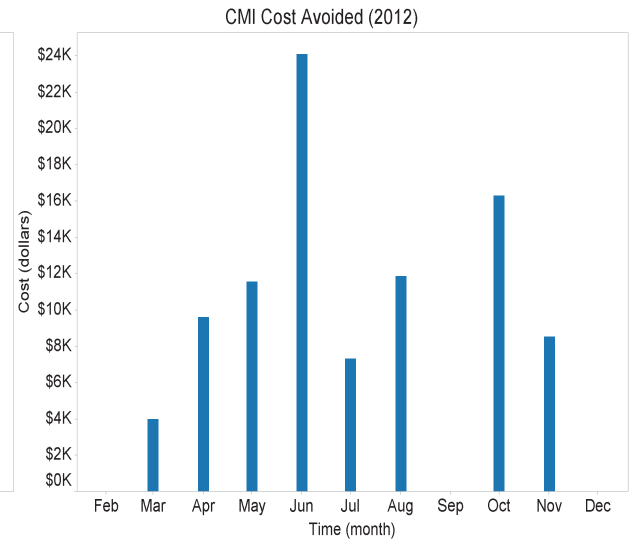


Figure 98. Dollar value of CMI avoided due to DA-CR

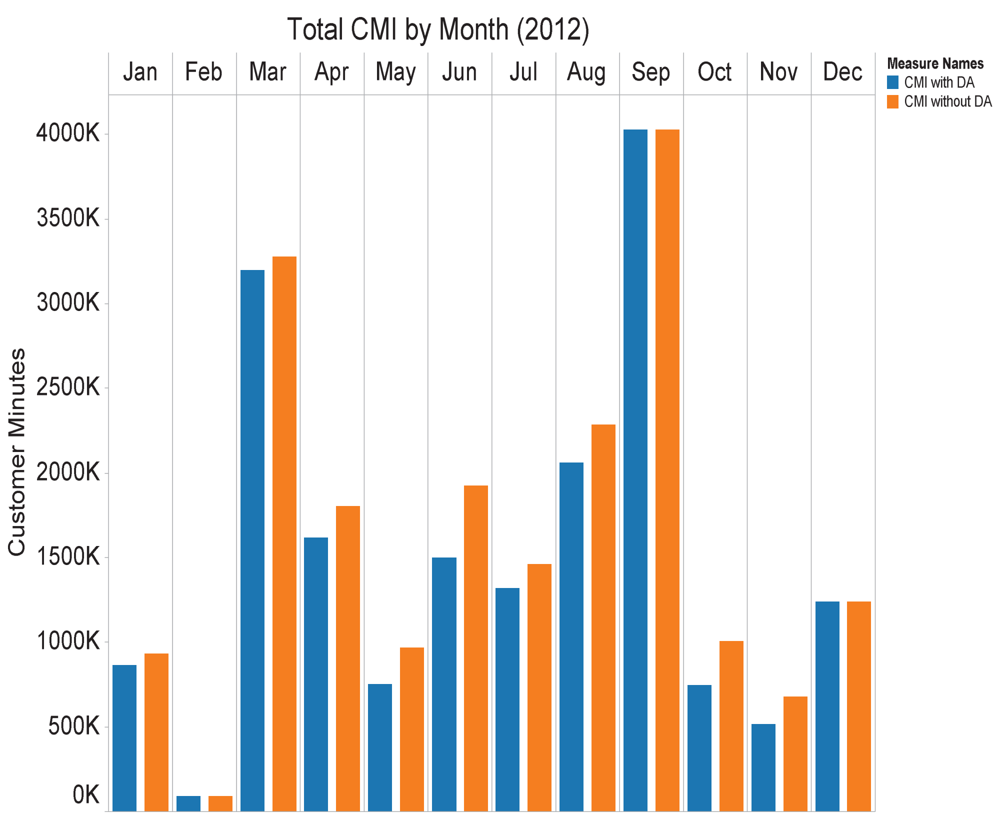


Figure 99. Total Project area CMI with and without DA-CR

Calculation Approach

The following queries and methods are used to generate presentation items:

- Distribution restoration CMI per circuit, substation, outage, and date were calculated by subtracting the time of the first customer call from the time of the outage in minutes multiplied by the number of customers affected by the outage.
- Distribution restoration CMI costs per circuit, substation, outage, and date were calculated by subtracting the time of the first customer call from the time of the outage in minutes multiplied by the number of customers affected by the outage times $.052 (dollars per minute).
- CMI avoided per circuit, substation, and month for non-jurisdictional major event days were calculated by selecting the CMI avoided reported by AEP Ohio.
- CMI avoided costs per circuit, substation, and month for non-jurisdictional major event days were calculated by multiplying the CMI avoided reported by AEP Ohio by $.052 (dollars per minute).

6.5.9 Reduced Transmission Congestion Cost (M24-CR)

6.5.9.1 Objective

By shifting circuit load, distribution automation has the potential to reduce the congestion component of PJM locational marginal pricing (LMP). This impact metric provides an analysis of this effect.

6.5.9.2 Organization of Results

No results are presently available.

6.5.9.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.9.4 Results of Data Collected to Date

Presentation of AEP Ohio study:

No results are presently available.

Data Sources

n/a

Calculation Approach

Without internal knowledge of how incremental load reductions affect PJM congestion costs, this analysis cannot be performed. Distribution feeder load data is provided under “Distribution Feeder Load” (M13-CR).

6.5.10 Truck Rolls Avoided (M25-CR)

6.5.10.1 Objective

The DA-CR system has the potential to reduce operations cost by reducing the number of truck rolls required for activities such as switching. This metric provides a count of the number of switching actions performed by the DA-CR system that would otherwise have required a truck roll for manual switching.

6.5.10.2 Organization of Results

Truck rolls avoided by automated DA-CR switching may be one of two types: Standard truck rolls are intended to represent a crew traveling from the service center to a switching location. Short truck rolls are intended to represent a crew traveling from one switching device to another nearby switching device on the same circuit or on an adjacent circuit.

Truck Rolls Avoided: these graphs show the total count of short and standard truck rolls avoided by month.

6.5.10.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.10.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of truck roll avoided data:

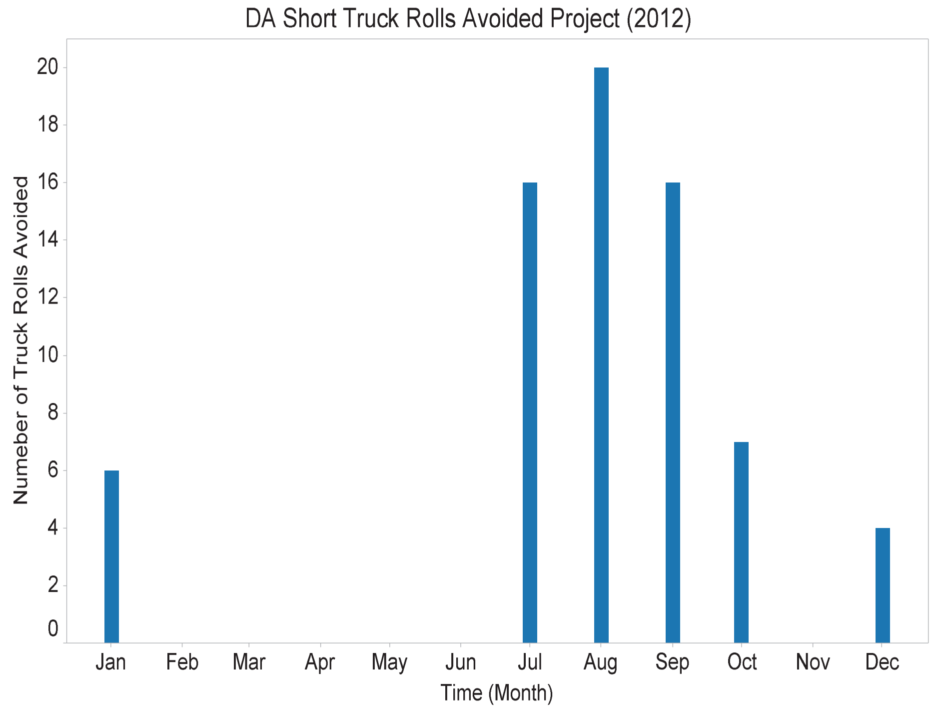


Figure 100. Short truck rolls avoided due to DA-CR

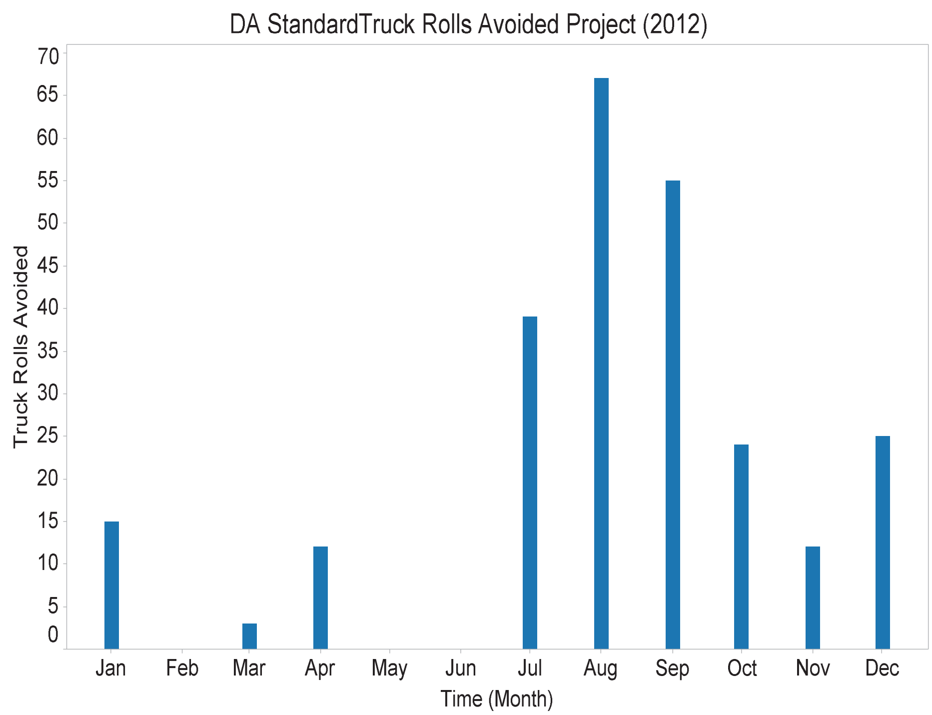


Figure 101. Standard truck rolls avoided due to DA-CR

Calculation Approach

Analysis was conducted by counting the number of remote switching operations and assigning these as either a short or standard truck roll avoided. Standard truck rolls are intended to represent a crew traveling from the service center to a switching location. Short truck rolls are intended to represent a crew traveling from one switching device to another nearby switching device on the same circuit or on an adjacent circuit.

The following queries and methods are used to generate presentation items:

- Short truck rolls avoided per equipment, equipment type, month, circuit, and substation due to DA-CR technology were calculated by selecting remote equipment switching events that occurred during multi-step restoration outages. These were combined with remote recloser switching events that occurred within five minutes of another remote recloser switching events on the same circuit.
- Standard truck rolls avoided per equipment, equipment type, month, circuit, and substation due to DA-CR technology were calculated by selecting remote recloser switching events which occurred more than 5 minutes after another remote recloser switching event on the same circuit that did not occur during an outage with a single restoration step.

6.5.11 SAIFI (M26-CR)

6.5.11.1 Objective

The DA-CR system has the potential to improve SAIFI by automatically reconfiguring circuits upon detected interruption. This metric provides a report of actual SAIFI for DA-CR Project feeders as well as a calculation of what SAIFI would have been without DA-CR.

6.5.11.2 Organization of Results

This metric presents a comparison of monthly SAIFI for System area circuits with and without DA-CR capabilities.

- SAIFI

  Each graph shows the total SAIFI per month for circuits with DA-CR and without. The second graph shows SAIFI for a single selected circuit.

6.5.11.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.11.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of SAIFI data:

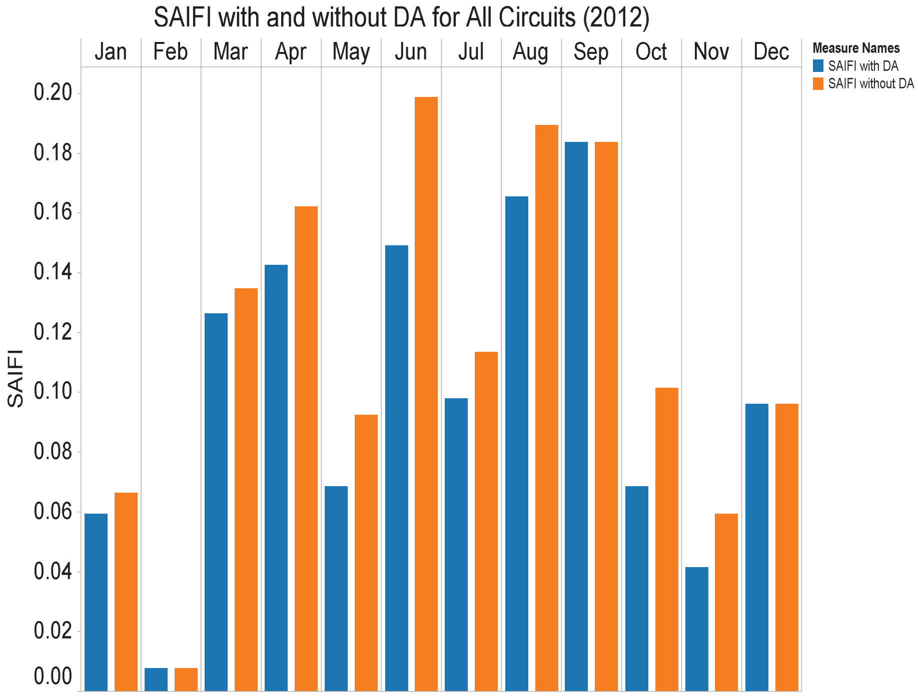


Figure 102. SAIFI for all System area circuits

Project Area (70 circuits)						
	2012			2011		
Year	With DA-CR	Without DA-CR	% Change	With DA-CR	Without DA-CR	% Change
SAIFI	1.228	1.429	-14.1%	1.591	1.668	-4.6%

Table 18. SAIFI Comparisons

AEP Circuit Number	SAIFI with DA	SAIFI without DA		AEP Circuit Number	SAIFI with DA	SAIFI without DA
Bexley - 0001006	0.0816	0.0816		Karl - 0000915	0.1728	0.1728
Bexley - 0001009	0.0830	0.0830		Karl - 0000916	0.0556	0.0556
Blacklick - 0026031	0.1538	0.1538		Karl - 0000917	0.1177	0.1177
Blacklick - 0026032	0.0001	0.0001		Karl - 0000918	0.3710	0.4480
Blendon - 0005601	0.0435	0.1516		Karl - 0000919	0.3538	0.3538
Blendon - 0005631	0.1975	0.3402		Karl - 0000920	0.0305	0.0305
Blendon - 0005632	0.1647	0.1647		Karl - 0000921	0.1808	0.1808
Blendon - 0005633	0.2176	0.2176		Karl - 0000922	0.1631	0.1631
Centerburg - 0027232	0.2816	0.2816		Kirk - 0008031	0.1727	0.1727
Clinton - 0002901	0.0439	0.1858		Kirk - 0008032	0.0347	0.0347
Clinton - 0002902	0.0309	0.0309		Mifflin - 0004201	0.1036	0.2235
Clinton - 0002906	0.0292	0.0292		Mifflin - 0004202	0.1503	0.2933
Clinton - 0002911	0.0095	0.0095		Mifflin - 0004203	0.0193	0.0193
Clinton - 0002914	0.0836	0.0836		Mifflin - 0004204	0.0121	0.0121
Corridor - 0000531	0.0383	0.0383		Mifflin - 0004205	0.1658	0.1658
Corridor - 0000532	0.2507	0.3727		Mifflin - 0004206		
Gahanna - 0004502	0.0225	0.0225		Mifflin - 0004207	0.0456	0.0456
Gahanna - 0004531	0.0404	0.0404		Mifflin - 0004208	0.2184	0.2184
Gahanna - 0004532	0.1444	0.1444		Mifflin - 0004209	0.0052	0.0052
Genoa - 0003902	0.1462	0.1462		Mifflin - 0004210	0.0271	0.0271
Jug Street - 0036531	0.0112	0.0112		Morse - 0005801	0.1449	0.1449
Jug Street - 0036532	0.2650	0.2650		Morse - 0005802	0.1984	0.1984
Karl - 0000901	0.1031	0.1031		Morse - 0005803	0.0093	0.0093
Karl - 0000902	0.1486	0.1486		Morse - 0005805	0.0323	0.0323
Karl - 0000903	0.2083	0.2131		Morse - 0005806	0.0765	0.0765
Karl - 0000904	0.0395	0.2926		Morse - 0005807	0.0920	0.0920
Karl - 0000905	0.0283	0.0283		Morse - 0005809	0.0220	0.0220
Karl - 0000906	0.0864	0.0864		Morse - 0005811		
Karl - 0000907	0.0465	0.0465		Morse - 0005812	0.2832	0.2832
Karl - 0000908	0.2097	0.2688		Morse - 0005815	0.0036	0.0036
Karl - 0000910	0.0268	0.1492		St. Clair - 0006410	0.0190	0.0190
Karl - 0000911	0.0109	0.0109		Taylor - 0009732	0.2118	0.2118
Karl - 0000912	0.0210	0.0210		Taylor - 0009733	0.0587	0.0587
Karl - 0000913	0.0495	0.0495		Westerville - 0005501	0.2928	0.2928
Karl - 0000914	0.1799	0.1799		Westerville - 0005502	0.1422	0.1422

Table 19. SAIFI with and without DA-CR for Project area circuits

Calculation Approach

Actual SAIFI data was reported directly by AEP Ohio. SAIFI without DA-CR was calculated using CMI avoided due to DA-CR.

The following queries and methods are used to generate presentation items:

- SAIFI per month, circuit, and substation with DA-CR was calculated by multiplying SAIFI for non-jurisdictional major event days reported by AEP Ohio by the number of customers served on the circuit reported by AEP Ohio.
- SAIFI per month, circuit, and substation without DA-CR was calculated by multiplying SAIFI for non-jurisdictional major event days reported by AEP Ohio by the number of customers served on the circuit reported by AEP Ohio and then adding the avoided customers interrupted for non-jurisdictional major event days reported by AEP Ohio.

6.5.12 SAIDI/CAIDI (M27-CR)

6.5.12.1 Objective

The DA-CR system has the potential to improve System Average Interruption Duration Index (SAIDI) by automatically reconfiguring circuits upon detected interruption DA-CR capability also has the potential to reduce the number of customers experiencing the outage. This metric provides a report of actual SAIDI and CAIDI for DA-CR Project feeders as well as a comparison of what SAIDI and CAIDI would have been without DA-CR.

6.5.12.2 Organization of Results

This metric presents a comparison of monthly SAIDI and CAIDI for System area circuits with and without DA-CR capabilities.

SAIDI and CAIDI: Each graph shows the total SAIDI or CAIDI per month for circuits with DA-CR and without in both the entire system and a selected circuit.

6.5.12.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.12.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of circuit reliability data:

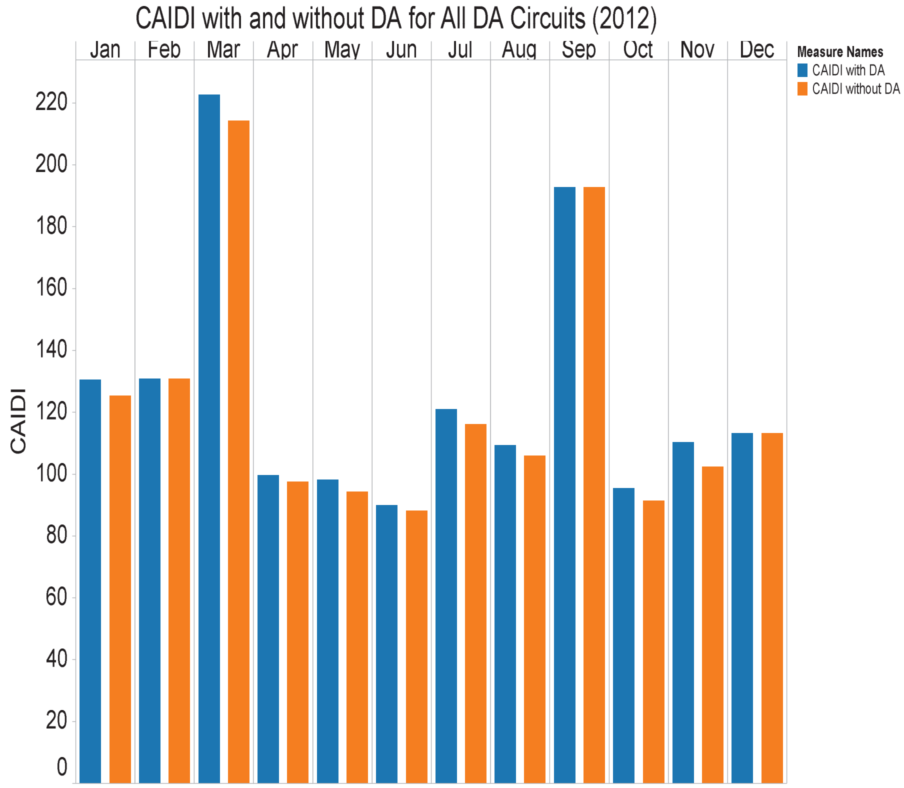


Figure 103. CAIDI for all Project area circuits with and without DA-CR

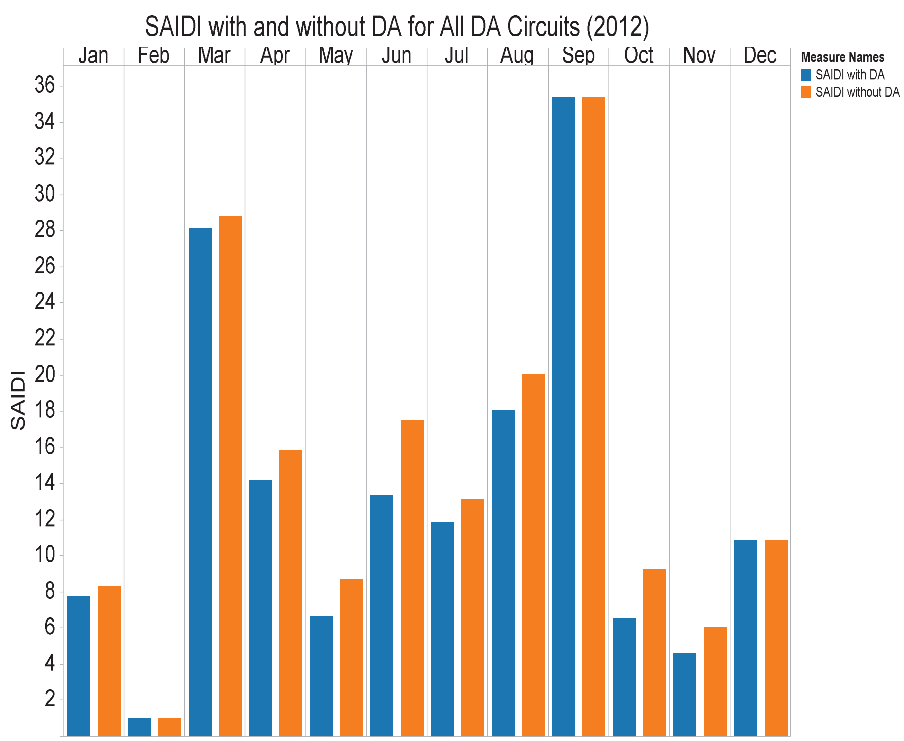


Figure 104. SAIDI for all Project area circuits

AEP Circuit Number	CAIDI with DA	CAIDI without DA	AEP Circuit Number	CAIDI with DA	CAIDI without DA
Bexley - 0001006	86.7	86.7	Karl - 0000915	323.5	323.5
Bexley - 0001009	101.5	101.5	Karl - 0000916	68.8	68.8
Blacklick - 0026031	79.6	79.6	Karl - 0000917	331.2	331.2
Blacklick - 0026032	81.7	81.7	Karl - 0000918	142.1	132.0
Blendon - 0005601	98.1	87.3	Karl - 0000919	63.3	63.3
Blendon - 0005631	107.0	97.0	Karl - 0000920	100.0	100.0
Blendon - 0005632	70.1	70.1	Karl - 0000921	93.1	93.1
Blendon - 0005633	29.0	29.0	Karl - 0000922	82.6	82.6
Centerburg - 0027232	162.8	162.8	Kirk - 0008031	89.0	89.0
Clinton - 0002901	69.0	79.7	Kirk - 0008032	101.9	101.9
Clinton - 0002902	326.7	326.7	Mifflin - 0004201	29.1	58.0
Clinton - 0002906	85.9	85.9	Mifflin - 0004202	418.3	254.8
Clinton - 0002911	112.7	112.7	Mifflin - 0004203	181.8	181.8
Clinton - 0002914	64.6	64.6	Mifflin - 0004204	113.3	113.3
Corridor - 0000531	186.4	186.4	Mifflin - 0004205	108.6	108.6
Corridor - 0000532	195.3	158.5	Mifflin - 0004206		
Gahanna - 0004502	157.4	157.4	Mifflin - 0004207	328.2	328.2
Gahanna - 0004531	512.8	512.8	Mifflin - 0004208	294.3	294.3
Gahanna - 0004532	107.9	107.9	Mifflin - 0004209	136.3	136.3
Genoa - 0003902	144.4	144.4	Mifflin - 0004210	129.2	129.2
Jug Street - 0036531	297.6	297.6	Morse - 0005801	136.0	136.0
Jug Street - 0036532	181.6	181.6	Morse - 0005802	155.6	155.6
Karl - 0000901	113.7	113.7	Morse - 0005803	170.9	170.9
Karl - 0000902	21.9	21.9	Morse - 0005805	98.1	98.1
Karl - 0000903	123.1	122.2	Morse - 0005806	136.2	136.2
Karl - 0000904	61.8	80.1	Morse - 0005807	257.2	257.2
Karl - 0000905	61.6	61.6	Morse - 0005809	125.1	125.1
Karl - 0000906	91.3	91.3	Morse - 0005811		
Karl - 0000907	158.2	158.2	Morse - 0005812	156.1	156.1
Karl - 0000908	132.8	121.8	Morse - 0005815	652.8	652.8
Karl - 0000910	177.1	99.9	St. Clair - 0006410	140.4	140.4
Karl - 0000911	165.5	165.5	Taylor - 0009732	72.5	72.5
Karl - 0000912	191.3	191.3	Taylor - 0009733	80.9	80.9
Karl - 0000913	131.9	131.9	Westerville - 0005501	141.5	141.5
Karl - 0000914	87.8	87.8	Westerville - 0005502	35.0	35.0

Table 20. CAIDI for all DA-CR circuits

AEP Circuit Number	SAIDI with DA	SAIDI without DA		AEP Circuit Number	SAIDI with DA	SAIDI without DA
Bexley - 0001006	7.07	7.07		Karl - 0000915	55.89	55.89
Bexley - 0001009	8.43	8.43		Karl - 0000916	3.83	3.83
Blacklick - 0026031	12.23	12.23		Karl - 0000917	38.97	38.97
Blacklick - 0026032	0.01	0.01		Karl - 0000918	52.73	59.13
Blendon - 0005601	4.27	13.24		Karl - 0000919	22.41	22.41
Blendon - 0005631	21.14	32.99		Karl - 0000920	3.05	3.05
Blendon - 0005632	11.54	11.54		Karl - 0000921	16.82	16.82
Blendon - 0005633	6.32	6.32		Karl - 0000922	13.48	13.48
Centerburg - 0027232	45.86	45.86		Kirk - 0008031	15.36	15.36
Clinton - 0002901	3.03	14.80		Kirk - 0008032	3.53	3.53
Clinton - 0002902	10.09	10.09		Mifflin - 0004201	3.02	12.97
Clinton - 0002906	2.51	2.51		Mifflin - 0004202	62.86	74.73
Clinton - 0002911	1.07	1.07		Mifflin - 0004203	3.51	3.51
Clinton - 0002914	5.40	5.40		Mifflin - 0004204	1.37	1.37
Corridor - 0000531	7.14	7.14		Mifflin - 0004205	18.02	18.02
Corridor - 0000532	48.94	59.07		Mifflin - 0004206		
Gahanna - 0004502	3.54	3.54		Mifflin - 0004207	14.96	14.96
Gahanna - 0004531	20.71	20.71		Mifflin - 0004208	64.29	64.29
Gahanna - 0004532	15.58	15.58		Mifflin - 0004209	0.71	0.71
Genoa - 0003902	21.12	21.12		Mifflin - 0004210	3.50	3.50
Jug Street - 0036531	3.33	3.33		Morse - 0005801	19.71	19.71
Jug Street - 0036532	48.13	48.13		Morse - 0005802	30.88	30.88
Karl - 0000901	11.72	11.72		Morse - 0005803	1.58	1.58
Karl - 0000902	3.26	3.26		Morse - 0005805	3.17	3.17
Karl - 0000903	25.65	26.05		Morse - 0005806	10.42	10.42
Karl - 0000904	2.44	23.45		Morse - 0005807	23.65	23.65
Karl - 0000905	1.74	1.74		Morse - 0005809	2.76	2.76
Karl - 0000906	7.89	7.89		Morse - 0005811		
Karl - 0000907	7.35	7.35		Morse - 0005812	44.21	44.21
Karl - 0000908	27.85	32.75		Morse - 0005815	2.32	2.32
Karl - 0000910	4.74	14.90		St. Clair - 0006410	2.67	2.67
Karl - 0000911	1.81	1.81		Taylor - 0009732	15.35	15.35
Karl - 0000912	4.02	4.02		Taylor - 0009733	4.75	4.75
Karl - 0000913	6.53	6.53		Westerville - 0005501	41.45	41.45
Karl - 0000914	15.79	15.79		Westerville - 0005502	4.97	4.97

Table 21. SAIDI for selected DA-CR circuit

Project Area (70 circuits)						
	2012			2011		
Year	With DA-CR	Without DA-CR	% Change	With DA-CR	Without DA-CR	% Change
SAIDI	161.5	178.3	-9.4%	179.2	185.6	-3.5%
CAIDI	131.6	124.7	5.5%	112.6	111.3	1.2%

Table 22. SAIDI/CAIDI Comparisons

Calculation Approach

Actual SAIDI and CAIDI data were reported directly by AEP Ohio. SAIDI and CAIDI without DA-CR were calculated using CMI avoided due to DA-CR.

The following queries and methods are used to generate presentation items:

- SAIDI per month, circuit, and substation with DA-CR was calculated by multiplying SAIDI for non-jurisdictional major event days reported by AEP Ohio by the number of customers served on the circuit reported by AEP.
- SAIDI per month, circuit, and substation without DA-CR was calculated by multiplying SAIDI for non-jurisdictional major event days reported by AEP Ohio by the number of customers served on the circuit reported by AEP Ohio and then adding the avoided customer minutes interrupted for non-jurisdictional major event days reported by AEP Ohio.
- CAIDI per month, circuit, and substation with DA-CR was calculated by dividing SAIDI with DA-CR by SAIFI with DA-CR.
- CAIDI per month, circuit, and substation without DA-CR was calculated by dividing SAIDI without DA-CR by SAIFI without DA-CR.

6.5.13 MAIFI (M28-CR)

6.5.13.1 Objective

The DA-CR system has the potential to affect Momentary Average Interruption Frequency Index (MAIFI). DA-CR may reduce the number of customers experiencing the outage, but may increase the number of momentary outages dues to the reactive reconfiguration capabilities. This metric provides an estimation of monthly MAIFI for each feeder in the DA-CR Project area by counting the number of recloser and breaker operations that result in interruptions lasting less than 5 minutes in duration yet do not result in a lockout.

6.5.13.2 Organization of Results

This metric presents a comparison of monthly MAIFI for System area circuits with and without DA-CR capabilities.

MAIFI: Each graph shows the total MAIFI per month for circuits with DA-CR and without. The second graph shows MAIFI for a single selected circuit.

6.5.13.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.13.4 Results of Data Collected to Date

The data and the data processing algorithms for calculating MAIFI have not yet been made available or developed sufficiently at this time for reporting in this Interim Report. Work will continue towards providing these data in the Final Report.

Presentation of MAIFI data:

Intentionally left Blank.

MAIFI data not available for this report.

Figure 105. MAIFI for all System area circuits

Intentionally left Blank.

MAIFI data not available for this report.

Figure 106. MAIFI for selected circuit

Calculation Approach

The calculation methodology is under development.

6.5.14 Outage Response Time (M29-CR)

6.5.14.1 Objective

The DA-CR system has the potential to improve outage response time by providing the utility with near real-time outage notification. This metric is intended to gauge the improvement in the utility's response time that occurs as a result of DA-CR notification.

6.5.14.2 Organization of Results

This metric is intended to gauge the improvement in outage response time that occurs as a result of DA-CR technology. In this context outage response time means the time it takes for AEP Ohio to become aware that an outage has occurred. This metric does not include the time it takes to correct the outage.

6.5.14.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.14.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of outage response time data:

Customer-reported lost power events have only been provided for January and February 2012. In this time range there are only two DA-CR reported outages that can be associated with customer events.

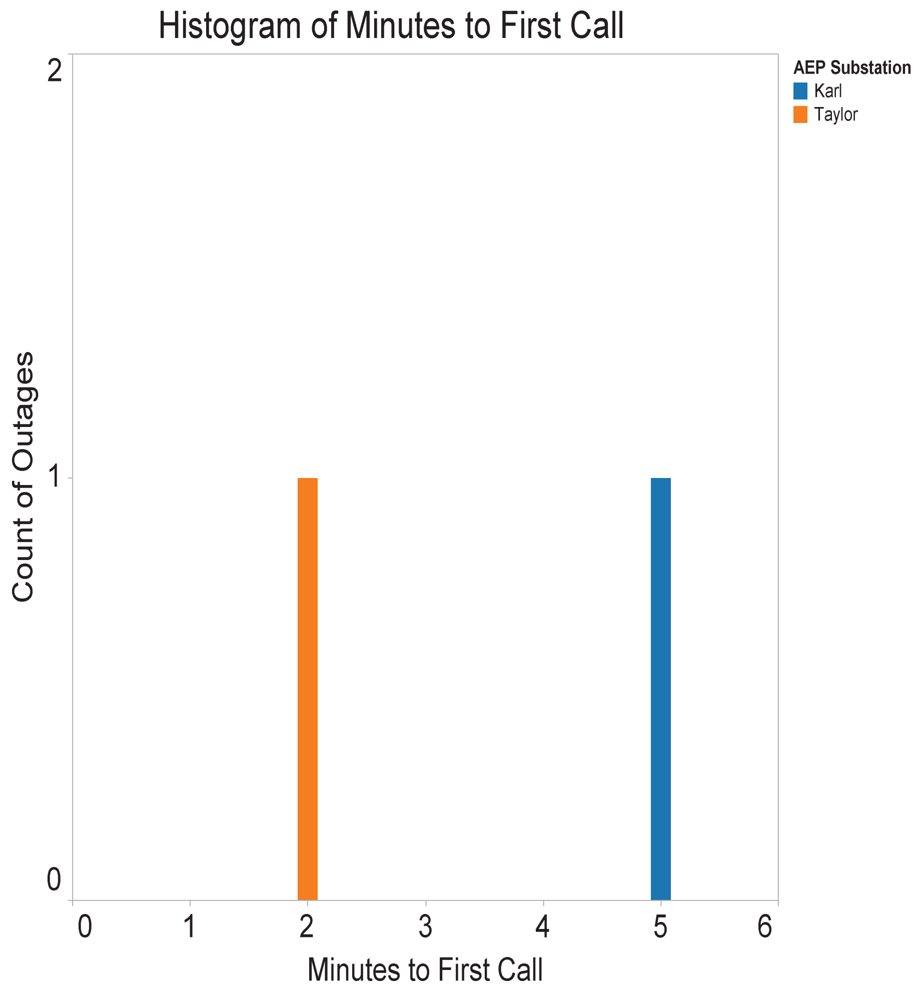


Figure 107. Histogram of outage response times

Calculation Approach

For each outage reported on circuits with DA-CR installed, the time of the first associated lost-power customer event was subtracted from the DA reported outage start time. This time difference was then used to plot a histogram.

6.5.15 Major Event Information (M30-CR)

6.5.15.1 Objective

This metric describes the DA-CR system's behavior and usage during major events that occur during the demonstration period.

6.5.15.2 Organization of Results

This metric presents the findings of an AEP Ohio produced study.

6.5.15.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.15.4 Results of Data Collected to Date

Presentation of major event data:

The following major events were extracted from a special AEP Ohio study enumerating these events. When applicable these events are identified on figures and charts affected by the event.

- Circuit reconfiguration (CR) systems had limited ability to restore customers within the first hour
- 1,420 customers on three feeders restored to service automatically
- CR disabled when DDC realized the magnitude of damage
- SCADA switching (53 remote recloser operations) of distribution line devices reduced crew hours to:
- Restore approximately 10,000 customers (of 145,713 customers in NE Columbus) to service after repairs
- Transfer and shed load on limited feeders in abnormal and extreme loading conditions
- Estimated savings of 30-60 minutes per truck roll, resulting in approximately 40 hours of crew time saved where resources could be utilized elsewhere on the system
- AMI meters utilized to close over 300 outage tickets without utilizing field resources for verification

Calculation Approach

This information will be supplied in the Final Report.

6.5.16 Distribution Operations Vehicle Miles (M31-CR)

6.5.16.1 Objective

The DA-CR system has the potential to reduce the number miles driven for activities such as switching. This metric provides an estimate of the number of vehicle miles avoided due to DA-CR and compares it with mileage from a like non-DA-CR area.

6.5.16.2 Organization of Results

This metric presents total vehicle miles avoided due to DA-CR by month

- DA-CR vehicle miles avoided

  This graph shows the total miles avoided per month.

6.5.16.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.16.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of vehicle data:

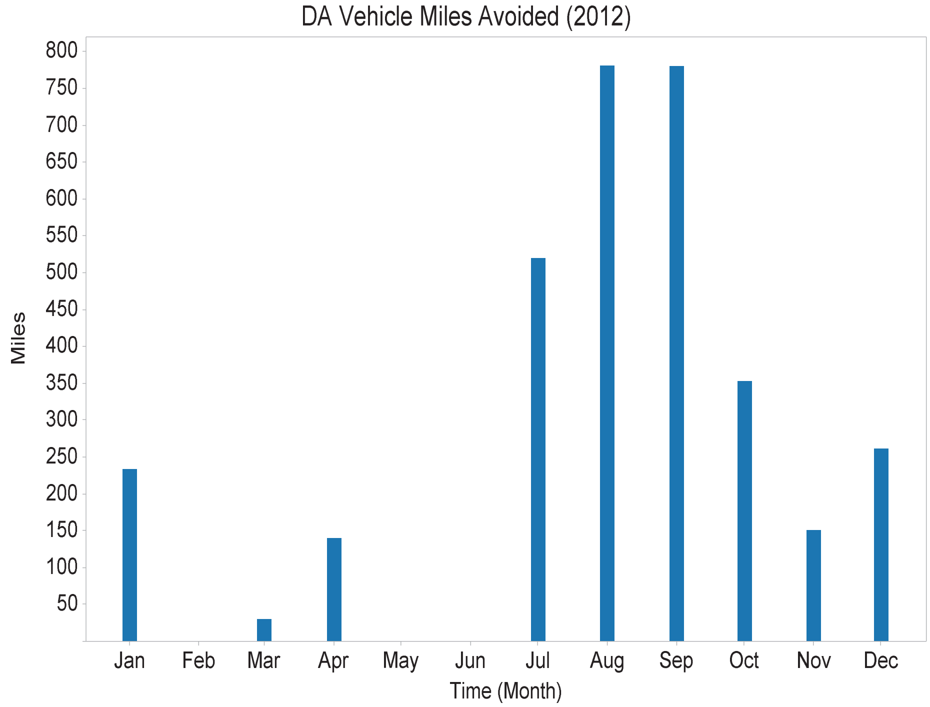


Figure 108. Vehicle mileage avoided due to DA-CR truck rolls avoided

Calculation Approach

Analysis was conducted by counting the number of remote switching operations and assigning these as either a short or standard truck roll avoided. Standard truck rolls are intended to represent a crew traveling from the service center to a switching location. Short truck rolls are intended to represent a crew traveling from one switching device to another nearby switching device on the same circuit or on an adjacent circuit. Vehicle mileage was determined based on conversion factors supplied by AEP Ohio.

The following queries and methods are used to generate presentation items:

- Distribution operation vehicle miles per service center, month, vehicle, and vehicle characteristics for sections of circuits with DA-CR were calculated by multiplying vehicle mileage by the percentage of the circuit with DA-CR divided by 100. The distribution operation vehicle miles per service center, month, vehicle, and vehicle characteristics for sections of circuits without DA-CR were calculated by multiplying vehicle mileage by the percentage of the circuit without DA-CR divided by 100.
- Vehicle miles avoided due to DA-CR technology per service center, circuit, and month were calculated by summing the sum of urban (5 miles), rural (20 miles), and combination (10 miles) standard truck roll distances for standard truck rolls avoided with the sum of urban (2 miles), rural (4 miles), and combination (3 miles) short truck roll distances for short truck rolls avoided.

6.5.17 CO_2 Emissions- Project (M32-CR)

6.5.17.1 Objective

Distribution Automation has the potential to reduce CO_2 emissions in two primary ways. First, the DA-CR system will reduce truck rolls associated with distribution system troubleshooting and maintenance. Second, the DA-CR system will reduce total electric consumption by optimizing system voltage and Volt-Amperes reactive ("VAR") flows. This impact metric provides an estimate of the amount of avoided and/or added CO_2 emitted during driving miles due to features of DA-CR technology.

6.5.17.2 Organization of Results

The following section describes the amount of CO_2 avoided due to DA-CR from the following sources.

Truck Rolls Avoided: this section contains monthly graphs showing the amount of CO_2 avoided due to the net number of truck rolls avoided in the Project area.

6.5.17.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.17.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of vehicle related CO_2 avoidance data:

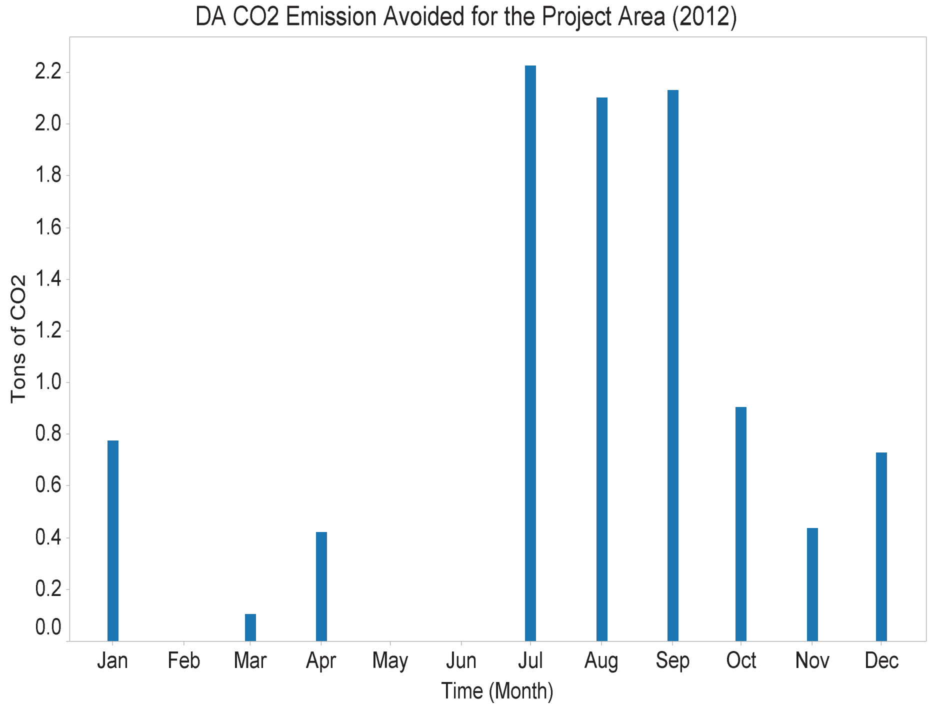


Figure 109. CO_2 Avoided due to DA-CR

Calculation Approach

CO_2 reduction was calculated as a function of vehicle miles avoided using emissions data specific to AEP Ohio's distribution service fleet vehicles.

The following queries and methods are used to generate presentation items:

- Short truck rolls avoided per equipment, equipment type, month, circuit, and substation due to DA-CR technology were calculated by selecting remote equipment switching events that occurred during multi-step restoration outages. These were combined with remote recloser switching events that occurred within five minutes of another remote recloser switching events on the same circuit.
- Standard truck rolls avoided per equipment, equipment type, month, circuit, and substation due to DA-CR technology were calculated by selecting remote recloser switching events which occurred more than 5 minutes after another remote recloser switching event on the same circuit that did not occur during an outage with a single restoration step.
- AEP Ohio determined an average fuel economy value for each vehicle. Corrected average monthly fuel efficiencies in miles per gallon per service center, month, and fuel type for vehicles used by the AEP Ohio Distribution business unit were calculated by

calculating the average of monthly vehicle mileages divided by monthly quantity of fuel for each vehicle. Because some suspect monthly vehicle mileages (i.e. 703,281 miles) were received, if the average of monthly vehicle mileages divided by monthly quantity of fuel divided by the average monthly average fuel economy value was not between .5 and 2, average monthly average fuel economies were substituted for the average of monthly vehicle mileages divided by monthly quantity of fuel to calculate the corrected average monthly fuel efficiencies.

- Tons of CO_2 avoided per service center, circuit, and month due to truck rolls avoided due to DA-CR technology were calculated by dividing vehicle miles avoided by the corrected average monthly fuel efficiency times (8.8 kg CO_2 emissions/gallon for gas engines, 10.1 kg CO_2 emissions/gallon for diesel engines) times 0.00110231131092 (kg to tons conversion factor).

6.5.18 Pollutant Emissions – Project (SO_X, NO_X, $PM_{2.5}$) (M33-CR)

6.5.18.1 Objective

Distribution Automation has the potential to reduce pollutant emissions in two primary ways. First, the DA-CR system will reduce truck rolls associated with distribution system troubleshooting and maintenance. Second, the DA-CR system will reduce total electric consumption by optimizing system voltage and Volt-Ampere reactive (VAR) flows. This impact metric provides an estimate of the amount of avoided and/or added pollutants emitted during driving miles due to features of DA-CR technology.

6.5.18.2 Organization of Results

The following section describes the amount of pollutants avoided due to DA-CR from the following sources.

Truck Rolls Avoided: This section contains monthly graphs showing the amount of pollutants avoided due to the net number of truck rolls avoided in the Project area.

6.5.18.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.18.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of vehicle related pollutant avoidance data:

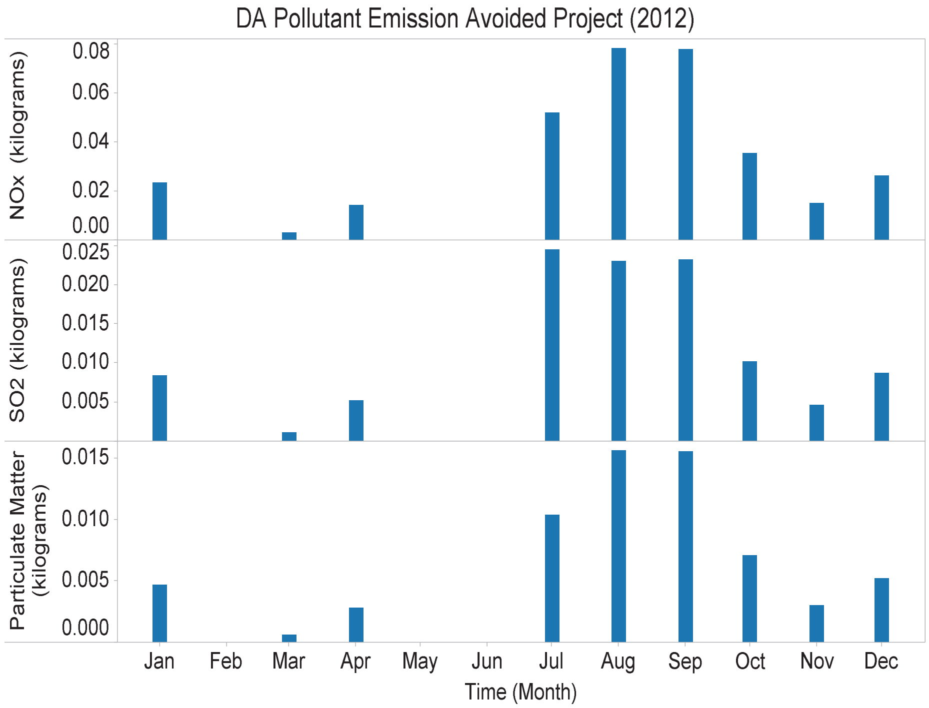


Figure 110. Pollutants Avoided due to DA-CR

Calculation Approach

Pollutant reduction was calculated as a function of vehicle miles avoided using emissions data specific to AEP Ohio's distribution service fleet vehicles.

The following queries and methods are used to generate presentation items:

- Short truck rolls avoided per equipment, equipment type, month, circuit, and substation due to DA-CR technology were calculated by selecting remote equipment switching events that occurred during multi-step restoration outages. These were combined with remote recloser switching events that occurred within five minutes of another remote recloser switching events on the same circuit.
- Standard truck rolls avoided per equipment, equipment type, month, circuit, and substation due to DA-CR technology were calculated by selecting remote recloser switching events which occurred more than 5 minutes after another remote recloser switching event on the same circuit that did not occur during an outage with a single restoration step.
- AEP Ohio determined average fuel economy value for each vehicle. Corrected average monthly fuel efficiencies in miles per gallon per service center, month, and fuel type for vehicles used by the AEP Ohio Distribution business unit were determined by calculating the average of monthly vehicle mileages divided by monthly quantity of fuel for each

vehicle. Because some suspect monthly vehicle mileages (i.e. 703,281 miles) were received, if the average of monthly vehicle mileages divided by monthly quantity of fuel divided by the average monthly average fuel economy value was not between .5 and 2, average monthly average fuel economies were substituted for the average of monthly vehicle mileages divided by monthly quantity of fuel to calculate the corrected average monthly fuel efficiencies.

- Kilograms of NO_X avoided per service center, circuit, and month due to truck rolls avoided due to DA-CR technology were calculated by multiplying vehicle mileage avoided times 0.05 g NO_X emissions/mi times 0.001 (g to kg conversion factor).
- Kilograms of $PM_{2.5}$ avoided per service center, circuit, and month due to truck rolls avoided due to DA-CR technology were calculated by multiplying vehicle mileage avoided times 0.01 g $PM_{2.5}$ emissions/mi times 0.001 (g to kg conversion factor).
- Kilograms of SO_2 avoided per service center, circuit, and month due to truck rolls avoided due to DA-CR technology were calculated by dividing vehicle miles avoided by the corrected average monthly fuel efficiency times (.165 g SO_2 emissions/gallon for gas engines, .0963 g SO_2 emissions/gallon for diesel engines) times 0.001 (g to kg conversion factor).

6.5.19 CO_2 Emissions – System (M34-CR)

6.5.19.1 Objective

The DA-CR system has the potential to reduce the number of truck rolls required for activities such as switching. This metric provides an estimate of the CO_2 emissions that would be avoided by eliminating these truck rolls throughout the entire System area.

6.5.19.2 Organization of Results

The following section describes the amount of CO_2 avoided due to DA-CR from the following sources.

Truck rolls avoided: this section contains monthly graphs showing the amount of CO_2 avoided due to the net number of truck rolls avoided in the System area.

6.5.19.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.19.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of vehicle related CO_2 avoidance data:

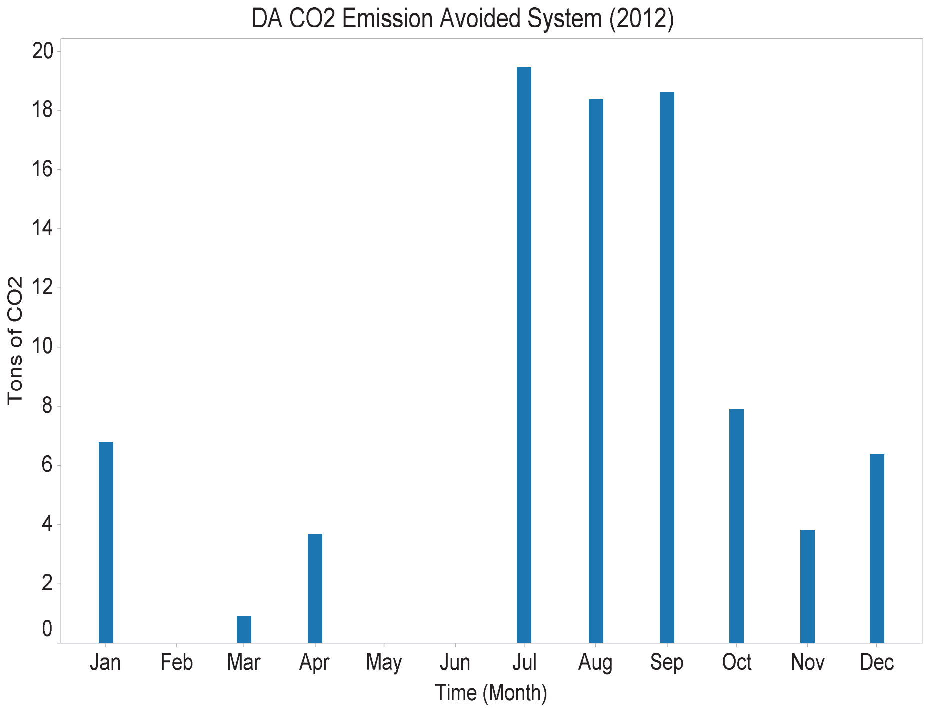


Figure 111. Potential System area CO_2 avoidance due to DA-CR

Calculation Approach

Project area CO_2 reduction was calculated as a function of vehicle miles avoided using emissions data specific to AEP Ohio's distribution service fleet vehicles. This reduction was then extrapolated to the System area based on number of circuit miles in each area.

The following queries and methods are used to generate presentation items:

- M34 - Tons of CO_2 per service center and month that would be avoided if DA-CR technology were deployed throughout the System area estimated truck rolls avoided were calculated by multiplying the tons of CO_2 eliminated due to truck rolls avoided due to DA-CR technology multiplied by the ratio of circuit miles without DA-CR technology to circuit miles with DA-CR technology.

6.5.20 Pollutant Emissions – System (SO_X, NO_X, $PM_{2.5}$) (M35-CR)

6.5.20.1 Objective

The DA-CR system has the potential to reduce the number of truck rolls required for activities such as switching. This metric provides an estimate of the pollutant emissions that would be avoided by eliminating these truck rolls throughout the entire System area.

6.5.20.2 Organization of Results

The following section describes the amount of pollutant avoided due to DA-CR from the following sources.

Truck Rolls Avoided: this section contains monthly graphs showing the amount of pollutant avoided due to the net number of truck rolls avoided in the System area.

6.5.20.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

6.5.20.4 Results of Data Collected to Date

Results are presented beginning on the next page.

Presentation of vehicle related pollutant avoidance data:

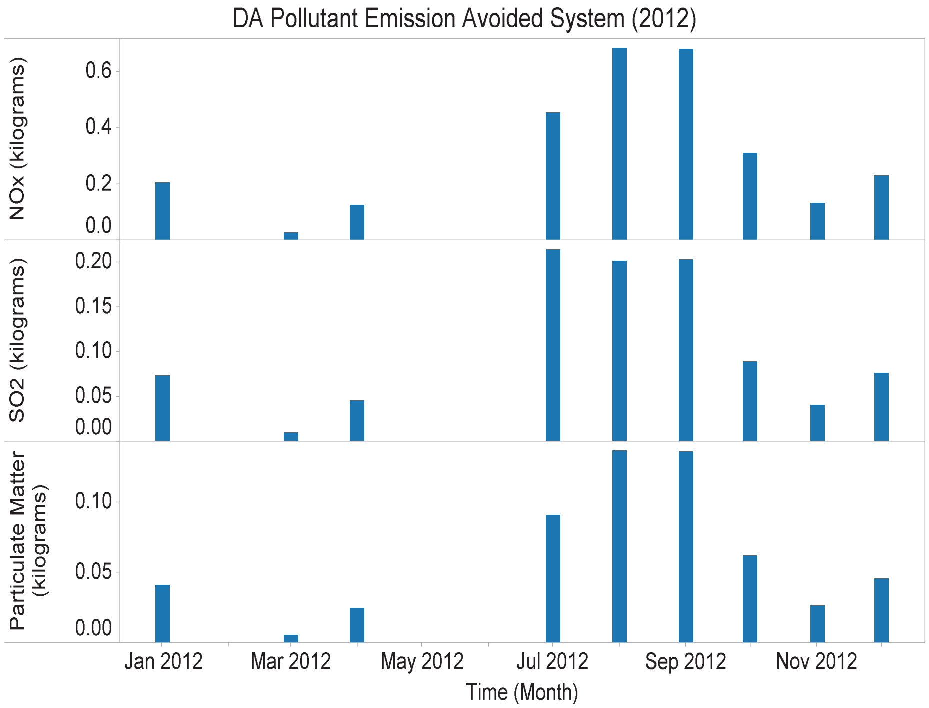


Figure 112. Potential System area pollutant avoidance due to DA-CR

Calculation Approach

Project area pollutant reduction was calculated as a function of vehicle miles avoided using emissions data specific to AEP Ohio's distribution service fleet vehicles. This reduction was then extrapolated to the System area based on number of circuit miles in each area.

The following queries and methods are used to generate presentation items:

- Kilograms of NO_X per service center and month that would be avoided if DA-CR technology were deployed throughout the AEP Ohio System area due to truck rolls avoided were calculated by multiplying the kilograms of NO_X avoided due to truck rolls avoided due to DA-CR technology by the ratio of circuit miles without DA-CR technology to circuit miles with DA-CR technology.
- Kilograms of $PM_{2.5}$ per service center and month that would be avoided if DA-CR technology were deployed throughout the AEP Ohio System area due to truck rolls avoided were calculated by multiplying the kilograms of $PM_{2.5}$ avoided due to truck rolls avoided due to DA-CR technology multiplied by the ratio of circuit miles without DA-CR technology to circuit miles with DA-CR technology.
- Kilograms of SO_2 per service center and month that would be avoided if DA-CR technology were deployed throughout the AEP Ohio System area due to truck rolls

avoided were calculated by multiplying the kilograms of SO_2 avoided due to truck rolls avoided due to DA-CR technology by the ratio of circuit miles without DA-CR technology to circuit miles with DA-CR technology.

6.6 DA-CR Observations

This section contains observations of the technology to date. Conclusions will be provided in the Final Report.

The most significant observations for DA-CR are its impacts to reliability and its use during major events.

Excluding major events, the Project circuits with DA-CR experienced 48 permanent fault outages in 2012. The addition of DA-CR technology reduced restoration times for 22 of those events, resulting in 22,427 customers experiencing either a shorter outage or none at all. The total avoided CMI for these customers was approximately 1.9 million minutes. In the 26 permanent faults for which DA-CR had no effect, the outages were primarily due to either faults occurring in the breaker zone, miscoordination of devices, communications failures, or the fault was located at the end of line.

Based on AEP Ohio's estimate of 5.2¢ per avoided CMI, the restoration costs avoided due to DA-CR were approximately $100,000. These numbers are illustrated in Table 23.

Project Area (70 circuits)						
Year	**Outages**	**Customers Interrupted**	**Customer Minutes Interrupted**	**# of Events (Automation Impacted CI)**	**Customers Restored via Automation**	**Customer Minutes Avoided**
2010	2,244	163,380	17,940,145	n/a	n/a	n/a
2011	1,951	177,147	19,953,044	5	8,615	715,045
2012	1,838	136,741	17,989,775	22	22,427	1,861,441

Table 23. DA-CR Outage Summary

Resulting from the 1.9 million avoided CMI, the reliability impacts for both SAIDI and SAIFI decreased by 9.7 percent and 14.1percent, respectively.

CAIDI is the average duration for customers experiencing sustained outages. The CAIDI reliability metric increased by 5.5 percent on the 70 DA-CR circuits. This was expected, because with DA-CR, the customers who would historically be restored through manual switching were now restored in less than 5 minutes through automatic switching, and were not part of the CAIDI calculation. In this case, the overall CAIDI includes only those customers experiencing an outage lasting more than five minutes.

On June 29, 2012, AEP Ohio experienced a major event that affected the Project area. The DA-CR system had limited ability to restore customers in the first hour of the storm. There were three successful reconfigurations of 1,420 customers that held for approximately 30 seconds. Due to the magnitude of damage and for safety purposes, AEP Ohio disabled the DA-CR system once a major storm was declared. The system was eventually turned on to aid in restoration. AEP Ohio utilized SCADA reclosers to restore approximately 10,000 customers of the 145,713 customers in the Project area impacted by the storm.

The following impact metric observations are inconclusive and require further analysis. They are presented in no particular order.

- Due to the small penetration of SMART Cooling participants on the DA-CR circuits, the DLC events have negligible impact to feeder load.
- Capacity deferrals are dependent on the initial loading of the circuits where DA-CR is installed, as well as load growth. Since load growth has been flat or negative during the Project time period, and the circuits where DA-CR was installed were not already overloaded or scheduled for upgrades, there have been no capacity deferrals for these specific circuits.
- There is no significant increase in equipment failure events evident from the data to date. It is likely that if DA-CR causes additional equipment failures due to increases in switching events, it will take several years to observe and measure such a change. The DA-CR itself does not appear to be creating short-term failure issues, as evidenced by zero equipment failures on the DA-CR circuits in 2012.
- There is no evidence that DA-CR itself creates a significant increase in maintenance costs.

7 DEMONSTRATED TECHNOLOGY – VOLT VAR CONTROL

7.1 PURPOSE

Volt VAR Control (DA-VVC), also known as Volt VAR Optimization (VVO), is a demand-side management program that can reduce energy consumption and demand without any needed interaction or “participation” from the consumer. Consumer end-use equipment (HVAC, lighting, appliances, etc.) is designed to operate at peak efficiency at a specific voltage. However, the voltage delivered is typically higher than this optimum voltage. Voltage levels are currently maintained using voltage regulators, load tap changers, and capacitor banks. This technology has worked for decades and has proven to be a cost effective way to maintain voltage levels.

When DA-VVC is added to a conventional circuit, the circuit can better control the voltage that is delivered to the meter and, subsequently, to the consumer’s end-use electrical devices. DA-VVC provides an opportunity to supply voltages that are closer to the designed voltage of the end-use equipment and thus increase the efficiency of the customer’s load by reducing excess energy. Consumers should realize lower consumption while maintaining the same level of comfort and service. In theory, optimizing the voltage supplied should ultimately reduce the amount of capacity and energy required on the power system.

DA-VVC also performs power factor (VAR support) optimization that brings the system closer to unity. For circuits without DA-VVC, corrections to power factor do not consider the entire system. DA-VVC introduces the ability to control power factor by taking the entire system into consideration when making adjustments.

7.2 TECHNOLOGY

Two separate DA-VVC systems were deployed as part of this study.

The first system was the General Electric Coordinated Volt VAR Control (CVVC) system. It utilized GE’s D400 controller to apply algorithms and logic to a given feeder via GE’s D200 controller acting as a data concentrator. These devices were able to command and control S&C IntelliCAP capacitor controllers connected to switched capacitor banks, as well as Cooper CL6-B voltage regulator controllers. The switched capacitor banks were able to be brought online to provide voltage and VAR support in order to smooth a circuit’s voltage profile. The Cooper CL6-B regulator controllers, connected to voltage regulators both in the substations and on the lines, were instructed to tap up or down to raise or lower the voltage profile on the same circuit.

The second system that AEP Ohio deployed for DA-VVC was manufactured by PCS Utilidata (PCS) and operates in a fashion similar to the GE system, albeit with some different components. The PCS system used a proprietary controller to command and control the same Cooper voltage regulator controllers and S&C IntelliCAP capacitor controllers. It also used a proprietary product called a Line Voltage Monitor to monitor voltage at the end of a line.

Figure 113 details a typical DA-VVC implementation.

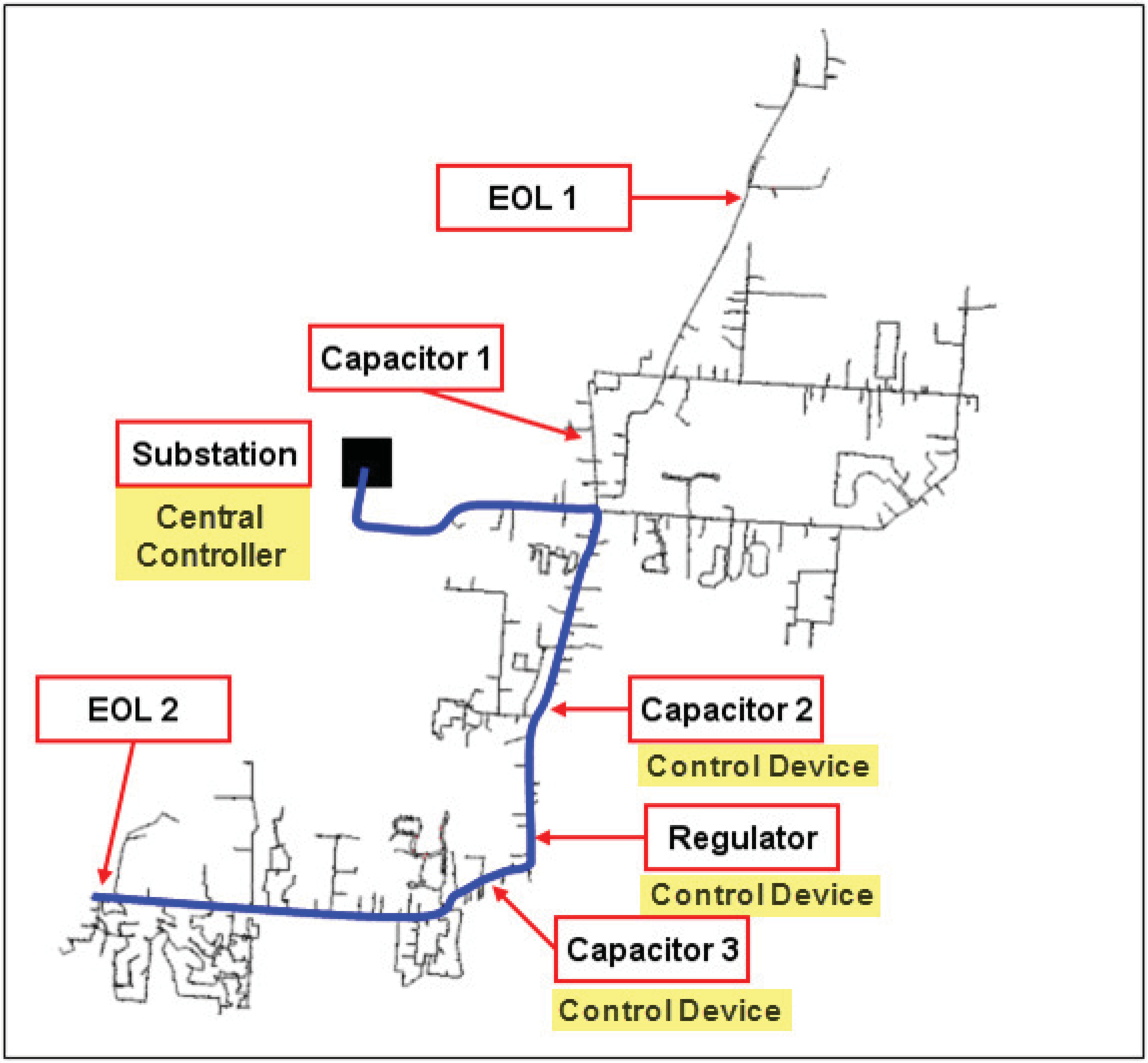


Figure 113. DA-VVC Example

As shown in Figure 113, controls were placed on regulators and capacitors on a specific circuit, with a central controller installed at the substation. The equipment in the field, including end-of-line monitors, supplies the central controller with data regarding the voltage on the circuit. The central controller at the substation processes this data and instructs the field controls to adjust voltage on the line as needed. The controllers and monitors work together to maintain the voltage and power factor at a desirable level, thus reducing overall energy consumption.

7.3 Implementation and Approach

Because DA-VVC technology was still in its infancy, no vendors had a "ready-to-go" system in place. AEP Ohio selected two vendors in order to determine which vendor best fulfilled the requirements for the implementation of the technology.

AEP Ohio elected to implement DA-VVC on both 13kV and 34.5kV circuits on 17 circuits. AEP Ohio installed the technology on existing equipment to determine the effectiveness on non-optimized circuits.

7.4 Benefits Analysis

DA-VVC technology is expected to affect AEP Ohio's grid, operations, and customers. Below are three high-level areas of intended benefits and descriptions of how AEP Ohio anticipates DA-VVC will affect these areas.

In order to evaluate the economic, reliability, and environmental impacts created by DA-VVC, detailed analysis is provided in the relative MBRP impacts metrics that follow.

7.4.1 Economic Benefits

Volt VAR technology has the potential to reduce energy consumption by leveling and lowering the voltage along a circuit. This reduction can translate into economic benefits for both the utility.

For the utility, the decreased demand may translate into delayed or cancelled generation investments. The size of the Project did not cause this, but when expanded on a regional level, this benefit could be realized.

The consumers' energy consumption is reduced without having to change any behaviors. The reduced consumption can also help AEP Ohio meet energy efficiency targets.

7.4.2 Reliability Benefits

The introduction of the distribution SCADA system and monitoring of regulator and capacitor controls, allows AEP Ohio to monitor voltage conditions and proactively repair equipment before it can cause power quality issues that prompt customer complaints.

7.4.3 Environmental Benefits

DA-VVC has the ability to provide environmental benefits by reducing generation needs through the optimization of voltage and power factor.

7.5 MBRP Impact Metric Details (DA-VVC)

7.5.1 Peak Load and Mix (M03-VVC)

7.5.1.1 Objective

DA-VVC has the potential to dynamically control voltage and power factors in feeders to reduce consumer energy consumption. The reduced energy consumption can result reduced costs, deferred capital investments, extended equipment life, and reduced fuel consumption. This impact metric provides an overview of residential electrical demand by circuit and the cumulative effects of DA-VVC for various circuits and months.

7.5.1.2 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

- For this metric, peak load and mix includes only residential customers.

7.5.1.3 Organization of Results

The following section presents load profile graphs for customers on DA-VVC circuits. These graphs each contain two lines, one line showing hours in which DA-VVC was active and one line showing hours in which DA-VVC was not active. Graphs have been generated for residential customers from a representative circuit for three months.

7.5.1.4 Results of Data Collected to Date

The figures on the following pages quantify the impact metric for this section.

Results for peak load and mix:

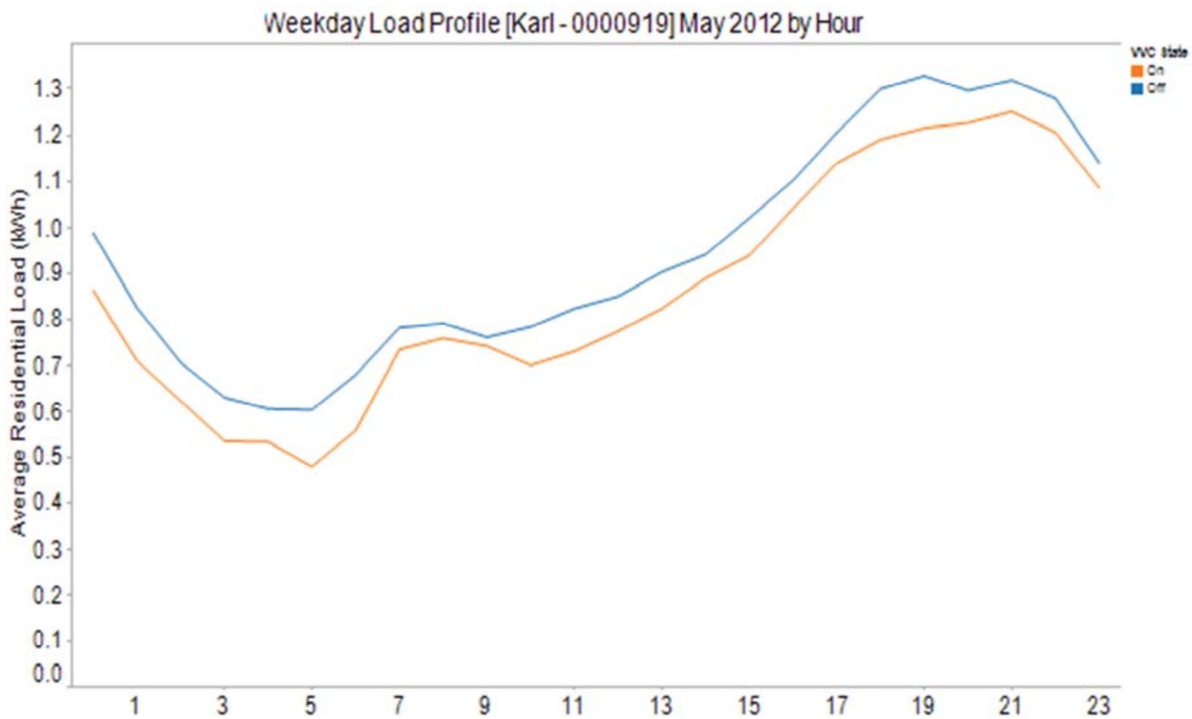


Figure 114. Temperature normalized hourly load with VVC on and off (May 2012)

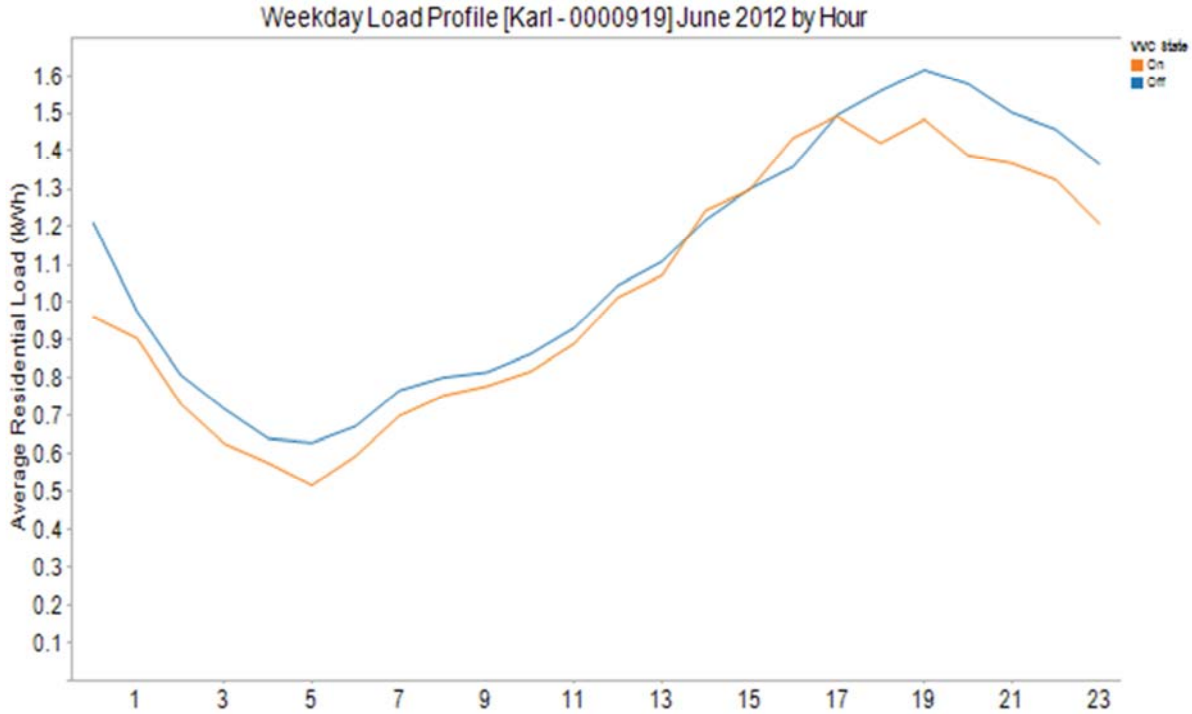


Figure 115. Temperature normalized hourly load with VVC on and off (June 2012)

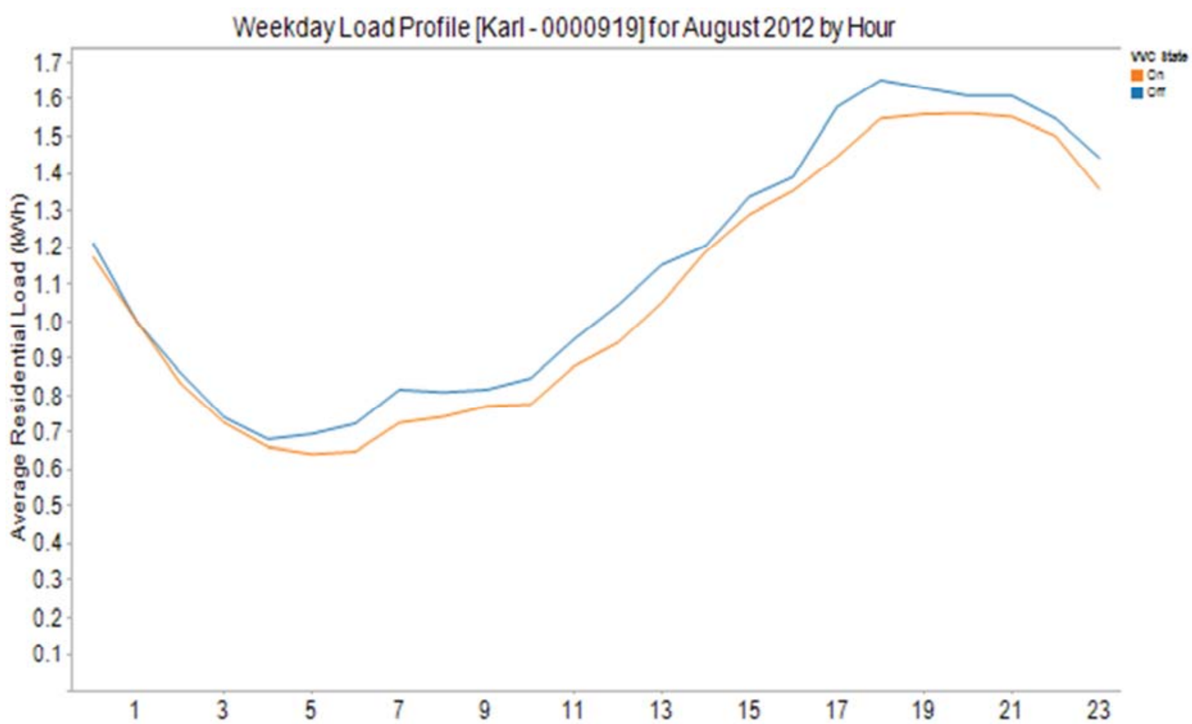


Figure 116. Temperature normalized hourly load with VVC on and off (Aug 2012)

Calculation Approach

Overview:

DA-VVC peak load and mix were analyzed in three steps:

1) Determine temperature correction functions
2) Apply temperature corrections
3) Bin data into load profiles

For the purposes of the Interim Report, peak load and mix was analyzed for one representative DA-VVC circuit. In future analysis, each DA-VVC circuit will be handled independently and the complete methodology will be repeated on a per circuit basis.

An extract of hourly data was created to select weekday load data from all residential customers on the circuit being analyzed. Each data point in this extract consists of a time stamp, average residential load aggregated over the entire circuit, and a temperature value. This data extract was then subdivided into two sets: One set for days during which the DA-VVC system was being operated in a day-on/day-off experimental fashion, and a second set for days in which the DA-VVC system was being operated in a steady on or off state.

Determining Temperature Normalizations:

Temperature normalization functions were determined from the steady state data set. First, the data set was grouped by hour of the day. Then, for each hour, an average load was calculated. Next, each record was assigned a load ratio equal to load reading divided by average load, as well as a temperature difference equal to the temperature reading minus 65 degrees F. For each hour, scatter plots were generated showing temperature difference versus load ratio and fitted using third order polynomial curves. The resulting polynomial functions were then used as temperature correction factors in subsequent stages of this analysis.

Applying Temperature Corrections:

For the purposes of this analysis, all raw temperature readings from the experimental day-on/day-off data set were corrected using third order polynomials calculated above. Unique correction functions were used for each hour of the day as well as for DA-VVC day-on versus DA-VVC day-off times. All load readings were normalized to a temperature of 65 degrees F.

Generating Load Profiles:

Load profile graphs were generated for each month by binning temperature corrected load values from the day-on/day-off data set by hour of the day. Separate series were used to show readings during times when DA-VVC was on versus readings taken during times when DA-VVC was off.

7.5.2 Distribution Feeder Load (M13-VVC)

7.5.2.1 Objective

DA-VVC is expected to have an impact on total feeder load by reducing the amount of power drawn by loads and maintaining the power factor close to unity. This metric examines the circuit load and voltage for DA-VVC equipped circuits.

7.5.2.2 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

7.5.2.3 Organization of Results

The following section presents load profile graphs for DA-VVC circuits based on circuit load data. Each graph contains two lines, one showing hours in which DA-VVC was active and one showing hours in which DA-VVC was not active. Graphs have been generated separately for each month.

7.5.2.4 Results of Data Collected to Date

The figures on the following pages quantify the impact metric for this section.

Results for circuit load by feeder:

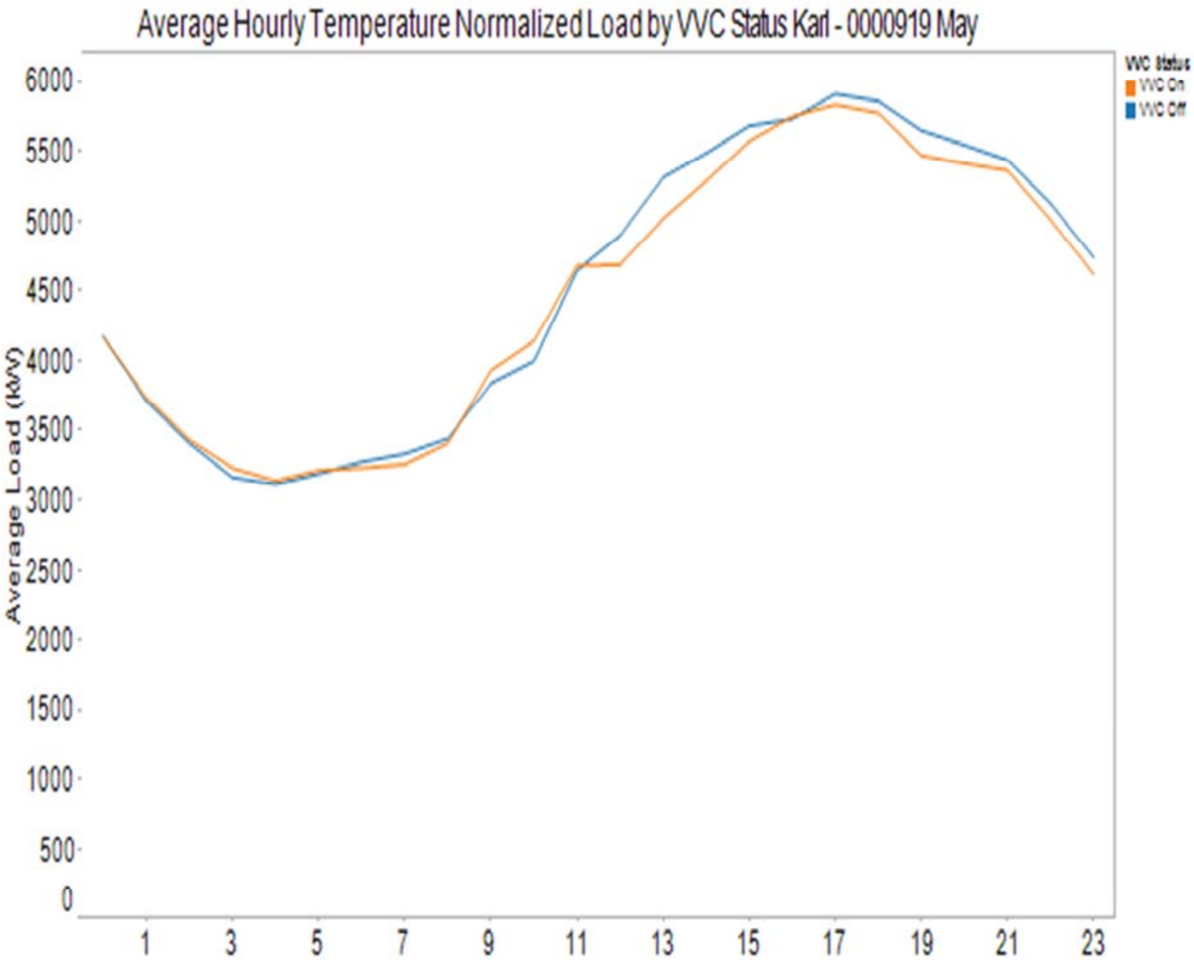


Figure 117. Comparison of VVC status times and total load reduction for Karl Road-0000919 (August 2012)

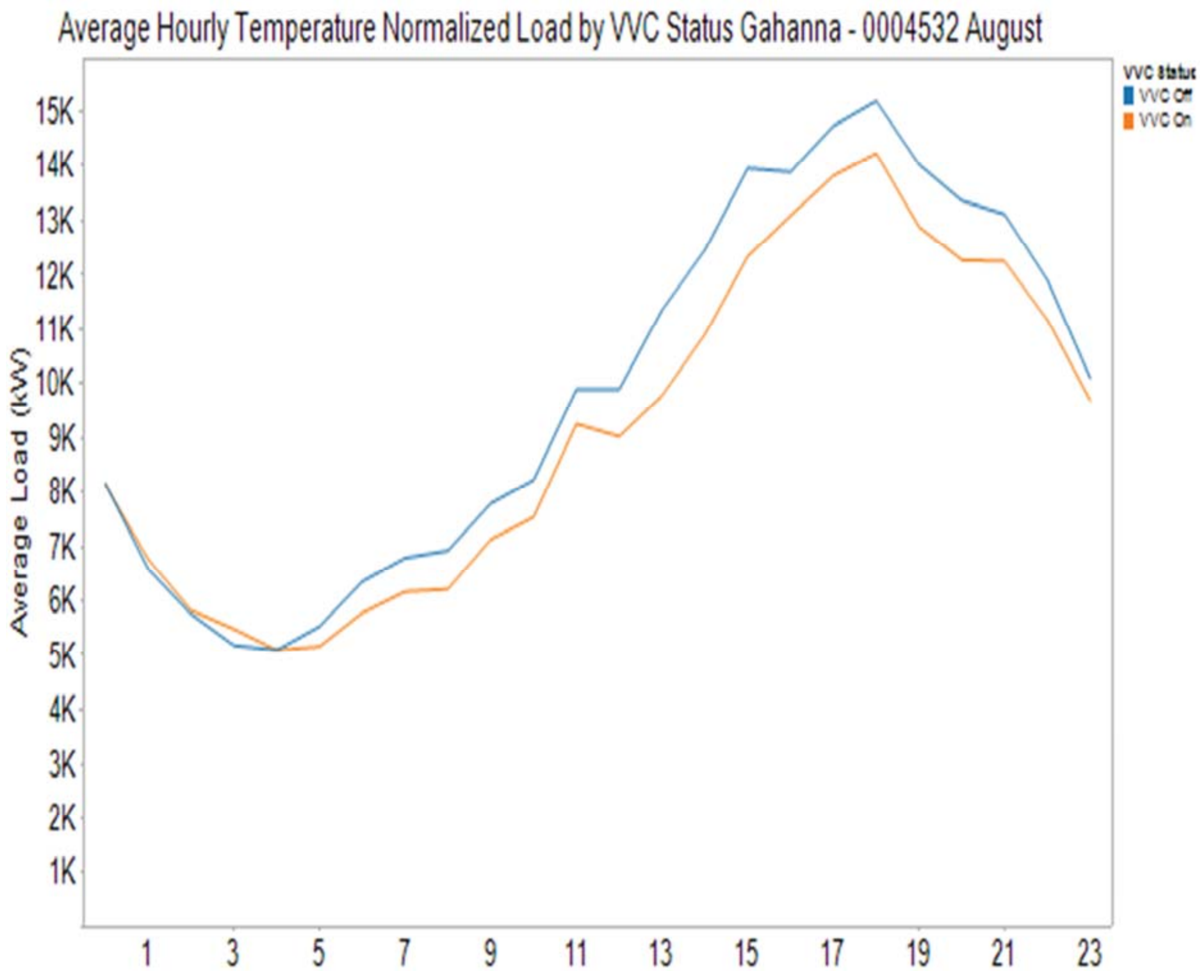


Figure 118. Comparison of VVC status times and total load reduction for Gahanna-0004532 (August 2012)

Calculation Approach

Overview:

The analysis of DA-VVC distribution feeder load was performed in three steps:

- Determine temperature correction functions
- Apply temperature corrections
- Bin data into load profiles

Note that for this analysis of distribution feeder load, each DA-VVC circuit was handled independently and the complete methodology repeated on a per circuit basis. An extract of hourly circuit load data was created with each data point consisting of a time stamp, average circuit load aggregated by hour, and a temperature value. This data extract was then subdivided into two sets. One set for days during which the DA-VVC system was being operated in a day-on/day-off experimental fashion, and a second set for days in which the DA-VVC system was being operated in a steady on or off state.

Determining Temperature Normalization:

Temperature normalization functions were determined from the steady state data set. First, the data set was grouped by hour of the day. Then, for each hour, an average load was calculated. Next, each record was assigned a load ratio equal to load reading divided by average load, as well as a temperature difference equal to the temperature reading minus 65 degrees F. For each hour, scatter plots were generated showing temperature difference versus load ratio and fitted using third order polynomial curves. The resulting polynomial functions were then used as temperature correction factors in subsequent stages of this analysis.

Applying Temperature Normalization:

For the purposes of this analysis, all raw temperature readings from the experimental day-on/day-off data set were corrected using third order polynomials calculated above. Unique correction functions were used for each hour of the day as well as for DA-VVC day-on versus DA-VVC day-off times. All load readings were normalized to a temperature of 65 degrees F.

Generating Load Profiles:

Load profile graphs were generated for each month by binning temperature corrected load values from the day-on/day-off data set by hour of the day. Separate series were used to show readings during times when DA-VVC was on versus readings taken during times when DA-VVC was off.

7.5.3 Deferred Distribution Capacity Investments (M15-VVC)

7.5.3.1 Objective

DA-VVC has the potential to dynamically control voltage and power factors on feeders to reduce customer energy consumption and losses. This reduced consumption can result in reduced costs, deferred capital investments, extended equipment life, and reduced fuel consumption. Distribution systems must be engineered and constructed to serve the peak load conditions at any given future date; as such, they are overbuilt for the majority of conditions. It is logical to conclude that if future peak demand on a given distribution circuit could be accurately predicted or reliably reduced, then the capital costs of marginally increasing that circuit's capacity could also be reduced. This impact metric compares the baseline feeder load profile against the impacts of DA-VVC technology and Consumer Programs to quantify the reduction in distribution capacity investments.

7.5.3.2 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

7.5.3.3 Organization of Results

This metric presents AEP's study of deferred distribution capacity investments due to DA-VVC.

7.5.3.4 Results of Data Collected to Date

No results are available for this metric. An explanation follows.

Presentation of AEP's Deferred Capacity Study:

AEP Ohio has reviewed planned projects in Distribution Load Forecasting where DA-VVC circuits would be involved. It did not appear that any projects were deferred as a result of DA-VVC being installed. This matter was discussed with AEP Ohio's local planning engineer who concurs that there weren't any projects that were deferred as a result of DA-VVC being deployed. That being said, deferring capital projects by installing DA-VVC is a potential benefit of DA-VVC but it just didn't occur for the circuits that were involved in the gridSMART Project.

Deferred Distribution Capacity Investments Study

Not available at this time.

Calculation Approach

No planned or deferred distribution capacity investments have occurred within the gridSMART Project area due to the DA-VVC technology deployment.

7.5.4 Equipment Failure Incidents (M16-VVC)

7.5.4.1 Objective

DA-VVC has the potential to dynamically control voltage and power factors on feeders to reduce load, customer energy consumption, and losses. This reduced demand can result in reduced costs, deferred capital investments, extended equipment life, and reduced fuel consumption.

Maintaining and replacing failed or damaged equipment can greatly impact operational costs. This impact metric examines the type and frequency of equipment failures by service center, substation feeder, and various time periods. A relationship between load conditions and equipment failure will be examined by correlating against weather conditions, which will act as a proxy for the load profile.

7.5.4.2 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

7.5.4.3 Organization of Results

The following section reports the number of equipment failure events that occurred on DA-VVC and non-DA-VVC circuits within the Project area.

- Equipment failure event counts for DA-VVC versus non-DA-VVC circuits

  This graph shows the number of equipment failures per year for each type of equipment tracked. The graph is divided into two sections, one showing the 17 DA-VVC circuits, and the other showing the test of the DA project area. This represents a population of approximately 80 circuits.

- Equipment failure rates for DA-VVC versus non-DA-VVC circuits

  This graph shows the number percent failure rate per year for each type of equipment tracked. Failure rates were calculated as a percentage of the population of each device type within the DA-VVC and non-DA-VVC areas. The graph is divided into two sections- one showing the 17 DA-VVC circuits, and the other showing the test of the DA project area. This represents a population of approximately 80 circuits.

7.5.4.4 Results of Data Collected to Date

The figures on the following pages quantify the impact metric for this section.

AEP OHIO — A unit of American Electric Power

Results for Equipment Failure Events:

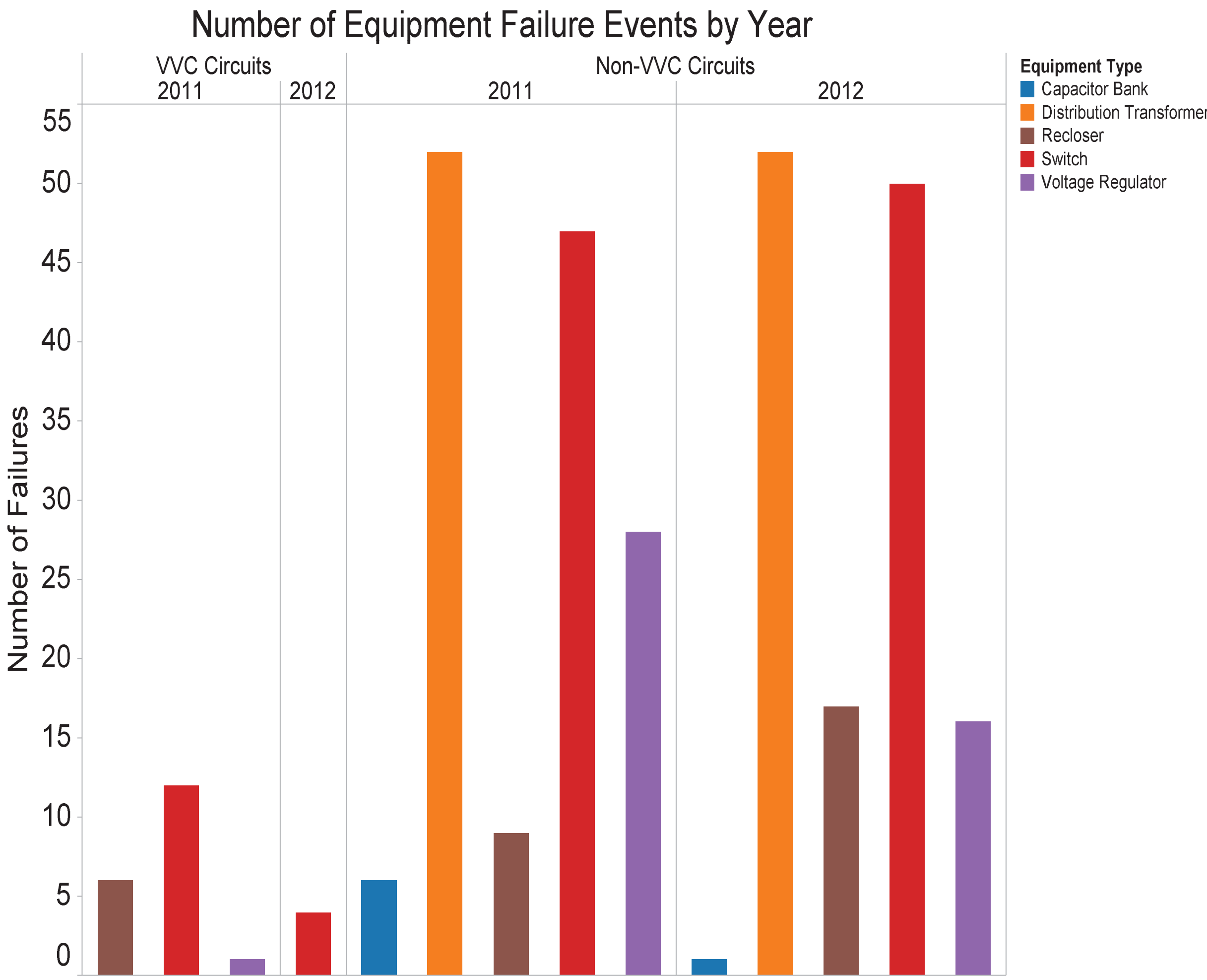


Figure 119. Count of equipment failures by year for VVC vs. non-VVC circuits

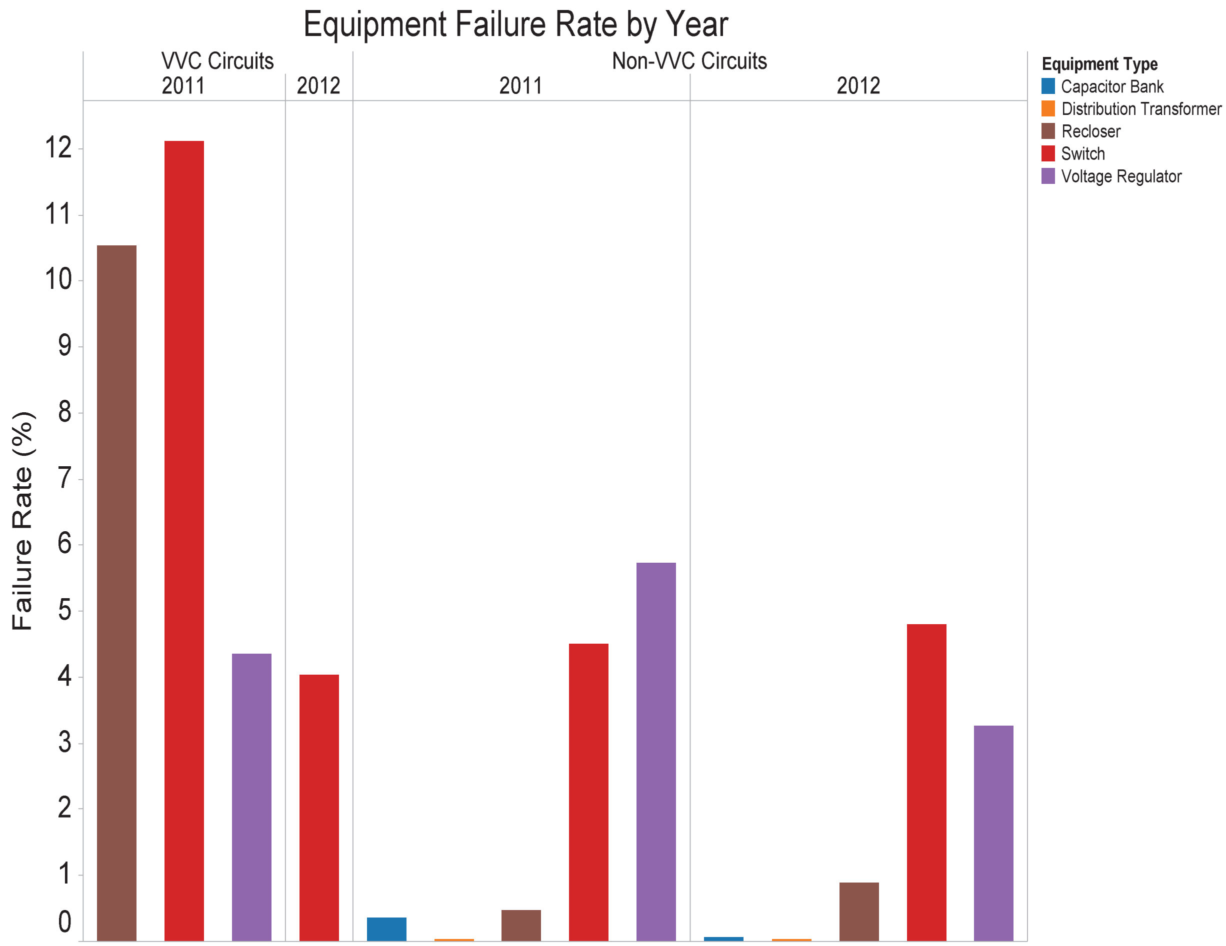


Figure 120. Equipment failure rate by year for VVC vs. non-VVC circuits

Calculation Approach

The following queries and methods used to generate presentation items:

- Equipment failure events per date, equipment type, circuit, and substation were selected by linking equipment compatible units to circuit equipment types.
- Hourly outdoor temperature in degrees Fahrenheit for Port Columbus International Airport was collected from the National Oceanic and Atmospheric Administration: http://hurricane.ncdc.noaa.gov/pls/plclimprod/poemain.accessrouter?datasetabbv=DS3505&countryabbv=&georegionabbv=
This information will be included in the final report.

7.5.5 Distribution Equipment Maintenance Cost (M17-VVC)

7.5.5.1 Objective

DA-VVC has the potential to dynamically control voltage and power factors on feeders to reduce customer energy consumption and losses. This reduced consumption can result in reduced costs, deferred capital investments, extended equipment life, and reduced fuel consumption. The addition of DA-VVC equipment has the potential to effect maintenance costs. This impact metric presents reported maintenance equipment costs by type for substation feeder and time range.

7.5.5.2 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

7.5.5.3 Organization of Results

The following section reports the maintenance related costs incurred on DA-VVC and non-DA-VVC circuits within the System area.

- Equipment maintenance for DA-VVC circuits

    This graph shows the cost in dollars per month within the DA-VVC project area for each maintenance cost component. This covers a population of 17 circuits.

- Equipment maintenance costs for non-DA-VVC circuits

    This graph shows the cost in dollars per month outside the DA-VVC project area but within the System area for each maintenance cost component. This covers a population of approximately 700 circuits.

7.5.5.4 Results of Data Collected to Date

The figures on the following pages quantify the impact metric for this section.

Results for monthly maintenance costs:

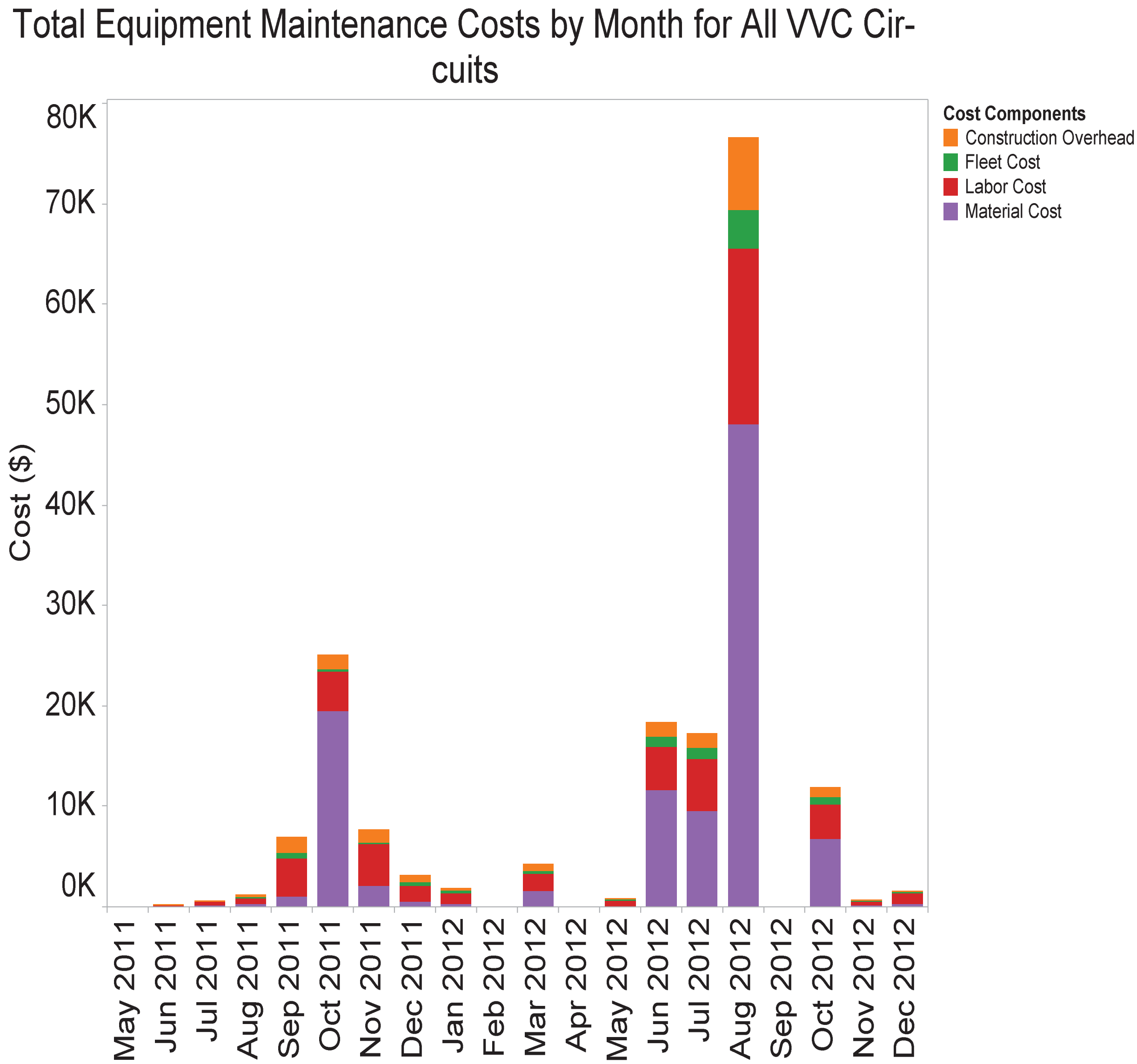


Figure 121. Breakdown of monthly maintenance costs for VVC circuits

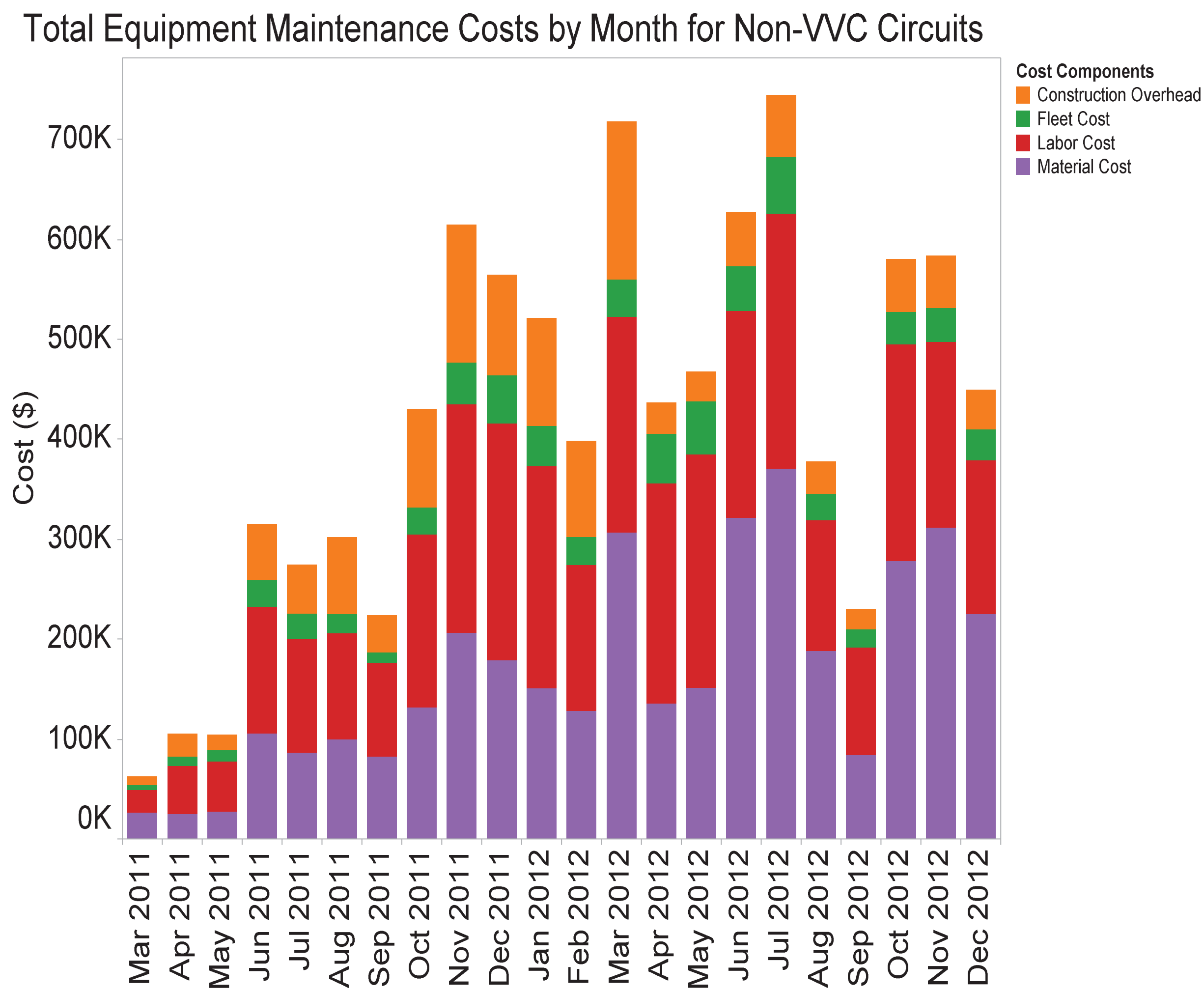


Figure 122. Breakdown of monthly maintenance costs for non-VVC circuits

Calculation Approach

The following queries and methods were used to generate presentation items:

- Distribution equipment maintenance labor, material, vehicle fleet, and construction overhead costs per circuit, substation, and work order close date were calculated by summing labor, material, vehicle fleet, and construction overhead costs.

7.5.6 Distribution Capacitor Switching Operations (M20-VVC)

7.5.6.1 Objective

Distribution capacitors are important pieces of equipment for maintaining unity power factor. If capacitors are improperly sized, improperly programmed, or not functioning due to equipment or controls failure, the feeder will deliver power in an inefficient manner. This impact metric examines the behavior of switched capacitor banks in the Project area and provides counts of how many non-DA-VVC and DA-VVC switching events occurred during the Project.

7.5.6.2 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

7.5.6.3 Organization of Results

The following section reports the number of capacitor switching events on DA-VVC and non-DA-VVC circuits within the AEP Ohio Project area.

- Count of Capacitor Switching Operations

  This graph shows counts of switching events per day within the DA-VVC project area and also for the non-DA-VVC portion of the Project area. The DA-VVC plot covers a population of 17 circuits while the non-DA-VVC plot covers a population of approximately 63 circuits.

- Average Capacitor Switching Operations per Circuit

  This graph shows per circuit averages of switching events per day within the DA-VVC project area and also for the non-DA-VVC portion of the Project area.

7.5.6.4 Results of Data Collected to Date

The figures on the following pages quantify the impact metric for this section.

Results for capacitor switching events:

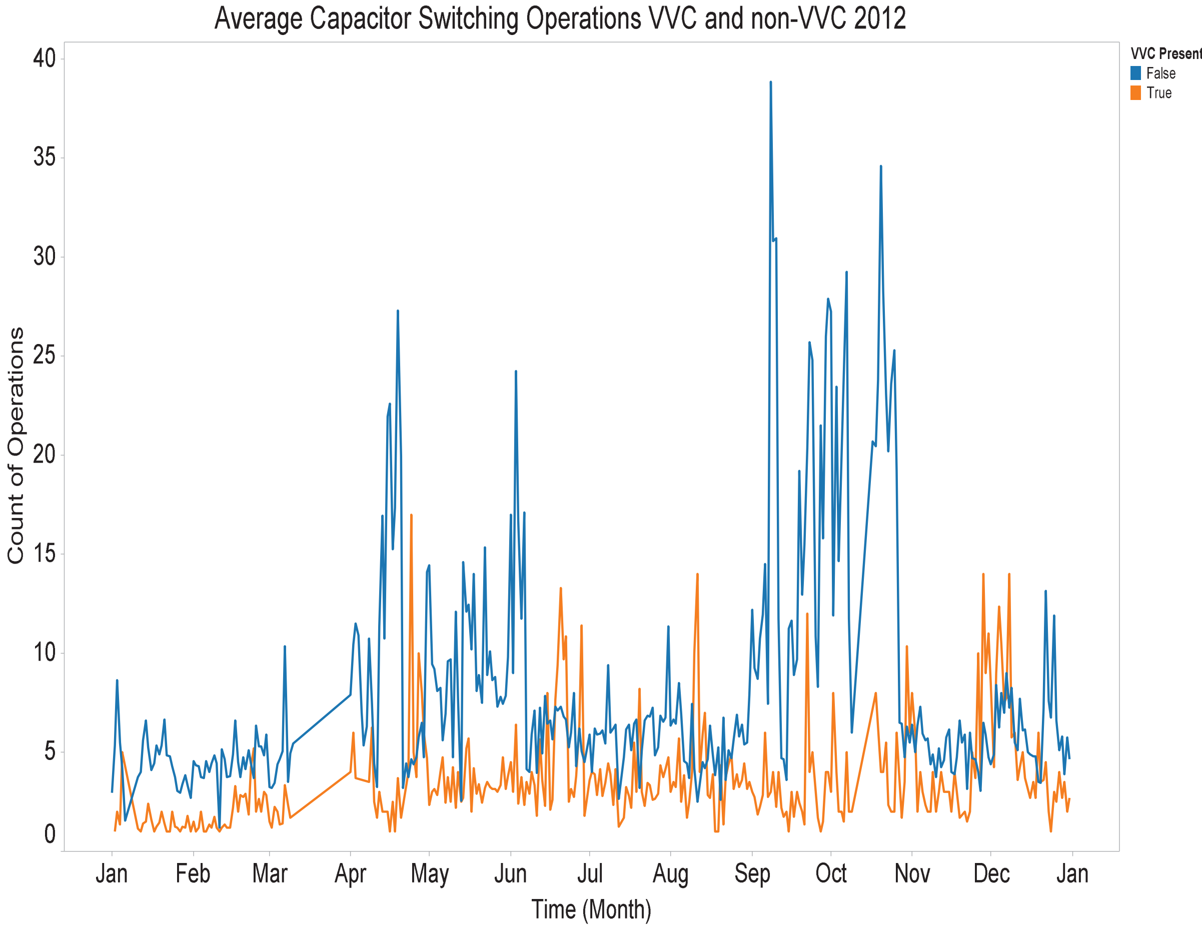


Figure 123. Average number of capacitor switching events per circuit VVC vs. non-VVC

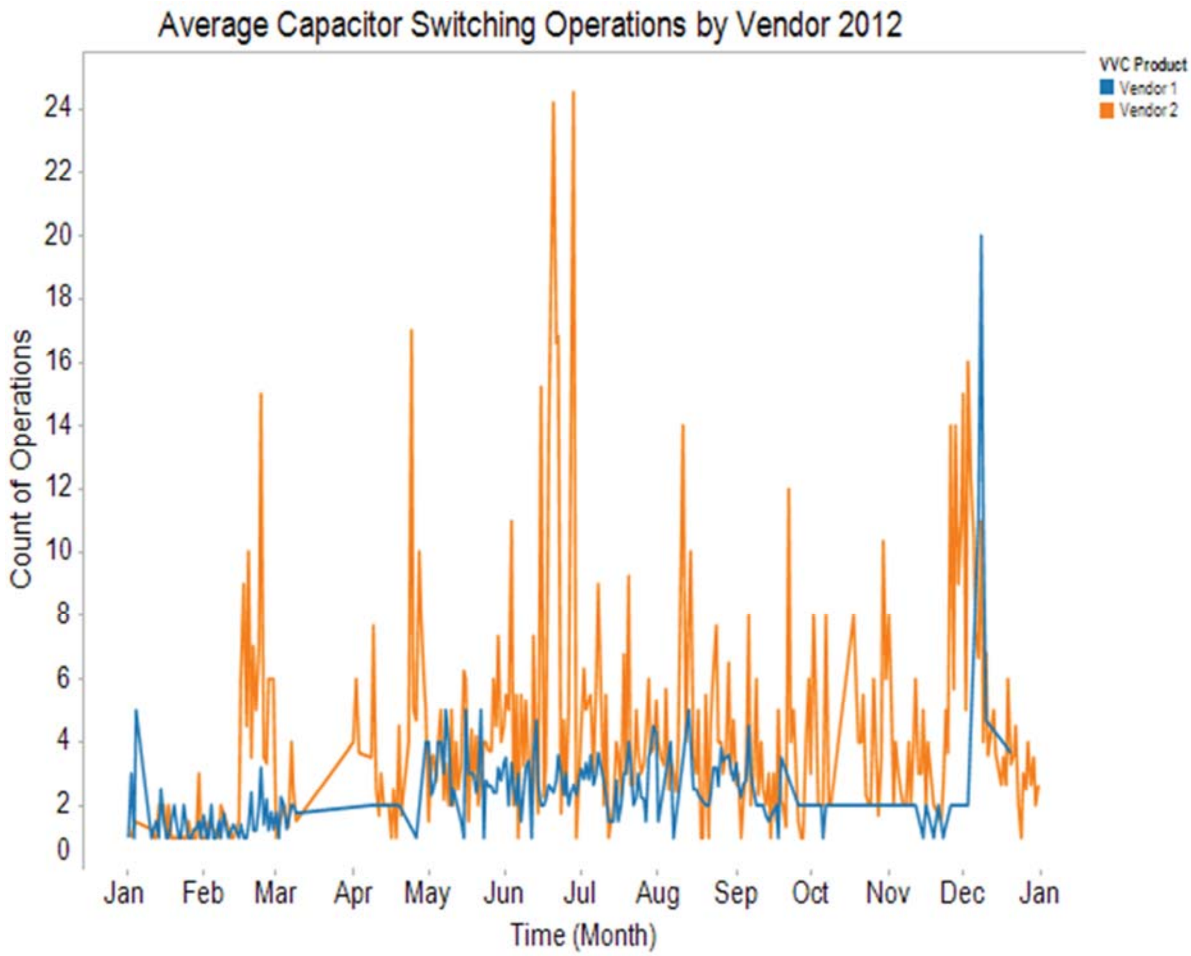


Figure 124. Average number of capacitor switching events per circuit

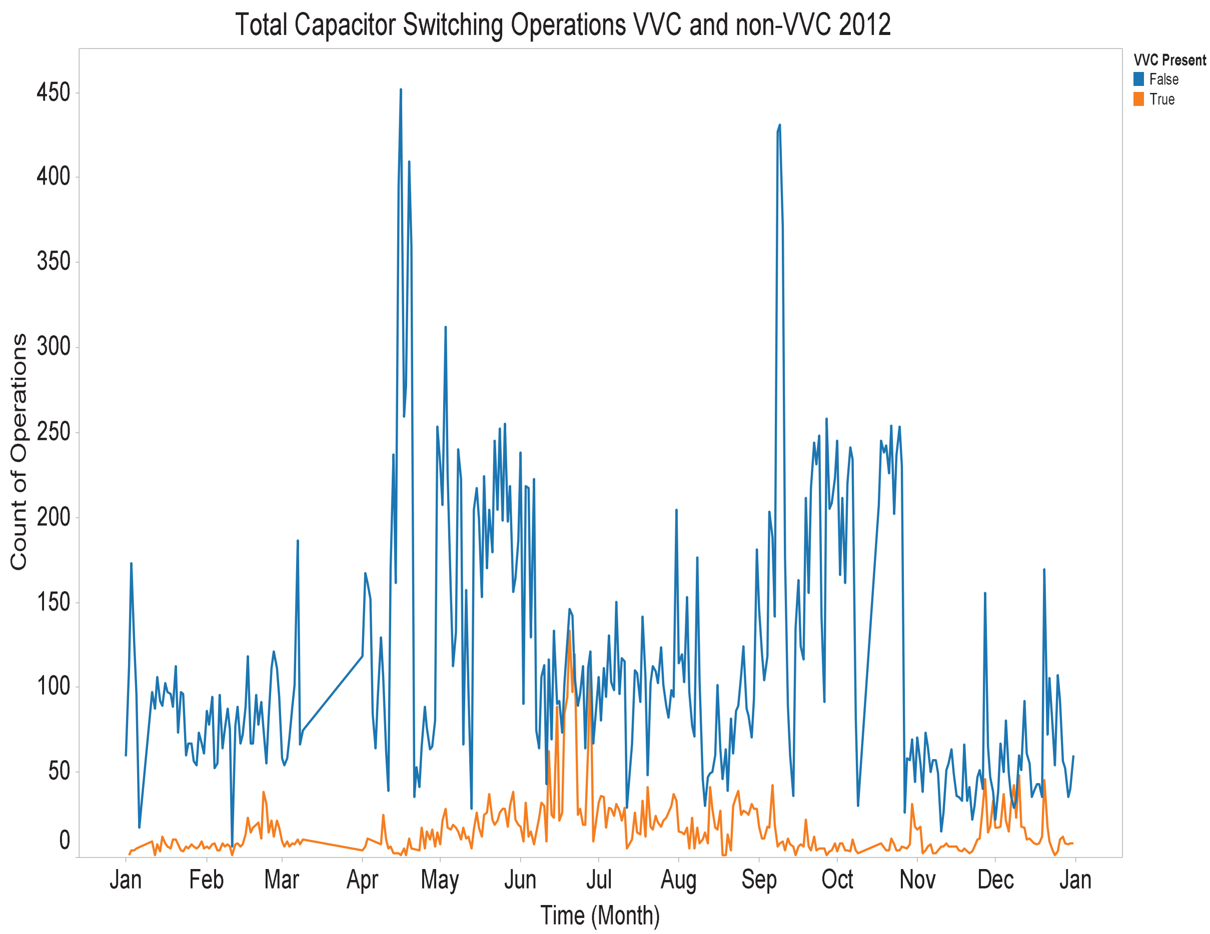


Figure 125. Total count of capacitor switching events for VVC and non-VVC circuits

Vendor 2 (11 circuits)	Vendor 1 (6 Circuits)
Karl-0000919	Gahanna-0004501
Karl-0000920	Gahanna-0004502
East Broad St.-0001405	Gahanna-0004503
East Broad St.-0001406	Gahanna-0004504
East Broad St.-0001408	Gahanna-0004505
Gahanna-0004531	Gahanna-0004506
Gahanna-0004532	
Taylor-0009733	
Blacklick-0026002	
Blacklick-0026004	
Blacklick-0026031	

Table 24. DA-VVC Circuit by equipment vendor

Calculation Approach

The following queries and methods used to generate presentation items:

- Distribution capacitor switching events per circuit, substation and day were selected by counting switching events where the equipment type was "capacitor".

7.5.7 Distribution Losses (%) (M22-VVC)

7.5.7.1 Objective

Distribution losses increase with the square of current flow through the system. One goal of DA-VVC technology is to reduce the total current flow through the distribution system through conservation voltage reduction. In principle, the DA-VVC system monitors the end of line voltage in order to regulate the voltage toward the bottom of the ANSI range of acceptable voltages causing customer loads to consume less energy. By delivering less energy and less current, the losses through the distribution system are also reduced. This impact metric presents the difference between feeder load measured at the substation via the SCADA system and the metered load measured through the AMI system. The net result is the total non-AMI metered load on the feeder, of which, losses are a component and are expected to be impacted by the presence of DA-VVC.

7.5.7.2 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

7.5.7.3 Organization of Results

The following section shows the non-AMI metered load on select DA-VVC circuits.

- AMI meter penetration by circuit

  This graph shows the percentage of meters that are AMI meters on each DA-VVC circuit. Further analysis of non-AMI metered load is conducted only for circuits that have at least 90 percent AMI meter penetration.

The subsequent graphs are presented in the order of most AMI penetration to least.

- Calculation of non-AMI metered power

  This graph illustrates the calculation of non-AMI metered power by showing measured feeder load, a summation of the AMI interval data for that feeder, and the non-AMI metered power for a representative distribution feeder. Non-AMI metered power is calculated as feeder load minus AMI summation.

- Non-AMI metered load

  The following section shows the non-AMI metered load on selected DA-VVC circuits. More detailed analysis is provided for times during which AEP Ohio implemented a day-on/day-off experimental strategy. This strategy consists of alternately enabling and disabling the DA-VVC system for 24-hour periods in order to demonstrate differences in circuit load, customer energy consumption, and losses.

A table of statistics is provided for circuits that exhibit day-on and day-off behavior.

7.5.7.4 Results of Data Collected to Date

The figures on the following pages quantify the impact metric for this section.

Results for non-AMI metered power:

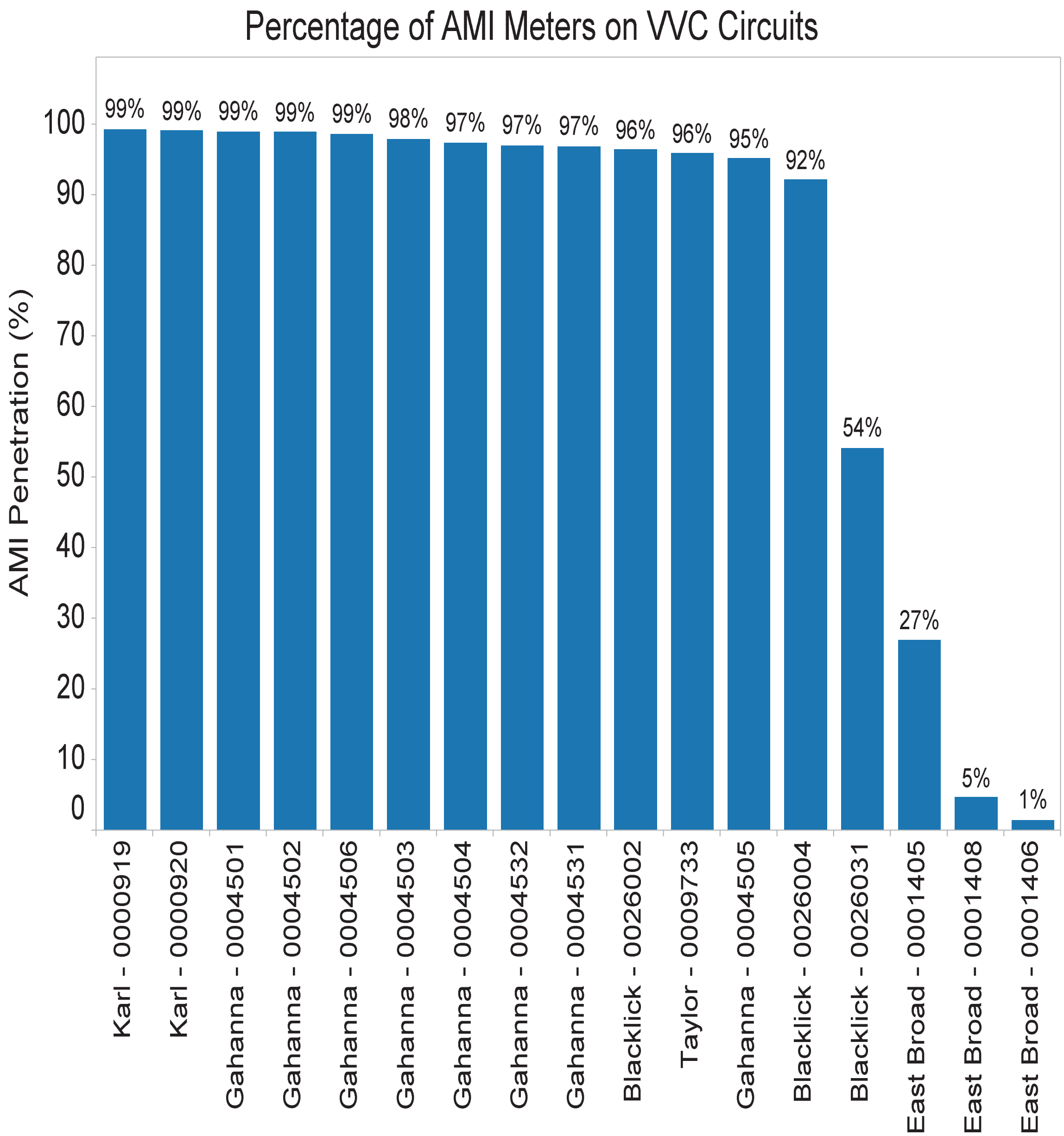


Figure 126. Percentage of AMI meters for each VVC circuit

Figure 127. Example calculation of non-AMI metered power for Karl 0000919 (Jan – Nov)

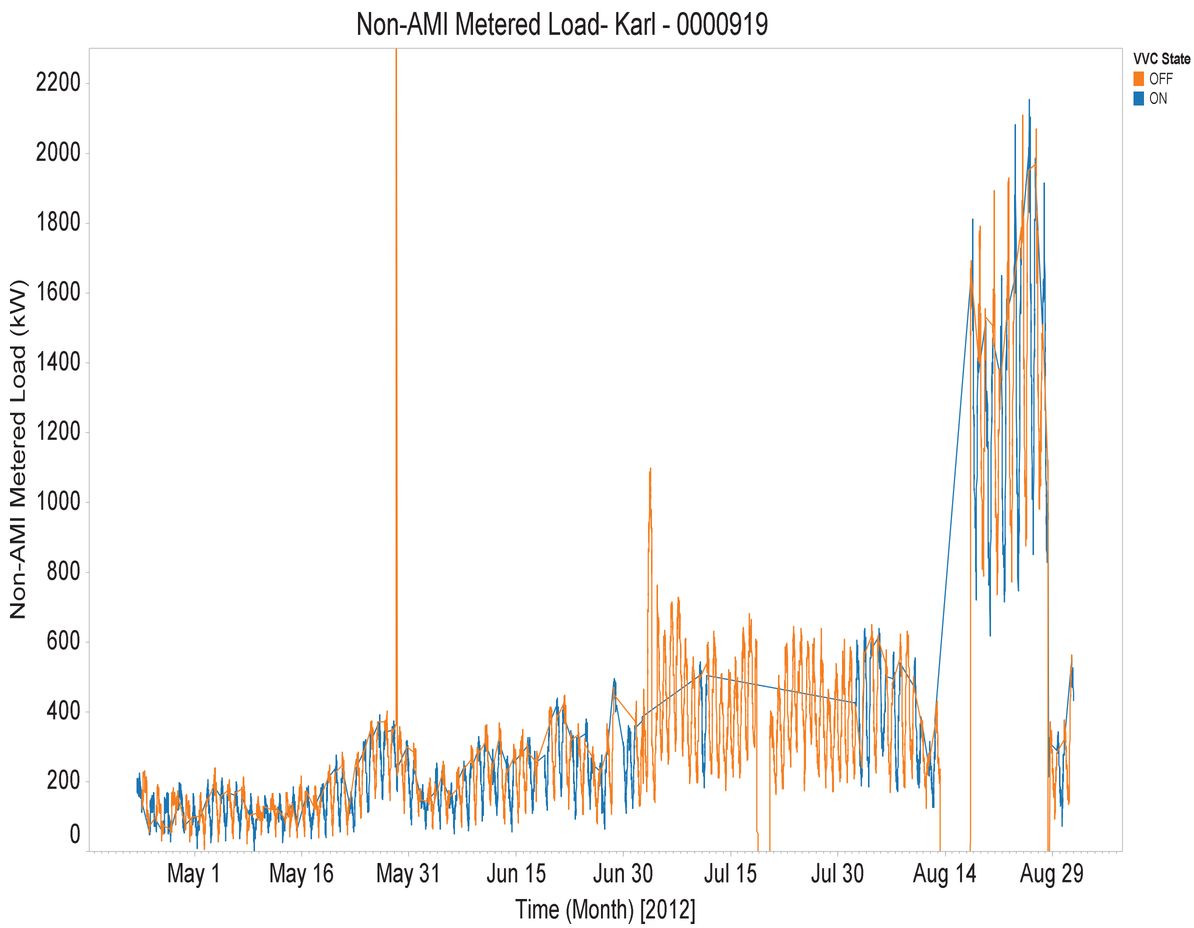


Figure 128. Non-AMI metered power versus time Karl-000919 (Apr-Jun)

The summary statistics for this circuit is as follows:

Karl 0000919 May-Jun 2012		
Volt-VAR Status	**Avg Power**	**% Difference**
On	171.0187	
Off	192.2625	11.0%
Outliers Removed		
On	171.0187	
Off	183.4525	6.8%

Table 25. Karl Circuit Statistics

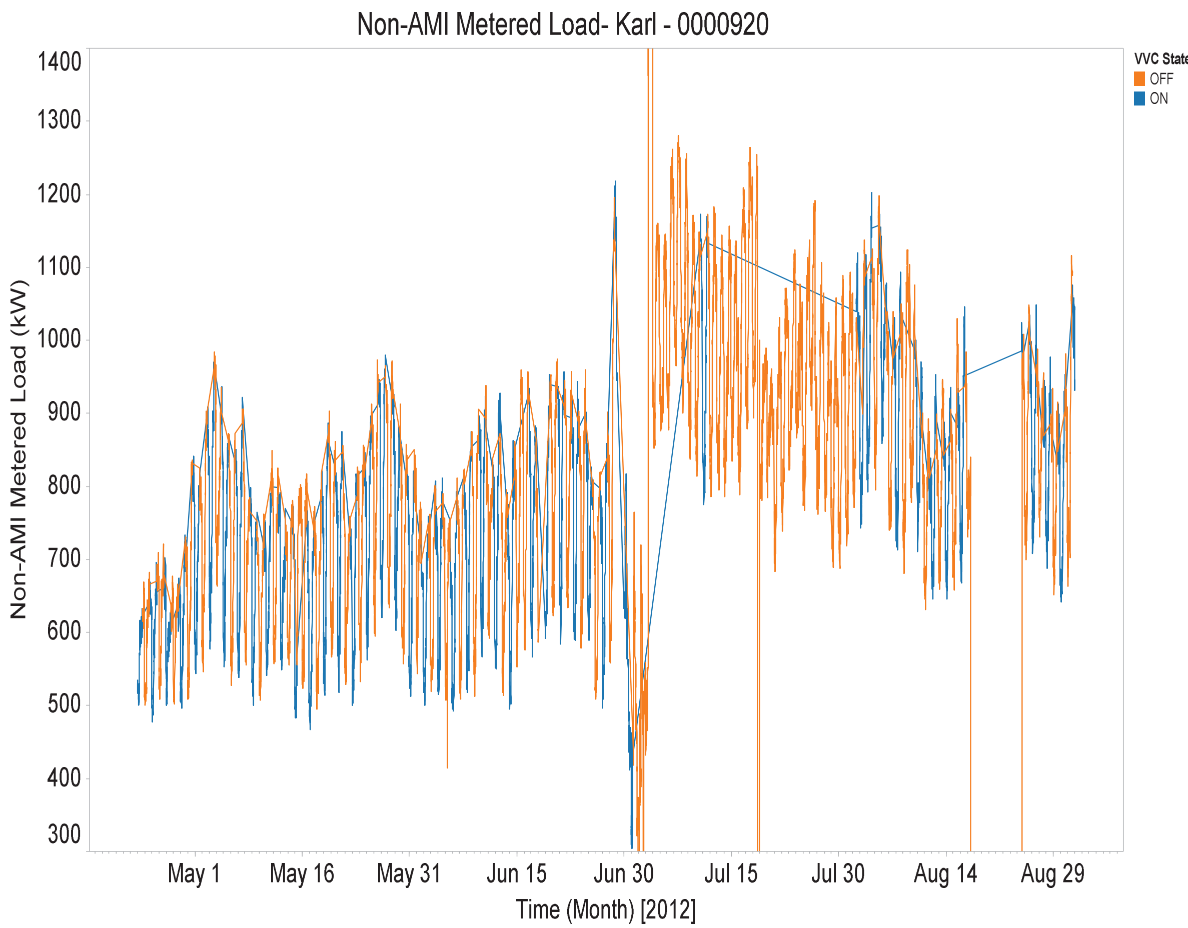


Figure 129. Non-AMI metered power versus time Karl-0000920 (Apr-Aug)

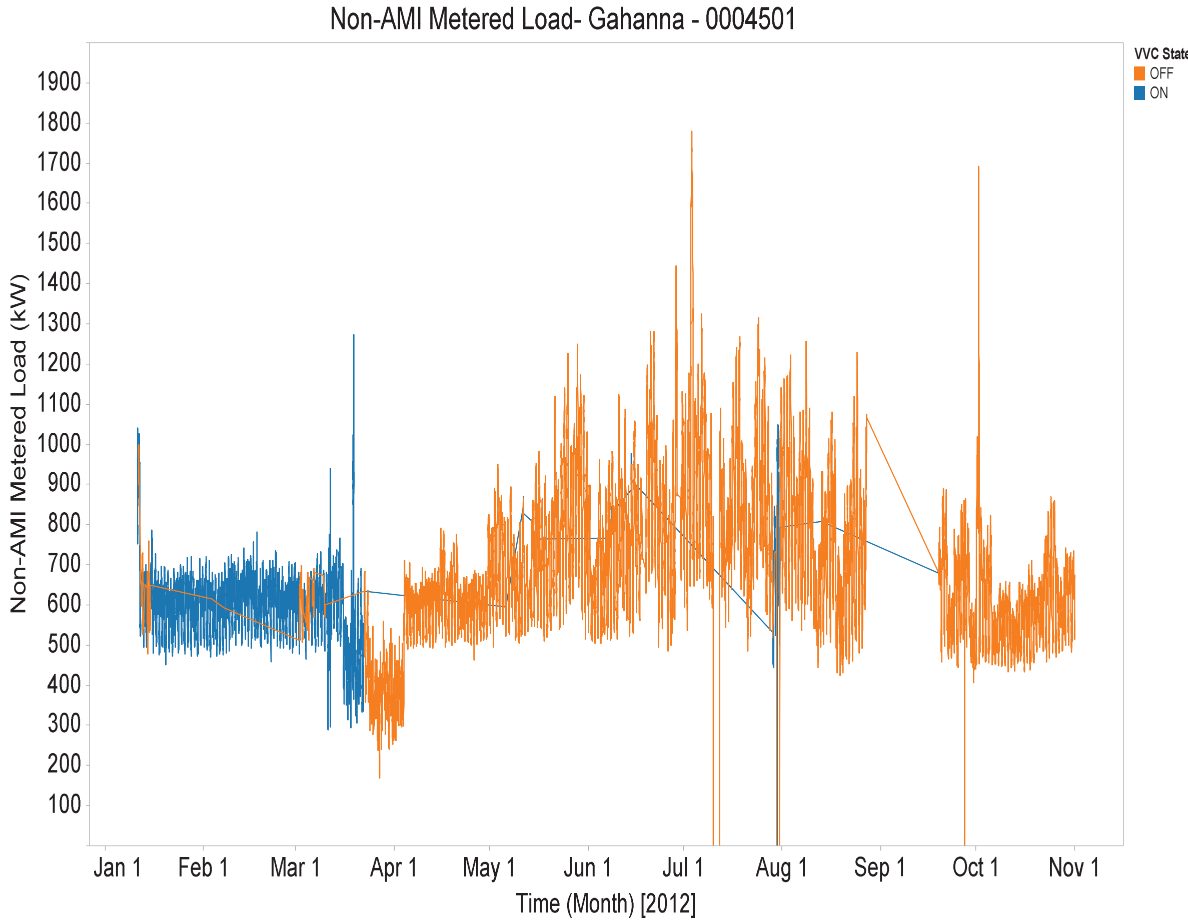


Figure 130. Non-AMI metered power versus time Gahanna-0004501 (Jan-Nov)

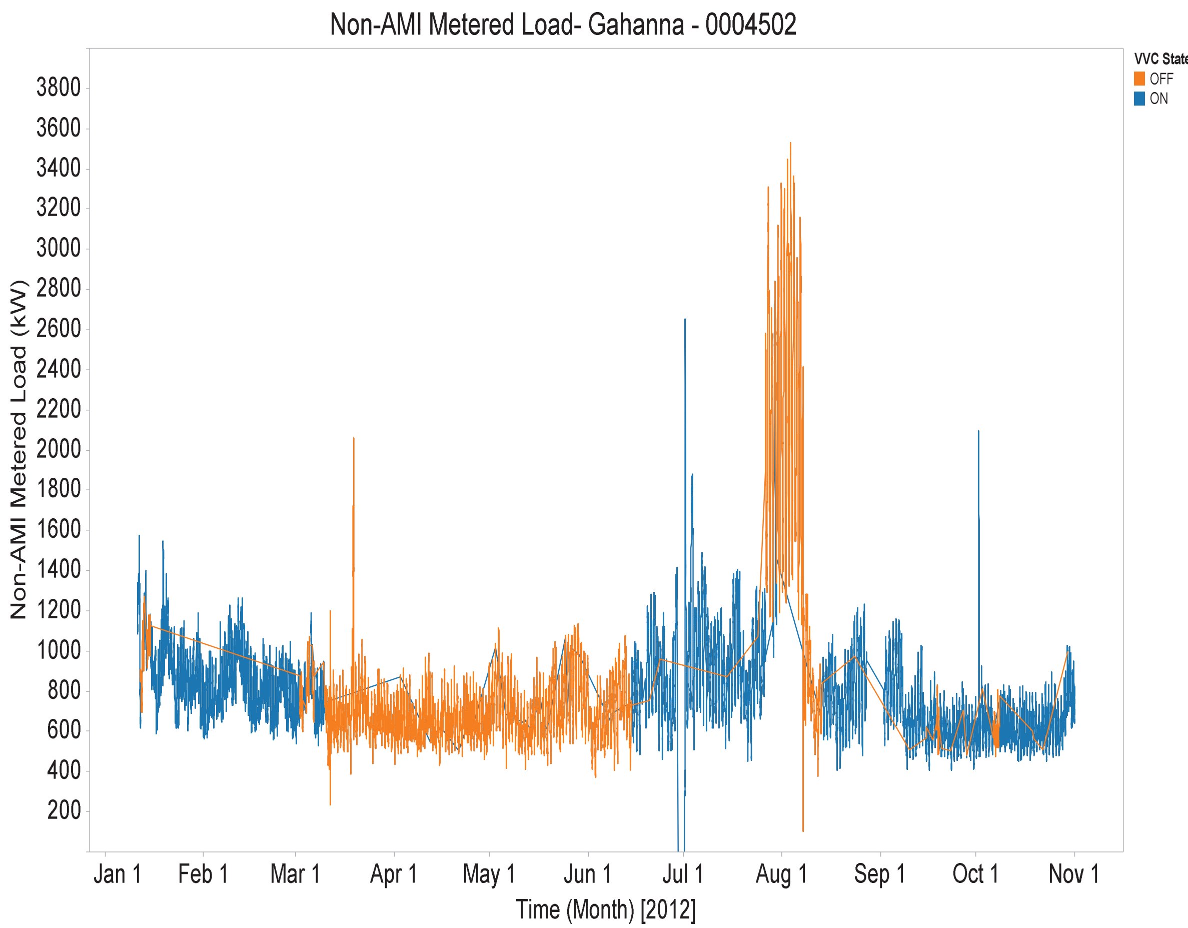


Figure 131. Non-AMI metered power versus time Gahanna-0004502 (Jan-Nov)

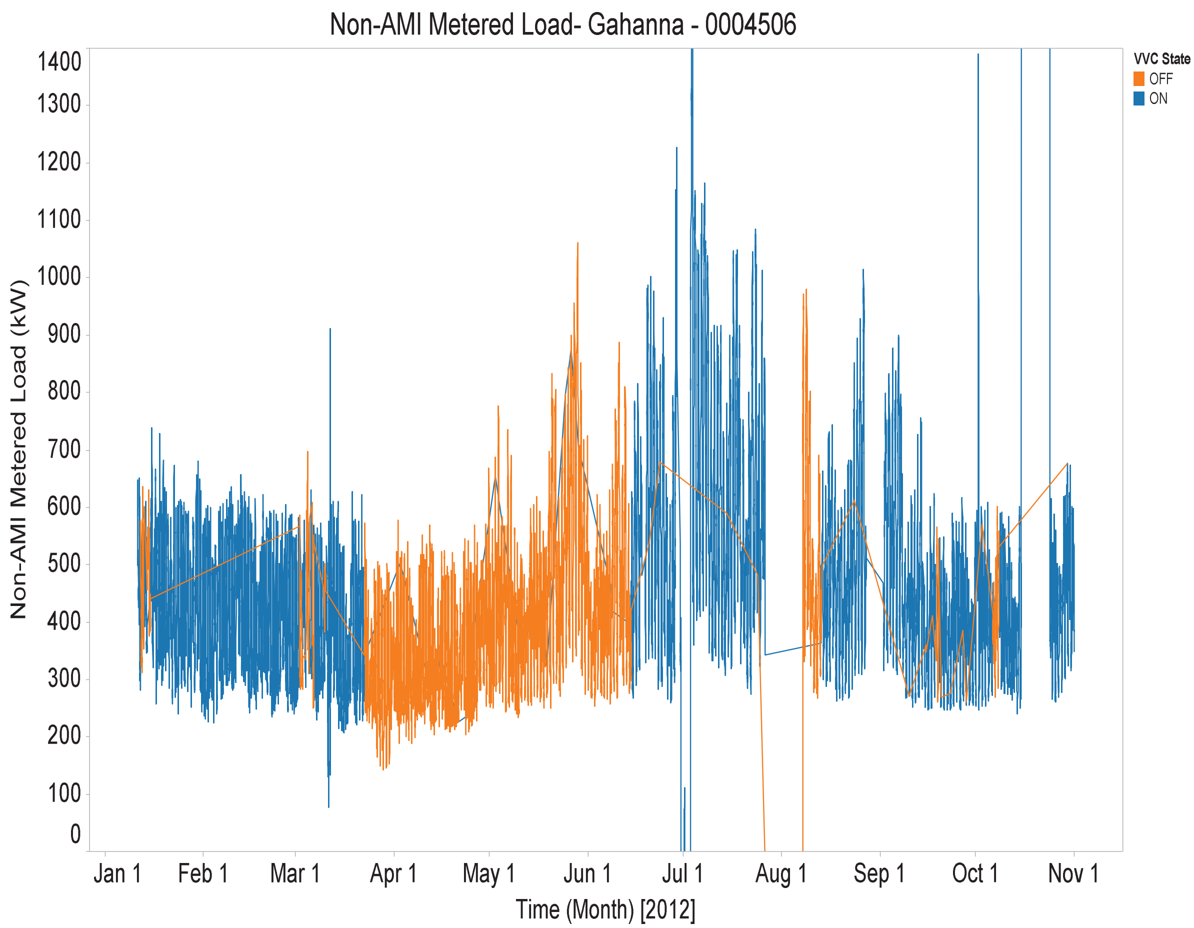


Figure 132. Non-AMI metered power versus time Gahanna-0004506 (Jan-Nov)

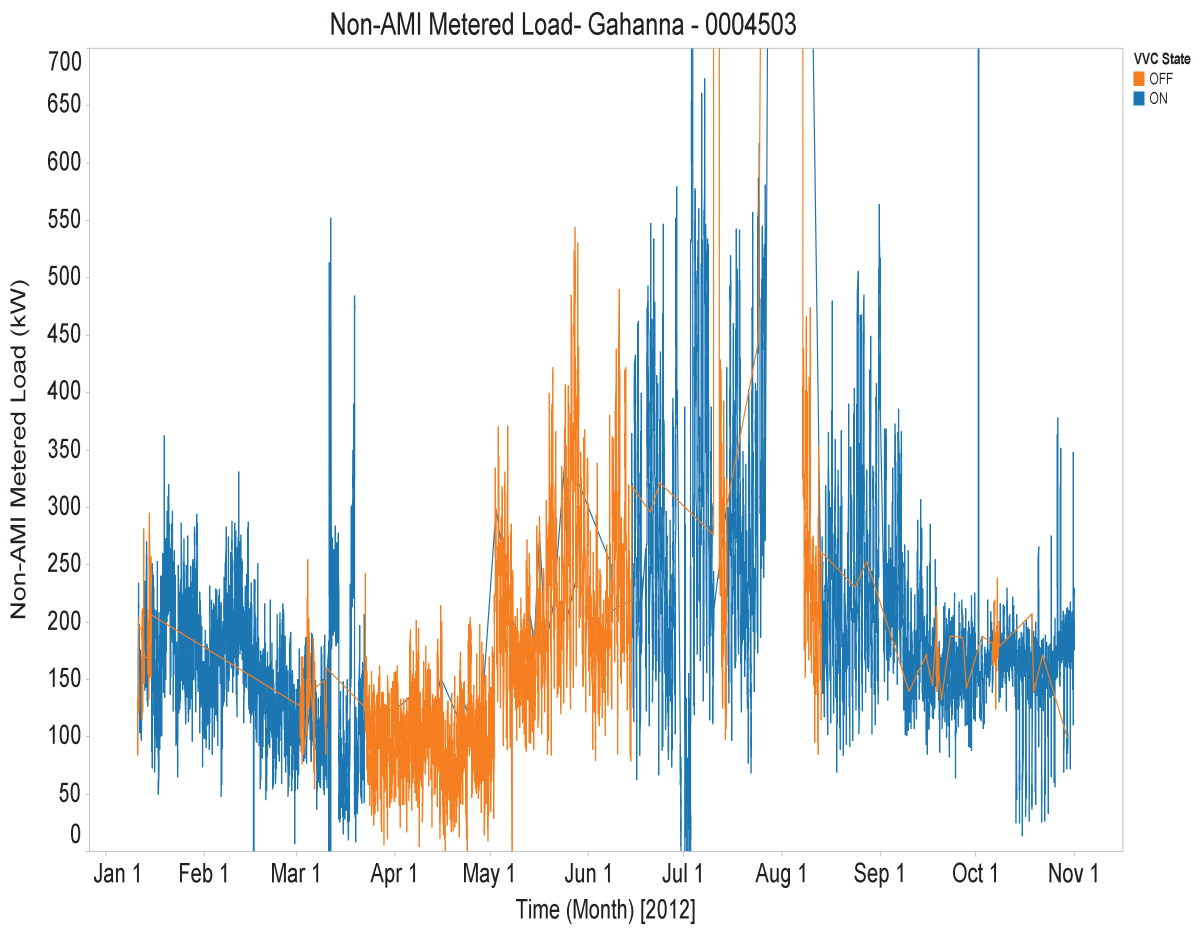


Figure 133. Non-AMI metered power versus time Gahanna-0004503 (Jan-Nov)

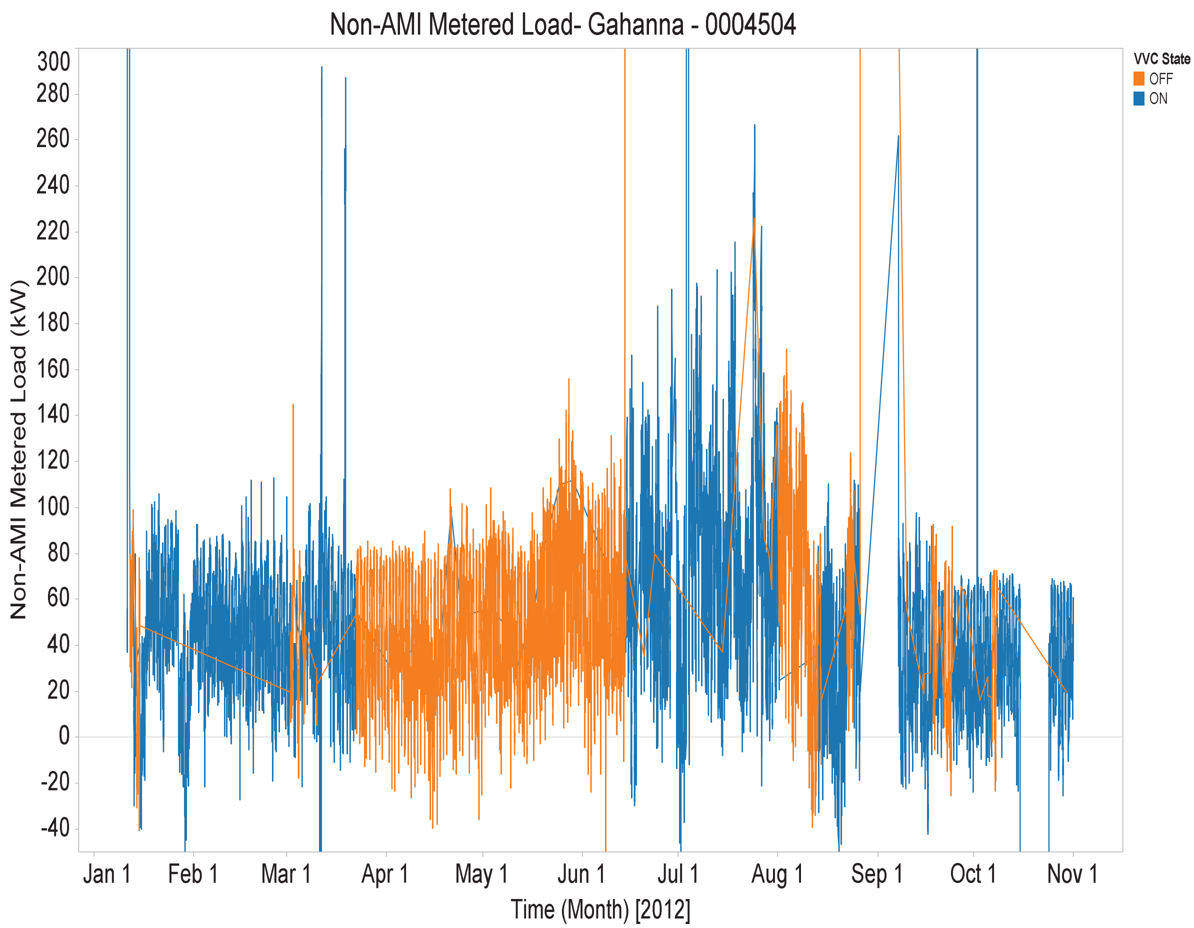


Figure 134. Non-AMI metered power versus time Gahanna-0004504 (Jan-Nov)

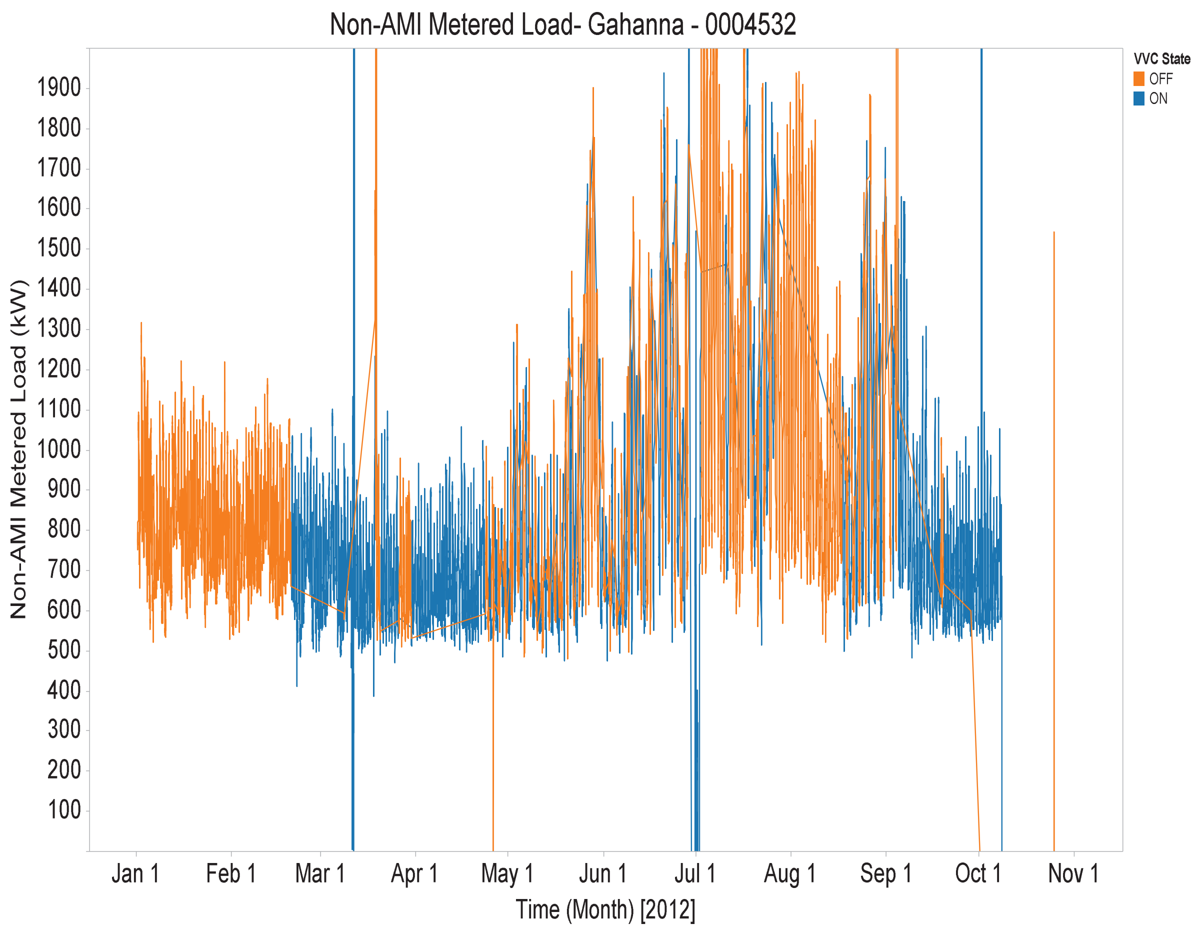


Figure 135. Non-AMI metered power versus time Gahanna-0004532 (Jan-Nov)

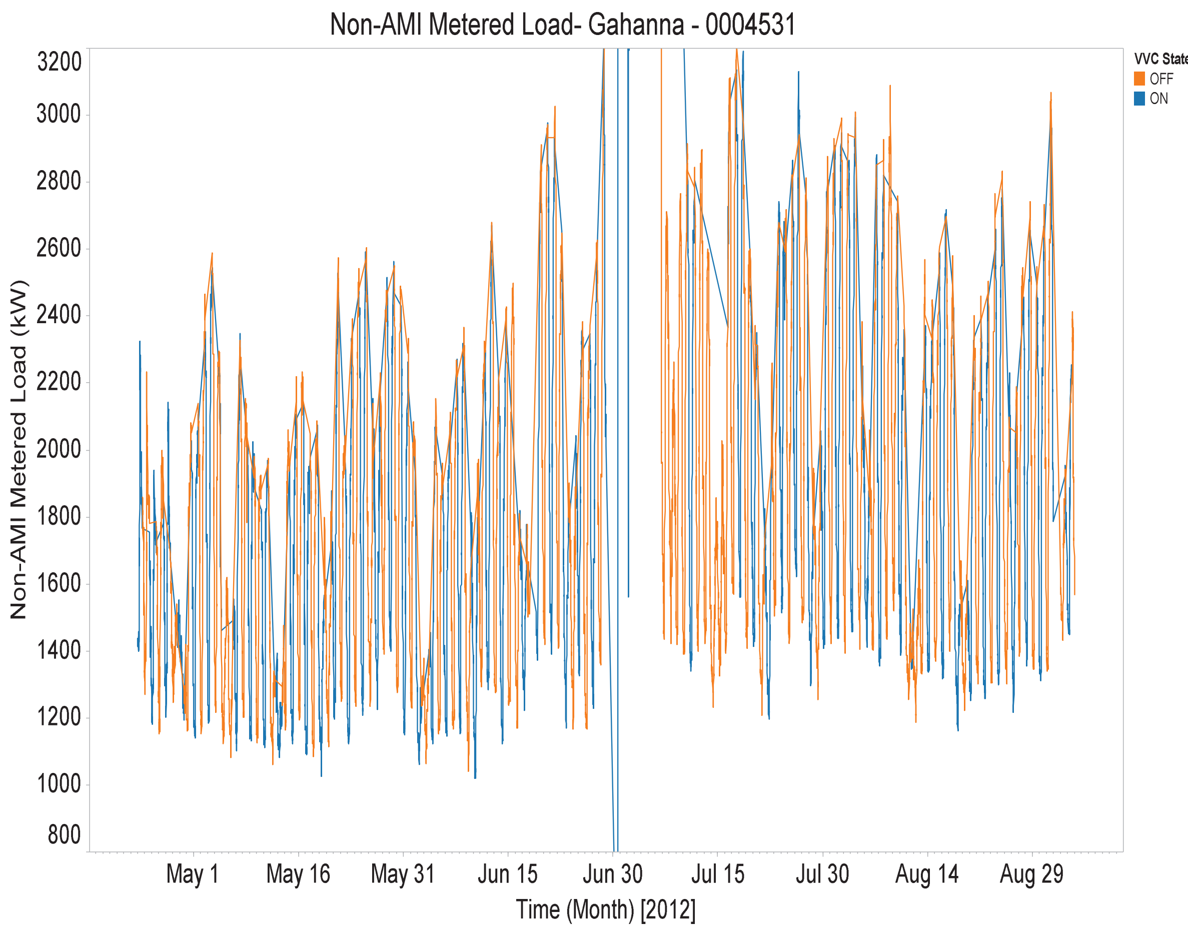


Figure 136. Non-AMI metered power versus time Gahanna-0004531 (Apr-Aug)

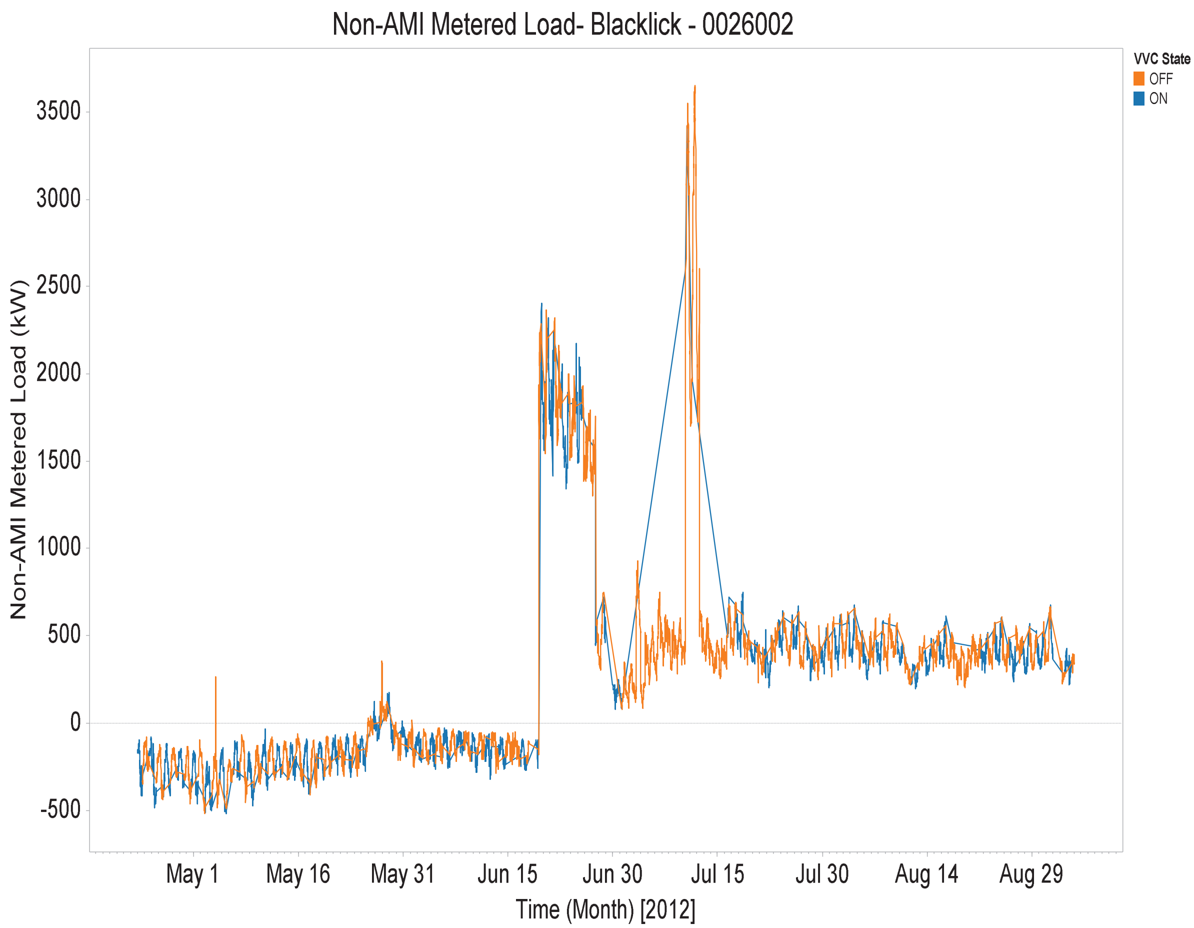


Figure 137. Non-AMI metered power versus time Blacklick-0026002 (May-Aug)

Note*: The negative period for non-metered load is likely due to a switching operation that moved AMI meters that are normally connected to this circuit to another circuit for this time period.*

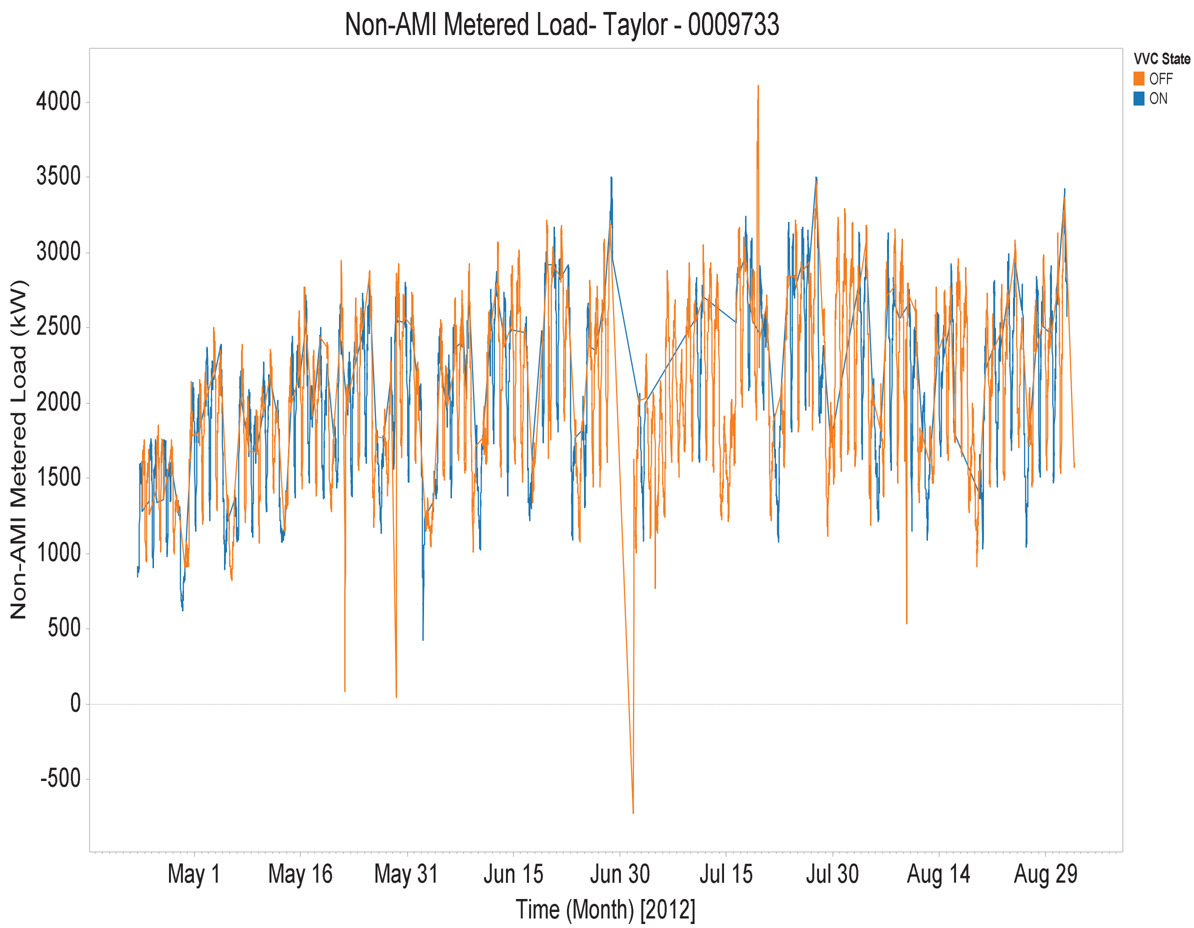


Figure 138. Non-AMI metered power versus time Taylor-0009733 (May-Aug)

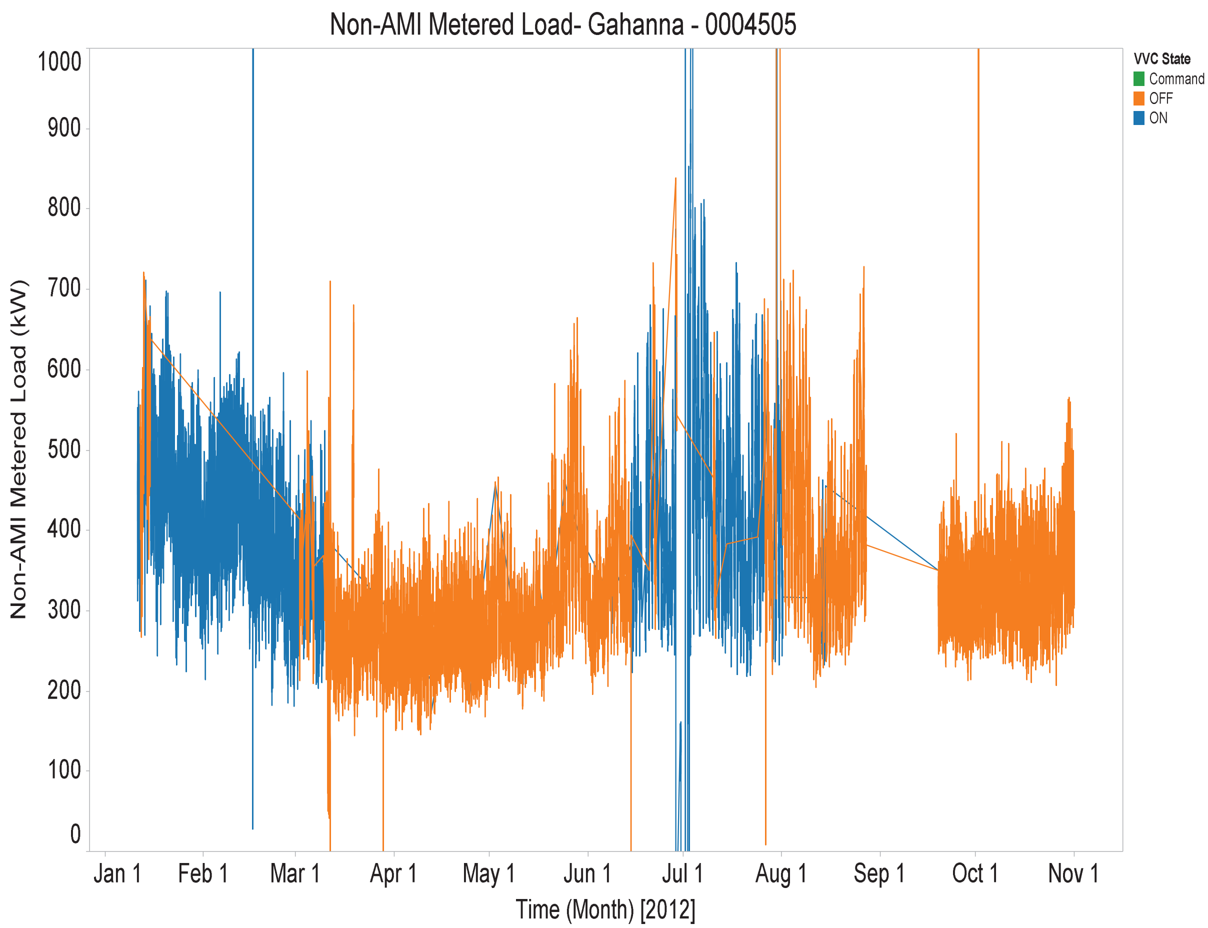


Figure 139. Non-AMI metered power versus time Gahanna-0004505 (Jan-Nov)

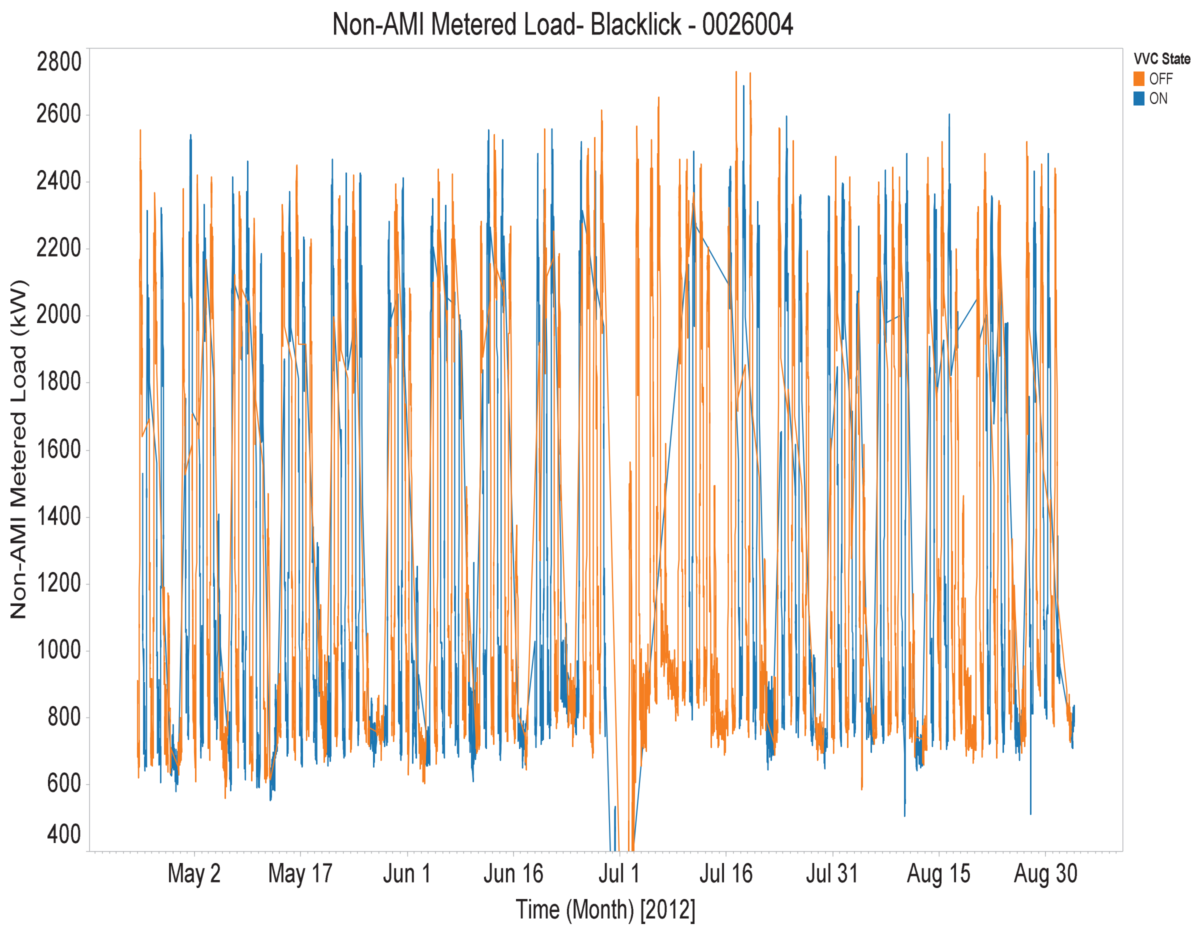


Figure 140. Non-AMI metered power versus time Blacklick-0026004 (May-Aug)

Calculation Approach

This data was calculated as a point by point subtraction of total AMI 15-minute interval data from 15-minute feeder load data. This represents all technical and non-technical losses. Next, a comparison was made showing changes in non-AMI metered load associated with DA-VVC status (on versus off).

The following queries and methods used to generate presentation items:

- Distribution unmetered load, energy theft, and losses per circuit, DA-VVC controller status, and time were calculated by subtracting the 15-minute interval readings from AMI meters on a circuit from the circuit load.

7.5.8 Distribution Power Factor (M23-VVC)

7.5.8.1 Objective

Power factor is an indication of how efficiently the distribution system is able to deliver power. A system operating at unity power factor is able to deliver more real power than one operating at either a leading or lagging power factor. This impact metric presents the reported power factor for feeders across various time ranges.

7.5.8.2 Organization of Results

The following section illustrates the power factor achieved for DA-VVC circuits when DA-VVC was on versus off. Each plot shows circuit load, power factor when lagging, and power factor when leading color coded by DA-VVC status.

7.5.8.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

7.5.8.4 Results of Data Collected to Date

The figures on the following pages quantify the impact metric for this section.

Results for distribution power factor:

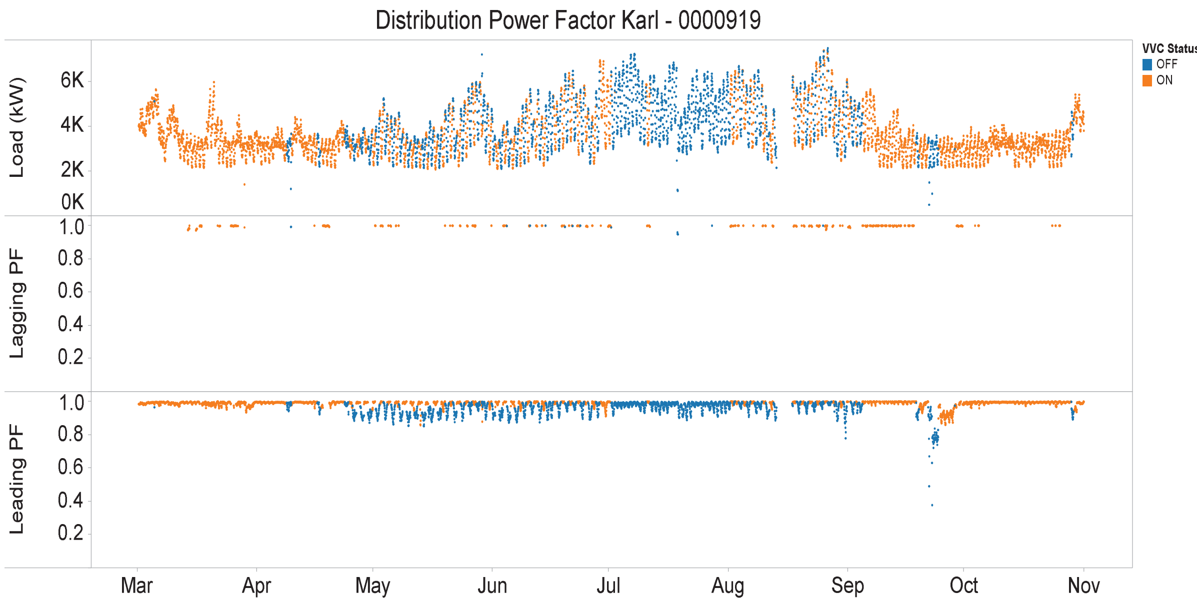


Figure 141. Circuit power factor for Karl - 0000919

Circuit	DA-VVC on Average Power Factor	DA-VVC off Average Power Factor
[Karl - 0000919]	0.98610	0.95960
[Karl - 0000920]	0.99047	0.99274
[Gahanna - 0004501]	0.99143	0.97210
[Gahanna - 0004502]	0.97960	0.98800
[Gahanna - 0004506]	0.98080	0.97840
[Gahanna - 0004503]	0.97370	0.98900
[Gahanna - 0004504]	0.95240	0.97220
[Gahanna - 0004532]	0.95980	0.97530
[Gahanna - 0004531]	0.98182	0.98560
[Blacklick - 0026002]	0.94830	0.92640
[Taylor - 0009733]	0.98060	0.97693
[Gahanna - 0004505]	0.98200	0.99315
[Blacklick - 0026004]	0.95380	0.97850
[Blacklick - 0026031]	0.99547	0.99380
[East Broad - 0001405]	0.97030	0.98790
[East Broad - 0001408]	0.98190	0.98510
[East Broad - 0001406]	0.97140	0.98050

Table 26. Average power factor by circuit (2012)

Calculation Approach

The following queries and methods used to generate presentation items:

- Power factors per circuit, DA-VVC controller status, and time were calculated by dividing the real power on the circuit by the apparent power on the circuit.

  Hourly outdoor temperature in degrees Fahrenheit for Port Columbus International Airport was collected from the National Oceanic and Atmospheric Administration: http://hurricane.ncdc.noaa.gov/pls/plclimprod/poemain.accessrouter?datasetabbv=DS3505&countryabbv=&georegionabbv=
  This information will be included in the final report.

7.5.9 Reduced Transmission Congestion Cost (M24-VVC)

7.5.9.1 Objective

The high voltage transmission system transmits power across long ranges from sources of generation to load centers. If load increases across a single or small group of transmission lines, that pathway can become a limiting factor for the transmission of power across the entire grid. Wholesale power markets account for this limiting factor through congestion costs imposed on the loads causing this congestion. One potential benefit of DA-VVC is the reduction of transmission congestion costs via demand reductions. This impact metric is not analyzed or presented in this report.

7.5.9.2 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

7.5.9.3 Organization of Results

No results are presently available.

7.5.9.4 Results of Data Collected to Date

No results are presently available.

Data Sources

No results are presently available.

Calculation Approach

Without internal knowledge of how incremental load reductions affect PJM congestion costs, this analysis cannot be performed.

7.5.10 CO_2 Emissions – Project Area (M32-VVC)

7.5.10.1 Objective

DA-VVC has the potential to dynamically control voltage and power factors on feeders to reduce customer energy consumption and losses. This reduced demand can result in energy conservation, reduced costs, deferred capital investments, extended equipment life, and reduced fuel consumption. The reduction in energy consumption from DA-VVC is expected to have a direct impact on reduced CO_2 emissions through a reduction in emissions from power generation plants. This impact metric presents the CO_2 emissions reduction as a function of conserved energy in the Project area.

7.5.10.2 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

7.5.10.3 Organization of Results

The following section provides an estimate of CO_2 reduction due to the reduction in energy use associated with the DA-VVC system. Positive numbers indicate a reduction in CO_2 emissions.

7.5.10.4 Results of Data Collected to Date

The results below quantify the impact metric for this section.

Presentation of CO_2 Avoided:

Total energy usage avoided during DA-VVC day-on/day-off experiments: 3,912 MWh
Total CO_2 emissions avoided during DA-VVC day-on/day-off experiments: 2,679 Metric Tons

Energy avoided if DA-VVC had been on continuously throughout 2012: 36,016 MWh
CO_2 avoided if DA-VVC had been on continuously throughout 2012: 24,835 Metric Tons

Calculation Approach

Energy reduction due to DA-VVC was estimated for each DA-VVC circuit during times when the system was operated in a day-on/day-off experimental fashion. This estimation is explained under M13 Distribution Feeder Load.

Since the AEP Ohio day-on/day-off experiment only operated over a subset of the year, roughly 10.9 percent of circuit load readings produced load reduction estimates. In order to accurately convey the potential energy savings associated with DA-VVC, these load reduction values were then extrapolated to the full number readings in a year in order to calculate what the load reduction would have been if the DA-VVC systems were simply enabled for all time during the year.

CO_2 avoided due to DA-VVC was then calculated by multiplying load reduction by a typical generation emissions factor of 0.68956 metric tons per MWh.

7.5.11 Pollutant Emissions – Project Area (SO_X, NO_X, $PM_{2.5}$) (M33-VVC)

7.5.11.1 Objective

DA-VVC has the potential to dynamically control voltage and power factors on feeders to reduce customer energy consumption and losses. This reduced demand can result in energy conservation, reduced costs, deferred capital investments, extended equipment life, and reduced fuel consumption. The reduction in energy consumption from DA-VVC is expected to have an impact on reduced pollutant emissions through a reduction in emissions from power generation plants. This impact metric presents the pollutant emissions reduction as a function of conserved energy in the Project area.

7.5.11.2 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

7.5.11.3 Organization of Results

The following section provides an estimate of pollutant reductions due to the reduction in energy use associated with the DA-VVC system. Positive numbers indicate a reduction in pollutant emissions.

7.5.11.4 Results of Data Collected to Date

The results below quantify the impact metric for this section.

Results for Pollutants Avoided:

Total energy usage avoided during DA-VVC day-on/day-off experiments: 3,912 MWh
Total NOx emissions avoided during DA-VVC day-on/day-off experiments: 4,613 kg
Total $PM_{2.5}$ emissions avoided during DA-VVC day-on/day-off experiments: 3,912 kg
Total SO_X emissions avoided during DA-VVC day-on/day-off experiments: 10,291 kg

Energy avoided if DA-VVC had been on continuously throughout 2012: 36,016 MWh
NOx avoided if DA-VVC had been on continuously throughout 2012: 42,475 kg
$PM_{2.5}$ avoided if DA-VVC had been on continuously throughout 2012: 36, 016 kg
SO_X avoided if DA-VVC had been on continuously throughout 2012: 94, 753 kg

Calculation Approach

Energy reduction due to DA-VVC was estimated for each DA-VVC circuit during times when the system was operated in a day-on/day-off experimental fashion. This estimation is explained under M13 Distribution Feeder Load.

Since the AEP Ohio day-on/day-off experiment only operated over a subset of the year, roughly 10.9 percent of circuit load readings produced load reduction estimates. In order to accurately convey the potential energy savings associated with DA-VVC, these load reduction values were then extrapolated to the full number readings in a year in order to calculate what the load reduction would have been if the DA-VVC systems were simply enabled for all time during the year.

NO_X avoided due to DA-VVC was then calculated by multiplying load reduction by a typical generation emissions factor of 1.17934 kg per MWh.

$PM_{2.5}$ avoided due to DA-VVC was then calculated by multiplying load reduction by a typical generation emissions factor of 1.0 kg per MWh.

SO_X avoided due to DA-VVC was then calculated by multiplying load reduction by a typical generation emissions factor of 2.63084 kg per MWh.

7.5.12 CO_2 Emissions – System Area (M34-VVC)

7.5.12.1 Objective

DA-VVC has the potential to dynamically control voltage and power factors on feeders to reduce customer energy consumption and losses. This reduced demand can result in energy conservation, reduced costs, deferred capital investments, extended equipment life, and reduced fuel consumption. The reduction in energy consumption from DA-VVC is expected to have a direct impact on reduced CO_2 emissions through a reduction in emissions from power generation plants. This impact metric presents the CO_2 emissions reduction as a function of conserved energy in the System area.

7.5.12.2 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

7.5.12.3 Organization of Results

The following section provides an estimate of potential CO_2 reduction due to the reduction in energy use associated with the DA-VVC system. These results are an extrapolation to the AEP Ohio System area based on energy reductions observed in the Project area. Positive numbers indicate a reduction in CO_2 emissions.

7.5.12.4 Results of Data Collected to Date

The figures on the following pages quantify the impact metric for this section.

Presentation of CO_2 Avoided:

System extrapolation of DA-VVC energy reduction: 906,125 MWh
System extrapolation of DA-VVC CO_2 emissions avoided: 624,827 Metric Tons

Calculation Approach

Energy reduction due to DA-VVC was estimated for each DA-VVC circuit during times when the system was operated in a day-on/day-off experimental fashion. This estimation is explained under M13 Distribution Feeder Load.

Since the AEP Ohio day-on/day-off experiment only operated over a subset of the year, roughly 10.9 percent of circuit load readings produced load reduction estimates. In order to accurately convey the potential energy savings associated with DA-VVC, these load reduction values were then extrapolated to the full number readings in a year and to the full number of circuits in the AEP Ohio System area in order to calculate what the potential load reduction would be if DA-VVC systems were installed system-wide and operated continuously.

CO_2 avoided due to DA-VVC was then calculated by multiplying extrapolated energy reduction by a typical generation emissions factor of 0.68956 metric tons per MWh. To determine the CO_2 reductions that would have been obtained if the entire AEP Ohio System area had deployed DA-VVC for all of 2012, the Project area reductions are multiplied by a factor of 25.159, which is the ratio of total energy in the system to energy in the DA-VVC circuits.

7.5.13 Pollutant Emissions – System Area (SO_X, NO_X, $PM_{2.5}$) (M35-VVC)

7.5.13.1 Objective

DA-VVC has the potential to dynamically control voltage and power factors on feeders to reduce customer energy consumption and losses. This reduced demand can result in energy conservation, reduced costs, deferred capital investments, extended equipment life, and reduced fuel consumption. The reduction in energy consumption from DA-VVC is expected to have a direct impact on reduced pollutant emissions through a reduction in emissions from power generation plants. This impact metric presents the pollutant emissions reduction as a function of conserved energy in the System area.

7.5.13.2 Organization of Results

The following section provides an estimate of potential pollutant reduction due to the reduction in energy use associated with the DA-VVC system. These results are an extrapolation to the AEP Ohio System area based on energy reductions observed in the Project area. Positive numbers indicate a reduction in pollutant emissions.

7.5.13.3 Assumptions

This section contains assumptions made when collecting, analyzing, and presenting the data. A full list of assumptions will be provided in the Final Report.

7.5.13.4 Results of Data Collected to Date

The results below quantify the impact metric for this section.

Presentation of CO_2 Avoided:

System extrapolation of DA-VVC energy reduction: 906,125 MWh
System extrapolation of DA-VVC NO_X emissions avoided: 1,068,629 kg
System extrapolation of DA-VVC $PM_{2.5}$ emissions avoided: 906,125 kg
System extrapolation of DA-VVC SO_X emissions avoided: 2,383,869 kg

Calculation Approach

Energy reduction due to DA-VVC was estimated for each DA-VVC circuit during times when the system was operated in a day-on/day-off experimental fashion. This estimation is explained under M13 Distribution Feeder Load.

Since the AEP Ohio day-on/day-off experiment only operated over a subset of the year, roughly 10.9 percent of circuit load readings produced load reduction estimates. In order to accurately convey the potential energy savings associated with DA-VVC, these load reduction values were then extrapolated to the full number readings in a year and to the full number of circuits in the AEP Ohio System area in order to calculate what the potential load reduction would be if DA-VVC systems were installed system wide and operated continuously.

NO_X avoided due to DA-VVC was then calculated by multiplying load reduction by a typical generation emissions factor of 1.17934 kg per MWh.

$PM_{2.5}$ avoided due to DA-VVC was then calculated by multiplying load reduction by a typical generation emissions factor of 1.0 kg per MWh.

SO_X avoided due to DA-VVC was then calculated by multiplying load reduction by a typical generation emissions factor of 2.63084 kg per MWh.

To determine the pollutant reductions that would have been obtained if the entire AEP Ohio System area had deployed DA-VVC for all of 2012, the Project area reductions are multiplied by a factor of 25.159, which is the ratio of total load in the system to load in the DA-VVC circuits.

7.6 DA-VVC Observations

This section contains observations of the technology to date. Conclusions will be provided in the Final Report.

DA-VVC is estimated to provide approximately a 3 percent reduction in feeder load, across all DA-VVC feeders. However, due to the inherently noisy nature of load, as well as the sample of data collected to date, the results are not yet statistically significant. For the Final Report, additional data and analysis is expected to increase the confidence in the measurement of impacts for DA-VVC.

Capacity deferrals are dependent on the initial loading of the circuits where DA-VVC is installed, as well as load growth. Since load growth has been flat or negative during the Project time period, and the circuits where DA-VVC was installed were not already overloaded or scheduled for upgrades, there have been no capacity deferrals for these specific circuits.

Due to the small size of the data set, no statistically significant trends in equipment failure rate are apparent. There is no evidence of a large increase or decrease in failure events attributable to DA-VVC to date.

For the majority of circuits, the non-AMI metered load is reduced slightly during the DA-VVC day-on periods. This reduction is associated with both losses and reductions in other non-AMI metered loads (e.g. street lights). The Final Report will include the full distribution of reductions in non-AMI metered load, as well as an assessment of seasonal, weather, and other variations, based on comparisons with baselines for all circuits.

The overall power factor across all circuits does not significantly improve in terms of pure distance from unity power factor, however – although this measure has not been adjusted for any load, weather, or seasonal factors. The Final Report will incorporate summary statistics across all DA-VVC circuits of the power factor impacts.

Preliminary assessments indicate that during the DA-VVC day-on/day-off experiment 2,679 Metric Tons of CO_2 were avoided, and that if DA-VVC were active during the entire year for the 17 demonstration circuits, an estimated 25,000 Metric Tons of CO_2 would have been avoided in 2012. This metric will be updated when more accurate assessment of energy conservation can be completed.

Preliminary analysis indicates that using DA-VVC full time for the Project circuits would result in an estimated annual reduction of 42,000 kg of NO_X, 36,000 kg of $PM_{2.5}$, and 95,000 kg of SO_X during 2012. This metric will be updated as a more accurate assessment of energy reductions is completed.

8 DEMONSTRATED TECHNOLOGY – COMMUNITY ENERGY STORAGE

8.1 PURPOSE

Community Energy Storage (CES) units are small-scale energy storage devices that are designed to connect to distribution transformers adjacent to consumers' properties. These units provide numerous benefits, such as peak load leveling, Volt VAR (reactive power) support, and increased reliability to consumers through backup power. They can also provide frequency regulation benefits when aggregated.

The most visible benefit to consumers will be the backup power feature when their main power source goes out. In these situations, the transition to backup power can happen so quickly that the consumer may not even be aware of the interruption.

8.2 TECHNOLOGY

AEP Ohio selected CES units containing lithium-ion batteries and power controller systems, provided by S&C Electric Company (S&C). AEP Ohio chose lithium-ion batteries to leverage the quantities and potential price reductions from the electric vehicle industry. The planned deployment also included a Distributed Energy Management (DEM) controller to aggregate the output of all CES units to provide up to 2 Megawatts (MW) of benefits to the utility.

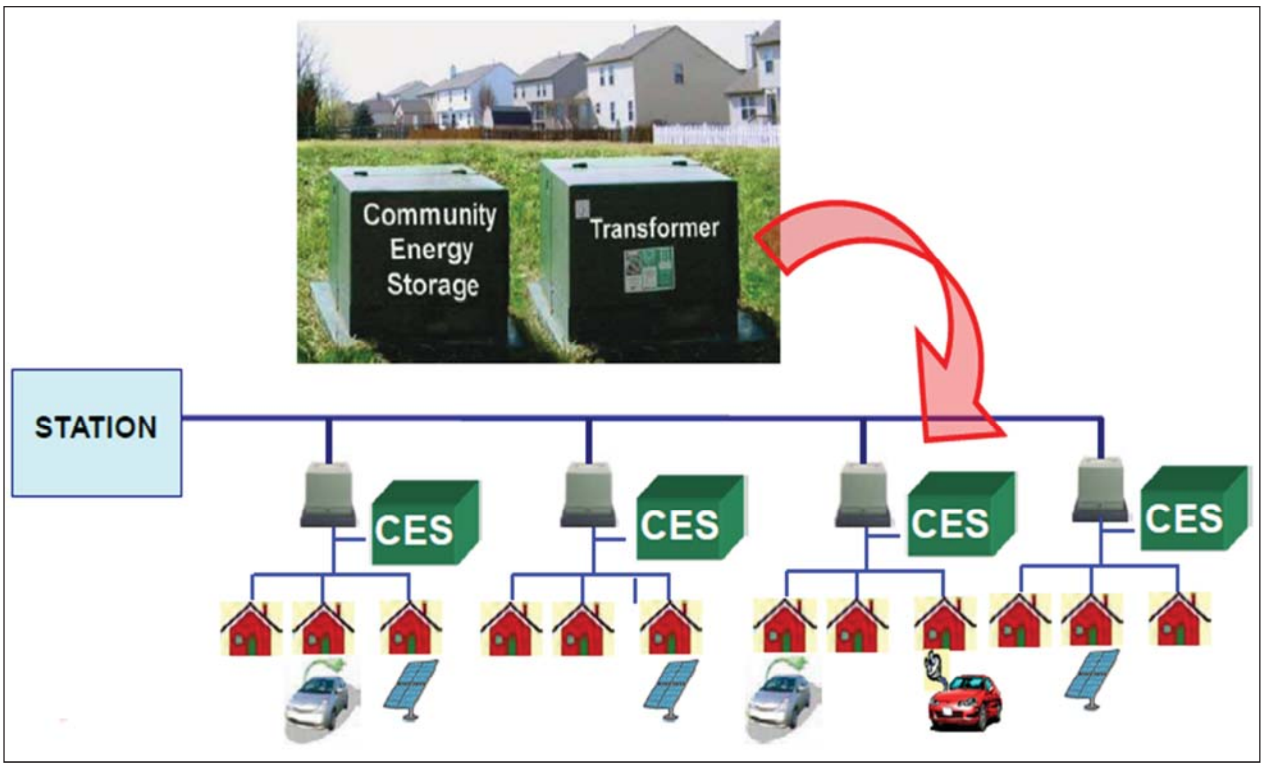


Figure 142. Typical CES Installation

8.3 Implementation and Approach

Originally, AEP Ohio planned on deploying 80 CES units in the Project area. Prior to deploying CES units, AEP Ohio and S&C performed extensive testing at AEP's Dolan Labs Research Center and at S&C's facility. After initial testing, AEP Ohio began field installations and commissioned 15 CES units into operations by December 31, 2011. Following this deployment, technical issues were discovered and the CES units were not performing to AEP Ohio's stringent standards. The CES units were removed from the field and returned to S&C.

AEP Ohio has continued to work closely with S&C to remedy technical issues and enhance the design and functionality of the CES units.

This component of the Project has been redefined to include a limited deployment of four CES units at an outdoor test environment on AEP Ohio property to continue extensive testing.

9 DEMONSTRATED TECHNOLOGY – ELECTRIC VEHICLES

9.1 PURPOSE

The introduction of electric vehicles into the consumer market has raised questions around grid and load preparedness for mass market adoption. AEP Ohio set out to gain a better understanding of the charging behavior of drivers of electric vehicles and to explore how consumer programs, Electric Vehicle Supply Equipment (EVSE) locations, and supply level affect users' charging behavior. AEP Ohio also examined the impact that electric vehicles may have on the utility system.

9.2 TECHNOLOGY

AEP Ohio deployed ten plug-in electric vehicles (PEV), nine Chevrolet Volts and one CODA; and one Ford Escape modified to be a plug-in hybrid electric vehicle (PHEV). Two battery electric vehicle (BEV) smart cars were also originally deployed, but were withdrawn from the program due to ongoing mechanical issues.

AEP Ohio deployed 36 EVSE charging stations in residential, workplace, and public locations. Level 1 chargers usually are provided by vehicle manufacturer and utilize a standard electrical outlet. AEP Ohio selected Ecotality's Blink EVSE as the Level 2 charger. Level 2 chargers are available in both wall mount and pedestal models, require installation, and utilize a 240 volt AC input electrical outlet. On average, a Volt requires 10 hours to fully charge on a Level 1 station and 3 ½ hours on a Level 2 charging station. Finally, AEP Ohio collaborated with EPRI to implement a data collection module to monitor vehicles and chargers.

9.3 IMPLEMENTATION AND APPROACH

AEP Ohio reviewed various vehicle manufacturers to evaluate all technologies. However, due to market penetration and vehicle availability, AEP Ohio was limited in vehicle options. Mechanical issues sidelined the BEV vehicles. Nissan Leaf vehicles were not included because the Leaf was not released in the Ohio market at the time of implementation.

AEP Ohio also explored the installation process of EVSE infrastructure. AEP Ohio chose participants with a wide range of demographics for the residential installations, including a residential apartment complex. AEP Ohio provided an AMI check meter for all installations to compare actual charging statistics to manufacturer accuracy claims. Most of the residential installations were non-billing meters; but two participants received actual EVSE billing meters. One participant had a second meter installed in parallel to the residential meter, and the other had the meter installed in an apartment complex. This allowed AEP Ohio to test the internal setup processes for meter and billing data detail and helped with present-day rate determinations.

AEP Ohio provided Level 1 and 2 workplace charging stations in multiple locations to determine consumer preferences with regard to charging level. AEP Ohio installed a meter at each charging station to capture charger usage at the workplace stations. AEP Ohio also collaborated with two commercial participants to create free public EVSE stations to promote the new technology. AEP Ohio managed the installation process for both locations. In addition, AEP Ohio worked with various government entities regarding building code issues. Because the technology is new, educating the building code inspection agencies was a requirement for installation approvals.

AEP Ohio will collaborate with The Ohio State University to analyze data from this technology.

9.4 PEV OBSERVATIONS

At the time of this Interim Report, no data is available. Conclusions will be provided in the Final Report.

10 DEMONSTRATED TECHNOLOGY – REAL-TIME PRICING WITH DOUBLE AUCTION

10.1 PURPOSE

The Real-Time Pricing with double auction (RTP_{da}) research project is a collaborative project among AEP, AEP Ohio, Battelle, Itron, and Pacific Northwest National Lab.

RTP_{da} allows consumers that participate in the SMART Choice program to take advantage of fluctuating electric prices throughout each day of the year. Feeder-based auctions are held for each five-minute usage interval. As a consumer program, RTP_{da} offers an approach for consumers of electricity to effectively manage power generation, transmission, and distribution in a more intelligent manner. As an alternate rate plan, RTP_{da} offers a complete demand response system that collects Pennsylvania, New Jersey, Maryland Interconnection, LLC (PJM) pricing, energy usage, and customer data, and then generates a priced based on a "double-auction" concept. The consumer's internal equipment then reacts to pricing changes based on consumer-defined equipment settings. Customers enrolled in RTP_{da} are given two new pieces of hardware: a Home Energy Manager (HEM) and an enhanced Programmable Communicating Thermostat (ePCT). The HEM is the central premise controller that executes algorithms and commands. It also monitors and controls the ePCT within the home according to consumer-selected settings of comfort versus savings, and set-up and set-back, and it also communicates with the AMI meter at the home and with the Smart Grid Dispatch (SGD) system at AEP's operations center.

Throughout the operations phase of the Project, RTP_{da} analysis was conducted in an effort to assess the impacts and effectiveness of the research project based on the following objectives:

- Identify reductions and changes in usage patterns;
- Determine benefits for both customer and utility;
- Determine predictable peak demand reduction;
- Determine ability to manage distribution feeder congestion;
- Determine ability to participate in PJM market;
- Determine technical and operational feasibility of a large scale deployment; and
- Assess lessons learned, technical and operational gaps, and overall customer experience and satisfaction.

10.2 TECHNOLOGY

The RTP_{da} program is a complex coupling of several different internal and external systems and data sources tied together for the very first time. Many of the systems and data flows are inter-dependent and all must function in order for the entire program to run properly. Figure 143 illustrates the systems and data involved in the program.

.

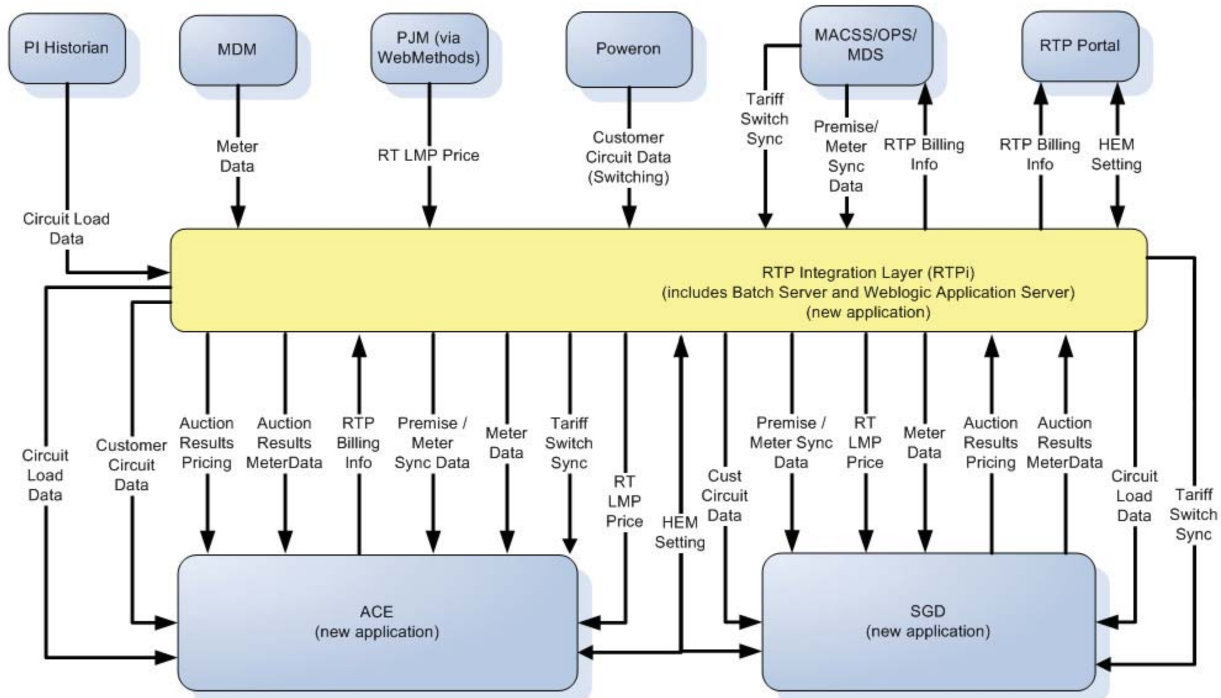


Figure 143. RTP$_{da}$ System Data Flow

10.2.1 Real Time Pricing Integration Layer

The Real-Time Pricing Integration Layer (RTPi) is critical to all RTP$_{da}$ functions. All system communications, with the exception of a cycle-based MACSS and Meter Data Management (MDM), communicate through the RTPi. The RTPi contains both batch and Weblogic application servers. A series of "topics" route different types of data between different systems. Adapters allow communication between different systems. These adapters retrieve information from several different sources and transform it to a format used by different target systems, allowing connections to be made between systems. A succession of several interfaces to accomplish a task is a "connection." For example, to get meter reading data from MDM to AEP Cost Engine (ACE), several different interfaces complete the connection from MDM to ACE; the MDM to RTPi interface, then the data transformation, and then the RTPi to ACE interface.

10.2.2 Smart Grid Dispatch

SGD is an external application created by Battelle. It performs a variety of functions within the RTP$_{da}$ program. All HEM commissioning is processed through the SGD application. SGD also receives all energy prices from PJM. These prices are used in the ongoing SGD auctions. SGD also receives the interval data from the meters to determine a cumulative projected demand for a feeder. This is used in the equation to determine auction prices. SGD must be synchronized with MACSS, MDM, and other internal applications to function properly.

SGD manages 288 auctions each day for each feeder in the Project area. The auction schedule is controlled by a clustered Quartz (Cron) job. Each auction begins one second after the previous auction ended for each feeder. The SGD PMC allows users to control different offset settings for these auctions.

At the onset of each auction, SGD gathers all parameters required to conduct an auction. It then obtains variable values and demand and supply bids, and executes an algorithm that calculates a sell bid for each feeder.

10.2.3 AEP Cost Engine

AEP Cost Engine (ACE) application is responsible for calculating the kWh and energy charge amounts for monthly customer bills. It sends this information to MACSS, which does final bill calculation. In order to do this, SGD sends ACE the following information:

- Circuit load
- Customer circuit
- Real-Time (RT)- Location Marginal Price (LMP) price
- Tariff
- Auction results

For each billing cycle, ACE is called when billing a customer with the 045 tariff. It then provides the detailed cost information to MACSS for inclusion on the bill.

AEP Ohio also created a graphical user interface for ACE to allowing the billing operations staff to adjust energy costs when errors occur.

10.2.4 Home Energy Manager

The HEM is a piece of hardware installed in the consumer's home and communicates with the SGD throughout the day. Because SGD is housed within the AEP firewall, HEM to SGD communication is heavily secured. Security Sockets Layer (SSL) technology is utilized to translate encrypted HEM packet data. For each HEM, AEP creates a unique security certificate. The list of security certificates is maintained on the network and accessed each time a HEM attempts to connect to the AEP network. A certificate revocation list is also consulted each time a HEM attempts to access the AEP network.

Each HEM bids for energy for each auction. The bid that each HEM makes for energy is a critical part of determining the clearing price of an auction. The sum of the HEM bids for a particular feeder equal the "demand" part of the clearing price equation. Each HEM bases its bid on a complex equation that looks at power use from the prior period, target setting of the ePCT and the current home temperature.

10.2.5 Auction Process

After installation and commissioning, the customer is placed on the correct RTP_{da} tariff category and begins participating in energy auctions. The auctions are a result of a complex formula that determines demand for a given feeder in the Project area and the price of wholesale electricity from PJM. For each feeder, AEP generates a virtual price and demand graph, which identifies the clearing price for each 5-minute increment for the feeder, as shown in Figure 144. The SGD is responsible for conducting these price auctions every 5 minutes of every day.

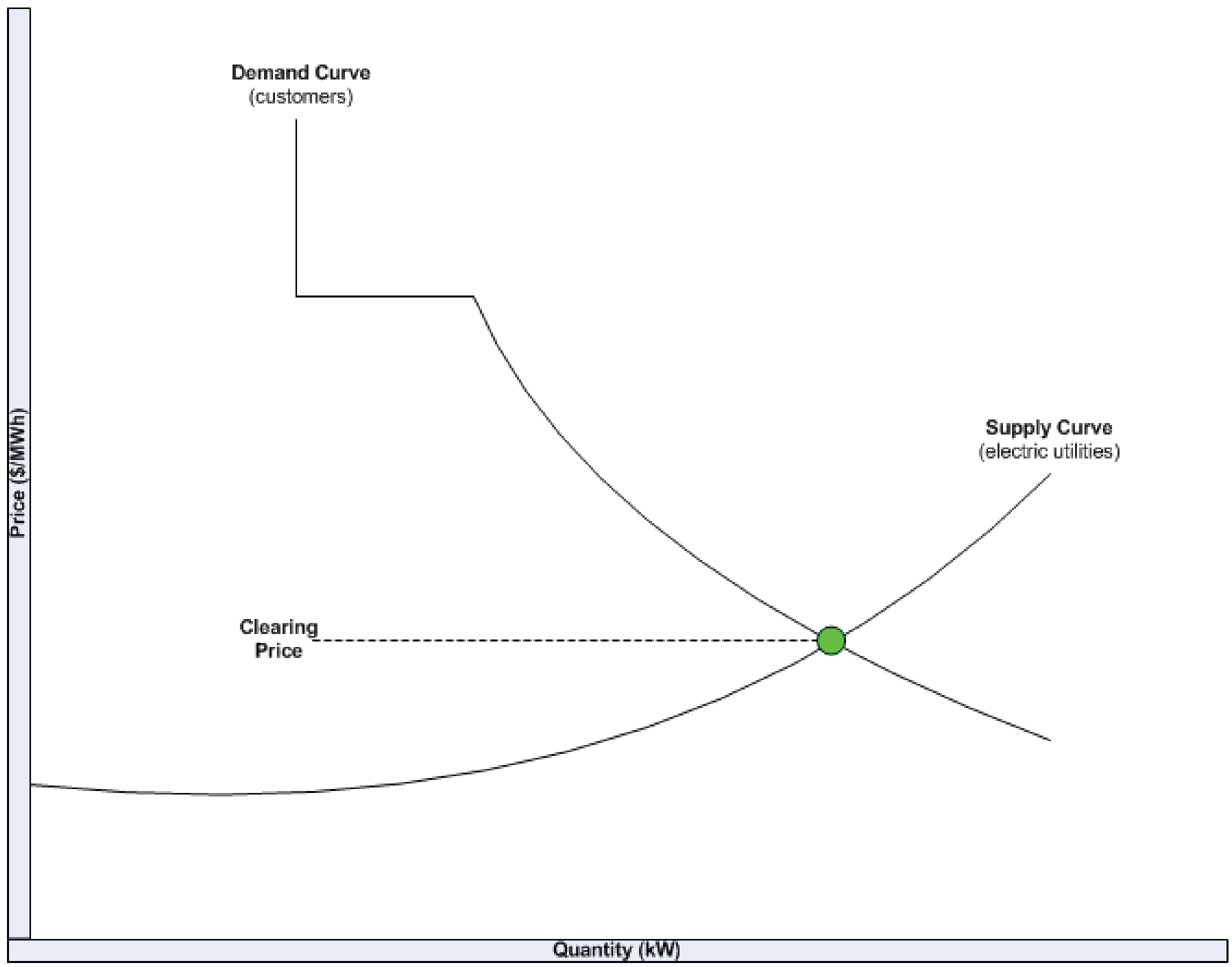


Figure 144. RTP_{da} Auction Clearing Price

When demand on a feeder is high, the energy price rises. The HEM has a control that consumers can set anywhere on a sliding scale between "comfort" and "savings." During times of high power prices, the HEM can automatically adjust the settings on the ePCT to lower the consumer's energy use if the consumer has selected a setting on the "savings" side of the scale. If the control is set to the "comfort" side, little to no changes to the desired temperature will be made during a time of high demand/pricing.

10.3 Implementation and Approach

Due to the complexity of the program, AEP Ohio elected to test the technology with employees located within the Project area before rolling it out to the general population. In fact, AEP created a fully-functional internal test environment prior to releasing the program. This internal environment, the Virtual Operations Test (VOT) environment, allowed AEP Ohio to develop and test this new technology prior to any actual installations occurring.

After successful implementation of the program in the VOT environment, AEP Ohio installed the supporting devices in the homes of participating AEP and AEP Ohio employees. Thereafter, non-employee customers were enrolled in RTP_{da}.

10.4 Analysis

For purposes of this Interim Report, no impact data are available. Analysis will be provided in the Final Report.

11 DEMONSTRATED TECHNOLOGY – INTEROPERABILITY

11.1 PURPOSE

AEP Ohio recognizes interoperability (IOP) as the capability of systems or units to provide and receive services and information between each other. IOP also uses the services and information exchanged to effectively operate together in predictable ways without significant user intervention, with the understanding that these interfaces are based on openly available standards or are made openly available to the smart grid community and supported by multiple, capable vendors.

The purpose of the Project was to give consumers the tools they needed to monitor and reduce their energy usage. By leveraging the benefits of AMI meters and circuit reconfiguration, all parties were able to benefit from the evaluation of new technologies, such as electric vehicles and smart appliances, as well as overall system improvements in energy efficiencies. This Project explored opportunities in this area by integrating commercially available products, new technologies, and new consumer products and services within a single, secure, two-way communication network between the utility and consumers. By combining lab tests of these technologies with field trials by actual consumers, the Project verified the adequacy of the technologies and their ability to interoperate.

In order to further the objective of demonstrating smart grid interoperability, the interoperability activity within the Project prescribed the specific steps undertaken to validate the interoperability of Project components and consequently, identify gaps in the current and proposed standards. The primary goal of the Interoperability activity was to provide an in-depth response to the interoperability objectives listed in the Statement of Project Objectives (SOPO), which required:

- A summary of the information exchange interfaces for communicating automation devices and systems (i.e., their points of connection with other elements of the system).
- A summary of how the Project provided openly available and proprietary aspects of the interface specifications, and how existing (legacy) communicating devices or systems were integrated into the Project.
- A summary of how the Project addressed response to failure and device upgrade scenarios, to mitigate impacts on the overall system.
- A summary of how the Project supported compatibility with the National Institute of Standards and Technology's (NIST) emerging smart grid framework for standards and protocols.

11.2 TECHNOLOGY

Interoperability is not a technology to be implemented, but rather a goal to be accomplished. The Interoperability plan for the Project was outlined to accomplish two goals. The first goal was to develop a plan to utilize to ensure interoperability between all systems, devices and data sources. The second goal was to document the extent to which the first goal was accomplished.

For the interoperability of the back office, the primary goal was to implement systems in such a way to protect against cascading failures. To accomplish this, the team implemented a communication standard and drove compliance to that standard. AEP Ohio engaged EPRI to assist in creating our interoperability plan. For this exercise, the team defined an interface as "a pairing of systems or actors." This resulted in the creation of many use cases for the 100+ gridSMART interfaces.

11.3 Implementation and Approach

The interoperability test plan was organized by topic area, such as Demand Response, Distribution Grid Management, AMI, etc. Each topic area contained a set of use cases analyzed to discover the number and purpose of interfaces that each involved. Each interface was then assessed in terms of whether a relevant standard existed, with particular emphasis being placed on the standards enumerated in NIST Special Publication 1108, "NIST Framework and Roadmap for Smart Grid Interoperability Standards." In addition, the interfaces were assessed by whether the relevant standards were implemented by the company and/or by its vendors in a manner that could be tested for standards compliance.

The Project's two-phase testing approach combined lab and field testing to obtain a complete evaluation of the Project. The first phase involved extensive lab testing of the technologies by exercising their full range of functions. The second phase involved field tests with a limited base of customers. This approach determined the functionality, reliability, security and overall system interoperability of the Project.

Because several different technologies were affected by interoperability, there is not a single approach for the cumulative group. Each Project technology area had a unique approach for implementing interoperability. However, some common themes prevailed through most of the Project area, such as CIM messaging and a thorough vendor selection process. The following sections cover both the back-office and field approaches to interoperability. Approach details on common and specific areas follow in this report.

11.3.1 Common Information Model Compliant Messaging

Common Information Model (CIM) compliant messages were implemented across several Project topic areas as a means of communication between systems. By implementing CIM-compliant messaging, a standard message format was created to exchange information between new and legacy systems, allowing for interoperability beyond AEP systems. This was part of the back-office strategy for interoperability.

11.3.2 Intelligrid

Intelligrid methodology provided a conceptual architecture that was implemented within platform-independent solutions.

AEP Ohio scoped and defined its interoperability test plan by means of the EPRI IntelliGrid methodology, with specific roadmaps for smart grid development and deployment. The IntelliGrid methodology starts with a conceptual architecture and then moves to development of a platform-independent architecture that provides a basis for integrating actual applications. The ultimate goal is architecture with vendor-specific aspects, but with the ability to plug in many different vendor applications as a result of industry interface standards. Legacy systems and technology are integrated via appropriate gateways and translators.

11.3.3 Advanced Metering Infrastructure

Interoperability for AMI consisted of lab testing and field analysis of the AMI network; from the UIQ user interface to the individual meters. This included access points and relays. Due to the proprietary nature of the UIQ system, interoperability testing was limited to the semantic response of the meters based on a specific user input within UIQ.

Within the meters, AEP Ohio analyzed the serial communications between the SSN network interface card and the GE metrology to verify basic connectivity and syntactic interoperability. This allowed us to document the use of ANSI C.12.18 and C.12.19 standards, as identified by NIST.

The field testing aspect of AMI interoperability focused on interoperability within the AMI network that is deployed in the Project area. AEP Ohio also tested other utility and consumer-owned devices that demonstrated possible interference issues during and after deployment.

11.3.4 Home Area Network/Internet Gateway

The Home Area Network (HAN) and Internet Gateway (IG) interoperability end-to-end lab testing was performed during the initial phase of the Project. It measured system responsiveness against the SOPO criteria and referenced the GridWise Architecture Council (GWAC) stack as it applied to semantic understanding, syntactical meaning, network interoperability, and basic connectivity.

The interoperability of the HAN and IG technologies underwent an end-to-end functionality test between communicating consumer electronic devices and the utility's back-office demarcation point for traditional IT applications. The communication occurred over two networks which were a proprietary AMI and a ZigBee-based HAN. For completeness, AEP Ohio tested different network topologies within the consumers' premises.

The field tests involved installation of quantities of the system components in actual consumer homes and neighboring infrastructures. AEP Ohio collected data equipment usage to determine the acceptance and interoperability of the technology in reducing peak demands.

11.3.5 Distribution Automation Circuit Reconfiguration

AEP Ohio based its approach to implementing and evaluating interoperability within the DA project on SCADA testing practices.

AEP Ohio tested the interfaces between all DA-CR devices to ensure end-to-end communication of accurate information. Each point was verified at the field device, in the substation, and in the back office at the Distribution Management System (DMS) to confirm that points were mapped appropriately within those devices. DMS also confirmed that polling was established such that data was distributed to the receiving systems within acceptable time constraints.

These tests resulted in evidence of semantic understanding and syntactic interoperability. It also, by the nature of the GWAC Interoperability Framework, produced a high level of confidence in the basic connectivity and network interoperability of the interface. The bidirectional communication of understood content allowed for the successful operation of the DA systems.

11.3.6 Volt VAR

AEP Ohio deployed and evaluated two separate DA-VVC systems. Both were evaluated for performance and interoperability.

The first was the General Electric Coordinated Volt VAR Control (CVVC) system, which utilizes controllers in the distribution stations that communicate with and control all regulators and capacitor banks on the distribution circuits associated with each substation.

The second system was the PCS Utilidata Adaptivolt system, which uses a controller located at the Gahanna substation to control all regulators and capacitor banks on 13kV Gahanna circuits.

AEP Ohio examined the interoperability of both systems with all devices with which they communicate. This included field devices such as capacitor banks, regulators, and end-of-line voltage monitors. All field communications occurred via a wireless connection. Substation-based devices, such as remote terminal units, substation capacitor banks, substation regulators, and circuit reconfiguration controllers, all communicate via wireless or wired networks. Finally, back-office systems were reached via backhaul communications.

11.3.7 RTP_{da}

Interoperability was a significant part of RTP_{da}. In order for the system to function, all pieces of the system must be in regular communication with one another.

The Integration Layer (RTPi) served as a central data collection and mediation point for most of the interfaces. CIM-compliant messaging was incorporated to ensure interoperability between legacy and new systems. By leveraging RTPi using CIM messaging, all interoperability was centralized and more easily tested.

AEP Ohio created a Java library to capture all CIM message definitions to ensure that all systems used the same message definitions and utilized the most current versions of the definitions.

11.4 Assessments

Where information is available, interim assessments of the interoperability effort are presented.

11.4.1 AMI

AMI interoperability involved both lab testing on an isolated test network, and field trials performed within the Project area on the network.

The lab test phase of AMI interoperability was performed on the AMI network devices to verify proper syntactic and semantic operation. Thirty I-210+c and Kv2c meters were utilized for testing with two access points and a relay for back-haul purposes.

Field testing of the AMI devices consisted of analysis of the deployed AMI system data as well as interviews with field personnel on issues encountered with the deployment. Interoperability issues encountered in the field were then recreated within the lab environment to assist in resolving any interoperability issues with existing utility and publically owned legacy devices. Due to the small sample size and pass/fail nature of the AMI testing, the Agresti-Coull interval was used for statistical analysis. Refer to figure 145 for the Agresti-Coull interval formula. This data is subject to change as testing continues.

11.4.1.1 AMI Lab Testing

Table 27 contains the results of the AMI lab testing efforts.

Samples	Success	p	Alpha	Confidence Level
1800	1606	0.892222222	0.05	0.95

	Lower Bound	Pass	Upper Bound	Margin of Error
Overall	96.1%	96.8%	97.5%	0.7%
On Demand Meter Read	98.9%	99.3%	99.8%	0.5%
	Samples	300	Success	298
Bulk Meter Read	94.5%	95.7%	96.8%	1.2%
	Samples	300	Success	287
Outage Notification	44.5%	47.3%	50.2%	2.9%
	Samples	300	Success	142
Outage Restoration	95.2%	96.3%	97.4%	1.1%
	Samples	300	Success	289
Ping	98.4%	99.0%	99.6%	0.6%
	Samples	300	Success	297
Remote Connect/Disconnect	96.8%	97.7%	98.5%	0.9%
	Samples	300	Success	293

Table 27. AMI Lab Testing Results

11.4.1.2 AMI Field Testing

AMI Field testing involved retrieving and analyzing system event data from the field to determine network performance within the context of the field deployment in order to verify semantic interoperability. Interviews were held with personnel involved with the deployment and support of the AMI network in order to pinpoint any issues encountered.

Analysis and testing is focused on answering the questions posed in the SOPO.

11.4.2 HAN

HAN interoperability testing involved both lab testing on an isolated test system and field trials performed within the Project area with devices supplied to customers. Results and analysis of each of these two types of end-to-end system tests are presented separately.

AEP Ohio used a statistical method known as the Agresti-Coull interval to interpret the gathered data. When used to analyze data sets with either small sample numbers or pass/fail proportions very close to 0 or 1, the Agresti-Coull method produces more accurate confidence interval values than the Wald interval does. For this, and other reasons, the Agresti-Coull interval method is used by NIST. The interval covered by the Agresti-Coull interval ( ) are displayed in Figure 145.

Figure 145. Agresti-Coull Interval

11.4.2.1 HAN Lab Testing

Lab testing consisted of full end-to-end system testing involving each device in a variety of configurations using a full array of test cases, which were developed in each of the following areas: connectivity, demand response/load control, pricing, metering, and text messaging. AEP Ohio tested each of the HAN devices independently, and in conjunction with other devices, to gain a thorough understanding of each device and its integration into the system.

Results of these tests are organized in three ways and presented in Table 28, Table 29, and Table 30. Each table provides separate results for the various categories covered. The results for each category include: total number of tests (e.g. Samples), number of tests which passed (e.g. Successes), calculated pass percentage (i.e. Pass), 95 percent confidence level statistical limits for this pass percentage (e.g. Lower Bound and Upper Bound), and margin of error on these calculations (e.g. MOE).

Table 28 presents the test results grouped by functional cluster. The five function sets listed above correspond to some of the ZigBee Smart Energy 1.1 clusters. The connectivity cluster includes test cases to examine the ability of the HAN Devices to recover from failure. Each test case targets one of these clusters so that all test runs using a particular test case are grouped together in this table.

This data is subject to change as testing continues.

Samples	Success	P	Alpha	Confidence Level
2124	1725	0.812146893	0.05	0.95

	Lower Bound	Pass	Upper Bound	MOE
Overall	79.5%	81.2%	82.8%	1.7%
Connectivity	16.7%	25.8%	37.4%	10.9%
	Samples	66	Success	17
DRLC	89.8%	91.9%	93.6%	1.9%
	Samples	777	Success	714
Pricing	73.5%	76.6%	79.5%	3.0%
	Samples	757	Success	580
Metering	30.0%	66.7%	90.3%	49.5%
	Samples	6	Success	4
Messaging	75.4%	79.2%	82.4%	3.5%
	Samples	518	Success	410

Table 28. HAN IOP Lab Results by Cluster

Table 29 presents the test results grouped by actor, the system component most responsible for the test failure. Most of the test runs involved all four of the actors listed. For each failed test, AEP Ohio assigned responsibility for the failure to just one of these four actors. Even in cases where multiple actors contributed to the overall failure, AEP Ohio chose the single most significant contributor. This data is subject to change as testing continues.

Samples	Success	P	Alpha	Confidence Level
2124	1725	0.812146893	0.05	0.95

	Lower Bound	Pass	Upper Bound	MOE
Overall	79.5%	81.2%	82.8%	1.7%
ESI	98.8%	99.2%	99.5%	0.4%
	Samples	2124	Success	2108
Back-Office / AMI	94.2%	95.2%	96.0%	0.9%
	Samples	2118	Success	2016
Zigbee Connection	98.7%	99.2%	99.5%	0.4%
	Samples	2124	Success	2106
HAN Device	86.2%	87.7%	89.0%	1.4%
	Samples	2124	Success	1863

Table 29. HAN IOP Lab Results by Actor

Table 30 presents more details on the HAN device category of the previous table. Here, HAN device test results are separated according to which specific HAN device was involved. HAN devices include PCTs, IHDs, LCSs, smart appliances, and HEMs. Although tests are most often performed with a single HAN device in the system, a second HAN device may be included as an instrument. When the system contains only one HAN device, the system is considered to be in Configuration A. When the system contains two HAN devices, one as a device under test and the other as an instrument, the system is considered to be in Configuration B. This data is subject to change as testing continues.

Device	Row	Lower Bound	Pass	Upper Bound	MOE
PCT1		97.8%	**99.0%**	99.6%	0.9%
		Samples	516	Success	511
PCT2		90.3%	**95.1%**	97.6%	3.8%
		Samples	144	Success	137
IHD1		**52.4%**	**57.2%**	**61.9%**	4.8%
		Samples	409	Success	234
IHD2		**67.8%**	**75.0%**	81.1%	6.8%
		Samples	160	Success	120
LCSW1		96.8%	**99.1%**	99.8%	1.5%
		Samples	223	Success	221
SA1		91.9%	**98.5%**	99.7%	4.1%
		Samples	66	Success	65
HEM1		92.4%	**95.5%**	97.4%	2.6%
		Samples	269	Success	257
HEM2		95.7%	**98.3%**	99.3%	1.9%
		Samples	232	Success	228
HEM3		**77.8%**	**85.7%**	91.1%	6.9%
		Samples	105	Success	90

Table 30. Further Break-out of HAN IOP Lab Results by Individual HAN Device

Table 30 presents more details on the HAN Device category of the previous table. Here, HAN device test results are separated according to which specific HAN device was involved. HAN devices include PCTs, IHDs, LCSs, smart appliance modules, and HEMs. Although tests are most often performed with a single HAN device in the system, a second HAN device may be included as an instrument. When the system contains only one HAN device, the system is considered to be in Configuration A. When the system contains two HAN devices, one as a device under test and the other as an instrument, the system is considered to be in Configuration B. This data is subject to change as testing continues.

11.4.2.2 HAN Field Trials

The field trial portion of the HAN interoperability project involved installation of HAN devices within volunteering customers' residences. Over the duration of the field trial, AEP Ohio performed a number of events for which system performance data was collected.

Analysis of this field event data is underway, with the goal of identifying statistics similar to those produced for the lab tests. Full results of this field event analysis will be included in the Final Report.

Analysis is focused on answering the following questions posed in the SOPO:

1. **DOE Requirement:** "The interacting parties' anticipated response to failure scenarios, particularly loss of communications, such that overall system impact is mitigated in the event of such failure."

   In response to this requirement, AEP Ohio will report on:

   a. Health and robustness of the HAN networks, with insights into the AMI network's effect on HAN network reliability;

   b. Success of provisioning and de-provisioning of HAN Devices, such as that which might occur after radio frequency (RF) or power loss;

   c. Hardware failures or malfunctions;

   d. Back-haul network availability; and

   e. Back-office software reliability.

2. **DOE Requirement:** "The anticipated process for upgrading devices or systems (hardware and software) so that overall system operation impact is mitigated."

   In response to this requirement, AEP Ohio will report on:

   a. Ability to successfully upgrade AMI device firmware without affecting HAN connectivity.

3. **DOE Requirement:** "The evidence that will be provided (interface specifications, interoperability test plans and results, reviews, and other engineering artifacts) to ensure interoperability at the interfaces of communicating automation devices and systems."

   In response to this requirement, AEP Ohio will report on:

   a. Success of load control events;

   b. Success of event-driven CPP events and scheduled pricing changes; and

   c. Success of text messaging events.

12 DEMONSTRATED TECHNOLOGY – CYBER SECURITY

12.1 PURPOSE

The smart grid utilizes various techniques and technologies to provide a more reliable and stable power grid. Many of the technologies used were new or redesigned and/or reprovisioned from a previous purpose. Both types introduced new risks to critical infrastructure components. The role of the cyber security technology was to ensure the security of all new and existing devices and networks. As required by the Funding Opportunity Announcement (FOA), "applicants must provide clear documentation that demonstrates that their proposed approach to cyber security will prevent broad based systemic failures in the electric grid in the event of a cyber security breach." This was accomplished by implementing security assessment processes, procedures, standards, and policies for all technology areas. Upon determining risk types and levels, AEP Ohio established acceptable levels of risk for each area, and designed, tested, and implemented strategies and mitigations.

12.2 TECHNOLOGY

The cyber security team was committed to ensuring that risk was reduced to the lowest acceptable level, not only for AEP Ohio, but also for its customers and the grid. This required extensive testing of all technologies. The following technologies were subjected to intensive cyber security testing:

- **GE i210+c Meter** – Primary meter deployed in residential applications throughout much of the demonstration area
- **GE KV2C** – Primary meter deployed in commercial establishments throughout the demonstration area
- **SSN UtilityIQ (UIQ)** – Primary control center for meter management and monitoring for AEP Ohio
- **SSN Demand Response Manager** – Provide demand response messages to specific devices within the customers' homes
- **SSN** – Provide a means to install demand response devices such as thermostats
- **Home Energy Manager (HEM) –** Provide interface to customer for the RTP_{da} program. This device received and sent signals from the customer's home to the utility.

12.3 IMPLEMENTATION AND APPROACH

AEP Ohio implemented a comprehensive cyber security plan that included a complete battery of vulnerability penetration tests starting with the meter through all points to the head-end system. The comprehensive testing strategy for the Project involved a series of steps strategically placed throughout the development and deployment cycle in the Project. The steps were as follows:

- Step 1 – Technology Review
- Step 2 – Risk Assessment
- Step 3 – Vulnerability Assessment
- Step 4 – Penetration Testing

In Step 1, which was conducted during the plan and construct phases of the Project, a technology review was completed on all technology components. This review entailed researching all of the capabilities of the product, whether there were plans to use them or not. Once the team determined the capabilities, it reviewed the products for potential points of attack. After that, it was determined whether security features were included. If security features existed, the team reviewed them to determine whether they were effective in the implementation scenarios that we planned for our environment. If risks still existed, the team determined the ability to eliminate them by disabling a feature or adding additional security features.

In Step 2, which was also conducted during the plan and construct phases of the Project, AEP Ohio conducted formal risk assessments on all technology components. These assessments reviewed each technology component in its entirety to determine the amount of risk to which AEP Ohio would be exposed from the solution or any of its components. During this assessment, the team assigned a rating to each level of risk. AEP Ohio then generated a final report and supplied it to the business unit which then reviewed it to determine the amount of acceptable risk. If the risk was determined to be too great to accept, AEP Ohio developed and implemented a remediation plan to reduce the risk to an acceptable level.

In Step 3, which was conducted at the end of the construct phase or the beginning of the test phase of the Project, AEP Ohio evaluated applications and hardware to determine if there were potential vulnerabilities in the product. AEP Ohio looked for things that could increase the possibility that the system could be attacked or breached through any of the components. In most cases, AEP Ohio used automated tools to perform these assessments, but manual testing was also completed.

Step 4 consisted of penetration testing for all technology areas. During this testing, AEP Ohio either contracted with a third party to conduct the testing; or in less resource-intensive circumstances, trained AEP personnel conducted the testing. This testing allowed AEP Ohio to validate any vulnerability not already been determined a “false positive.” A false positive is a circumstance where a vulnerability assessment identified a potential threat, but after further testing, was determined to be safe.

During Steps 3 and 4, AEP Ohio developed final reports that outlined the severity of the vulnerabilities identified and the recommended actions for remediation. If the determined risk was greater than the acceptable level, a remediation plan was developed and implemented.

AEP Ohio subjected all technology components of the Project to this complete battery of tests, including penetration testing. During this process, AEP Ohio found various vulnerabilities and risks. In the vast majority of these cases, AEP Ohio remediated or mitigated the risks. Those that are yet to be addressed are being tracked and monitored until such a time as they are deemed to no longer be a risk to the organization or are remediated.

13 COMMERCIALIZATION

13.1 PURPOSE

As part of the Project, commercialization opportunities are being assessed for a number of technologies being demonstrated in partnership* with participating companies, including the market readiness of emerging technologies, the economic impact of such commercial activities and lessons learned. A wide variety of Commercial Partners have committed to help in evaluating and advancing promising technologies. The Commercialization Working Group (AEP, AEP Ohio, Battelle, and The Ohio State University) provided a forum for sharing information necessary to complete outcome-oriented business plans that evolve and create market-ready smart grid products by including consideration of existing markets, distribution channels, and manufacturing capabilities.

The end goal is to track commercial progress of smart grid technologies, report to DOE how the AEP Ohio gridSMART Demonstration Project has accelerated commercialization of smart grid technologies, and develop a comprehensive set of market intelligence, tactical guidance, and a cost-benefit analysis for Commercial Partners based on a regulated utility market.

**Note: The use of the words 'partner' and 'partnership' herein is intended to indicate a mutually beneficial collegial relationship, rather than a partnership as defined under state law.*

13.2 CONCLUSIONS

No data are available for this Interim Report. A discussion of the conclusions will be provided in the Final Report.

14 WORKFORCE PLANNING

14.1 PURPOSE

The purpose of the workforce plan is to provide a narrative summary which outlines the construction of the workforce required to support gridSMART implementation.

The workforce plan enables AEP Ohio to understand what the workforce requirements to successfully design, operate, and maintain gridSMART and provides valuable information for future AEP gridSMART deployments.

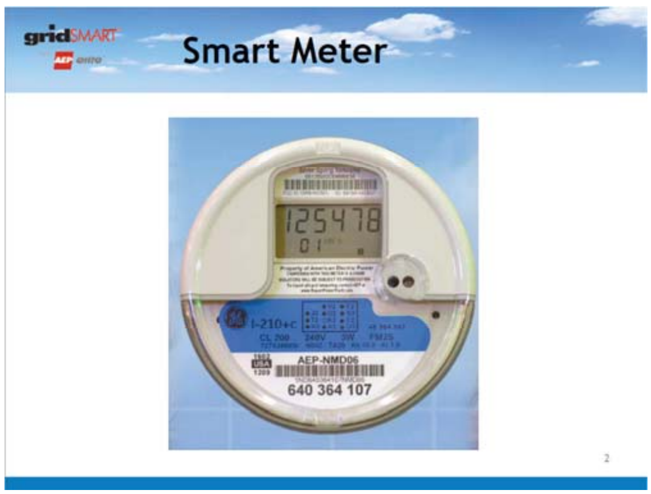
14.2 CONCLUSIONS

No data are available for this Interim Report. A discussion of conclusions will be provided in the Final Report

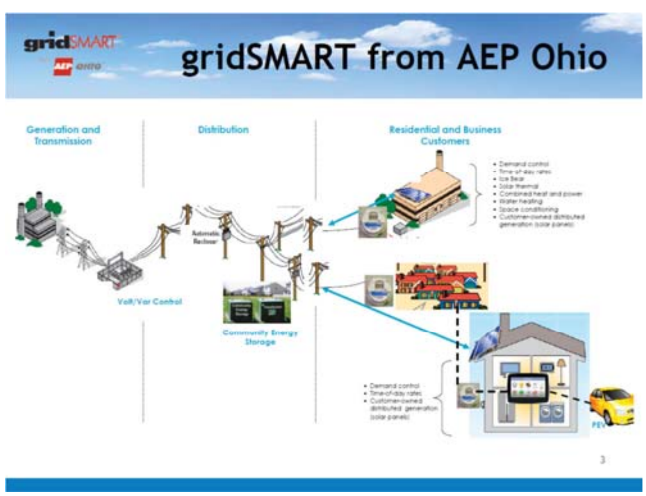
15 APPENDIX A – GRIDSMART PROGRAM OVERVIEW

A smart meter is an all-digital electric meter. Your older analog meter had spinning dials, but as you can see from the picture, a smart meter has digital numbers and no moving parts. A smart meter provides near real-time readings and secure transfer of your usage information to AEP Ohio. Customer benefits of smart meters include

- Reducing outage response time.
- Eliminating the need for monthly on-site meter readings by a meter reader.
- Providing more accurate and frequent meter readings.
- Making new pricing options possible.

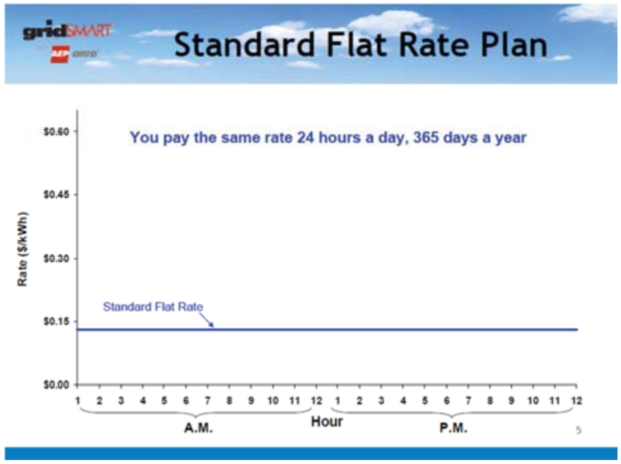


gridSMART is an AEP Ohio initiative that modernizes the electric grid to improve distribution and provides customers with better information and new ways to manage their electricity use and costs. Smart meters are the backbone of gridSMART and enable the new technology and pricing initiatives, including easy-to-use in-home display devices, electric vehicles and smart appliances.



15.1 SMART SHIFT OVERVIEW

Let's talk in a little more detail about what you now pay for the electricity delivered to your home, or the rate that you are charged.

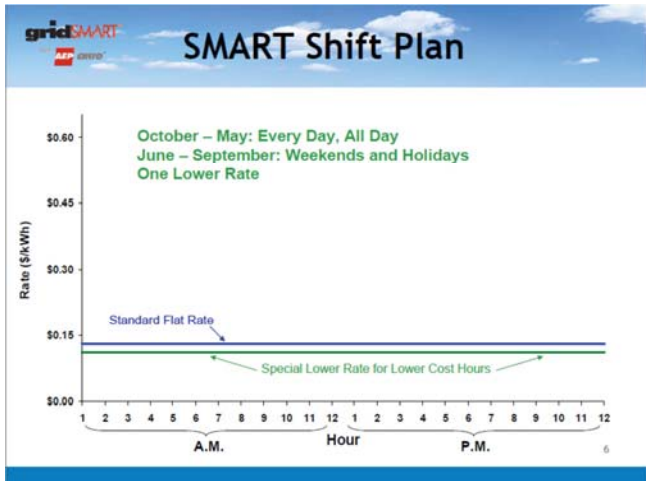


To make things simple, most people currently pay a flat rate for electricity all the time, day or night, seven days a week with very minor seasonal variations for summer and winter. That rate for AEP Ohio is about 13 cents per kilowatt hour. Any questions?

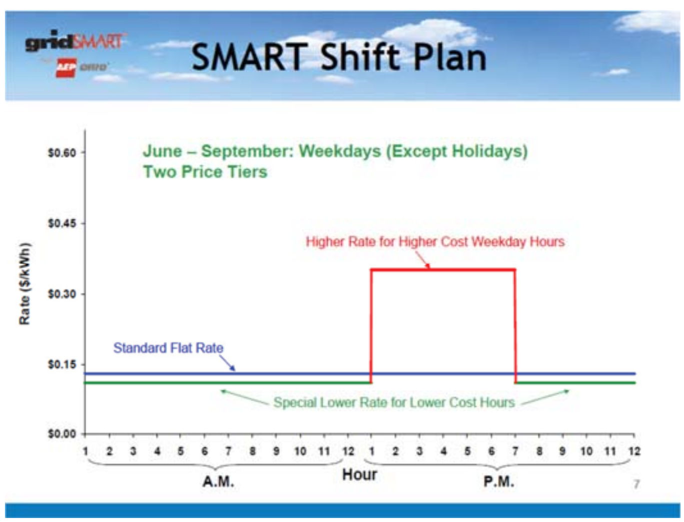
But, in fact, electricity doesn't cost the same every hour of every day of the year. The prices are often the highest in the summer, on weekday afternoons when temperatures are soaring and businesses, schools and homes are all using power at very high levels.

Because you have a smart meter, you could participate in a program called SMART Shift that rewards you for reducing your energy use during those summer afternoons and early evenings.

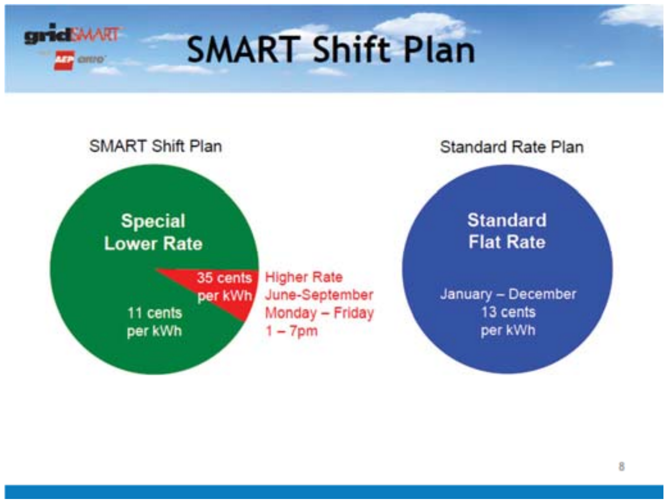
With SMART Shift, you receive a different rate for electricity depending on when you use it. All day, every day October through May and weekends and holidays during June through September, you pay 11 cents per kilowatt-hour.



In the summer, there are two pricing tiers. Again, with SMART Shift, participants are charged a higher cost for electricity during times when demand is greater and the cost to generate electricity is at its highest. So from June through September, 1pm-7pm Monday through Friday, excluding holidays, you would be billed at 35 cents per kilowatt hour. The remainder of the time, you would be billed at 11 cents per kilowatt hour. You could take advantage of the lower rates by moving a portion of your high electricity usage to lower cost hours, such as waiting until after 7pm to run your dishwasher or clothes dryer or you could raise the temperature setting on your thermostat from 1-7pm on weekdays, especially during those hours that nobody is at home.



Here is a summary of how the SMART Shift rates compare to the standard flat rate. Again, most of the time you would pay the special lower rate of 11 cents per kilowatt hour, and you'd pay the higher rate only during those designated times in the summer.

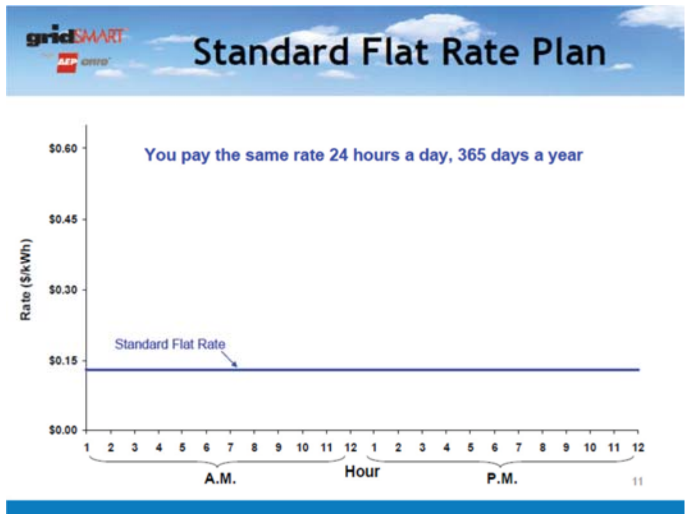


15.2 SMART SHIFT PLUS OVERVIEW

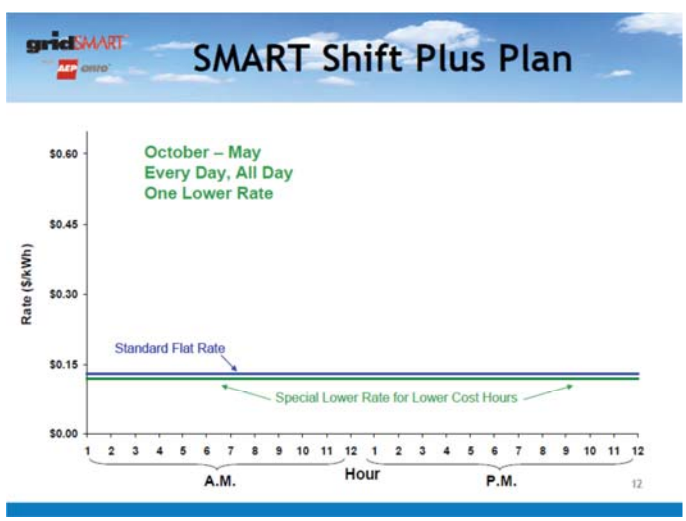
Now we'd like to go over another program called SMART Shift Plus. It is an expansion of the SMART Shift Program that further rewards customers for using electricity wisely and offers a free programmable thermostat and a small device called a Power Display, both installed free-of-charge by a licensed contractor.

The Power Display allows you to see in real time how much electricity you are using and your average cost per hour so you can make decisions to reduce your usage and save money. You can compare your usage to other homes like yours, and see how your usage can change based on the outside temperature. The Power Display can also estimate your electric usage and costs for the month, so you're aware of how much you are using and can stay within your budget.

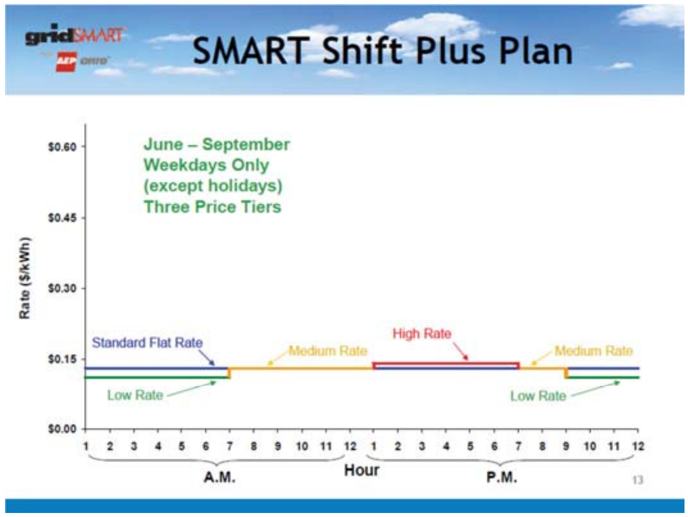
So, let's look at the pricing details for SMART Shift Plus.



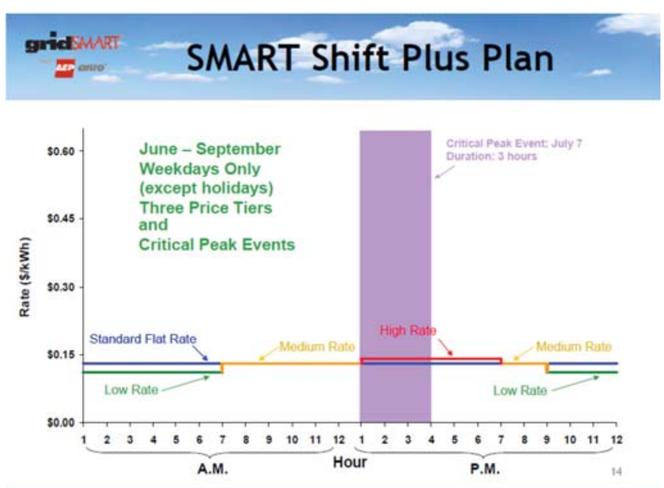
As I mentioned before, currently your electricity rate is about 13 cents per kilowatt hour regardless of when you use it.



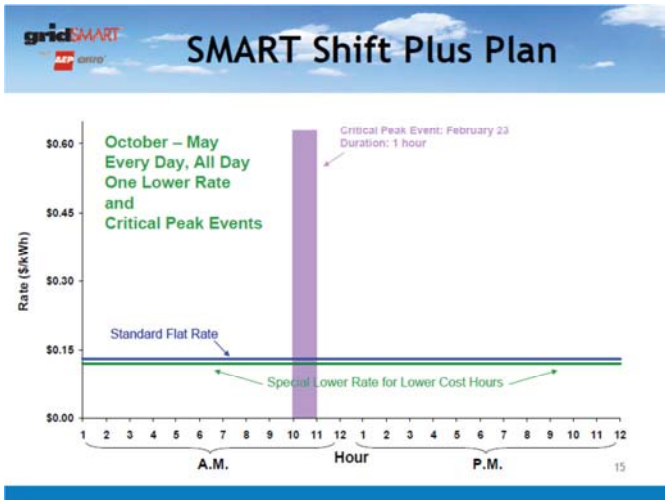
With SMART Shift Plus, you'll pay only 12 cents per kilowatt hour regardless of when you use it during the months of October through May.



From June through September, and only on weekdays, there are low, medium and high cost hours for different times of the day, as shown here on the graph. The low rate is 11 cents per kilowatt hour, the medium rate is 13 cents per kilowatt hour and the high rate is 14 cents per kilowatt hour in the summer months of June through September.



There may also be up to 15 different critical peak periods or “events” throughout the year. Each event will last no longer than five hours. Events are typically called when the forecast supply of electricity is predicted to be less than or close to the amount anticipated for the following day. During these rare events, you are billed at the critical peak rate of 65 cents per kilowatt hour.

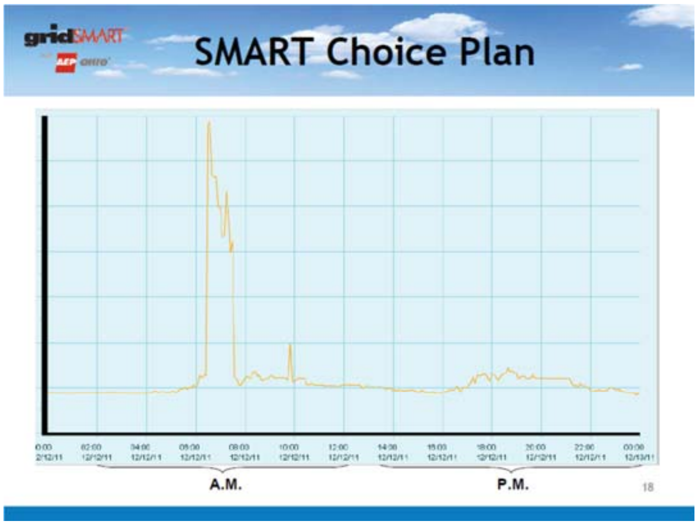


These events can occur at different times of day and any month of the year, even the months of October through May in which you pay the special low rate every hour of every day of the month except during an event, which are billed at 62 cents per kilowatt hour.

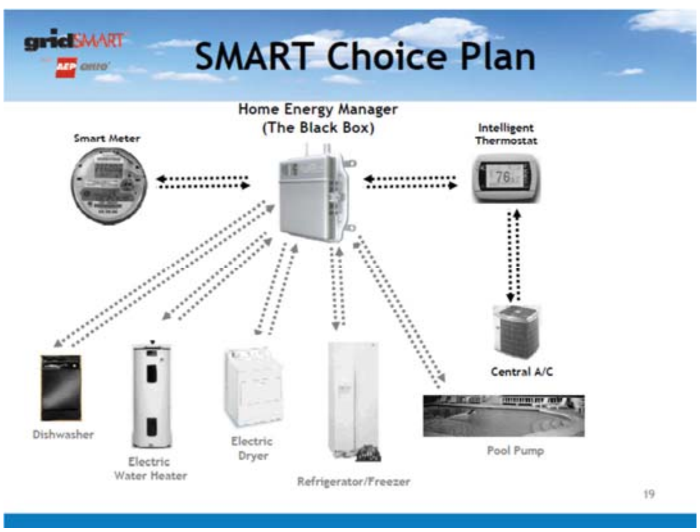
The free thermostat and Power Display can help you save money during these critical peak events as well as during other times. Since your Power Display will communicate with your Smart Meter, AEP Ohio will notify you a day prior to a critical peak event through the device to allow you to adjust your electric use accordingly if you want. You can also choose to be notified via a phone message or email, or both. Also, you can set your Power Display to automatically adjust your thermostat's temperature setting a few degrees during critical peak pricing events, helping you to save money during an event. Of course, if you are home at the time and find the few degrees change in temperature to be uncomfortable then you can always bump the thermostat back to where it was before the event, you simply pay the higher charge for the electricity used during the event.

15.3 SMART CHOICE OVERVIEW

So far we have talked about your existing flat rate plan where you pay the same amount for electricity year round regardless of the time of day or night that you use it. We have also talked about the SMART Shift and SMART Shift Plus programs that provide you with lower and higher rates during fixed hours in specific months of the year. The price that AEP Ohio pays to obtain electricity for you varies throughout the day. Prices are relatively low at night when overall use is low. But sometimes prices are higher, depending on things like supply and demand or excessively hot weather. The price for electricity actually adjusts every five minutes and is one piece of the total price of electricity. Smart Meters enable a new way of paying for electricity based on these price fluctuations, called SMART Choice.



With SMART Choice your rate changes in real time, every five minutes, according to the actual price that AEP Ohio pays. One of the largest users of electricity in most homes is the central air conditioning unit. With SMART Choice you will receive a new programmable thermostat that communicates wirelessly to your smart meter via a small module that is installed out of sight.



While SMART Choice will initially only control your central air conditioning based on your comfort versus savings preferences, it could later also interact with other high energy use devices in the home such as dishwashers, electric water heaters, electric dryers, refrigerators and/or freezers and pool pumps.

The Home Energy Manager module (or HEM for short), works with your new thermostat to automatically fine tune your home's temperature based on your preferences and the changing cost of electricity. You simply set your preferences for comfort versus savings once and the HEM helps you to save money every minute of every day. As that famous infomercial states, just 'set it and forget it!'

The programmable thermostat will show you what your current electric use, or demand, is for the last five minutes, the current five minute price for electricity, your targeted temperature, the current temperature and the number of degrees difference based on your preferences.

The thermostat will also have a programming screen to allow you to set your preference for comfort versus savings and will show you the number of degrees your set temperature may vary in order to save you money. The more you move the setting to 'SAVE' the greater the temperature may change, but never more than the number of degrees indicated.

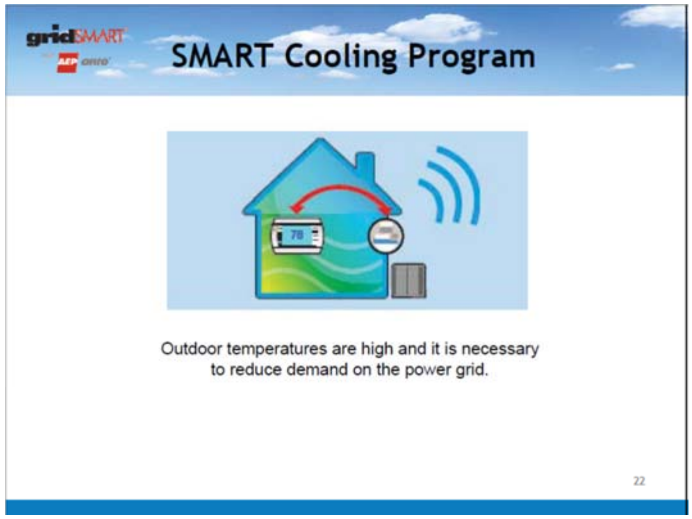
Of course, if you maximize your savings and a resulting change in temperature is uncomfortable, you can always manually change the thermostat to whatever temperature you prefer. But you will be paying more for the electricity used to hit that cooler temperature. You never lose control.

Because the thermostat always shows you the current price of electricity, you can also reduce your cost by taking actions to conserve electricity during those times when prices are higher. For example, you can adjust the use of your air conditioning, electric water heater and by avoiding using washing machines, electric dryers, dishwashers and other high demand appliances during times when electricity is priced higher and instead using those appliances in lower cost times.

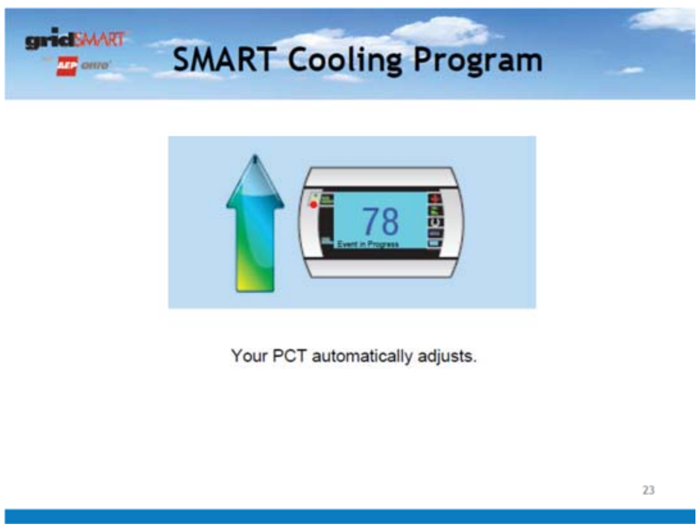
While AEP Ohio does not yet offer this plan to its customers, it is interested in getting your thoughts on it tonight.

15.4 SMART Cooling Overview

Here is how SMART Cooling works.

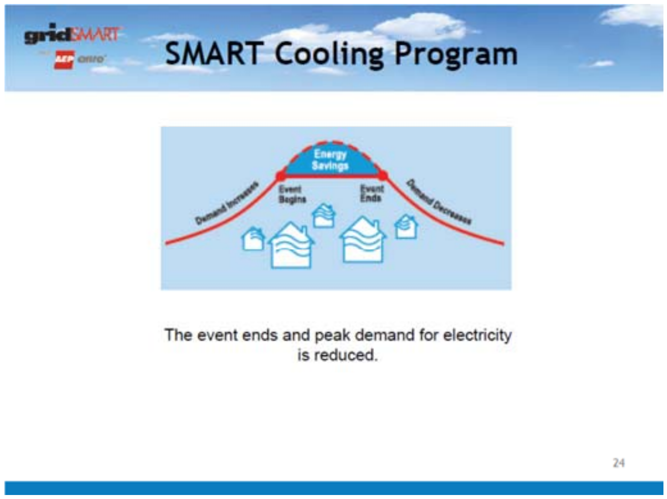


When outdoor temperatures are high and it is necessary to reduce demand on the power grid, a secure wireless signal is sent from AEP Ohio to your smart meter and your thermostat is automatically adjusted.



The temperature setting on your thermostat will be raised no more than four degrees. These adjustments, which are also referred to as events, may occur up to fifteen different times during the months of May through September. Events will only occur between the hours of noon and eight PM. During an event your thermostat will display a text message and a colored light indicating an event is in progress. An event lasts no more than six hours

AEP OHIO
A unit of American Electric Power



When the event ends a secure wireless signal is sent from AEP Ohio to your smart meter and your thermostat returns to its original programmed temperature setting. You will earn a bill credit during the months of May through September. It will be eight dollars each month if your thermostat is automatically adjusted for all events during that calendar month. If you opt out of one event, by manually adjusting your thermostat when an event is in progress, the eight dollar credit is reduced to four dollars. If you opt out of more than one event during a month, there is no credit for that month. The credit amounts are lower for those few customers that only use a small amount of electricity in the summer months.

In addition to the monthly bill credits, you can also save on heating and cooling costs by programming your new thermostat.