EXHIBIT NO. ______

BEFORE
THE PUBLIC UTILITIES COMMISSION OF OHIO

In the Matter of the Application of Ohio Power Company to Initiate its gridSMART® Phase 3 Project.	)))	Case No. 19-1475-EL-RDR

DIRECT TESTIMONY OF
SCOTT S. OSTERHOLT
ON BEHALF OF
OHIO POWER COMPANY

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SCOTT S. OSTERHOLT

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ON BEHALF OF
OHIO POWER COMPANY

PERSONAL DATA

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Scott S. Osterholt, and my business address is 700 Morrison Road, Gahanna, Ohio 43230.

Q. BY WHOM ARE YOU EMPLOYED AND WHAT IS YOUR POSITION?

A. I am employed by Ohio Power Company, known as "AEP Ohio" or the "Company," as Director – Grid Modernization.

Q. WOULD YOU PLEASE DESCRIBE YOUR EDUCATIONAL AND PROFESSIONAL BACKGROUND?

A. I received a Bachelor of Business Administration from Mount Vernon Nazarene University. Following employment with an electric cooperative and serving AEP under a contracting arrangement, I joined AEP Ohio in 1996 in the Distribution Region Engineering Group. In 1997, I transferred to Appalachian Power Company, an AEP Ohio affiliate, to lead the engineering activities for its Lynchburg, Virginia district. In 1999, I joined AEP Communications as Manager of Network Projects and was responsible for engineering, construction, and project management of new fiber optic deployments and associated telecom services. In 2002, I joined the AEP IT Telecommunication team and managed fiber maintenance and customer support. I returned to AEP Ohio in 2006 as Work Scheduling Supervisor, and between 2006 and 2009, I led a transformational project where we moved routine utility service scheduling from a local work scheduling group to the call center through a software program called eScheduler. In 2009, I was promoted to Manager – Incremental Distribution Infrastructure, and for the past ten years, I have managed all aspects of the gridSMART®[1] advanced distribution technology deployment. I was promoted to the position of Director – Distribution Risk and Project Management in 2016, and became Director – Grid Modernization in 2018. All told, I have more than twenty-five years of experience in the electric utility industry, including substantial experience in implementing new technologies, and much of my twenty years at AEP have been focused on implementing new technology.

Q. WHAT ARE YOUR RESPONSIBILITIES AS DIRECTOR – GRID MODERNIZATION?

A. I am responsible for directing the smart grid and grid modernization activities for AEP Ohio, including day-to-day management responsibility for AEP Ohio's gridSMART program.

Q. HAVE YOU PREVIOUSLY SUBMITTED TESTIMONY IN ANY REGULATORY PROCEEDINGS?

A. Yes. I testified before the Public Utilities Commission of Ohio ("Commission") in Case No. 13-1939-EL-RDR and submitted testimony in Case No. 16-1852-EL-SSO on behalf of the Company.

Q. ARE YOU SPONSORING ANY EXHIBITS WITH YOUR TESTIMONY?

A. Yes, I am sponsoring the following exhibits as accompanying documents:

- Exhibit SSO-1 – History of AEP Ohio's gridSMART Program

[1] "gridSMART" is a registered trademark of American Electric Power Company, Inc.

- Exhibit SSO-2 – gridSMART Phase 3 Technology Descriptions: DACR, VVO, AMI
- Exhibit SSO-3 – Revised Phase 3 Full System Feasibility Study Final Report

PURPOSE OF TESTIMONY

Q. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. The purpose of my testimony is to describe AEP Ohio's proposed gridSMART Phase 3 implementation ("Phase 3 project"). This Phase 3 project is a continuation of the completed Phase 1 project and current Phase 2 project to expand the reliability benefits of Distribution Automation Circuit Reconfiguration (DACR), the energy efficiency and retail power cost savings of Volt/Var Optimization (VVO), and complete the Advanced Metering Infrastructure (AMI) deployment to AEP Ohio's remaining customers.

As part of my testimony, I will describe the grid modernization technologies that are now being deployed for the Phase 2 project, and are proposed for continuation in the Phase 3 Project. This Phase 3 proposal also includes the following additional technologies: distribution Supervisory Control and Data Acquisition (D-SCADA), fiber connections, intelligent distribution line sensors, Incremental VVO, the "It's Your Power" Application ("App" or "app"), and functionality to provide AMI data to competitive retail electric service (CRES) providers via electronic data interchange (EDI) for customers on time of use (TOU) programs. These components are collectively referred to as the "Phase 3 Technologies," or simply as the Phase 3 project. I will provide additional testimony on the proposed deployment of these new additions to Ohio's gridSMART project. Also, I will provide an overview of the business case (including benefits and costs) associated with the proposed deployment of the Phase 3 project. The Company's proposed Phase 3 project is consistent with the Commission's PowerForward initiative to deliver grid modernization benefits to Ohio customers.

PROPOSED GRIDSMART PHASE 3 OVERVIEW

Q. PLEASE GIVE AN OVERVIEW OF AEP OHIO'S PROPOSED PHASE 3 IMPLEMENTATION.

A. AEP Ohio's proposed Phase 3 project includes:

- Deploying additional DACR;
- Deploying D-SCADA;
- Deploying additional VVO;
- Completing the deployment of AMI in the remainder of AEP Ohio's service area;
- Installation of fiber optical cable to select Access Points (APs);
- An Intelligent Distribution Line Sensors Demonstration;
- An Incremental VVO Pilot;
- Continued deployment of the It's Your Power App; and
- Adding functionality to provide AMI data to CRES providers via EDI for customers on TOU programs

A revised Phase 3 Full System Feasibility Study ("Phase 3 FS Report") accompanies my testimony and AEP Ohio's Application to the Commission in this case ("Application"). Exhibit SSO-3, the accompanying Phase 3 FS Report, describes the business cases prepared that support the proposed DACR, VVO, and AMI deployments. A summary of all DACR, VVO, and AMI business case results is provided in Section 5, pp. 16-17 of the Phase 3 FS Report and summarized in Table 1 below.

Table 1
15-Year Business Case Summary for DACR, VVO, and AMI

Description	Total
Present Value Benefits	$1,023,981,269
Present Value Costs	$790,648,175
Net Present Value	$233,333,094
Benefit-Cost Ratio	1.30
Reduced CO_2 Emissions	6,771,425 t

The proposed Phase 3 deployment of DACR, VVO, and AMI results in a net present value (NPV) of nearly $233M for AEP Ohio customers. Stated another way, for every $1.00 spent in project costs, the aggregate deployment yields $1.30 in benefits. Additionally, the Phase 3 program delivers nearly 6.8M tons of reduced CO_2 emissions. Expanding the Phase 3 deployment to include D-SCADA, Intelligent Distribution Line Sensors, Fiber, Incremental VVO, the It's Your Power App, and AMI via EDI for TOU customers as shown in Table 2, also yields a positive NPV for Company customers.

Table 2
15-Year Business Case Summary for the Phase 3 Technologies

Description	Total
Present Value Benefits	$1,184,223,809
Present Value Costs	$937,916,796
Net Present Value	$246,307,013
Benefit-Cost Ratio	1.26
Reduced CO_2 Emissions	6,771,425 t

This holistic approach provides for Present Value Benefits of $1,184,223,809 with a positive NPV of $246,307,013. Stated another way, for every $1.00 spent on project costs, customers will realize a benefit of $1.26. The inclusion of D-SCADA increases the NPV. Inclusion of Intelligent Distribution Line Sensors, Fiber, Incremental VVO, the It's Your Power App, and AMI via EDI for TOU customers results in a slight decrease in the NPV, but only because not all of the benefits of these technologies have been quantified by the Company. The Company anticipates that the NPV and Benefit to Cost Ratio would increase if monetarized benefits for Intelligent Distribution Line Sensors, Fiber, and Incremental VVO could be calculated. I will provide additional details regarding AEP Ohio's proposed Phase 3 project later in this testimony, including technology descriptions and their respective benefits and costs.

Q. ARE THE PROJECT COSTS FOR DACR, VVO, AND AMI SIMILAR TO PHASE 2?

A. Yes, but the costs reflect increases that AEP Ohio has experienced through the current deployment efforts, as well as others that the Company anticipates. One of the largest cost differences is labor cost. With the labor shortage in the electrical industry, the Company expects this to drive up anticipated project labor expenses. The Company has also adjusted the anticipated costs to reflect cost of living increases as well as a larger allocation of labor to be completed by contractors and consultants.

Q. WHAT IS THE IMPLEMENTATION PERIOD FOR PHASE 3?

A. The Company is proposing to install DACR, VVO, and fiber over a 10-year period; D-SCADA over a 5-year period; Intelligent Distribution Line Sensors over a 5-year period; AMI over a 4-year period; and Incremental VVO and AMI data via EDI over a one-year to 18-month period. The Company proposes to continue to market the It's Your Power App over a 5-year period.

Q. WHAT FACTORS WERE CONSIDERED WHEN DEVELOPING THIS DEPLOYMENT TIMELINE?

A. AEP Ohio believes strongly in the customer benefits of the gridSMART technologies and would like to deploy them as quickly as possible. The Company expects to complete the deployments within the timeline previously referenced, but there are a few factors that could limit our ability to achieve these deployment timeline goals. Currently, there are distribution line resource constraints across the entire industry. The Company also wants to make sure that there is adequate time to successfully preplan for the deployment after Commission approval. The Company will strive to meet the noted deployment timelines but will avoid sacrificing overall project success to hit these targets.

Q. DOES AEP OHIO'S PROPOSED GRIDSMART PHASE 3 DEPLOYMENT ALIGN WITH THE COMMISSION'S POWERFORWARD INITIATIVE?

A. Yes. PowerForward is the Commission's review of the latest in technological and regulatory innovation that could serve to enhance the consumer electricity experience. Through this series, the Commission intends to chart a clear path forward for future grid modernization projects, innovative regulations, and forward-thinking policies. Consistent with the Commission's PowerForward Roadmap, AEP Ohio plans to complete its installation of AMI meters throughout its service territory. Along with AMI, the It's Your Power App and CRES provider access to interval data will help enhance the customer experience. The Company will also deploy additional VVO, DACR, and D-SCADA to modernize the distribution grid and install a dark fiber network in rural areas. Intelligent distribution line sensors will deploy new technology that will provide additional data that can be used by the Company to help monitor the health of its distribution grid.

The PowerForward effort has an active working group, the Data and Modern Grid Workgroup (DWG), which has been established to help consumers and authorized third parties in Ohio realize the potential of data from smart meters. The effort will create protocols for data privacy protections; allow customers to obtain real-time, or near real-time, access to their customer energy usage data (CEUD) through the connection of qualified home area network (HAN) devices; and prescribe a uniform methodology across the electric distribution utility companies for third parties to obtain CEUD, including a method for competitive retail electric service providers to obtain important wholesale market data, *i.e*. total hourly energy obligation, peak load contribution, and network service peak load values.[2] The following AEP Ohio gridSMART efforts align with these data initiatives:

- AMI Interval Data availability on a customer portal: AEP Ohio has developed tools and programs that enable customers to gain insight about their electricity consumption by showing data in sub-hour segments on their online account;
- AMI Interval data on a smart phone application: The It's Your Power App provides an additional tool that allows customers to achieve energy savings through the insight from seeing sub-hour usage information in real-time powered by the AMI meter;
- Customer Interval Data made available to CRES: Through the gridSMART program efforts, the Company will expand the sharing of customer interval data in a way that allows the CRES providers to more efficiently obtain this information via EDI for customers on a TOU program;
- Settling with CRES providers using AMI data: Through the gridSMART program, current functionality has been established to settle with CRES providers using the actual AMI interval data for customers on a TOU rate or customers with consumption greater than 200KW. The Company will upgrade systems to settle with CRES providers for customer consumption using AMI interval data for all customers in the

[2] https://www.puco.ohio.gov/industry-information/industry-topics/powerforward/powerforward-collaborative-and-workgroups/data-and-modern-grid-workgroup/

future. Costs and associated cost recovery will be addressed outside of this application.

DACR

Q. PLEASE DESCRIBE DACR.

A. DACR stands for Distribution Automation Circuit Reconfiguration, a category of advanced electric distribution infrastructure. The DACR technology proposed in AEP Ohio's gridSMART program, which was described in both Phase 1 and 2, as well as Exhibit SSO-2, principally involves the installation of "smart" reclosers on the distribution grid. A recloser is a piece of distribution infrastructure that is capable of sensing faults on a distribution circuit and automatically cutting off electricity flows (*i.e.*, "opening" the circuit) by isolating the faulted section of line. The smart reclosers installed through the gridSMART program have much more functionality, have communications capabilities, limit the impact of outages on our customers, and provide critical operational information.

Q. WHAT ARE THE BENEFITS OF DACR?

A. DACR reduces the frequency of outages for customers where the technology is deployed. It also provides maintenance and safety benefits.

First, when smart reclosers are installed at key points in the distribution grid, these reclosers – in conjunction with a centralized controller – can automatically identify and react to outages. Without any required input from human operators, this DACR technology can reconfigure circuits so that outages are isolated to the smallest area practical and electric service is automatically restored to customers in other areas. In most cases, this reconfiguration process takes less than two minutes. Although the cause of the outage must still be assessed and potential repair work completed, DACR limits the impact to customers in the affected area and can prevent other customers from experiencing an outage.

Second, DACR provides detailed information about outages to dispatchers in AEP Ohio's DDC, as well as to line personnel working in the field. Without DACR, dispatchers and line personnel have only limited visibility regarding faults on the grid. Often, dispatchers and line personnel must rely on reports from customers to know an outage has occurred, and sometimes line personnel must physically inspect equipment and segments of the distribution grid to determine the extent of an outage and diagnose its cause. With DACR, however, dispatchers and line personnel receive information from smart reclosers regarding the existence and location of faults. This significantly improves the ability of dispatchers and line personnel to diagnose, prioritize, and resolve outages.

Third, the ability to remotely operate smart reclosers provides significant safety and maintenance advantages. One example is when circuits require switching for maintenance, construction, or returning to normal configuration following an outage event. For "non-smart" reclosers, line personnel must physically visit the reclosers and perform the switching at the pole location. With DACR and smart reclosers, this switching can be accomplished remotely by a distribution dispatcher. This allows for improved safety and reduced response time by directing line personnel to other trouble areas more quickly.

Q. WHAT ARE SAIFI AND SAIDI?

A. The System Average Interruption Frequency Index (SAIFI) is defined as the average number of times that a customer experiences an outage during a specific period of time, usually a year. SAIFI is determined by dividing the total number of customer interruptions during the time period by the total number of customers served.

The System Average Interruption Duration Index (SAIDI) indicates the total duration of interruptions for the average customer across the electric system during a predefined period of time such as a month or a year. It is commonly measured in minutes or hours of interruption. Mathematically it is the total number of customer minutes of interruption divided by the total number of customers on the system. As an example, a SAIDI of 100 means the average customer served for a given period experiences a total of 100 minutes of power interruption.

Q. PLEASE SUMMARIZE THE DACR RESULTS FROM PHASE 1 CIRCUITS.

A. The gridSMART Phase 1 deployment has beneficially impacted customer reliability every year since it was deployed. The annual SAIDI and SAIFI values excluding major event days for the group of seventy circuits included in Phase 1 have been better with DACR than it would have been without DACR installed. The annual impact on the reliability indices is shown in the table below. As shown below in Table 3, the average annual savings in SAIFI for the most recent three years has been 21%, while the savings in SAIDI has been 15%.

Table 3: DACR Results Summary

Year	DACR Impact	
	SAIFI	**SAIDI**
2011	-3.6%	-2.8%
2012	-12.4%	-8.2%
2013	-24.9%	-20.0%
2014	-15.5%	-9.2%
2015	-8.6%	-6.1%
2016	-18.3%	-13.5%
2017	-28.0%	-19.7%
2018	-15.6%	-12.9%

Q. WHAT ARE THE EXPECTED RESULTS FROM THE DACR DEPLOYMENT FOR GRIDSMART PHASE 3?

A. AEP Ohio anticipates an improvement in reliability for customers on deployed DACR circuits, similar to the results the Company has seen from the Phase 1 deployment as shown above in Table 3. While there are many factors that affect the overall reliability experience for a customer, all else being equal, AEP Ohio anticipates a gross 15.8% average annual SAIFI improvement (based on a three-year average), excluding major events, attributable to DACR on distribution schemes and circuits where this technology is deployed. For purposes of this evaluation, DACR schemes and circuits will be reviewed on an aggregate basis – that is, reductions in SAIFI will be presented on all gridSMART Phase 3 DACR circuits together, rather than on a circuit-by-circuit basis.

In addition to the 15.8% SAIFI improvement noted above, the Phase 3 DACR deployment will also reduce customer minutes of interruption (CMI). This is an alternative method of measuring reliability that also incorporates interruption durations. The estimated CMI reduction is up to 11,000,000 per year on deployed circuits.

Q. PLEASE SUMMARIZE THE BUSINESS CASE FOR DACR.

A. The DACR business case presented in the Phase 3 FS Report (Exhibit SSO-3) is a benefit-cost analysis that compares the cost of AEP Ohio's proposed DACR deployments with the estimated economic benefits achievable by reducing customer outage frequency to improve electric service reliability. AEP Ohio's DACR business case includes a 15-year benefit-cost analysis to estimate the NPV (*i.e.* reliability benefits minus costs) to deploy DACR technology on 146 candidate schemes involving 711 distribution circuits within the proposed Phase 3 project area to achieve an average 15.8 percent reduction in SAIFI.

Out of the 146 candidate schemes involving 711 distribution circuits that were studied by AEP Ohio, 80 schemes impacting 416 distribution circuits had positive 15-year NPVs where the benefits of improved reliability achievable with DACR exceeded the cost of deployment. These schemes and circuits collectively provide an estimated 15-year NPV of $219,962,699 in reliability benefits to customers. In other words, the proposed deployment of DACR on these 80 schemes and 416 distribution circuits is anticipated to deliver $1.63 of DACR-related reliability benefits per $1.00 of DACR-related capital and O&M costs incurred. The benefit-cost analysis process of preparing prioritized business cases has been described in the Phase 2 Feasibility and Selection Study Draft Report previously filed in Case No. 18-0203-EL-RDR and in Exhibit SSO-3. The prioritization and selection process is dynamic, and the Company plans to update the data associated with circuit selection on a periodic basis, which may yield additional circuit candidates.

Q. PLEASE DESCRIBE HOW DACR OPERATIONS WILL BE MONITORED TO CONFIRM THAT THE BENEFITS OF DACR ARE DELIVERED TO CUSTOMERS.

A. Each outage event on a DACR circuit is reviewed to ensure that the system is operating as designed and that maximum customer savings are being achieved. Metrics are recorded during each of those event reviews. The metrics include the number of customers that would have experienced sustained interruptions (potential customers interrupted, or CI), the number of customers that were restored as a result of the DACR operation (CI avoided), the percentage of customers restored, and the estimated customer minutes of interruption that were saved (CMI avoided) because of the DACR operation. These metrics can each be summarized for all DACR operations during any given time period.

Table 4 below shows the accumulated metrics for the 70 circuits included in the Phase 1 DACR project. The values summarize outages in which a reconfiguration option was available since deployment through 2018 excluding major event days.

Table 4: Phase I DACR Accumulated Metrics Results

Potential CI	CI Avoided	Restored Customer %	CMI Avoided
416,689	207,995	49.9%	17,263,585

DISTRIBUTION SCADA

Q. PLEASE DESCRIBE DISTRIBUTION SUPERVISORY CONTROL AND DATA ACQUISITION.

A. Distribution Supervisory Control and Data Acquisition, or D-SCADA, is very similar to the DACR technology that I previously described. The major difference is that there is no automatic circuit reconfiguration component; with DACR, there are two or more interconnected distribution circuits, which allows for the automatic switching and reconfiguration as necessary to isolate and limit an outage to the smallest area impacting the fewest number of customers that are practical. With D-SCADA, automatic switching and reconfiguration does not occur.

Q. WHAT ARE THE BENEFITS OF D-SCADA?

A. Similar to DACR, D-SCADA provides detailed information about outages to dispatchers in AEP Ohio's Distribution Dispatch Center (DDC), as well as to line personnel working in the field. Without this technology, dispatchers and line personnel have only limited visibility regarding faults on the grid. With D-SCADA, however, dispatchers and line personnel receive information from smart reclosers regarding the existence and location of faults. Additionally, in some cases where the deployed circuit has a physical connection to an adjacent circuit, dispatchers are able to manually reconfigure circuits to enable power restoration to the maximum number of customers. This significantly improves the ability of dispatchers and line personnel to diagnose, prioritize, and resolve outages, thereby reducing restoration time.

D-SCADA also offers a host of qualitative benefits, including:

- Improved operational safety for crews - Adding visibility to distribution lines will help crews better assess operating conditions prior to any switching operation, including those associated with outage restoration activities.
- Improved public safety - The proposed reclosers are equipped with microprocessor-based controls and communications enabling them to be remotely opened to de-energize a suspected downed "live" power line in lieu of waiting for crews to arrive on-site. Also, these recloser and controls can sense and detect faults faster and more accurately than traditional protective equipment.
- Improved distribution grid visibility and situational awareness for distribution operators and crews – This capability positions AEP Ohio for future reliability and operating enhancements involving DACR deployment, Distribution Management (DMS)/ Supervisory Control and Data Acquisition (SCADA) improvements, Distributed Energy Resource Management System (DERMS), etc.
- Timely detection and reporting of momentary interruptions for follow-up and investigation that otherwise may lead to potential outages - Timely detection and reporting of momentary interruptions by the proposed reclosers and controls will enable distribution operations to investigate more quickly and follow-up with any remedial actions that heretofore may have eventually caused a potential outage.
- Future detection of distribution line device loading and maintenance issues (*e.g.*, low recloser control battery power) - These devices produce large amounts of a data that can help develop better preventative maintenance programs and planning for circuit

growth. Analytics is important because of the information provided to multiple groups enabling them to better plan and be proactive to changes in the grid.

Q. DOES D-SCADA SUPPORT THE COMMISSION'S POWERFORWARD EFFORTS?

A. Yes, similar to other grid modernization efforts, the D-SCADA deployment is consistent with PUCO PowerForward initiatives. The additional data from these proposed D-SCADA deployments advances and modernizes the electric distribution utility forecasting and planning processes.

Q. PLEASE DESCRIBE THE COMPANY'S D-SCADA PROPOSAL RELATIVE TO GRIDSMART PHASE 3.

A. After evaluating 564 candidate circuits that have limited or no physical interconnections to other adjacent circuits or have a negative DACR NPV, 160 circuits have a positive business case for D-SCADA. The Company proposes to deploy D-SCADA on these 160 circuits. Many of the D-SCADA candidate circuits are located in rural locations, where there is either limited or no physical connection to an adjacent circuit. This also supports the Companies rural broadband initiatives and creates more rural fiber connectivity to the first communicating field device outside of the substations.

Q. WHAT ARE THE EXPECTED RESULTS FROM THE D-SCADA DEPLOYMENT FOR GRIDSMART PHASE 3?

A. AEP Ohio's D-SCADA on 160 distribution circuits within the proposed Phase 3 project area is expected to achieve an average ten percent improvement in Customer Average Interruption Duration Index (CAIDI). CAIDI represents outage restoration duration, or CMI divided by CI.

Q. PLEASE DESCRIBE THE DEPLOYMENT TIMELINE FOR D-SCADA.

A. The Company plans to deploy D-SCADA over the first 5 years after a Commission order approving the deployment.

Q. PLEASE SUMMARIZE THE BUSINESS CASE FOR D-SCADA.

A. AEP Ohio's D-SCADA business case includes a 15-year benefit-cost analysis to estimate the NPV to deploy D-SCADA technology on 564 distribution circuits within the proposed Phase 3 project area to achieve an average ten percent improvement in CAIDI. Candidate circuits have limited or no physical interconnections to other adjacent circuits or have a negative DACR NPV.

Out of the 564 distribution circuits that were studied by AEP Ohio, 160 distribution circuits had positive 15-year NPVs where the benefits of improved reliability achievable with D-SCADA exceeded the cost of deployment. These circuits collectively provide an estimated 15-year NPV of $88,283,605 in reliability benefits to customers. In other words, the proposed deployment of D-SCADA on these 160 distribution circuits is anticipated to deliver $2.31 of D-SCADA-related reliability benefits per $1.00 of D-SCADA-related capital and O&M costs incurred. The prioritization and selection process is dynamic, and the Company plans to update the data associated with circuit selection on a periodic basis, which may yield additional circuit candidates.

Q. PLEASE DESCRIBE HOW D-SCADA OPERATIONS WILL BE MONITORED TO CONFIRM THAT THE BENEFITS OF D-SCADA ARE DELIVERED TO CUSTOMERS.

A. AEP Ohio anticipates achieving a ten percent (10%) annual CAIDI improvement, excluding major events, attributable to D-SCADA on the circuits on which that technology is deployed. For purposes of this metric, performance will be presented on an aggregated circuit-basis – that is, CAIDI will be presented on all gridSMART Phase 3 D-SCADA circuits together, rather than on a circuit-by-circuit basis. Outage data on the D-SCADA circuits will be reviewed to help ensure that the resources and processes are operating as designed and that CMI savings are being achieved. Performance will be evaluated by comparing post-deployment aggregated CAIDI to pre-deployment CAIDI.

VVO

Q. PLEASE DESCRIBE VVO.

A. VVO stands for Volt/Var Optimization. Broadly speaking, VVO provides energy efficiency benefits related to reducing voltage levels on the distribution grid. VVO, which was described in both Phase 1 and 2, is also described in Exhibit SSO-2. AEP Ohio is required to deliver electric service to customers within specific voltage ranges. However, due to various factors, AEP Ohio experiences voltage drops as electrical energy travels through the distribution system.

VVO technology involves installing "smart" distribution infrastructure that allows AEP Ohio to measure voltage on various parts of the grid and to adjust voltage to respond to fluctuating voltage conditions. Over time, this allows AEP Ohio to achieve an overall reduction in grid voltage levels while ensuring that voltage at the meter never drops below the permissible range.

Q. WHAT ARE THE BENEFITS OF VVO?

A. VVO improves energy efficiency and reduces CO_2 emissions by reducing energy usage and optimizing circuit distribution voltages and power factor (*i.e.* reducing VAR loads). All things being equal, lower voltage levels equate to lower energy usage. Therefore, by allowing AEP Ohio to deliver energy at lower voltage levels, VVO allows AEP Ohio's customers to realize an overall reduction in energy consumption on circuits where the technology is installed. The benefits of deploying VVO are reductions in demand, energy usage (*i.e.* improved energy efficiency), and CO_2 emissions. In addition, reduced energy usage by customers translates into lower retail power costs.

Q. WHAT ARE THE EXPECTED RESULTS FROM THE VVO DEPLOYMENT FOR GRIDSMART PHASE 3?

A. Similar to Phase 1 results, AEP Ohio expects to achieve a 3 percent average improvement in energy efficiency (or reduction in energy usage) attributable to VVO on distribution buses and circuits where this technology is deployed plus an additional 1 percent using meter interval data from the current Phase 2 and proposed Phase 3 AMI deployments. In addition, these improvements in energy efficiency through reduced energy consumption also reduce retail power costs of customers. For purposes of this evaluation, VVO buses and circuits will be reviewed on an aggregate basis – that is, reduction in energy usage in circuit loads will be evaluated on all gridSMART Phase 3 VVO circuits together, rather than on a circuit-by-circuit basis.

Q. PLEASE SUMMARIZE THE BUSINESS CASE FOR VVO.

A. The VVO business case presented in the Phase 3 FS Report (Exhibit SSO-3) is a benefit-cost analysis that compares the cost of AEP Ohio's proposed VVO deployments with the estimated retail power cost savings to customers achievable by optimizing distribution voltages and power factor (*i.e.*, reduce VAR loads) to reduce energy consumption.

Out of the 445 candidate buses involving 973 circuits that were studied by AEP Ohio, 190 substation buses impacting 492 distribution circuits had positive 15-year NPVs where the benefit of customer power cost savings achievable exceeded the cost of deployment. These buses and circuits collectively provide an estimated 15-year NPV of $91,246,725 in customer power cost savings. In other words, the proposed deployment of VVO on these 190 substation buses and 492 distribution circuits is anticipated to deliver $1.28 of VVO related power cost savings per $1.00 of VVO-related capital and O&M costs incurred. In addition to these benefits, improved energy efficiency on these buses and circuits associated with VVO is estimated to reduce CO_2 emissions by 6,611,509 metric tons over 15 years. The benefit-cost analysis process of preparing prioritized business cases has been described in the Phase 2 Feasibility and Selection Study Draft Report previously filed in Case No. 18-0203-EL-RDR and in Exhibit SSO-3. The prioritization and selection process is dynamic, and the Company plans to update the data associated with circuit selection on a periodic basis, which may yield additional circuit candidates.

Q. PLEASE DESCRIBE HOW VVO OPERATIONS WILL BE MONITORED TO ENSURE THAT THE ANTICIPATED BENEFITS OF VVO ARE DELIVERED TO CUSTOMERS.

A. VVO operations will be monitored by the AEP Ohio's DDC and the Grid Modernization teams. AEP Ohio will also implement Measurement & Verification (M&V) protocols to evaluate the impact of the VVO system in addition to ongoing disturbance testing to continually measure the energy savings and voltage reductions provided by the VVO system. The M&V protocols will continue through the deployment period.

The net change or reduction in demand and energy that may be realized by deploying VVO are measures associated with improving energy efficiency.

- Energy efficiency includes:
  - MW saved
  - MWh saved
- Previous installation of VVO has shown an average of 3 percent reduction in energy and demand, lowering the end user consumption with nothing required by the customer, leading to bill savings.

<u>AMI</u>

Q. PLEASE DESCRIBE AMI.

A. AMI, which was described in prior gridSMART phases, as well as in Exhibit SSO-2, uses internal communications systems to convey near real-time energy use and load information to both AEP Ohio and to the customer. AMI provides the capability to monitor equipment and can quickly convey information about certain malfunctions and operating conditions, as well as provide a host of customer benefits.

Q. WHAT IS THE BUSINESS CASE AND SUPPORTING JUSTIFICATION FOR AMI?

A. AEP Ohio is proposing to bring the benefits of AMI to the remainder of its customers, predominantly in rural areas not yet covered by the Phase 2 deployment, by deploying approximately 475,000 AMI meters. The baseline value provided by AMI is improved meter reading and grid operations. Since the proposed Phase 3 AMI deployment will cover an area already equipped with a legacy drive-by automated meter reading (AMR) system employing one-way radio communication technology, the Phase 3 AMI business case will only capture the incremental benefits above those already realized with AMR.

Those benefits include incremental meter reading benefits plus the new benefits of the ability to remotely connect and disconnect meters, reduced bad debt expenses on past due accounts, and utilizing meter interval data to expand and promote energy efficiency programs.

In addition to these benefits, AMI generates real-time customer and operational data that can be utilized by increasingly sophisticated software to drive a multitude of other benefits for customers. Distributed Energy Resources (DERs), such as electric vehicles, will soon have significant operational and customer impacts, and the smart home will increase the ability of customers and their smart devices to engage with the grid, including through time of use rates and home energy management.

Tangible benefits identified by AEP Ohio are estimated to yield an estimated 159,916 metric tons of reduced CO_2 emissions from vehicles over the same 15-year period. Additionally, AEP Ohio asserts that AMI is a necessary part of gridSMART Phase 3 for a variety of reasons including, but not necessarily limited to:

- An additional 1 percent in energy efficiency (or reduction in energy usage) is achievable with VVO if meter interval data from AMI is available.
- AMI, when paired with tariff options and the HAN, can empower customers to control their energy usage by providing near real-time information and usage data, allowing them to better understand their energy consumption and potentially reduce their electricity bill. The HAN is a dedicated network connecting devices in the home such as displays, load control devices, and "smart appliances," into the overall smart metering system. These savings can be driven via direct communications with smart devices in the home.

- Customers can receive a faster response to service requests, including meter reading and service connection, due to remote execution of those activities.
- AEP Ohio can also improve service response and worker safety. Additionally, power quality monitoring can improve customer satisfaction while tamper detection capability deters energy theft. Less personal interaction with energized equipment also improves employee and public safety.
- Customers will be able to participate in time of use or future incentivized rate programs.
- AMI will enable AEP Ohio to improve outage detection and service restoration processes.
- AMI will enable more reliable and cost-effective integration of DERs. As customers adopt technologies like electric vehicles and behind-the-meter storage, AMI data will allow AEP Ohio to detect new customer assets, predict their system impact, and assess and deploy options for reliable and cost-effective integration, including both system upgrades and optimization / demand management.

FIBER CONNECTIONS

Q. PLEASE GIVE AN OVERVIEW OF THE COMPANY'S PROPOSAL TO DEPLOY FIBER CONNECTIONS.

A As part of the Phase 3 project, AEP Ohio will install fiber optical cable (also known as fiber connections, dark fiber, or fiber) to select Access Points (APs) and the first distribution line device outside the station for DACR and VVO circuits rather than installing the traditional wireless communication to these devices. Implementing fiber enhances the smart grid technologies already deployed, as well as offers both individual and societal benefits, which are detailed below.

Q. WHY DOES THE COMPANY WANT TO DEPLOY FIBER CONNECTIONS AS PART OF PHASE 3?

A. The Company wants to deploy fiber to enhance smart grid technologies, which include advanced metering infrastructure and other grid modernization efforts that I discuss throughout my testimony. Fiber is an essential resource for utilities because it offers a host of operational benefits, such as improving cybersecurity and reducing dependency and expenses related to third party cellular providers. Additionally, as utilities continue to install fiber for their business purposes, there is an opportunity to overlap their efforts with rural broadband expansion initiatives.

Q. HOW DOES THE PHASE 3 PLANNED FIBER DEPLOYMENT REDUCE CYBER SECURITY EXPOSURE?

A. Installing fiber that is owned by AEP Ohio allows the Company to monitor for threats at every point in the communications and gives the Company control over the hardening, use, and protection of the network components earmarked for its purposes. Additionally, the fiber would be maintained by the Company, which restricts access to the fiber, for such purposes as maintenance, to only Company personnel. Therefore, the Company would have control over repairs and would not have to rely on the availability and scheduling of third party infrastructure providers should network issues arise. The actual physical construction of fiber also helps mitigate cybersecurity risk. Since fiber consists of multiple glass strand bundles, physically cutting into the line to try to intercept data will more than likely end in a ruined line with no effective data communication. Also, since fiber uses light transmission instead of frequency transmission, there is no radiant signal that can be intercepted. This feature of fiber also prevents cross-talk and radio frequency interference.

Q. HOW DOES THE PHASE 3 PLANNED FIBER DEPLOYMENT REDUCE DEPENDENCY AND RECURRING EXPENSES?

A. The revised communication plan eliminates a majority of the need for wireless dependency on third party cellular providers due to using a wireless mesh and fiber optic communication system. In areas where the fiber connections will be deployed, the communication network will be owned and controlled by AEP Ohio which reduces the dependency on a third party to ensure that the communication system is functioning adequately. Therefore, in times of critical need or significant outages from a large weather event, AEP Ohio will be able to respond in a way that best serves our restoration efforts rather than relying on a third party who's restoration efforts may not match ours. Additionally, reducing the need for public cellular wireless communication reduces the ongoing expense for third party monthly cellular expenses by approximately $5.3 million over a 10-year period. Also, owning the facilities reduces forced expensive upgrades from third parties for such items as equipment or the latest wireless technology (example: moving from 3G to 4G).

Q. ARE THERE COMPANY COST SAVINGS ASSOCIATED WITH DEPLOYING FIBER CONNECTIONS?

A. Yes, the fiber will displace the ongoing monthly expenses associated with cellular backhaul for the typical 10 devices per circuit. However, the deployment cost of fiber will be a higher cost. The incremental costs for a 15-year period results in a $52.6M cost which will likely be offset by anticipated dark fiber leases on these fiber segments as well as other AEP Ohio fiber equal or greater to this $52.6M. AEP Ohio plans to lease all excess dark fiber capacity above the Company's operational needs to third parties to enable the macro-economic benefits of the high-speed broadband connectivity.

Q. DOES THE PHASE 3 DEPLOYMENT OF FIBER PROVIDE OPPORTUNITIES FOR RURAL BROADBAND EXPANSION INITIATIVES?

A. Yes. Rural America is suffering economically due, at least in part, to a lack of adequate internet access, despite the recognized benefits high-speed service can provide to rural communities. In 2010, the Federal Communications Commission (FCC) stated that high-speed internet, "like electricity a century ago, is a foundation for economic growth, job creation, global competitiveness, and a better way of life. It is enabling entire new industries and unlocking vast new possibilities for existing ones. It is changing how we educate children, deliver health care, manage energy, ensure public safety, engage government, and access, organize, and disseminate knowledge."[3]

The Company believes that electric utilities are well positioned to deploy fiber infrastructure to support broadband expansion. Electric utilities are modernizing their electric grid and adding more communications infrastructure to existing utility assets in order to gather the data needed to create a smart system. For an incremental expense, these communications advancements can be leveraged beyond an electric utilities' core purposes in order to facilitate broadband expansion for customers, particularly in unserved and underserved areas.

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[3] Federal Communications Commission. *Connecting America: The National Broadband Plan*. 2010. https://transition.fcc.gov/national-broadband-plan/national-broadband-plan.pdf.

Fiber broadband expansion can be cost-prohibitive in rural markets due to topography challenges, low population densities, and prolonged permitting processes. Electric utilities are uniquely positioned to help overcome these barriers due to their existing infrastructure in such areas. Allowing electric utilities to engage with Internet Service Providers (ISPs) and other stakeholders can yield significant economies of scale by reducing an ISP’s required investment, while also providing the Company with the capacity needed to provide these same regions with the benefits of smart grid technologies. AEP Ohio supports strategies that provide rural America with the technological infrastructure it needs as economically and efficiently as possible, thus improving broadband and utility reliability and increasing economic opportunity for these areas.

Q. WHAT ARE THE BENEFITS OF EXPANDING THE BROADBAND AS PART OF THE PHASE 3 DEPLOYMENT?

A. From a macro perspective, broadband expansion creates economic, education, workforce, government, healthcare, and societal benefits. Broadband helps catalyze economic development through enhanced job creation, agricultural returns, business attraction and retention, and access to labor markets. Broadband access also facilitates telecommuting, which allows all workers to live where they want without sacrificing access to career opportunities. In turn, residential broadband access can augment regional home values. A report out of The Ohio State University estimated that reaching full broadband coverage in Ohio would generate $1-2 billion conservatively and up to $6.6 billion in economic benefits.[4]

In addition, as more government services transition to being online, access to broadband enables constituents to register their vehicles, pay taxes, procure licenses, communicate with elected officials, and more. High-speed connectivity also enables live streaming of municipal, state, and federal proceedings, which can provide invaluable information to the public as well as forums for civic engagement.

Broadband also enhances access to healthcare, particularly in those communities without a brick and mortar medical facility. Healthcare professionals are now able to utilize telemedicine, which enables the rapid digital transfer of information, to evaluate, diagnose, and treat patients in remote locations. Voice-activated devices and panic alarms connected to broadband can also help improve the quality of life for senior citizens, those that are disabled, and their caregivers.

From an individual lens, American households save on entertainment, healthcare, housing, food, apparel, automotive, subscriptions, gasoline, healthcare, and bill pay from the efficiencies enabled by broadband access. Modern social interaction, communication, entertainment and broadband are undeniably interwoven. Educators are also integrating broadband into the classroom and utilizing distance learning so that children and adults can access educational materials remotely. Those with sufficient broadband access are also able to utilize smart home technologies that allows consumers to connect and run

[4] Connecting the Dots of Ohio's Broadband Policy, The Ohio State University C. William Swank Program in Rural-Urban Policy, April 2017: https://aede.osu.edu/sites/aede/files/publication_files/Connecting%20the%20Dots%20of%20Ohio%20Broadband_0.pdf

various aspects of their home (ex: appliances, security system, thermostat, etc.) via a smart device.

Finally, as discussed above in the AMI section of my testimony, having broadband in conjunction with gridSMART technologies can develop and improve efficiencies that can reduce emissions, which benefits the environment.

Q. WHAT IS THE PROPOSED FIBER DEPLOYMENT PLAN FOR THE AMI, DACR, AND VVO DEPLOYMENTS?

A. For the AEP Ohio gridSMART Phase 2 deployment, public cellular was utilized exclusively for data backhaul for AMI, DACR, and VVO technologies. The Company plans to amend this deployment practice for the proposed Phase 3 project for deployments in regions which lack high-speed broadband availability for the customers in the area. In these regions, the Company intends to install fiber optic cable to the DACR and VVO devices just outside the substation or in close proximity to existing Company-owned fiber optic cables. The Company will target devices that can be connected via fiber optic cable by a new fiber segment of approximately one (1) mile or less. This fiber will serve the data backhaul for these DACR and VVO systems. Similarly, the Company intends to install fiber optic cable to the AMI APs in broadband unserved and underserved regions if the AP is approximately a mile from an existing Company-owned fiber optic cable or substation. As part of its deployment review, the Company will evaluate other factors, such as nearby telecom communication connection points, the number of nearby unserved or underserved customers, etc.

The Company acknowledges that defining a region that is unserved or underserved by broadband is challenging due to numerous factors, including the size of the census tract, the age of the data, anomalies in the collection of the data, and the definition of high-speed broadband, etc. The Company will gather the best available data to support whether a majority of an area has access to high-speed broadband as defined by the FCC. Currently, the official FCC broadband definition is a minimum of 25 Megabits per second (Mbps) download and 3 Mbps upload. If this definition changes during the deployment timeframe, the Company's assessment criteria will be amended to stay current with the FCC definition.

Q. WILL ALL PROPOSED FIBER CONNECTIONS HAVE DARK FIBER AVAILABLE FOR THIRD PARTY USE?

A. Yes. AEP Ohio will design the fiber optic cable sizing to balance cost and need for the specific area and target having adequate excess fiber capacity to serve the underserved need of the community where the fiber is being deployed. Typically, AEP Ohio will deploy a fiber cable with a minimum of 96 total fibers. The utility communication need for fibers and associated spares within these new fiber optical cables is expected to be 48 or less. The remaining dark fiber, which will encompass the majority of the system, will be made available to various groups including new and existing broadband providers to expand their service coverage and eliminate the upfront capital investment into building the infrastructure that would otherwise be required to deliver high-speed broadband services to customers in the area.

Q. HOW WILL THE COMPANY ACCOUNT FOR THE REVENUE FROM DARK FIBER LEASES?

A. AEP Ohio expects that revenue will be used to offset deployment costs for the specific fiber asset. The Company expects to receive significant revenues from third party use.

Please see the testimony of Dona Seger-Lawson for further details on how the revenue will be applied.

Q. ARE THERE STILL RURAL AREAS THAT DO NOT HAVE ACCESS TO BROADBAND TELECOM SERVICES?

A. Yes. The FCC reports that 39% of rural Americans (~23 million people) lack access to 25 Mbps download/ 3 Mbps upload (the current federal definition of "broadband") services.[5] As of Ohio's latest broadband mapping update in May 2017, 300,000 rural households (equating to approximately 1 million residents) and 88,500 Ohio businesses did not have broadband access. Due to the lack of broadband in some areas of the state, families often spend their evenings parked outside of local libraries, or visiting fast food restaurants with Wi-Fi access, so that children can complete homework assignments. State leadership has recognized the need to explore non-traditional service models to address Ohio's ongoing connectivity needs, particularly in rural areas.[6]

Q. HOW DO THESE SMART GRID FIBER CONNECTIONS ENABLE FURTHER EXPANSION OF BROADBAND SERVICE TO RURAL CUSTOMERS?

A. Making dark fiber leases available to ISPs will significantly reduce the barriers to entering a rural market by curtailing their construction and permitting costs. While typical fiber construction is approximately $50,000/mile, leasing dark fiber should be at a fraction of this capital expenditure/costs. As a result, AEP Ohio expects that the proposed Phase 3 deployment will incentivize build-out in the traditionally difficult to

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[5] Federal Communications Commission 2016 Broadband Progress Report, January 29th, 2016: https://www.fcc.gov/reports-research/reports/broadband-progress-reports/2016-broadband-progress-report

[6] Hannah Capitol Connection, ODOT, InnovateOhio Consider Opening Highway Areas to Drive Broadband Investment, *The Hannah Report*, June 20, 2019.

serve areas of Ohio, enabling rural customers to see an expansion or upgrade of broadband services in their area.

Q. DOES THE COMPANY ENVISION ADDITIONAL PHASE 3 FIBER CONSTRUCTION BEYOND WHAT HAS BEEN PREVIOUSLY DESCRIBED?

A. Yes, as part of the Phase 3 planning and engineering efforts, the Company plans to assess the nearby facilities and may deviate from its previously described plan to further enable broadband connectivity. For example, if there is a local telecom facility near a planned fiber construction route or a nearby Phase 3 distribution device, the Company will evaluate and may make slight adjustments to expand the fiber installation to connect these facilities.

Q. HAS THE COMPANY DEVELOPED A COST MODEL FOR DARK FIBER LEASES?

A. No, but as part of the project initiation phase post-approval, AEP Ohio plans to gather dark fiber lease data and understand competitive market prices to optimize both the use of the fiber and the cost savings for AEP Ohio customers. AEP Ohio plans to establish non-discriminatory pricing to facilitate numerous users of the fiber.

Q. DOES THE COMPANY ENVISION FIBER DEPLOYMENTS BEYOND MIDDLE MILE?

A. AEP Ohio does not currently plan to offer last mile or end-user broadband service. However, if the rules changed to allow AEP Ohio to offer these services to customers and traditional ISPs did not take the opportunity to expand to these rural customers, AEP Ohio will evaluate the business case associated with offering these services. Additionally, AEP Ohio would evaluate on a case-by-case basis for select and strategic further connections of middle mile fiber. An example of this would be to extend fiber to the additional DACR or VVO devices if there was a telecom ISP in close proximity and the area is unserved or underserved by broadband, or experiencing another need for enhanced connectivity.

Q. ARE THESE FIBER BENEFITS AND COSTS REFLECTED IN THE AMI, DACR, AND VVO BUSINESS CASE ANALYSIS?

A. No, since there is the possibility that the dark fiber lease revenue will offset the incremental costs associated with deploying fiber these costs and benefits were not included in the business case evaluation. AEP Ohio believes that these fiber connections should not be reviewed in the traditional way of evaluating the total cost effectiveness by evaluating the total benefits and comparing them to total costs. While there is a possibility that this review would yield favorable results once the data is collected, the proposed fiber connections would be implemented in a way that help achieve the State's policy objectives of facilitating high-speed broadband connectivity in unserved and underserved communities and the numerous societal benefits that accompany this. Additionally, as mentioned previously, the proposed fiber connections allow the Company to deliver grid modernization assets in a way that is more secure. The total platform of technologies proposed in the AEP Ohio gridSMART Phase 3 application yields, in total, more benefits than costs and is the basis for our position that the entire portfolio should be approved so AEP Ohio can deliver these benefits to our customers as shown in Table 2.

INTELLIGENT DISTRIBUTION LINE SENSORS

Q. PLEASE DESCRIBE THE COMPANY'S INTELLIGENT DISTRIBUTION LINE SENSOR PROPOSAL RELATIVE TO GRIDSMART PHASE 3.

A. AEP Ohio, as part of its gridSMART Phase 3 deployment, is proposing a demonstration to deploy intelligent distribution line sensors to determine the value of this technology by collecting timely data about the condition of the Company's distribution system in areas that currently lack this type of visibility. Specifically, the Company plans to continue to deploy this technology in conjunction with current traditional circuit reliability improvement efforts. Additionally, the Company plans on incorporating this technology with underground residential distribution (URD) cable as part of a program, which would enable quicker restoration.

Q. PLEASE DESCRIBE INTELLIGENT DISTRIBUTION LINE SENSORS AND WHY THIS TECHNOLOGY IS WELL-SUITED FOR THE PHASE 3 DEPLOYMENT.

A. Intelligent distribution line sensors are devices that are attached to the distribution lines and continuously monitor various parameters of the lines in real time (*e.g.*, current, voltage, fault currents). These devices use a variety of communication capabilities that can be integrated with AEP Ohio's existing DMS, SCADA and Outage Management System (OMS) technologies to identify when a fault occurs. By analyzing the data from the intelligent distribution line sensors placed at strategic locations, AEP Ohio is able to:

- Monitor the state of the grid in real time.
- Identify faults and outages faster.
- Locate approximate outage locations with greater accuracy.

This technology meshes well with the Phase 3 deployment, as it provides additional information that helps the Company to operate its system and improve reliability. Availability of this information expedites the outage recovery process, as crew search areas are narrowed, and patrolling times are reduced because it is no longer necessary to patrol the entire circuit to locate a problem.

Q. ARE INTELLIGENT DISTRIBUTION LINE SENSORS NEW TECHNOLOGY?

A. While the technology itself is not new, using it in a programmatic fashion would be a new approach used by the Company. Intelligent distribution line sensors are a proven technology, but the Company is currently only using this approach to solve specific reliability issues on a case-by-case basis. Using them on a case-by-case basis can help improve reliability at the circuit level, whereas a programmatic approach helps improve the visibility and reliability of the distribution system.

Q. WHAT ARE THE BENEFITS OF INTELLIGENT DISTRIBUTION LINE SENSORS?

A. As mentioned above, intelligent distribution line sensors improve the visibility of the system by helping to locate faults within an approximate location, allowing crews to hone in on outage areas. The improved visibility brought about by intelligent distribution line sensors, in coordination with other technologies, such as SCADA, also positively impacts reliability, as crews are now able to respond to outages in a timelier manner.

Q. WHAT ARE THE VARIOUS SCENARIOS FOR THE DEPLOYMENT OF INTELLIGENT DISTRIBUTION LINE SENSORS?

A. The Company is proposing three approaches as part of its demonstration, which are outlined below:

- **900 units on non-SCADA stations:**

  It is estimated there are approximately 300 circuits that do not have some type of SCADA system that is actively reporting data at the distribution feeder level. SCADA provides monitoring capability, and therefore more visibility into the status of the circuit breaker and remote operating capability, which can allow personnel to perform some of the switching and sectionalizing activities remotely instead of manually by a crew in the field, reducing overall restoration time. Without SCADA or similar technologies, station exit faults as well as feeder lockouts on these stations are difficult to troubleshoot. Gaining visibility of these circuits will provide a better understanding of how the circuits function normally and help assist outage restoration efforts. Installing distribution line sensors within this program results in the ability to gather the necessary real-time data to aid in operating the distribution grid with more visibility into the performance of the various components of the grid. Generally, intelligent distribution line sensors can be a cost effective way to gather this data in advance of a large capital project investment at the substation.

- **1,000 units on hard-to-patrol segments on the Phase 3 DACR circuits:**

  As detailed above, the DACR program provides significant reliability benefits for the Company's customers. To recap, DACR functions by adding automated sectionalizing devices to circuit schemes to restore customers after an event. These schemes work to avoid customer interruptions by isolating customers from faulted sections of the distribution line. However, there are currently zones between these devices that contain several miles of infrastructure with little visibility to where the fault may have occurred. Intelligent distribution line sensors deployed in these zones would help reduce the amount of response time and locating the faults within these hard-to-patrol zones to reduce the total outage time for impacted customers.

- **<u>1,200 units as a trial to learn the reliability improvement on locations with no other reliability improvement efforts:</u>**

  Intelligent distribution line sensors help provide visibility into the distribution system. This additional data helps the Company understand how the grid is functioning in normal and abnormal conditions (*e.g.*, major storms). Some of the intelligence gathered from these intelligent distribution line sensors include fault location, presence of voltage, and loading. This intelligence can help the Company with circuit planning and locating the fault during an outage to reduce the overall outage for customers.

Q. WHAT ARE THE BENEFITS ASSOCIATED WITH EACH OF THE THREE DEPLOYMENT SCENARIOS DESCRIBED?

A. Deploying intelligent distribution line sensors at stations without SCADA improves the visibility of distribution feeders, as well as improves the ability to troubleshoot faults at these stations. Coupling intelligent distribution line sensors on DACR and D-SCADA circuits improves fault location capability, and reduces the amount of time personnel need to locate faults on circuits. Placing intelligent distribution line sensors in various locations that have not been part of other reliability efforts would increase the visibility of these circuits, as well as reduce the amount of time personnel need to locate faults on circuits.

Q. WHAT ARE THE ESTIMATED COSTS FOR THE PROPOSED DEPLOYMENT OF INTELLIGENT DISTRIBUTION LINE SENSORS?

A. Over a five-year deployment period, intelligent distribution line sensors would cost approximately $9.9 million in capital. O&M for intelligent distribution line sensors over this same period would be approximately $1.8 million.

INCREMENTAL VVO

Q. IS THE COMPANY AWARE OF ANY OTHER TECHNOLOGIES THAT HAVE THE POTENTIAL TO FURTHER INCREASE THE SAVINGS DERIVED FROM THE VVO PROGRAM?

A. Yes, AEP Ohio has identified three distinct generations of VVO technologies that are available today to optimize the distribution system and reduce demand and/or energy usage through Conservation Voltage Reduction (CVR). To date, the Company has evaluated first- and second-generation VVO technologies and has deployed the best available systems from these genres. Third- or "power electronics-based" VVO technologies have emerged. These innovations address rising grid voltage fluctuations that have become visible through the widespread adoption of advanced metering infrastructure.

Q. WHAT IS THE COMPANY'S PROPOSAL FOR THIS THIRD GENERATION, OR INCREMENTAL VVO TECHNOLOGY?

A. The Company would like to deploy a pilot project to assess the incremental performance of power electronics-based VVO/CVR technologies that would also demonstrate successful integration of power electronics-based VVO/CVR technologies with the first- and second-generation systems previously deployed by AEP Ohio.

Q. PLEASE DESCRIBE THE INCREMENTAL VVO TECHNOLOGY IN MORE DETAIL.

A. The Phase 3 implementation of additional VVO, as described earlier in my testimony, reduces demand and energy consumption by flattening and lowering the voltage on circuits. This is achieved by measuring the voltage on the primary distribution line at critical points on each circuit and lowering the voltage to the lower range of the required voltage levels. Since the voltage is measured on the primary distribution system, there are limits to how much the voltage is lowered to allow for voltage drop on the secondary side of the distribution system. This is where the incremental VVO technology, or DVCs, come into play.

The DVCs will work autonomously along with the Company's existing VVO system and AMI. Voltage fluctuates on both the primary and secondary distribution systems as conditions change on the systems and customers' loads turn on and off. DVCs have the ability to flatten and/or lower voltage on the secondary distribution system that many electrical loads require. The DVCs accomplish this extremely quickly (sub-cycle response) by injecting reactive power (volt-ampere reactive, or VARs) instantaneously when needed. The result is that the voltage fluctuations are "smoothed" out on the secondary distribution system as well as areas of the primary distribution system. This allows the current VVO system and AMI to measure voltage that is smoother with fewer fluctuations, and thus lower the voltage further.

Q. WHAT DOES THE COMPANY WANT TO ACCOMPLISH WITH AN INCREMENTAL VVO PILOT?

A. A pilot project would examine and inform future decision-making with regard to options to maximize customer benefits by a) increasing the benefits, including energy savings and DER integration hosting capacity, to customers served by upgraded circuits by boosting the number of DVCs on these circuits, and/or b) increasing the number of customers benefitting from VVO/CVR services by deploying DVCs to expand the number of VVO circuits that can be cost-effectively upgraded (increase of eligible circuits thanks to improved NPV due to the deployment of DVCs).

Q. WHAT POTENTIAL BENEFITS DOES INCREMENTAL VVO TECHNOLOGY PROVIDE?

A. As previously described, VVO technologies provide benefits to customers in the form of energy savings, peak demand reductions, technical loss reduction, visibility and situational awareness, enhanced DER hosting capacity, and capital expense deferral/avoidance (*e.g.*, line reconductoring), among others. These have the added benefit because they do not require customer engagement, behavioral change, behind-the-meter-investment/retrofits, etc.

However, there are two major constraints to the benefits delivered by VVO technologies – the amount of voltage reductions that can be achieved and the number of VVO-upgraded circuits that serve customers. Navigant Research has conducted an analysis for California, which refers to power electronics-based VVO technologies as "secondary volt-var optimization," that shows how DVCs can address these constraints to expand the benefits delivered by VVO.

- Power electronics-based VVO technologies can augment the voltage reductions, and thereby boost the associated benefits, achieved by traditional VVO approaches by as much as 50% or more.
- Power electronics-based VVO technologies also can enable significant expansion (~20% or more) in the number of circuits that can be cost-effectively upgraded to deliver VVO benefits.
- Power electronics-based VVO technologies are scalable, in that the number of DVC devices deployed per circuit can be increased as needed, to provide a measure of future-proofing benefits.
- Power electronics-based VVO technologies are cost-effective, with benefit-cost ratios exceeding 4X on a stand-alone basis and elevating combined deployments to 1.8X (vs 1.35X for traditional VVO systems). Energy savings costs as low as $0.01 per kWh avoided are noted.

Q. WHAT IS THE SCOPE OF THE PROPOSED INCREMENTAL VVO PILOT?

A. AEP Ohio proposes a power electronics-based VVO technology pilot project encompassing 20 circuits, involving the installation and evaluation of 340 DVC units at a cost of approximately $1.2 million. A pilot project for power electronics-based VVO technologies would provide the data necessary to inform decisions on the number of DVCs to install per feeder, ranging between 5-15+ depending on several variables (*e.g.*, primary voltage, circuit length, loading conditions, etc.), and possible desired outcomes for customers (*e.g.*, power quality, energy savings, peak demand reductions, DER hosting capacity, etc.).

Additionally, this pilot project would allow AEP Ohio to compare the incremental performance and cost profiles of power electronics-based VVO technologies atop 1) non-VVO-upgraded feeders, 2) first-generation VVO-upgraded feeders, and 3) second-generation AMI-enabled VVO-upgraded feeders.

Furthermore, this pilot project would assess the speed and reliability with which power electronics-based VVO technologies can be deployed in the field, to inform the staging of inclusion of these systems into AEP Ohio's ongoing grid modernization activities.

Q. HOW WILL THE SUCCESS OF THE INCREMENTAL VVO PILOT BE MEASURED?

A. Currently, AEP Ohio is collecting M&V data on the circuits deployed during VVO Phase 2. This M&V data establishes the reduction of the voltage and energy savings from the baseline (without VVO technology). At the completion of the standard VVO M&V, the AMI module will be switched on and measurements of further reduction to voltage and energy savings based upon VVO plus the AMI module will be established to determine a new baseline of total savings from the standard VVO plus AMI module. Finally, the DVC technology will be installed on the secondary of the distribution transformers and the technology turned on. The DVC technology is designed to stabilize the voltage on the customer's secondary and does not directly reduce the voltage from the feeder. However, voltage levels in the customer secondary will be closely monitored to determine whether the VVO voltage targets can be further lowered based upon the voltage stability provided by the DVC device. Further voltage reductions from the established VVO plus AMI Module baseline established prior to the trial can be attributed to the DVC technology.

<u>IT'S YOUR POWER</u>

Q. DOES AEP OHIO'S PHASE 3 DEPLOYMENT GIVE CUSTOMERS ACCESS TO AMI INTERVAL DATA?

A. Yes, the Company's residential and commercial customers have access to AMI interval data. Residential customers have access to AMI interval data via an Energy Dashboard, which is a web portal, and Energy Reports including Home Energy Reports, High Bill/Usage Alerts and Weekly Energy Breakdown Reports. Residential customers who receive Home Energy Reports save an average of 11kWh/month per customer or 132kWh/customer annually.

Commercial customers will have access to Energy Usage Graphs, Charts and Insights embedded on their MyAccount and Energy Reports including Monthly Energy Reports, High Usage Alerts and Weekly Energy Reports.

Q. HOW WILL CUSTOMERS BE ABLE TO OBTAIN REAL-TIME AMI INTERVAL DATA?

A. The Company has an application, or "app," called "It's Your Power" that serves as a platform to give customers the ability to access and utilize real-time AMI data. The app combined with AMI through an in-home Energy Bridge will provide for better home energy management and access to real-time usage information. Currently, customers see just under 2% energy savings using the app. However, the Company anticipates that customers will achieve additional energy savings as they become more familiar with the app, and as additional app features are added over time. This Phase 3 filing includes a 5-year continuation of the It's Your Power app.

Q. WHAT IS THE ENERGY BRIDGE?

A. The Energy Bridge is a device offered by the Company that connects the It's Your Power app with a customer's AMI meter, giving access to energy usage in real-time. The Energy Bridge also offers access to a suite of additional energy management tools that allows customers to control all of their smart home devices, including bulbs, switches, and sensors.

Q. DO THE IT'S YOUR POWER APP AND ENERGY BRIDGE HAVE ANY OTHER BENEFICIAL FEATURES?

A. Yes, It's Your Power coupled with the Energy Bridge provides customers real-time energy usage (every 3 seconds). This additional tool aligns with the PowerForward initiative, as it helps enable smart home management. It's Your Power provides customers the ability to see disaggregated appliance usage, appliance health and coaching, set budgets, receive notifications, and control other smart connected devices in the home like thermostat, smart lights, and EV charging. The advisor cards within It's Your Power are customized to individual users coaching the customer on best actions to take with personalized tips and information regarding whole house usage.

Q. WHAT ARE THE ESTIMATED COSTS TO DEPLOY AND MANAGE THE AMI INTERVAL DATA APP- IT'S YOUR POWER?

A. For the 5-year program, the average annual cost to provide the It's Your Power app is $1.275 million per year. The Company estimates that approximately 8-9% of the customers that receive an AMI meter during Phase 3 deployment will download the app.

Of this amount, the Company anticipates approximately half will request and receive an Energy Bridge.

CRES PROVIDER ACCESS TO INTERVAL DATA AND PJM SETTLEMENT

Q. DO THE COMPETITIVE RETAIL ELECTRIC SERVICE PROVIDERS HAVE ACCESS TO AMI INTERVAL DATA?

A. Yes, via the CRES Business Partner Portal that was developed as part of the gridSMART Phase 2 project. 15-minute interval data is available for all AMI customers via the portal that enables CRES providers to evaluate customer usage to determine if they would benefit from a Time of Use (TOU) program.

Q. HOW SOON IS DATA AVAILABLE IN AEP OHIO'S SYSTEM TO VIEW THE INTERVAL DATA?

A. Generally, data is available as close to day-after load as possible (*i.e.*, usage day) for Validated, Edited and Estimated (VEE) 15-minute interval data on an individual account level.

Q. DOES AEP OHIO PROPOSE TO STREAMLINE THE CRES PROCESS FOR GATHERING AMI INTERVAL DATA?

A. Yes, as part of the Phase 3 efforts, AEP Ohio will expand the CRES data sharing to include sharing AMI interval data for CRES TOU product customers to CRES providers via EDI to enable a more automated transmittal of data that is more efficient for the CRES providers. EDI data automates the gathering of the information for the CRES providers. Today, the CRES providers must access the portal to retrieve the information. Once the CRES provider retrieves the information manually, they must also manually add the data to their system in order to bill the customer. Adding EDI functionality for

CRES TOU product customers will allow the CRES to have machine-to-machine access of data.

Q. WHAT ARE THE ESTIMATED COSTS ASSOCIATED WITH IMPROVING THE ACCESS TO AMI INTERVAL DATA VIA EDI FOR THE CRES PROVIDERS?

A. The project expenses to accomplish the described functionality for CRES access to AMI interval data for CRES TOU product customers is estimated to be approximately $0.7M.

Q. DOES AEP OHIO CURRENTLY PERFORM PJM SETTLEMENT USING ACTUAL AMI INTERVAL DATA?

A. AEP Ohio performs final 60-day settlement using AMI interval data for all AMI customers on a CRES TOU program or that have greater than 200kw of electricity demand.

Q. DOES AEP OHIO PROPOSE TO EXPAND HOW IT PERFORMS PJM SETTLEMENT WITH AMI INTERVAL DATA FOR ANY ADDITIONAL CUSTOMER TYPES?

A. AEP Ohio is exploring the possibility of expanding the existing program, which would allow market settlement of all customers using AMI interval data. Once AEP Ohio has completed a full analysis of such an expansion, the Company will make a subsequent filing regarding an implementation plan.

CUSTOMER OUTREACH AND EDUCATION

Q. DOES AEP OHIO INTEND TO COMPLETE OUTREACH AND EDUCATION FOR THE PROGRAMS?

A. Yes, the Company plans to continue outreach showcasing new technologies AEP Ohio is deploying. The Company has created several visual displays, which are collectively known as "The Smart Energy Experience" (TSEE). These displays will continue to be used during Phase 3 at various fairs, festivals, and home shows near locations where new technology is being deployed. The displays include an AMI kiosk, a mobile app bar where customers can learn about the benefits of their AMI meter and how to utilize It's Your Power and the Energy Dashboard. There are augmented reality walls to highlight energy savings, as well as augmented reality goggles that show how technologies such as DACR and VVO are benefiting customers. The Company will also continue to produce marketing materials to support educating our customers, as well as reach out in a "grass roots" way to homeowners' associations. The Company will have a social media plan in place, finding new and innovative ways to reach our customers in the mediums they engage in on a daily basis.

Q. WHAT ARE THE COSTS FOR CUSTOMER OUTREACH AND EDUCATION?

A. The costs for the Customer Outreach and Education are approximately $7.44 million over a 10-year period, or an average of $744,000 per year.

Q. DOES THIS CONCLUDE YOUR DIRECT TESTIMONY?

A. Yes.

HISTORY OF AEP OHIO'S GRIDSMART PROGRAM

gridSMART Phase 1 Summary

AEP Ohio secured approval from the Commission in Case Nos. 08-917-EL-SSO and 08-918-EL-SSO to move forward with its original gridSMART Phase 1 Project ("Phase 1 project") as a result of its Electric Security Plan filing from 2008.

AEP Ohio took a community-based approach and incorporated a full suite of advanced smart grid technologies for 110,000 consumers in an area selected for its concentration and diversity of distribution infrastructure and consumers. It was organized and aligned around:

- Technology, implementation, and operations
- Consumer and stakeholder acceptance
- Data management and benefit assessment

Combined, these functional areas served as the foundation of the Project to integrate commercially available products, innovative technologies, and new consumer products and services within a secure two-way communication network between the utility and consumers. The Phase 1 project included Advanced Metering Infrastructure ("AMI"), Distribution Management System ("DMS"), Distribution Automation Circuit Reconfiguration ("DACR"), Volt-VAR Optimization ("VVO"), and Consumer Programs ("CP"). These technologies were combined with two-way consumer communication and information sharing, demand response, dynamic pricing, and consumer products, such as plug-in electric vehicles and smart appliances. In addition, the Project incorporated comprehensive cyber security capabilities, interoperability, and a data assessment that, with grid simulation capabilities, made the demonstration results an adaptable, integrated solution for AEP Ohio and the nation.

The Phase 1 project improved distribution operations and improved reliability by identifying and responding to outages more quickly. In addition, the Phase 1 project improved distribution efficiency by reducing customer energy consumption (and retail power costs), reduced peak demand, and significantly reduced carbon emissions.

A. DACR Phase 1 Results - The gridSMART Phase 1 deployment has beneficially impacted customer reliability every year since it was deployed. The annual SAIDI and SAIFI values excluding major event days for the group of seventy circuits included in Phase 1 has been better with DACR than it would have been without DACR installed. The annual impact on the reliability indices is shown in the table below. The average annual savings in SAIFI for the most recent three years has been 21%, while the savings in SAIDI has been 15%.

	DACR Impact	
Year	**SAIFI**	**SAIDI**
2011	-3.6%	-2.8%
2012	-12.4%	-8.2%
2013	-24.9%	-20.0%
2014	-15.5%	-9.2%
2015	-8.6%	-6.1%
2016	-18.3%	-13.5%
2017	-28.0%	-19.7%
2018	-15.6%	-12.9%

B. VVO Phase 1 Results - VVO provided an average of approximately 3 percent reduction in circuit load on deployed circuits. Also, assuming VVO deployed on distribution circuits operated continuously during 2012 and 2013, the chart below represents estimated annual reductions in pollutants from fossil resources from the proposed VVO deployment:

Measurement	Anticipated Reduction
SOX	2,322,000 kg
NOX	1,041,000 kg
PM2.5	883,000 kg

gridSMART Phase 2 Summary

Based on the success of the Phase 1 project, AEP Ohio filed an application for its gridSMART Phase 2 Project ("Phase 2 project") under Case No. 13-1939-EL-RDR, which was approved by the Commission on February 1, 2017. The larger Phase 2 project follows the success of the Phase 1 project by deploying proven technology solutions to deliver AMI, DACR, and VVO related benefits to more customers over a larger portion of AEP Ohio's service area. For example:

- AMI offers operational savings, reduced CO2 emissions (i.e. truck rolls), improved safety for meter electricians, provides "last gasp" data enabling quicker identification and response to outages, improves customer satisfaction by enabling energy efficiency and providing interval data for Competitive Retail Electric Service ("CRES") providers, and enables future demand response programs.
- DACR delivers economic benefits of improved electric service reliability associated by reducing outage frequency (and reducing customer minutes of interruption assuming average outage duration is unchanged).
- VVO improves energy efficiency by reducing energy consumption (and CO2 emissions) and reducing customers' retail power costs.

GRIDSMART PHASE 3 TECHNOLOGY DESCRIPTIONS: DACR, VVO, AMI

Distribution Automation Circuit Reconfiguration (DACR)

DACR stands for Distribution Automation Circuit Reconfiguration, a category of advanced electric distribution infrastructure. A DACR circuit scheme includes two or more interconnected distribution circuits served from one or more substations that can be automatically switched and reconfigured as necessary to isolate and limit an outage to the smallest area impacting the fewest number of customers that is practical. The DACR technology proposed in AEP Ohio's gridSMART program principally involves the installation of "smart" reclosers on the distribution grid. A recloser is a piece of distribution infrastructure that is capable of sensing faults on a distribution circuit and automatically cutting off electricity flows (i.e., "opening" the circuit) by isolating the faulted section of line. AEP Ohio has already installed reclosers on many parts of its distribution grid, but these reclosers have only limited functionality. The smart reclosers installed through the gridSMART program have much more functionality. Most importantly, the smart reclosers are capable of transmitting to – and receiving signals from – a centralized control and responding automatically to limit the impact of outages on our customers. The smart reclosers also provide critical information to the control center regarding faults on AEP Ohio's distribution grid as well as enabling the control center to operate the reclosers remotely.

Volt/Var Optimization (VVO)

VVO stands for Volt/Var Optimization. Broadly speaking, VVO provides energy efficiency benefits related to reducing voltage levels on the distribution grid. AEP Ohio is required to deliver electric service to customers within specific voltage ranges. For example, for customers receiving secondary voltage service (including most residential and small commercial customers), AEP Ohio is required to provide electric service between 114 and 126 volts at the meter.

Due to various factors, AEP Ohio experiences voltage drops as electrical energy travels through the distribution system. Thus, AEP Ohio often sets transformers at substations to "push out" electric energy at higher voltages. By the time the electric energy reaches meters down the circuit, the voltage may have dropped to lower levels. The load factors that cause these voltage drops can fluctuate over time.

Currently, in areas where VVO has not been installed, AEP Ohio regulates voltage through ordinary, "non-smart" voltage regulators and capacitors. These devices provide no visibility into actual voltage levels on the grid. Thus, voltage levels must be set higher at the substation than might otherwise be needed to ensure that voltage does not drop below the lowest acceptable range for customers at the end of the circuit for all circumstances throughout the year.

VVO technology involves installing "smart" distribution infrastructure that allows AEP Ohio to measure voltage on various parts of the grid and to adjust voltage to respond to fluctuating voltage conditions. Specifically, the gridSMART VVO program involves the installation of voltage sensors at key parts of the grid that are capable of transmitting real-time voltage information at 30 second intervals to a centralized control. In addition, “smart” controls are installed on capacitors and regulators that allow the VVO control to automatically increase and decrease voltage levels remotely.

These “smart” voltage control technologies allow AEP Ohio to adopt a “nimble” approach to voltage control. Through VVO, AEP Ohio can increase voltage when necessary to compensate for voltage drops and reduce voltage at times when voltage drops are low. Over time, this allows AEP Ohio to achieve an overall reduction in grid voltage levels while ensuring that voltage at the meter never drops below the permissible range.

Advanced Metering Infrastructure (AMI)

Three features comprise the AMI system: “smart” meters, two-way communications networks and the information technology systems to support their interaction. AMI uses internal communications systems to convey near real-time energy use and load information to both AEP Ohio and to the customer.

AMI provides capability to monitor equipment and can quickly convey information about certain malfunctions and operating conditions. It also facilitates customers’ ability to achieve benefits related to certain future customer-owned advanced technologies and appliances.

PATRICK ENGINEERING

AEP Ohio

Revised Phase 3 Full System Feasibility Study Final Report

Revised Phase 3 Full System Feasibility Study Final Report

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Revised Phase 3 Full System Feasibility Study Report

1 Executive Summary

Ohio Power Company ("AEP Ohio") received approval to proceed with its Smart Grid Phase 2 plan from the Public Utilities Commission of Ohio ("Commission") in February 2017. That plan describes how AEP Ohio proposes to deploy advanced metering infrastructure ("AMI"), distribution automation circuit reconfiguration ("DACR"), and Volt-VAR optimization ("VVO") technology within specific locations of AEP Ohio's service area.

In addition to approving AEP Ohio's Smart Grid Phase 2 plan, the Commission's order required that AEP Ohio prepare and submit two engineering and feasibility and selection studies. The "Phase 2 Feasibility and Selection Study" report ("Phase 2 report") was submitted by AEP Ohio to the Commission in February 2018. That report describes how AEP Ohio will prioritize and select locations where AMI, DACR, and VVO will be deployed within the Smart Grid Phase 2 project area. Section 3 of the Phase 2 report describes feasibility and selection study objectives applicable for both AEP Ohio's authorized Smart Grid Phase 2 and future anticipated Smart Grid Phase 3 deployments. A common theme among all the objectives identified in Table 1 of the Phase 2 report is to "maximize customer and company benefits for the technologies proposed." [1] Section 4 of the Phase 2 report presents specific metrics and prioritization processes that fulfill all Table 1 objectives for AMI, DACR, and VVO. In addition, Section 4 describes how DACR and VVO metrics will be monetized to develop a prioritized business case portfolio analysis of all proposed DACR and VVO candidates, how the portfolios will be annually updated, and how DACR and VVO candidates will ultimately be selected for deployment.

This document, the "Revised Phase 3 Full System Feasibility Study" ("Phase 3 report") presents the latest version of a benefit-cost analysis or business case for all future anticipated AMI, DACR, and VVO Phase 3 deployments within all remaining areas of AEP Ohio's service area. [2] This latest version is an update of the original Phase 3 report submitted to the Commission in June 2018. Similar to the June 2018 report, Sections 2 and 3 of this Phase 3 report updates the prioritized business case portfolio analysis of all DACR and VVO distribution bus candidates as described in Section 4 of the Phase 2 report. For this reason, the Phase 2 report should be regarded as a companion reference document to this Phase 3 report (and the original June 2018 report) to avoid repetitive content describing the business case portfolio analysis development process.

In contrast to DACR and VVO, the Phase 2 report does not describe the business case development process for AMI. The Phase 2 report describes how AEP Ohio's approved AMI deployment will be prioritized across 43 cities within the Phase 2 AMI deployment area, but does not discuss an AMI business case. Section 4

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[1] Commission Order and Opinion dated February 1, 2017, Section IV (1) (B) (iii).

[2] AEP Ohio eliminated distribution circuits from the business case for a variety reasons. Circuits excluded from the Revised Phase 3 Full System Feasibility Study include, but are not necessarily limited to: 4 kV circuits, network circuits, circuits serving a few dedicated customers, circuits with insufficient capacity, or circuits have inadequate (or no) interconnections with adjoining circuits, etc.

of this updated Phase 3 report will present all relevant benefit and cost estimates, and business case results for a proposed Phase 3 AMI deployment within the remainder of AEP Ohio's service territory. Finally, Section 6 consists of an Appendix providing updated details of the prioritized DACR and VVO business case portfolio analysis for all candidate DACR schemes and VVO distribution buses and a description of all financial assumptions used throughout all DACR, VVO, and AMI business cases.

2 DACR Business Case and Portfolio Analysis

AEP Ohio has prepared a benefit-cost analysis or "business case portfolio analysis" for every DACR scheme candidate proposed for a Phase 3 deployment. All the benefit and cost data and associated assumptions used to prepare DACR business case portfolio analysis is presented in Sections 2.1. Results of the business case portfolio analysis for all Phase 3 DACR scheme candidates are summarized in Section 2.2.

2.1 DACR Benefit and Cost Data and Assumptions

AEP Ohio's 2013 application to the Commission seeking approval of its proposed Smart Grid Phase 2 plan included a business case justifying the proposed deployment of DACR on selected circuits throughout the AEP Ohio's service territory. The benefits component of this DACR business case was based on the societal economic benefits to customers associated with improved electric service reliability that is well documented through research sponsored by the U.S. Department of Energy's Lawrence Berkley National Laboratory ("LBNL").[3] In addition to AEP Ohio, LBNL's sponsored research has been referenced in numerous studies and by other electric utilities to justify their proposed smart grid programs. AEP Ohio's application of the methodology described in LBNL sponsored research to estimate the value of improved distribution reliability achievable with DACR was recognized and approved by order of the Commission in February 2017.

The Phase 3 business case portfolio analysis prepared for every DACR scheme candidate is based on the same LBNL methodology and approach previously used by AEP Ohio and previously accepted by the Commission to monetize reliability improvements associated with DACR. However, the Phase 3 study relies on updated estimates on the value of improved electric service reliability published by LBNL and reliability data for the three year period ending calendar year 2017 on all candidate DACR schemes and circuits.[4, 5] Updated estimates on the value of improved electric service reliability for LBNL's methodology are reproduced in Table 1 on page 3.

A properly designed DACR business case portfolio analysis includes the capital costs and operations and maintenance ("O&M") costs required to purchase, deploy, own, and maintain DACR infrastructure to realize the anticipated reliability benefits. A description of these costs incurred by AEP Ohio over the 15

[3] The economic benefits of improving electric service reliability is based on the LBNL sponsored research of Sullivan, M., Mercurio, M., Schellenberg, J., & Eto, J. in their (2010) paper "How to Estimate the Value of Service Reliability Improvements."

[4] Sullivan, M., Schellenberg, J., & Blundell, M. (Jan 2015). *Updated Value of Service Reliability Estimates for Electric Utility Customers in the United States (LBNL-6941E)* (p. xii). Ernest Orlando Lawrence Berkeley National Laboratory.

[5] All AEP Ohio reliability data excludes transmission outages and major event days.

year time horizon of the DACR business case portfolio analysis is provided in Table 2 on pages 3-4.

Table 1
Estimated Interruption Cost per Event by Duration and Customer Class

Duration (Min)	Residential	Small C&I	Med-Large C&I
Momentary	$4.22	$445	$14,001
30	$4.86	$562	$16,476
60	$5.51	$699	$19,246
240	$10.27	$2,032	$42,654
480	$18.59	$5,070	$90,894
960	$35.02	$9,788	$178,886

Table 1 Notes:

1. Interruption costs per event by duration and customer class represents the outage cost associated with an individual interruption for a typical or average sized customer within the meta-database used by the principal investigators who performed the LBNL sponsored research. Table durations represent customer average interruption duration index ("CAIDI") values.
2. See Footnote 4 on page 2 of this report for the LBNL source where these estimated interruption costs are published. The interruption costs above published by LBNL are in 2013 dollars. These costs have been escalated to 2019 dollars within the DACR business case portfolio analysis using the Consumer Price Index published by the U.S. Bureau of Labor Statistics.
3. Example calculation:

   Assume a distribution circuit serves 1000 residential customers, 100 small C&I customers, and 2 medium & large C&I customers. Also, assume the circuit has a circuit CAIDI of 60 minutes and a system average interruption frequency index ("SAIFI") of 1.00. (The system average interruption duration index or "SAIDI" is 60 minutes.)

   The annual societal economic cost of interruptions on this circuit is 1000 residential customers × $5.51 per residential customer + 100 small C&I customers × $699 per small C&I customer + 2 medium & large C&I customer x $19,246 per medium & large C&I customer = $113,902. If the annual outage frequency is reduced by 50 percent (SAIFI is 0.50 and CAIDI is unchanged) the annual economic cost of interruptions is reduced by half, i.e. $113,902 × 0.50 = $56,951.

Table 2
Description of Capital and O&M Costs for DACR Infrastructure

1. Substation infrastructure

   Includes estimated capital costs associated with breaker control upgrades, new or upgraded remote terminal units, control house panel upgrades, and station yard cable raceway upgrades including fiber optic or other control cabling replacements.

2. Distribution line infrastructure

   Includes initial capital costs, O&M costs for each candidate distribution circuit and DACR scheme associated with:

a) Reclosers/controls or recloser control upgrades

b) Voltage regulator banks/controls or regulator bank control upgrades

c) Switched capacitor bank/controls or capacitor bank control upgrades

3. Communication infrastructure

   Includes initial and replacement capital costs and O&M costs for each candidate distribution circuit and DACR scheme associated with cellular LTE and/or mesh radios installed at (or near) each recloser, voltage regulator bank, and switched capacitor bank location.

4. Information technology infrastructure

   Includes initial and replacement capital costs and O&M costs associated with all DACR controller hardware, software licensing, fees and maintenance support.

2.2 DACR Business Case and Portfolio Analysis Results

AEP Ohio has prepared a benefit-cost analysis or "business case" for 146 DACR schemes involving 711 distribution circuits identified as candidates for a possible Smart Grid Phase 3 deployment.[6] As described within the Phase 2 report, a business case for each DACR scheme candidate is essential to ensure that AEP Ohio is delivering the greatest monetized benefits of improved electric service reliability minus the costs (i.e. ***net*** benefits) previously identified in Table 2 to procure, deploy, operate, and maintain the proposed DACR infrastructure.

The business case prepared for each DACR scheme candidate represents the net benefit "cash flows" that are discounted at AEP Ohio's after-tax weighted cost of capital to estimate the 15 year net present value ("NPV") of the proposed scheme.[7] These net benefit cash flows include the monetized LBNL benefits associated with improved reliability, initial and replacement capital costs, and O&M costs associated with substation, distribution, communication, and information technology ("IT") infrastructure.[8] Also, these cash flows incorporate the combined tax effects associated with the depreciation of capitalized infrastructure assets and the tax effects associated with annual O&M expenses. The cash flow model for DACR scheme "CRA991" provided in Table 3 on page 6 illustrates all the annual cash flows that yields a 15 year NPV of $7,034,782 in the bottom right corner of the table.

[6] Each DACR circuit scheme candidate includes 2 or more interconnected distribution circuits served from one or more substations that can be automatically switched and reconfigured as necessary to isolate and limit an outage to the smallest area impacting the fewest number of customers that is practical.

[7] The term "net benefit cash flows" or simply "cash flows" used hereinafter within this report include benefits from the perspective of customers such as the societal economic benefit of improved reliability and improved energy efficiency / reduced retail power costs associated with DACR and VVO respectively. Also, the term net benefit cash flows or simply cash flows also includes operational savings associated with AMI.

[8] AEP Ohio operating savings associated with outage restoration and lost retail revenue were originally examined, but eventually discarded from the DACR business cases because their contributions were negligible.

This level of business case modeling detail illustrated in Table 3 was repeated for each of the other 145 DACR scheme candidates before assembling all business case results into AEP Ohio's DACR portfolio. This DACR portfolio of DACR scheme candidates was then prioritized and ranked by their individual 15 year NPV values in descending order from candidates with the highest NPV to candidates with the lowest (or most negative) to identify DACR scheme candidates delivering the greatest value to AEP Ohio customers. A graphical summary of the NPV results for all 146 Phase 3 DACR scheme candidates is provided in Figure 1.

The business case developed for all 146 DACR scheme candidates is based on a common set of financial assumptions and notes that are summarized within Section 6.3 (Appendix) of this Phase 3 report. Among the 146 DACR scheme candidates investigated, 80 schemes impacting 416 distribution circuits have business cases with positive 15 year NPV values. Collectively, these 80 DACR schemes deliver to AEP Ohio customers improved electric service reliability estimated to have a 15 year present value societal economic benefit of $569,908,200 compared to the estimated 15 year present value cost of $349,945,501 to deploy, own, operate, and maintain the needed DACR infrastructure. (The 15 year NPV for all 80 schemes is $219,962,699.) In other words, AEP Ohio customers realize $1.63 in DACR benefits for every dollar of DACR related capital and O&M costs incurred over 15 years on these 80 schemes. A tabular listing of all 146 DACR scheme candidates graphically illustrated in Figure 1 is provided in Table 10 of Section 6.1 (Appendix). The DACR scheme candidates with the 10 highest 15 year NPV values from Table 10 is reproduced in Table 4 on page 7.

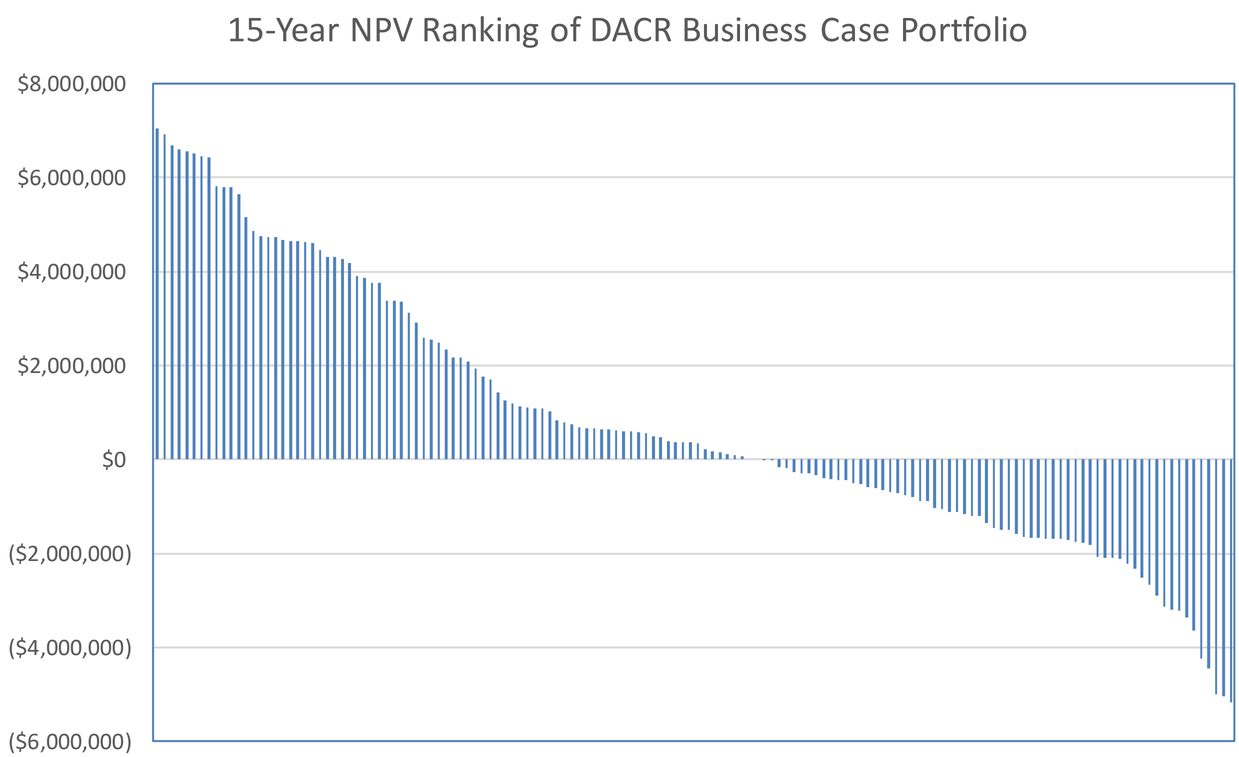

Figure 1: Prioritized Business Case Portfolio of DACR Schemes

Table 3
Cash Flow Model for Highest Ranked DACR Scheme "CRA991"

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Capital Related Costs	$3,948,800	$9,870	$9,870	$9,870	$9,870	$0	$0	$0	$0	$0	$364,839	$0	$0	$0	$0
Capital Cost - Substation Infrastructure	$1,145,510	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capital Cost - Distribution Infrastructure	$2,405,165	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capital Cost - Communication Infrastructure	$345,450	$9,870	$9,870	$9,870	$9,870	$0	$0	$0	$0	$0	$350,509	$0	$0	$0	$0
Capital Cost - Info Tech Infrastructure	$52,675	$0	$0	$0	$0	$0	$0	$0	$0	$0	$14,330	$0	$0	$0	$0
Capital Cost - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - Capital Costs	$3,948,800	$9,870	$9,870	$9,870	$9,870	$0	$0	$0	$0	$0	$364,839	$0	$0	$0	$0
Depreciation Related Costs															
Dep Exp - Substation Infrastructure	$25,456	$25,456	$25,456	$25,456	$25,456	$25,456	$25,456	$25,456	$25,456	$25,456	$25,456	$25,456	$25,456	$25,456	$25,456
Dep Exp - Distribution Infrastructure	$75,161	$75,161	$75,161	$75,161	$75,161	$75,161	$75,161	$75,161	$75,161	$75,161	$75,161	$75,161	$75,161	$75,161	$75,161
Dep Exp - Communication Infrastructure	$23,030	$23,688	$24,346	$25,004	$25,662	$25,662	$25,662	$25,662	$25,662	$25,662	$26,657	$26,657	$26,657	$26,657	$26,657
Dep Exp - Info Tech Infrastructure	$10,535	$10,535	$10,535	$10,535	$10,535	$0	$0	$0	$0	$0	$2,866	$2,866	$2,866	$2,866	$2,866
Dep Exp - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Tax Benefit of Dep - Substation Infrastructure	$5,570	$5,570	$5,570	$5,570	$5,570	$5,570	$5,570	$5,570	$5,570	$5,570	$5,570	$5,570	$5,570	$5,570	$5,570
Tax Benefit of Dep - Distribution Infrastructure	$16,445	$16,445	$16,445	$16,445	$16,445	$16,445	$16,445	$16,445	$16,445	$16,445	$16,445	$16,445	$16,445	$16,445	$16,445
Tax Benefit of Dep - Com Infrastructure	$5,039	$5,183	$5,327	$5,471	$5,615	$5,615	$5,615	$5,615	$5,615	$5,615	$5,833	$5,833	$5,833	$5,833	$5,833
Tax Benefit of Dep - Info Tech Infrastructure	$2,305	$2,305	$2,305	$2,305	$2,305	$0	$0	$0	$0	$0	$627	$627	$627	$627	$627
Tax Benefit of Dep - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - Tax Benefit of Depreciation	$29,359	$29,503	$29,647	$29,791	$29,935	$27,630	$27,630	$27,630	$27,630	$27,630	$28,475	$28,475	$28,475	$28,475	$28,475
Net Book - Substation Infrastructure	$1,120,054	$1,094,598	$1,069,143	$1,043,687	$1,018,231	$992,775	$967,320	$941,864	$916,408	$890,952	$865,496	$840,041	$814,585	$789,129	$763,673
Net Book - Distribution Infrastructure	$2,330,004	$2,254,842	$2,179,681	$2,104,519	$2,029,358	$1,954,197	$1,879,035	$1,803,874	$1,728,712	$1,653,551	$1,578,390	$1,503,228	$1,428,067	$1,352,905	$1,277,744
Net Book - Communication Infrastructure	$322,420	$308,602	$294,126	$278,992	$263,200	$237,538	$211,876	$186,214	$160,552	$134,890	$123,162	$96,504	$69,847	$43,190	$16,533
Net Book - Info Tech Infrastructure	$42,140	$31,605	$21,070	$10,535	$0	$0	$0	$0	$0	$0	$11,464	$8,598	$5,732	$2,866	$0
Net Book - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Property Tax - Substation Infrastructure	$34,162	$33,385	$32,609	$31,832	$31,056	$30,280	$29,503	$28,727	$27,950	$27,174	$26,398	$25,621	$24,845	$24,068	$23,292
Property Tax - Distribution Infrastructure	$71,065	$68,773	$66,480	$64,188	$61,895	$59,603	$57,311	$55,018	$52,726	$50,433	$48,141	$45,848	$43,556	$41,264	$38,971
Property Tax - Communication Infrastructure	$9,834	$9,412	$8,971	$8,509	$8,028	$7,245	$6,462	$5,680	$4,897	$4,114	$3,756	$2,943	$2,130	$1,317	$504
Property Tax - Info Tech Infrastructure	$1,285	$964	$643	$321	$0	$0	$0	$0	$0	$0	$350	$262	$175	$87	$0
Property Tax - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - Property Tax	$116,346	$112,534	$108,703	$104,851	$100,979	$97,128	$93,276	$89,425	$85,573	$81,721	$78,645	$74,675	$70,706	$66,737	$62,767
Operations & Maintenance Expense	$126,654	$128,002	$130,227	$132,490	$134,791	$137,341	$139,401	$141,492	$143,615	$145,769	$146,719	$148,919	$151,153	$153,420	$155,722
O&M - Substation Infrastructure	$34,365	$34,881	$35,404	$35,935	$36,474	$37,021	$37,577	$38,140	$38,712	$39,293	$39,882	$40,481	$41,088	$41,704	$42,330
O&M - Distribution Infrastructure	$72,155	$73,237	$74,336	$75,451	$76,583	$77,731	$78,897	$80,081	$81,282	$82,501	$83,739	$84,995	$86,270	$87,564	$88,877
O&M - Communication Infrastructure	$16,034	$16,575	$17,128	$17,695	$18,274	$19,076	$19,363	$19,653	$19,948	$20,247	$19,352	$19,643	$19,937	$20,236	$20,540
O&M - Info Tech Infrastructure	$4,100	$3,309	$3,359	$3,409	$3,460	$3,512	$3,565	$3,618	$3,673	$3,728	$3,745	$3,801	$3,858	$3,916	$3,975
O&M - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - O&M Expenses	$126,654	$128,002	$130,227	$132,490	$134,791	$137,341	$139,401	$141,492	$143,615	$145,769	$146,719	$148,919	$151,153	$153,420	$155,722
Customer Benefits	$1,256,258	$1,281,478	$1,307,204	$1,333,446	$1,360,215	$1,387,521	$1,415,375	$1,443,789	$1,472,773	$1,502,339	$1,532,498	$1,563,263	$1,594,646	$1,626,658	$1,659,314
Operating Benefits	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operating Benefits & Expenses Net of Taxes	($160,472)	($158,404)	($157,005)	($155,620)	($154,249)	($155,537)	($154,138)	($152,762)	($151,412)	($150,086)	($147,579)	($146,197)	($144,842)	($143,512)	($142,209)
Depreciation Tax Benefit	$29,359	$29,503	$29,647	$29,791	$29,935	$27,630	$27,630	$27,630	$27,630	$27,630	$28,475	$28,475	$28,475	$28,475	$28,475
Property Tax Expense	$90,889	$87,912	$84,918	$81,909	$78,885	$75,876	$72,867	$69,858	$66,850	$63,841	$61,437	$58,336	$55,236	$52,135	$49,034
O&M Expense	$98,942	$99,995	$101,733	$103,501	$105,299	$107,291	$108,900	$110,534	$112,192	$113,875	$114,617	$116,336	$118,081	$119,852	$121,650
Operating Benefits	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - Cash Flow Net of Taxes	($160,472)	($158,404)	($157,005)	($155,620)	($154,249)	($155,537)	($154,138)	($152,762)	($151,412)	($150,086)	($147,579)	($146,197)	($144,842)	($143,512)	($142,209)
Annual Customer & Utility Net Cash Flow	($2,853,014)	$1,113,204	$1,140,329	$1,167,956	$1,196,096	$1,231,984	$1,261,238	$1,291,027	$1,321,361	$1,352,253	$1,020,080	$1,417,066	$1,449,804	$1,483,146	$1,517,104
Cumulative Customer & Utility Net Cash Flow	($2,853,014)	($1,739,810)	($599,481)	$568,475	$1,764,571	$2,996,554	$4,257,792	$5,548,819	$6,870,180	$8,222,433	$9,242,514	$10,659,579	$12,109,384	$13,592,530	$15,109,634
Annual PV Customer & Utility Cash Flow	($2,646,581)	$957,938	$910,278	$864,871	$821,622	$785,041	$745,531	$707,922	$672,129	$638,073	$446,507	$575,393	$546,092	$518,229	$491,738
Cumulative NPV Customer & Utility Cash Flow	($2,646,581)	($1,688,643)	($778,365)	$86,506	$908,128	$1,693,169	$2,438,700	$3,146,621	$3,818,751	$4,456,824	$4,903,330	$5,478,724	$6,024,815	$6,543,044	$7,034,782

Table 4
Prioritized Business Case Portfolio of DACR Schemes (Top 10)

Candidate	Rank	NPV	PV Benefits	PV Costs	Circuits	Total	Rule 11	District	District Sub-Area
CRA991	1	$7,034,782	$12,465,319	$5,430,537	7	7	0	Columbus	Columbus, SW - 65
CRC200	2	$6,906,261	$12,856,299	$5,950,038	8	15	0	Columbus	Columbus, SE - 64
CRC517	3	$6,684,020	$12,009,602	$5,325,581	7	22	0	Columbus	Columbus, SE - 64
CRC414	4	$6,607,554	$10,326,328	$3,718,774	5	27	0	Columbus	Columbus, NW - 66
CRC013	5	$6,549,871	$15,097,977	$8,548,106	10	37	0	Chillicothe	Portsmouth - 82
CRA999	6	$6,516,946	$12,011,153	$5,494,208	7	44	0	Columbus	Columbus, SE - 64
CRC407	7	$6,446,330	$10,304,355	$3,858,026	5	49	0	Columbus	Columbus, NW - 66
CRA109	8	$6,437,162	$15,818,159	$9,380,997	11	60	0	Canton	North Canton - 20, South Canton - 21
CRA996	9	$5,818,869	$11,217,561	$5,398,692	7	67	0	Columbus	Columbus, SW - 65
CRC518	10	$5,801,212	$9,614,601	$3,813,388	5	72	0	Columbus	Columbus, SE - 64, Columbus, SW - 65

The DACR business case and portfolio analysis presented in this report assumes AEP Ohio will utilize the same DACR technology in previous and current deployments approved by the PUCO to achieve a reduction in outage frequency (SAIFI) of 15.8 percent. AEP Ohio continues to examine additional technologies to further enhance distribution reliability and deliver additional customer benefits. These technologies may be included as part of AEP Ohio's formal application to the PUCO seeking approval of a Phase 3 DACR deployment or may be proposed to the PUCO at a later date as part of a separate application and proceeding. In addition, AEP Ohio continues to examine business processes, evaluate the recent performance of existing DACR schemes, and review other external performance outcomes that may contribute to additional reductions in outage frequency and/or outage duration.

3 VVO Business Case and Portfolio Analysis

AEP Ohio has prepared a benefit-cost analysis or "business case portfolio analysis" for every VVO bus candidate proposed for a Phase 3 deployment. All the benefit and cost data and associated assumptions used to prepare VVO business case portfolio analysis is presented in Sections 3.1. Results of the business case portfolio analysis for all Phase 3 VVO bus candidates are summarized in Section 3.2.

3.1 VVO Benefit and Cost Data and Assumptions

The net change or reduction in demand and energy that may be realized by deploying VVO are measures associated with improving energy efficiency. Estimating AEP Ohio improvements in energy efficiency achievable with VVO required that calendar year 2017 data on peak loads, and retail sales and revenue data by customer rate class and distribution circuit be collected and totalized for each Phase 3 VVO bus candidate. The benefits of improved energy efficiency are monetized by estimating reductions in customers' retail power costs associated with a given average percent reduction in voltage and energy at each VVO bus.

A properly designed VVO business case portfolio analysis includes the capital costs and operations and maintenance ("O&M") costs required to purchase, deploy, own, and maintain VVO infrastructure to realize the anticipated reliability benefits. A description of these costs incurred by AEP Ohio over the 15 year time horizon of the VVO business case portfolio analysis is provided in Table 5.

Table 5
Description of Capital and O&M Costs for VVO Infrastructure

1. Substation infrastructure

   Includes estimated capital costs associated with voltage regulator control upgrades, voltage regulator bank replacements, new or upgraded remote terminal units, control house panel upgrades, and station yard cable raceway upgrades including fiber optic or other control cabling replacements.

2. Distribution line infrastructure

   Includes initial capital costs and O&M costs for each candidate distribution circuit and VVO distribution bus associated with:

   a) Voltage regulator banks/controls or regulator bank control upgrades
   b) Switched capacitor bank/controls or capacitor bank control upgrades
   c) New line voltage monitors

3. Communication infrastructure

   Includes initial and replacement capital costs and O&M costs for each candidate distribution circuit and VVO distribution bus associated with cellular LTE and/or mesh radios installed at (or near) each voltage regulator bank, switched capacitor bank, and line voltage monitor locations.

4. Information technology infrastructure.

   Includes initial and replacement capital costs and O&M costs associated with all VVO controller hardware, VVO and AMI module software licensing, fees and maintenance support.

3.2 VVO Business Case and Portfolio Analysis Results

AEP Ohio has prepared a benefit-cost analysis or "business case" for 445 VVO buses involving 973 distribution circuits identified as candidates for a possible Smart Grid Phase 3 deployment. As described within the Phase 2 report, a business case for each VVO bus candidate is essential to ensure that AEP Ohio is delivering the greatest monetized benefits of energy efficiency from the perspective customers, i.e. retail power cost savings minus the costs (i.e. *net* benefits) previously identified in Table 5 to procure, deploy, operate, and maintain the proposed VVO infrastructure.

The business case prepared for each VVO bus candidate represents the net benefit cash flows that are discounted at AEP Ohio's after-tax weighted cost of capital to estimate the 15 year net present value ("NPV") of the proposed scheme. These net benefit cash flows include retail customer power costs savings, initial and replacement capital costs, and O&M costs associated with substation, distribution, communication, and information technology ("IT") infrastructure.[9, 10] Also, these cash flows incorporate the combined tax effects associated with the depreciation of capitalized infrastructure assets and the tax effects associated with annual O&M expenses. The cash flow model for VVO bus "E.WOOSTER 1X" provided in Table 7 on page 11 illustrates all the annual cash flows that yields a 15 year NPV of $1,413,711 in the bottom right corner of the table.

This level of business case modeling detail illustrated in Table 7 was repeated for each of the other 445 VVO bus candidates before assembling all business case results into AEP Ohio's VVO portfolio. This VVO portfolio of VVO bus candidates was then prioritized and ranked by their individual 15 year NPV values in descending order from candidates with the highest NPV to candidates with the lowest (or most negative) to identify VVO bus candidates delivering the greatest value to AEP Ohio customers. A graphical summary of the NPV results for all 445 Phase 3 VVO bus candidates is provided in Figure 2.

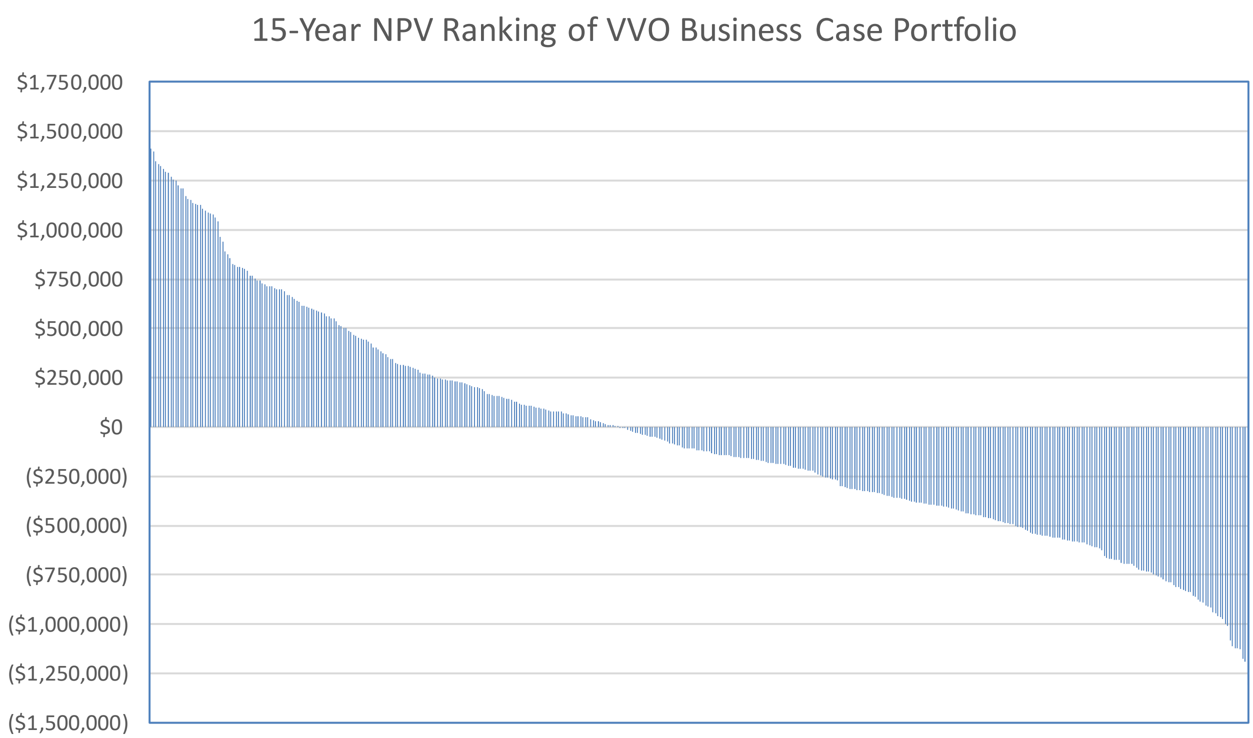

Figure 2: Prioritized Business Case Portfolio of VVO Distribution Buses With AMI

[9] AEP Ohio operating savings associated with deferred plant investment was originally investigated, but eliminated from the VVO business case because no tangible benefits could be estimated or their contributions were negligible.

[10] Reductions in CO_2 are identified in the business case, but not monetized pending establishment of an incentivized U.S. cap-and-trade, tax credit, or other program.

The business case developed for all 445 VVO bus candidates is based on a common set of financial assumptions and notes that are summarized within Section 6.3 (Appendix) of this Phase 3 report. Among the 445 VVO bus candidates investigated, 190 buses impacting 492 distribution circuits have business cases with positive 15 year NPV values. Collectively, these 190 VVO buses with positive business cases deliver greater energy efficiency (and reduced retailed power costs) yielding an estimated 15 year present value benefit of $414,035,474. In contrast, AEP Ohio incurs an estimated 15 year present value capital and O&M cost of $322,788,749 to procure, deploy, operate, and maintain the needed VVO infrastructure. (The 15 year NPV for all 190 buses is $91,246,725.) In other words, AEP Ohio retail customers realize $1.28 in VVO benefits for every dollar of VVO related capital and O&M costs incurred over 15 years on these 190 buses. In addition, improved energy efficiency associated with VVO is estimated to reduce CO_2 emissions by 6,611,509 metric tons ("t") over 15 years.[11] A tabular listing of all 445 VVO bus candidates graphically illustrated in Figure 2 is provided in Table 11 of Section 6.2 (Appendix). The VVO bus candidates with the 10 highest 15 Year NPV values from Table 11 is reproduced in Table 6.

Table 6

Prioritized Business Case Portfolio of VVO Buses (Top 10)

Candidate	Rank	NPV	PV Benefits	PV Costs	Reduced CO2	Circuits	Total	OHA
E.WOOSTER 1X	1	$1,413,711	$3,414,614	$2,000,903	57,979	3	3	2
ZUBER 1X	2	$1,400,035	$3,400,938	$2,000,903	57,373	3	6	1
CLINTON 2Y	3	$1,347,376	$3,543,115	$2,195,739	48,668	4	10	0
DELAWARE 2Y	4	$1,334,621	$2,474,862	$1,140,241	39,113	2	12	0
BROOKSIDE 1X	5	$1,324,917	$3,847,521	$2,522,604	71,377	4	16	0
WEST CANTON 3X	6	$1,307,386	$1,901,720	$594,334	33,704	1	17	0
CLINTON 2X	7	$1,296,188	$3,491,926	$2,195,739	50,011	4	21	1
WHITE RD 1X	8	$1,290,359	$3,812,963	$2,522,604	66,810	4	25	0
S.SIDELIM 3X	9	$1,270,645	$3,271,548	$2,000,903	56,410	3	28	1
N.LIBERTY 3X	10	$1,254,954	$2,734,170	$1,479,216	40,431	2	30	0

All the VVO business case portfolio analysis results heretofore presented within this Phase 3 report assumes AEP Ohio will utilize its VVO vendor's proprietary software to achieve greater voltage reduction and energy efficiency by analyzing metering interval and voltage data wherever AMI is deployed. The VVO vendor asserts that AEP Ohio can achieve an average 4 percent reduction in energy usage (and retail power costs) if AEP Ohio integrates the vendor's proprietary software with its other VVO hardware and software wherever AMI is deployed. However, the VVO vendor asserts only an average 3 percent voltage reduction can be achieved if AEP Ohio doesn't have AMI interval and voltage data (i.e. no AMI has been deployed) and doesn't procure and integrate the vendor's software with its other VVO infrastructure.

AEP Ohio's VVO business case portfolio analysis is significantly impacted if AMI isn't deployed where VVO is proposed, the VVO vendor's proprietary software isn't purchased and integrated with the vendor's other systems, and average voltage and energy reduction is limited to 3 percent. A graphical summary of these impacts on NPV results for all 445 Phase 3 VVO bus candidates is provided in Figure 3 on page 12.

[11] The official symbol for the metric ton in the International System of Units ("SI") is "t".

Table 7

Cash Flow Model for Highest Ranked VVO Bus “E.WOOSTER 1X”

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Capital Related Costs	$1,268,940	$2,925	$2,925	$2,925	$2,925	$0	$0	$0	$88,786	$0	$106,365	$0	$0	$0	$0
Capital Cost - Substation Infrastructure	$666,180	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capital Cost - Distribution Infrastructure	$363,690	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capital Cost - Communication Infrastructure	$104,760	$2,925	$2,925	$2,925	$2,925	$0	$0	$0	$0	$0	$106,365	$0	$0	$0	$0
Capital Cost - Info Tech Infrastructure	$134,310	$0	$0	$0	$0	$0	$0	$0	$88,786	$0	$0	$0	$0	$0	$0
Capital Cost - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - Capital Costs	$1,268,940	$2,925	$2,925	$2,925	$2,925	$0	$0	$0	$88,786	$0	$106,365	$0	$0	$0	$0
Depreciation Related Costs															
Dep Exp - Substation Infrastructure	$14,804	$14,804	$14,804	$14,804	$14,804	$14,804	$14,804	$14,804	$14,804	$14,804	$14,804	$14,804	$14,804	$14,804	$14,804
Dep Exp - Distribution Infrastructure	$11,365	$11,365	$11,365	$11,365	$11,365	$11,365	$11,365	$11,365	$11,365	$11,365	$11,365	$11,365	$11,365	$11,365	$11,365
Dep Exp - Communication Infrastructure	$6,984	$7,179	$7,374	$7,569	$7,764	$7,764	$7,764	$7,764	$7,764	$7,764	$8,066	$8,066	$8,066	$8,066	$8,066
Dep Exp - Info Tech Infrastructure	$26,862	$26,862	$26,862	$26,862	$26,862	$0	$0	$0	$17,757	$17,757	$17,757	$17,757	$17,757	$0	$0
Dep Exp - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Tax Benefit of Dep - Substation Infrastructure	$3,239	$3,239	$3,239	$3,239	$3,239	$3,239	$3,239	$3,239	$3,239	$3,239	$3,239	$3,239	$3,239	$3,239	$3,239
Tax Benefit of Dep - Distribution Infrastructure	$2,487	$2,487	$2,487	$2,487	$2,487	$2,487	$2,487	$2,487	$2,487	$2,487	$2,487	$2,487	$2,487	$2,487	$2,487
Tax Benefit of Dep - Com Infrastructure	$1,528	$1,571	$1,613	$1,656	$1,699	$1,699	$1,699	$1,699	$1,699	$1,699	$1,765	$1,765	$1,765	$1,765	$1,765
Tax Benefit of Dep - Info Tech Infrastructure	$5,877	$5,877	$5,877	$5,877	$5,877	$0	$0	$0	$3,885	$3,885	$3,885	$3,885	$3,885	$0	$0
Tax Benefit of Dep - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - Tax Benefit of Depreciation	$13,131	$13,174	$13,217	$13,259	$13,302	$7,425	$7,425	$7,425	$11,310	$11,310	$11,376	$11,376	$11,376	$7,491	$7,491
Net Book - Substation Infrastructure	$651,376	$636,572	$621,768	$606,964	$592,160	$577,356	$562,552	$547,748	$532,944	$518,140	$503,336	$488,532	$473,728	$458,924	$444,120
Net Book - Distribution Infrastructure	$352,325	$340,959	$329,594	$318,229	$306,863	$295,498	$284,133	$272,768	$261,402	$250,037	$238,672	$227,306	$215,941	$204,576	$193,210
Net Book - Communication Infrastructure	$97,776	$93,522	$89,073	$84,429	$79,590	$71,826	$64,062	$56,298	$48,534	$40,770	$37,234	$29,168	$21,102	$13,036	$4,970
Net Book - Info Tech Infrastructure	$107,448	$80,586	$53,724	$26,862	$0	$0	$0	$0	$71,029	$53,271	$35,514	$17,757	$0	$0	$0
Net Book - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Property Tax - Substation Infrastructure	$19,867	$19,415	$18,964	$18,512	$18,061	$17,609	$17,158	$16,706	$16,255	$15,803	$15,352	$14,900	$14,449	$13,997	$13,546
Property Tax - Distribution Infrastructure	$10,746	$10,399	$10,053	$9,706	$9,359	$9,013	$8,666	$8,319	$7,973	$7,626	$7,279	$6,933	$6,586	$6,240	$5,893
Property Tax - Communication Infrastructure	$2,982	$2,852	$2,717	$2,575	$2,427	$2,191	$1,954	$1,717	$1,480	$1,243	$1,136	$890	$644	$398	$152
Property Tax - Info Tech Infrastructure	$3,277	$2,458	$1,639	$819	$0	$0	$0	$0	$2,166	$1,625	$1,083	$542	$0	$0	$0
Property Tax - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - Property Tax	$36,872	$35,125	$33,372	$31,613	$29,848	$28,813	$27,778	$26,743	$27,874	$26,298	$24,850	$23,264	$21,679	$20,634	$19,590
Operations & Maintenance Expense	$71,068	$72,208	$73,382	$74,574	$75,786	$77,084	$78,240	$79,414	$80,276	$81,480	$82,351	$83,586	$84,840	$86,113	$87,405
O&M - Substation Infrastructure	$19,985	$20,285	$20,589	$20,898	$21,212	$21,530	$21,853	$22,181	$22,513	$22,851	$23,194	$23,542	$23,895	$24,253	$24,617
O&M - Distribution Infrastructure	$10,911	$11,074	$11,240	$11,409	$11,580	$11,754	$11,930	$12,109	$12,291	$12,475	$12,662	$12,852	$13,045	$13,241	$13,439
O&M - Communication Infrastructure	$4,838	$4,999	$5,165	$5,334	$5,507	$5,751	$5,838	$5,925	$6,014	$6,104	$5,844	$5,932	$6,021	$6,111	$6,203
O&M - Info Tech Infrastructure	$35,334	$35,849	$36,387	$36,933	$37,487	$38,049	$38,620	$39,199	$39,458	$40,050	$40,651	$41,260	$41,879	$42,507	$43,145
O&M - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - O&M Expenses	$71,068	$72,208	$73,382	$74,574	$75,786	$77,084	$78,240	$79,414	$80,276	$81,480	$82,351	$83,586	$84,840	$86,113	$87,405
Customer Benefits	$331,191	$339,521	$348,060	$356,813	$365,787	$374,987	$384,418	$394,086	$403,997	$414,157	$424,573	$435,252	$446,198	$457,420	$468,924
Operating Benefits	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Operating Benefits & Expenses Net of Taxes	($71,192)	($70,675)	($70,179)	($69,694)	($69,219)	($75,302)	($75,397)	($75,505)	($73,177)	($72,886)	($72,370)	($72,096)	($71,837)	($75,900)	($76,094)
Depreciation Tax Benefit	$13,131	$13,174	$13,217	$13,259	$13,302	$7,425	$7,425	$7,425	$11,310	$11,310	$11,376	$11,376	$11,376	$7,491	$7,491
Property Tax Expense	$28,805	$27,440	$26,070	$24,696	$23,317	$22,509	$21,700	$20,891	$21,775	$20,544	$19,413	$18,174	$16,935	$16,120	$15,304
O&M Expense	$55,518	$56,409	$57,326	$58,257	$59,204	$60,218	$61,121	$62,038	$62,712	$63,653	$64,333	$65,298	$66,277	$67,271	$68,280
Operating Benefits	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - Cash Flow Net of Taxes	($71,192)	($70,675)	($70,179)	($69,694)	($69,219)	($75,302)	($75,397)	($75,505)	($73,177)	($72,886)	($72,370)	($72,096)	($71,837)	($75,900)	($76,094)
Annual Customer & Utility Net Cash Flow	($1,008,941)	$265,921	$274,955	$284,194	$293,643	$299,685	$309,021	$318,581	$242,034	$341,271	$245,839	$363,156	$374,362	$381,520	$392,830
Cumulative Customer & Utility Net Cash Flow	($1,008,941)	($743,020)	($468,064)	($183,870)	$109,774	$409,458	$718,479	$1,037,059	$1,279,093	$1,620,364	$1,866,203	$2,229,358	$2,603,720	$2,985,240	$3,378,070
Annual PV Customer & Utility Cash Flow	($935,937)	$228,831	$219,486	$210,446	$201,709	$190,964	$182,665	$174,690	$123,114	$161,032	$107,608	$147,458	$141,009	$133,307	$127,328
Cumulative NPV Customer & Utility Cash Flow	($935,937)	($707,106)	($487,621)	($277,175)	($75,465)	$115,499	$298,164	$472,855	$595,969	$757,000	$864,608	$1,012,066	$1,153,075	$1,286,383	$1,413,711

Assuming AMI is not deployed and only an average 3 percent voltage and energy reduction can be achieved, the number of VVO bus candidates with positive business cases falls from 190 buses and 492 distribution circuits to 69 buses and 197 distribution circuits. Collectively, these 69 VVO buses with positive business cases deliver an average 3 percent reduction in energy usage (and retail power costs) with an estimated 15 year present value benefit of $135,669,131 compared to $414,035,474 if AMI is deployed and an average 4 percent voltage can be achieved. AEP Ohio's 15 year present value capital and O&M cost to procure, deploy, operate and maintain less VVO infrastructure falls from $322,788,749 to $122,931,982 if AMI is not deployed. However, the overall impact is that AEP Ohio retail customers realize $1.10 in VVO benefits for every dollar of VVO related capital and O&M costs incurred over 15 years if AMI isn't deployed versus $1.28 in VVO benefits for every dollar VVO costs if AMI is deployed. In addition, less energy efficiency associated with a less ambitious VVO deployment is estimated to reduce CO_2 emissions by 2,177,893 t versus 6,611,509 t over 15 years.

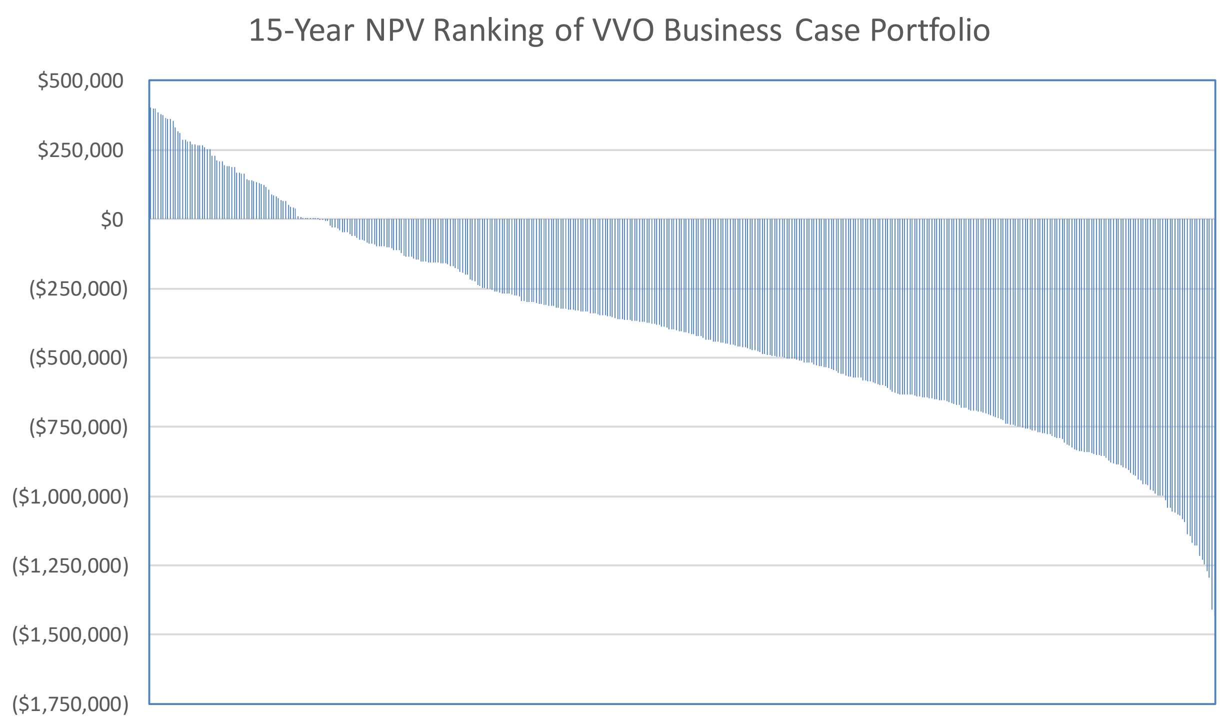

Figure 3: Revised Prioritized Business Case Portfolio of VVO Distribution Buses Without AMI

The VVO business case and portfolio analysis presented in this report assumes AEP Ohio will utilize the same VVO technology in previous and current deployments approved by the PUCO. However, AEP Ohio intends to monitor rapidly emerging technologies such as photovoltaics, electric vehicle charging loads and infrastructure requirements, micro grids, and demand response that can all potentially impact future proposed VVO deployments. These technologies (and perhaps others) have potential to alter load shapes and energy usage patterns that may influence how AEP Ohio reliably serves customers' future power requirements.

4 AMI Business Case

The remainder of AEP Ohio's service territory where AMI may be deployed as part of a proposed Smart Grid Phase 3 project is already equipped with a legacy drive-by automated meter reading ("AMR") system employing one-way radio communication technology. Preparing an AMI business case for a proposed Phase 3 AMI deployment typically begins with identifying and estimating relevant benefits and costs associated with one or more AMI vendors and communication technologies.[12] However, AEP Ohio is presently deploying as part of its Smart Grid Phase 2 project a Silver Spring Networks™ ("SSN") AMI solution. (SSN has recently been acquired by Itron™.) The AMI business case assumes this Itron-SSN solution will be expanded as part of a future Smart Grid Phase 3 deployment because the costs associated with expansion are relatively well known. [13] Also, the cost of expanding the existing Itron-SSN solution doesn't depend on legacy systems or processes; in other words, the cost to expand the existing Itron-SSN solution is the same regardless of if AMI replaces traditional manual meter reading or the existing AMR system. (The choice of communication technology will be revisited later in this section.)

In contrast to costs, many of the benefits associated with AMI are impacted by the legacy systems or processes that AMI is intended to replace or augment. For example, AMR has displaced traditional meter reading and the added benefit of migrating from a legacy AMR system to AMI represents an incremental impact on the AMI business case; benefits originally realized with AMR cannot be recaptured. Aside from incremental metering reading benefits, additional benefits identified by AEP Ohio is based on the ability to remotely connect and disconnect meters, reduce bad debt expenses on past due accounts, and provide the meter interval data needed to expand and promote energy efficiency.

AEP Ohio's AMI business case results is similar to the experience of other utilities replacing legacy AMR system with AMI; the cost of migrating from AMR to AMI is not impacted and fewer tangible benefits result in negative business cases. Similar to DACR and VVO, the AMI business case represents the net benefit cash flows discounted at AEP Ohio's after-tax weighted cost of capital to estimate the 15 year net present value ("NPV") of the proposed Phase 3 AMI deployment. These net benefit cash flows include the aforementioned benefits, initial and replacement capital costs, and O&M costs associated with smart meters, communication, and information technology ("IT") infrastructure. Also, these cash flows incorporate the combined tax effects associated with the depreciation of capitalized infrastructure assets and the tax effects associated with annual O&M expenses. The cash flow model for the AMI business case provided in Table 8 on page 15 illustrates all the annual cash flows that yields a negative 15 year NPV of $77,876,330 in the bottom right corner of the table. Not illustrated in the cash flow model is the 15 year reduction in CO_2 emissions from vehicles, which is estimated to be 159,916 t. [14]

[12] AMI may include a variety of communication technologies such as licensed radio frequency ("RF"), unlicensed RF mesh, or power line carrier that enables two-way communications.

[13] AEP Ohio's Itron-SSN solution features unlicensed RF mesh communication technology and public LTE carriers.

[14] Reductions in CO_2 are identified in the business case, but not monetized pending establishment of an incentivized U.S. cap-and-trade, tax credit, or other program.

A major factor contributing to a negative AMI business case is the estimated cost of deploying RF mesh communication infrastructure in the remaining portion AEP Ohio's service area that is predominantly rural. AEP Ohio has reexamined its communication options and concludes RF mesh remains today the preferred technology that provides the desired communication flexibility.[15, 16] For example, RF mesh leverages today's existing public cellular LTE network. However, the flexibility of RF mesh doesn't preclude AEP Ohio from deploying hybrid communication infrastructure in the future such as private cellular LTE, licensed RF, and fiber optic cable, etc.[17] AEP Ohio asserts that AMI is a desirable and necessary technology as part of a future Smart Grid Phase 3 deployment for a variety of reasons including, but not necessarily limited to:

1. The ability of VVO to "maximize customer and company benefits" is dependent on AMI to provide meter interval and voltage data. [18]
2. AMI is required to fulfil a Phase 2 report Table 1 objective to ". . . provide customers and CRES providers with customer interval data . . . [and] develop such systems and processes using a phase-in approach, and transfer as much data as possible to customers and CRES providers through the implementation stages." [19] Existing and future customers would not have the opportunity to participate in existing or future energy efficiency programs if AMI is not deployed.
3. AMI will be leveraged to enable the deployment of additional smart grid technologies such as smart street lighting, demand management, etc. and,
4. AMI will augment AEP Ohio's outage management system and service restoration processes.

[15] A goal of AEP Ohio when reexamining its communication options was to leverage existing AMI IT technology and communication infrastructure and avoid the added expense of operating and maintaining AMI systems from multiple vendors. Similarly, power line carrier as an alternative communication path has limited bandwidth and flexibility.

[16] Power line carrier ("PLC") was an alternative considered by AEP Ohio for rural portions of the utility's service area, but PLC has limited bandwidth and flexibility for applications beyond AMI.

[17] These other communication technologies can also be leveraged for DACR, VVO, and other future applications.

[18] Commission Order and Opinion dated February 1, 2017, Section IV (1) (B) (iii).

[19] Commission Opinion and Order dated February 1, 2017, Section IV (B), Par. (21).

Table 8

Cash Flow Model for AMI Business Case

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Capital Related Costs	$10,494,544	$27,048,799	$27,588,475	$11,055,676	$290,503	$1,268,811	$294,166	$306,526	$314,898	$318,444	$1,372,524	$332,371	$336,126	$344,481	$351,547
Capital Cost - Substation Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Capital Cost - Distribution Infrastructure	$2,797,720	$22,830,917	$23,289,240	$9,306,721	$181,285	$184,845	$188,547	$192,319	$196,242	$200,158	$204,147	$208,295	$212,436	$216,655	$221,127
Capital Cost - Communication Infrastructure	$511,552	$4,167,132	$4,247,724	$1,696,671	$56,149	$56,992	$50,947	$58,714	$62,331	$61,117	$62,034	$65,179	$63,908	$67,149	$68,832
Capital Cost - Info Tech Infrastructure	$7,185,272	$50,750	$51,511	$52,284	$53,068	$1,026,975	$54,672	$55,492	$56,325	$57,169	$1,106,344	$58,897	$59,781	$60,678	$61,588
Capital Cost - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - Capital Costs	$10,494,544	$27,048,799	$27,588,475	$11,055,676	$290,503	$1,268,811	$294,166	$306,526	$314,898	$318,444	$1,372,524	$332,371	$336,126	$344,481	$351,547
Depreciation Related Costs															
Dep Exp - Substation Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Dep Exp - Distribution Infrastructure	$186,515	$1,708,576	$3,261,192	$3,881,640	$3,893,726	$3,906,048	$3,918,618	$3,931,440	$3,944,522	$3,957,866	$3,971,476	$3,985,362	$3,999,525	$4,013,968	$4,028,710
Dep Exp - Communication Infrastructure	$34,103	$311,912	$595,094	$708,205	$711,949	$715,748	$719,144	$723,059	$727,214	$731,289	$735,424	$739,769	$744,030	$748,507	$753,095
Dep Exp - Info Tech Infrastructure	$1,437,054	$1,447,204	$1,457,507	$1,467,963	$1,478,577	$246,918	$247,702	$248,498	$249,306	$250,127	$266,000	$266,845	$267,703	$268,574	$269,457
Dep Exp - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Tax Benefit of Dep - Substation Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Tax Benefit of Dep - Distribution Infrastructure	$40,809	$373,836	$713,549	$849,303	$851,947	$854,643	$857,394	$860,199	$863,061	$865,981	$868,959	$871,997	$875,096	$878,256	$881,482
Tax Benefit of Dep - Com Infrastructure	$7,462	$68,246	$130,207	$154,955	$155,774	$156,606	$157,349	$158,205	$159,114	$160,006	$160,911	$161,862	$162,794	$163,773	$164,777
Tax Benefit of Dep - Info Tech Infrastructure	$314,428	$316,648	$318,902	$321,190	$323,513	$54,026	$54,197	$54,371	$54,548	$54,728	$58,201	$58,386	$58,573	$58,764	$58,957
Tax Benefit of Dep - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - Tax Benefit of Depreciation	$362,699	$758,731	$1,162,658	$1,325,449	$1,331,234	$1,065,275	$1,068,940	$1,072,776	$1,076,724	$1,080,715	$1,088,071	$1,092,245	$1,096,463	$1,100,793	$1,105,216
Net Book - Substation Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Net Book - Distribution Infrastructure	$2,611,205	$23,733,546	$43,761,594	$49,186,676	$45,474,235	$41,753,031	$38,022,960	$34,283,840	$30,535,559	$26,777,851	$23,010,522	$19,233,455	$15,446,366	$11,649,053	$7,841,469
Net Book - Communication Infrastructure	$477,449	$4,332,668	$7,985,298	$8,973,764	$8,317,965	$7,659,208	$6,991,011	$6,326,666	$5,661,784	$4,991,612	$4,318,221	$3,643,630	$2,963,509	$2,282,151	$1,597,888
Net Book - Info Tech Infrastructure	$5,748,218	$4,351,763	$2,945,768	$1,530,088	$104,579	$884,637	$691,607	$498,601	$305,619	$112,662	$953,005	$745,057	$537,135	$329,238	$121,369
Net Book - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Property Tax - Substation Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Property Tax - Distribution Infrastructure	$79,642	$723,873	$1,334,729	$1,500,194	$1,386,964	$1,273,467	$1,159,700	$1,045,657	$931,335	$816,724	$701,821	$586,620	$471,114	$355,296	$239,165
Property Tax - Communication Infrastructure	$14,562	$132,146	$243,552	$273,700	$253,698	$233,606	$213,226	$192,963	$172,684	$152,244	$131,706	$111,131	$90,387	$69,606	$48,736
Property Tax - Info Tech Infrastructure	$175,321	$132,729	$89,846	$46,668	$3,190	$26,981	$21,094	$15,207	$9,321	$3,436	$29,067	$22,724	$16,383	$10,042	$3,702
Property Tax - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - Property Tax	$269,525	$988,748	$1,668,126	$1,820,561	$1,643,852	$1,534,055	$1,394,020	$1,253,828	$1,113,340	$972,405	$862,593	$720,475	$577,884	$434,943	$291,602
Operations & Maintenance Expense	$2,333,232	$4,238,961	$6,224,601	$7,086,544	$7,094,841	$7,206,319	$7,337,442	$7,471,389	$7,608,318	$7,747,800	$7,894,382	$8,039,479	$8,187,377	$8,338,164	$8,492,413
O&M - Substation Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
O&M - Distribution Infrastructure	$417,760	$1,233,375	$2,088,137	$2,457,886	$2,381,233	$2,423,842	$2,467,314	$2,511,750	$2,557,016	$2,603,210	$2,650,435	$2,698,554	$2,747,753	$2,797,890	$2,849,164
O&M - Communication Infrastructure	$91,314	$842,524	$1,621,573	$1,950,108	$1,989,100	$2,029,135	$2,069,436	$2,110,748	$2,153,345	$2,196,686	$2,242,578	$2,287,753	$2,333,715	$2,380,677	$2,428,992
O&M - Info Tech Infrastructure	$1,824,158	$2,163,062	$2,514,891	$2,678,550	$2,724,508	$2,753,342	$2,800,692	$2,848,891	$2,897,956	$2,947,904	$3,001,369	$3,053,172	$3,105,909	$3,159,598	$3,214,257
O&M - Customer Infrastructure	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal - O&M Expenses	$2,333,232	$4,238,961	$6,224,601	$7,086,544	$7,094,841	$7,206,319	$7,337,442	$7,471,389	$7,608,318	$7,747,800	$7,894,382	$8,039,479	$8,187,377	$8,338,164	$8,492,413
Customer Benefits	$60,848	$558,627	$1,076,367	$1,291,736	$1,317,667	$1,344,120	$1,371,103	$1,398,628	$1,426,705	$1,455,346	$1,484,562	$1,514,365	$1,544,766	$1,575,777	$1,607,411
Operating Benefits	$164,519	$1,510,397	$2,910,246	$3,492,552	$3,562,665	$3,634,186	$3,707,142	$3,781,563	$3,857,478	$3,934,917	$4,013,910	$4,094,490	$4,176,686	$4,260,533	$4,346,064
Operating Benefits & Expenses Net of Taxes	($1,542,053)	($2,145,233)	($2,729,656)	($2,904,400)	($2,712,278)	($2,923,679)	($2,856,059)	($2,789,207)	($2,723,173)	($2,657,552)	($2,617,212)	($2,552,416)	($2,488,131)	($2,424,430)	($2,361,711)
Depreciation Tax Benefit	$362,699	$758,731	$1,162,658	$1,325,449	$1,331,234	$1,065,275	$1,068,940	$1,072,776	$1,076,724	$1,080,715	$1,088,071	$1,092,245	$1,096,463	$1,100,793	$1,105,216
Property Tax Expense	$210,553	$772,410	$1,303,140	$1,422,222	$1,284,177	$1,198,404	$1,089,009	$979,490	$869,741	$759,643	$673,858	$562,835	$451,443	$339,778	$227,800
O&M Expense	$1,822,721	$3,311,476	$4,862,658	$5,536,008	$5,542,490	$5,629,576	$5,732,010	$5,836,649	$5,943,618	$6,052,581	$6,167,092	$6,280,441	$6,395,979	$6,513,774	$6,634,273
Operating Benefits	$128,522	$1,179,922	$2,273,484	$2,728,382	$2,783,154	$2,839,026	$2,896,019	$2,954,157	$3,013,462	$3,073,957	$3,135,667	$3,198,615	$3,262,827	$3,328,329	$3,395,145
Subtotal - Cash Flow Net of Taxes	($1,542,053)	($2,145,233)	($2,729,656)	($2,904,400)	($2,712,278)	($2,923,679)	($2,856,059)	($2,789,207)	($2,723,173)	($2,657,552)	($2,617,212)	($2,552,416)	($2,488,131)	($2,424,430)	($2,361,711)
Annual Customer & Utility Net Cash Flow	($11,975,748)	($28,635,405)	($29,241,763)	($12,668,340)	($1,685,114)	($2,848,371)	($1,779,123)	($1,697,105)	($1,611,366)	($1,520,650)	($2,505,174)	($1,370,423)	($1,279,491)	($1,193,134)	($1,105,848)
Cumulative Customer & Utility Net Cash Flow	($11,975,748)	($40,611,153)	($69,852,917)	($82,521,257)	($84,206,371)	($87,054,741)	($88,833,864)	($90,530,968)	($92,142,335)	($93,662,985)	($96,168,159)	($97,538,582)	($98,818,073)	($100,011,206)	($101,117,054)
Annual PV Customer & Utility Cash Flow	($11,109,229)	($24,641,424)	($23,342,495)	($9,380,904)	($1,157,538)	($1,815,030)	($1,051,658)	($930,590)	($819,644)	($717,533)	($1,096,558)	($556,454)	($481,940)	($416,895)	($358,438)
Cumulative NPV Customer & Utility Cash Flow	($11,109,229)	($35,750,653)	($59,093,148)	($68,474,051)	($69,631,590)	($71,446,620)	($72,498,278)	($73,428,869)	($74,248,513)	($74,966,046)	($76,062,604)	($76,619,058)	($77,100,998)	($77,517,893)	($77,876,330)

5 Revised Phase 3 Full System Feasibility Study Summary

Results of the DACR, VVO, and AMI business cases previously presented within this Phase 3 report can now be aggregated to provide a summary of the Revised Phase 3 Full System Feasibility Study. Viewed holistically, AEP Ohio asserts these business cases support a proposed Smart Grid Phase 3 deployment of DACR, VVO, and AMI within AEP Ohio's remaining service territory. This holistic view of the DACR, VVO, and AMI business cases provided in Table 9 includes a total column that assumes these projects are independent of each other. In reality, the VVO business case illustrated in Table 9 is dependent on the assumption that AMI will also be deployed to deliver an average 4 percent reduction in energy consumption and retail power costs savings to AEP Ohio customers.

Table 9
15 Year Business Case Summary for DACR, VVO and AMI

Description	DACR	VVO	AMI	Total
Present Value Benefits	$569,908,200	$414,035,474	$40,037,595	$1,023,981,269
Present Value Costs	$349,945,501	$322,788,749	$117,913,925	$790,648,175
Net Present Value	$219,962,699	$91,246,725	($77,876,330)	$233,333,094
Benefit-Cost Ratio	1.63	1.28	0.34	1.30
Reduced CO_2 Emissions	Not Applicable	6,611,509 t	159,916 t	6,771,425 t

Table 9 Notes:

1. The DACR column represents totals for the 80 schemes impacting 416 distribution circuits that have positive 15 year NPV business case outcomes.
2. The VVO column represents totals for the 190 buses impacting 492 distribution circuits that have positive 15 year NPV values business case outcomes.
3. VVO business case results assumes AMI is deployed and AMI interval and voltage data is available to achieve an average 4 percent voltage and energy reduction.
4. The total column assumes the proposed DACR, VVO, and AMI projects are independent of each other and any project with a positive business case may be selected for deployment. In other words, the proposed DACR, VVO, and AMI projects do not represent mutually exclusive projects where the acceptance of one or more projects implies that other projects must be rejected. Mutually exclusive projects arise for a variety of reasons including, but not necessarily limited to: dependencies that exist among projects, funding or budgeting constraints, or the existence of projects that differ in scale, size, or timing of cash flows where projects should be selected on the basis of NPV.
5. Present value benefits and present value costs include the effects of combined federal/state income taxes and property taxes where appropriate. Present value benefits is the sum of the annual benefit cash flows that are discounted at AEP Ohio's after-tax weighted average cost of

capital. Similarly, present value costs is the sum of the annual cost cash flows that are discounted at AEP Ohio's after-tax weighted average cost of capital.

6. The benefit-cost ratio is defined as ratio of the present value benefits to the present value costs.
7. Other items of interest.

All business case results presented within this Phase 3 report including annual benefits, costs, and net benefits (i.e. benefits minus costs) are discounted by AEP Ohio's after-tax cost of capital, which is subject to change. A comparison of the non-discounted benefits and costs in the table below is useful to illustrate the overall scale of the net benefits delivered to AEP Ohio retail customers assuming that DACR, VVO, and AMI are all part of a future Smart Grid Phase 3 deployment. All DACR and VVO totals within the table only include DACR schemes and VVO buses with positive business cases.

Description	DACR	VVO	AMI	Total
Non-discounted benefits	$1,013,158,954	$739,795,573	$75,006,685	$1,827,961,212
Non-discounted costs	$453,930,875	$440,478,348	$176,123,738	$1,070,532,961
Non-discounted net benefit	$559,228,079	$299,317,225	($101,117,053)	$757,428,251
Ratio of benefits-to-costs	2.23	1.68	0.43	1.71

6 Appendix

Section 6.1 provides a tabular summary of business case results for all 146 DACR scheme candidates and 711 distribution circuits included within the Revised Phase 3 Full System Feasibility Study.

Section 6.2 provides a tabular summary of business case results for all 445 VVO bus candidates and 973 distribution circuits included within the Revised Phase 3 Full System Feasibility Study.

Section 6.3 provides a compilation of all financial evaluation and other assumptions used to develop the DACR business case and portfolio analysis, the VVO business case and portfolio analysis, and the AMI business case.

6.1 Prioritized Portfolio Analysis of DACR Scheme Candidates

Table 10
Prioritized Business Case Portfolio of DACR Schemes

Candidate	Rank	NPV	PV Benefits	PV Costs	Circuits	Total	Rule 11	District	District Sub-Area
CRA991	1	$7,034,782	$12,465,319	$5,430,537	7	7	0	Columbus	Columbus, SW - 65
CRC200	2	$6,906,261	$12,856,299	$5,950,038	8	15	0	Columbus	Columbus, SE - 64
CRC517	3	$6,684,020	$12,009,602	$5,325,581	7	22	0	Columbus	Columbus, SE - 64
CRC414	4	$6,607,554	$10,326,328	$3,718,774	5	27	0	Columbus	Columbus, NW - 66
CRC013	5	$6,549,871	$15,097,977	$8,548,106	10	37	0	Chillicothe	Portsmouth - 82
CRA999	6	$6,516,946	$12,011,153	$5,494,208	7	44	0	Columbus	Columbus, SE - 64
CRC407	7	$6,446,330	$10,304,355	$3,858,026	5	49	0	Columbus	Columbus, NW - 66
CRA109	8	$6,437,162	$15,818,159	$9,380,997	11	60	0	Canton	North Canton - 20, South Canton - 21
CRA996	9	$5,818,869	$11,217,561	$5,398,692	7	67	0	Columbus	Columbus, SW - 65
CRC518	10	$5,801,212	$9,614,601	$3,813,388	5	72	0	Columbus	Columbus, SE - 64, Columbus, SW - 65
CRC211	11	$5,796,865	$9,059,815	$3,262,950	4	76	1	Columbus	Columbus, SW - 65
CRC433	12	$5,643,259	$10,246,377	$4,603,118	5	81	2	Newark	Mt Vernon - 51
CRA987	13	$5,150,980	$9,918,629	$4,767,650	5	86	0	Newark	Belmont - 61
CRC210	14	$4,854,330	$10,169,299	$5,314,969	7	93	0	Columbus	Columbus, SE - 64
CRA111	15	$4,753,632	$9,082,538	$4,328,906	5	98	1	Canton	North Canton - 20, South Canton - 21
CRC002	16	$4,736,549	$8,838,253	$4,101,704	5	103	0	Chillicothe	Chillicothe - 20
CRA104	17	$4,732,845	$9,839,789	$5,106,944	6	109	0	Canton	North Canton - 20
CRC508	18	$4,665,132	$9,333,319	$4,668,187	6	115	0	Columbus	Columbus, NE - 63, Columbus, SE - 64
CRA113	19	$4,644,907	$6,255,809	$1,610,902	2	117	0	Canton	North Canton - 20
CRC019	20	$4,640,757	$11,550,548	$6,909,791	8	125	2	Chillicothe	Ironton - 81
CRC021	21	$4,623,144	$7,341,148	$2,718,004	3	128	0	Chillicothe	Chesapeake - 22
CRA120	22	$4,598,691	$14,199,086	$9,600,395	11	139	1	Newark	Coshocton - 82
CRA397	23	$4,450,131	$17,207,274	$12,757,143	14	153	0	Canton	Wooster - 70
CRC028	24	$4,318,799	$8,400,907	$4,082,108	5	158	1	Athens	Gallipolis - 14
CRC994	25	$4,310,009	$8,150,307	$3,840,298	5	163	0	Columbus	Columbus, SE - 64
CRC416	26	$4,256,207	$6,515,513	$2,259,307	3	166	2	Columbus	Columbus, NE - 63, Columbus, NW -66
CRC434	27	$4,190,811	$10,569,362	$6,378,552	7	173	2	Athens	McConnelsville - 13
CRC507	28	$3,907,411	$7,797,567	$3,890,156	5	178	0	Columbus	Columbus, NE - 63, Columbus, SE - 64
CRC993	29	$3,854,860	$6,353,492	$2,498,632	3	181	0	Western Ohio	Kenton - 34
CRC201	30	$3,765,261	$8,353,931	$4,588,670	6	187	0	Columbus	Columbus, SW - 65
CRC411	31	$3,759,182	$9,784,629	$6,025,447	8	195	0	Columbus	Columbus, NW - 66
CRA119	32	$3,383,181	$5,158,615	$1,775,434	2	197	0	Canton	New Philadelphia - 71
CRA118	33	$3,382,220	$6,209,904	$2,827,683	3	200	0	Canton	New Philadelphia - 71
CRA998	34	$3,346,352	$5,577,616	$2,231,264	3	203	1	Columbus	Columbus, SE - 64
CRC205	35	$3,117,419	$8,563,644	$5,446,225	7	210	0	Columbus	Columbus, SW - 65

Candidate	Rank	NPV	PV Benefits	PV Costs	Circuits	Total	Rule 11	District	District Sub-Area
CRC036	36	$2,909,945	$6,625,345	$3,715,400	4	214	0	Athens	Marietta - 260
CRC998	37	$2,598,281	$9,418,394	$6,820,113	9	223	0	Columbus	Columbus, NW - 66
CRC988	38	$2,557,782	$7,160,900	$4,603,118	5	228	1	Canton	East Liverpool - 51
CRC014	39	$2,485,467	$6,365,400	$3,879,933	4	232	0	Chillicothe	Portsmouth - 82
CRC223N	40	$2,327,337	$6,207,270	$3,879,933	4	236	0	Newark	Newark - 50
CRC982	41	$2,177,399	$4,705,935	$2,528,536	3	239	0	Columbus	Columbus, NE - 63, Delaware - 62
CRC430	42	$2,176,268	$9,836,684	$7,660,416	9	248	0	Newark	Mt Vernon - 51
CRA110	43	$2,086,887	$11,522,737	$9,435,850	11	259	0	Canton	South Canton - 21
CRC521	44	$1,936,325	$3,711,759	$1,775,434	2	261	0	Athens	Crooksville - 11
CRC402	45	$1,774,763	$4,777,824	$3,003,061	4	265	0	Columbus	Columbus, NW - 66
CRA333	46	$1,711,384	$3,815,882	$2,104,499	2	267	0	Canton	New Philadelphia - 71, Wooster - 70
CRC204	47	$1,429,941	$4,454,328	$3,024,386	4	271	0	Columbus	Columbus, SW - 65
CRC519	48	$1,248,383	$5,851,514	$4,603,131	5	276	0	Athens	Crooksville - 11
CRC025	49	$1,189,960	$3,688,592	$2,498,632	3	279	0	Chillicothe	Wellston - 16
CRA115	50	$1,122,069	$5,725,200	$4,603,131	5	284	0	Canton	South Canton - 21
CRC020	51	$1,099,340	$2,737,668	$1,638,328	2	286	0	Chillicothe	Ironton - 81
CRC011	52	$1,084,027	$3,023,994	$1,939,966	2	288	1	Chillicothe	Seaman - 23
CRC005	53	$1,078,763	$5,746,950	$4,668,187	6	294	0	Chillicothe	Chillicothe - 20
CRC004	54	$1,018,301	$3,845,985	$2,827,683	3	297	1	Chillicothe	Chillicothe - 20
CRA600	55	$833,574	$14,827,925	$13,994,351	17	314	0	Western Ohio	Findlay - 33
CRC509	56	$780,968	$5,109,880	$4,328,913	5	319	0	Columbus	Columbus, SE - 64
CRA993	57	$749,025	$3,943,416	$3,194,391	4	323	0	Columbus	Columbus, SW - 65
CRA368	58	$689,697	$5,741,802	$5,052,104	6	329	0	Canton	Steubenville - 50
CRC410	59	$659,085	$2,910,919	$2,251,834	3	332	0	Columbus	Columbus, NW - 66
CRA101	60	$653,407	$4,845,207	$4,191,800	5	337	0	Canton	North Canton - 20, South Canton - 21
CRC419	61	$650,102	$2,315,857	$1,665,755	2	339	0	Columbus	Columbus, NE - 63
CRC983	62	$636,250	$3,858,054	$3,221,804	4	343	0	Athens	Lancaster - 22
CRC513	63	$613,099	$2,388,533	$1,775,434	2	345	1	Columbus	Columbus, SE - 64
CRA117	64	$609,232	$2,713,730	$2,104,499	2	347	0	Canton	New Philadelphia - 71
CRC418	65	$604,037	$2,544,003	$1,939,966	2	349	1	Columbus	Delaware - 62
CRA100	66	$588,079	$7,782,318	$7,194,239	9	358	0	Canton	North Canton - 20
CRA367	67	$562,122	$7,773,551	$7,211,429	8	366	1	Canton	Steubenville - 50
CRC001	68	$492,595	$6,967,564	$6,474,969	8	374	0	Chillicothe	Chillicothe - 20
CRA989	69	$480,087	$6,858,639	$6,378,552	7	381	0	Newark	Cambridge - 81
CRC207	70	$388,798	$1,966,802	$1,578,003	2	383	0	Columbus	Columbus, SW - 65
CRC018	71	$375,771	$5,088,581	$4,712,810	5	388	1	Chillicothe	Ironton - 81
CRA125	72	$375,464	$2,479,963	$2,104,499	2	390	0	Western Ohio	Bucyrus - 11
CRC427	73	$367,148	$1,868,371	$1,501,223	2	392	0	Columbus	Columbus, NE - 63
CRC437	74	$353,419	$6,622,291	$6,268,872	7	399	1	Newark	Zanesville - 80
CRA985	75	$208,265	$3,035,949	$2,827,683	3	402	0	Newark	Belmont - 61
CRA102	76	$166,855	$2,632,576	$2,465,721	3	405	0	Canton	North Canton - 20
CRC026	77	$160,431	$2,264,930	$2,104,499	2	407	0	Chillicothe	Portsmouth - 82

Candidate	Rank	NPV	PV Benefits	PV Costs	Circuits	Total	Rule 11	District	District Sub-Area
CRC520	78	$105,808	$3,985,741	$3,879,933	4	411	0	Athens	Crooksville - 11
CRC425	79	$87,422	$2,346,729	$2,259,307	3	414	1	Columbus	Delaware - 62
CRC417	80	$73,395	$1,613,783	$1,540,388	2	416	0	Columbus	Columbus, NW - 66
CRC422	81	$0	$0	$0	0	416	0	Columbus	Columbus, NE - 63, Delaware - 62
CRC027	82	$0	$0	$0	0	416	0	Chillicothe	Wellston - 16
CRC023	83	($10,809)	$2,093,690	$2,104,499	2	418	0	Chillicothe	Portsmouth - 82, Wellston - 16
CRC016	84	($11,685)	$2,815,998	$2,827,683	3	421	1	Chillicothe	Portsmouth - 82
CRC010	85	($160,988)	$3,225,361	$3,386,349	4	425	0	Chillicothe	Seaman - 23
CRA133	86	($179,782)	$3,425,939	$3,605,721	4	429	0	Western Ohio	Fremont - 12
CRC436	87	($274,403)	$4,328,715	$4,603,118	5	434	0	Newark	Zanesville - 80
CRC405	88	($288,689)	$3,628,899	$3,917,589	5	439	0	Columbus	Columbus, NE - 63, Columbus, NW - 66
CRC042	89	($299,174)	$2,693,041	$2,992,216	3	442	1	Athens	Marietta - 260
CRC214	90	($331,200)	$1,444,234	$1,775,434	2	444	0	Western Ohio	Paulding - 31
CRA400	91	($392,799)	$4,539,383	$4,932,182	5	449	0	Newark	Cambridge - 81
CRA114	92	($427,022)	$1,677,477	$2,104,499	2	451	0	Canton	South Canton - 21
CRA108	93	($447,540)	$4,769,083	$5,216,623	6	457	0	Canton	North Canton - 20, South Canton - 21
CRA988	94	($447,607)	$2,160,704	$2,608,312	3	460	0	Newark	Cambridge - 81
CRA990	95	($509,100)	$3,370,833	$3,879,933	4	464	0	Newark	Belmont - 61
CRC432	96	($518,710)	$1,256,724	$1,775,434	2	466	0	Newark	Mt Vernon - 51
CRA994	97	($591,181)	$1,717,315	$2,308,495	3	469	0	Columbus	Columbus, SW - 65
CRC421	98	($608,517)	$3,281,632	$3,890,149	5	474	0	Columbus	Columbus, NW - 66
CRC008	99	($648,813)	$3,954,305	$4,603,118	5	479	2	Chillicothe	Seaman - 23
CRA373	100	($687,392)	$2,304,823	$2,992,216	3	482	2	Canton	Steubenville - 50
CRA112	101	($723,021)	$942,734	$1,665,755	2	484	0	Canton	South Canton - 21
CRA107	102	($764,258)	$2,008,586	$2,772,844	3	487	0	Canton	North Canton - 20
CRC992	103	($801,348)	$2,026,335	$2,827,683	3	490	0	Western Ohio	Kenton - 34, Lima - 30
CRC409	104	($883,456)	$645,180	$1,528,636	2	492	0	Columbus	Columbus, NW - 66
CRA105	105	($895,043)	$699,409	$1,594,453	2	494	0	Canton	North Canton - 20
CRA334	106	($1,024,324)	$1,803,360	$2,827,683	3	497	0	Canton	Wooster - 70
CRC017	107	($1,061,511)	$3,541,620	$4,603,131	5	502	0	Chillicothe	Portsmouth - 82
CRC986	108	($1,107,389)	$1,720,294	$2,827,683	3	505	0	Canton	Steubenville - 50
CRA984	109	($1,107,932)	$3,166,134	$4,274,066	5	510	0	Newark	Belmont - 61
CRA103	110	($1,153,812)	$3,142,189	$4,296,001	5	515	0	Canton	North Canton - 20
CRC209	111	($1,200,270)	$5,149,333	$6,349,603	8	523	0	Columbus	Columbus, SW - 65
CRC997	112	($1,212,850)	$4,931,074	$6,143,924	8	531	0	Columbus	Columbus, NW - 66
CRA106	113	($1,357,165)	$336,003	$1,693,168	2	533	0	Canton	North Canton - 20
CRC987	114	($1,466,666)	$1,361,018	$2,827,683	3	536	0	Canton	East Liverpool - 51
CRA124	115	($1,500,218)	$275,216	$1,775,434	2	538	0	Western Ohio	Bucyrus - 11
CRC423	116	($1,508,973)	$1,154,178	$2,663,151	3	541	0	Columbus	Delaware - 62
CRC213	117	($1,584,644)	$1,966,224	$3,550,868	4	545	0	Western Ohio	Paulding - 31
CRA611	118	($1,638,411)	$137,023	$1,775,434	2	547	0	Western Ohio	Ottawa - 35
CRC223W	119	($1,661,745)	$1,165,938	$2,827,683	3	550	0	Western Ohio	Paulding - 31

Candidate	Rank	NPV	PV Benefits	PV Costs	Circuits	Total	Rule 11	District	District Sub-Area
CRA335	120	($1,669,330)	$435,169	$2,104,499	2	552	0	Canton	Wooster - 70
CRA134	121	($1,686,143)	$1,086,701	$2,772,844	3	555	0	Western Ohio	Fremont - 12
CRC516	122	($1,697,167)	$78,268	$1,775,434	2	557	0	Columbus	Columbus, SW - 65
CRC428	123	($1,697,203)	$3,629,099	$5,326,302	6	563	0	Columbus	Delaware - 62
CRA128	124	($1,717,414)	$387,085	$2,104,499	2	565	0	Western Ohio	Upper Sandusky - 13
CRC400	125	($1,761,908)	$510,483	$2,272,391	3	568	0	Columbus	Columbus, NW - 66
CRC408	126	($1,767,772)	$2,083,199	$3,850,970	5	573	0	Columbus	Columbus, NW - 66, Columbus, SW - 65
CRA126	127	($1,816,181)	$4,562,384	$6,378,565	7	580	0	Western Ohio	Willard - 14
CRA601	128	($2,066,593)	$4,651,259	$6,717,852	8	588	0	Western Ohio	Findlay - 33
CRC216	129	($2,093,295)	$5,008,455	$7,101,750	8	596	0	Western Ohio	Van Wert - 32
CRA621	130	($2,098,070)	$4,674,629	$6,772,699	8	604	0	Western Ohio	Lima - 30
CRC989	131	($2,124,623)	$538,528	$2,663,151	3	607	0	Western Ohio	Ottawa - 35
CRC991	132	($2,217,882)	$2,385,236	$4,603,118	5	612	0	Western Ohio	Findlay - 33, Lima - 30
CRA986	133	($2,326,104)	$2,835,679	$5,161,783	6	618	0	Newark	Belmont - 61
CRA131	134	($2,515,788)	$1,035,080	$3,550,868	4	622	0	Western Ohio	Tiffin - 10
CRA123	135	($2,670,424)	$1,044,977	$3,715,400	4	626	0	Western Ohio	Bucyrus - 11
CRC984	136	($2,889,473)	$1,778,714	$4,668,187	6	632	0	Columbus	Columbus, SE - 64
CRA121	137	($3,128,861)	$1,474,256	$4,603,118	5	637	0	Newark	Coshocton - 82
CRA130	138	($3,199,836)	$2,061,410	$5,261,246	5	642	0	Western Ohio	Fremont - 12, Tiffin - 10
CRC412	139	($3,226,409)	$2,321,665	$5,548,073	7	649	0	Columbus	Columbus, NW - 66
CRC401	140	($3,354,561)	$1,164,052	$4,518,613	6	655	0	Columbus	Columbus, NW - 66
CRA622	141	($3,632,233)	$9,254,996	$12,887,229	16	671	0	Western Ohio	Lima - 30
CRA135	142	($4,244,064)	$1,082,252	$5,326,316	6	677	0	Western Ohio	Fremont - 12
CRA127	143	($4,438,022)	$2,170,131	$6,608,153	8	685	0	Western Ohio	Upper Sandusky - 13
CRC219	144	($4,993,374)	$2,831,547	$7,824,921	9	694	0	Western Ohio	Paulding - 31
CRC215	145	($5,035,644)	$3,841,527	$8,877,171	10	704	0	Western Ohio	Lima - 30, Van Wert - 32
CRA610	146	($5,166,654)	$1,047,378	$6,214,033	7	711	0	Western Ohio	Ottawa - 35

6.2 Prioritized Portfolio Analysis of VVO Bus Candidates

Table 11
Prioritized Business Case Portfolio of VVO Distribution Buses

Candidate	Rank	NPV	PV Benefits	PV Costs	Reduced CO2	Circuits	Total	OHA
E.WOOSTER 1X	1	$1,413,711	$3,414,614	$2,000,903	57,979	3	3	2
ZUBER 1X	2	$1,400,035	$3,400,938	$2,000,903	57,373	3	6	1
CLINTON 2Y	3	$1,347,376	$3,543,115	$2,195,739	48,668	4	10	0
DELAWARE 2Y	4	$1,334,621	$2,474,862	$1,140,241	39,113	2	12	0
BROOKSIDE 1X	5	$1,324,917	$3,847,521	$2,522,604	71,377	4	16	0
WEST CANTON 3X	6	$1,307,386	$1,901,720	$594,334	33,704	1	17	0
CLINTON 2X	7	$1,296,188	$3,491,926	$2,195,739	50,011	4	21	1
WHITE RD 1X	8	$1,290,359	$3,812,963	$2,522,604	66,810	4	25	0
S.SIDELIM 3X	9	$1,270,645	$3,271,548	$2,000,903	56,410	3	28	1
N.LIBERTY 3X	10	$1,254,954	$2,734,170	$1,479,216	40,431	2	30	0
NEW LEXINGTON 3X	11	$1,252,510	$3,253,413	$2,000,903	44,225	3	33	0
ROCKHILL 4X	12	$1,223,402	$3,115,355	$1,891,953	46,868	3	36	0
LAZELLE (#0098) 1X 2X	13	$1,211,775	$4,256,086	$3,044,311	67,234	5	41	0
MARION ROAD 25E3-4Y	14	$1,211,357	$3,157,341	$1,945,984	41,374	3	44	1
ASTOR (#0046) 1Y 2Y	15	$1,172,381	$4,503,710	$3,331,329	75,625	6	50	0
NORTH ZANESVILLE 1X	16	$1,156,724	$2,418,025	$1,261,302	33,641	2	52	0
MORSE ROAD (#0058) 1Y 2Y	17	$1,151,588	$5,020,224	$3,868,636	81,535	6	58	0
WEST CANTON 4X	18	$1,137,523	$1,731,857	$594,334	30,808	1	59	1
BRIGGSDALE (#0073) 1X 2X	19	$1,133,449	$3,134,352	$2,000,903	44,637	3	62	0
W.MELROSE 1X	20	$1,128,670	$3,651,274	$2,522,604	66,044	4	66	0
WILSON ROAD 3X	21	$1,127,021	$2,785,491	$1,658,470	59,848	3	69	0
WESTERVILLE (#0055) 1X 2X	22	$1,106,661	$3,107,564	$2,000,903	46,032	3	72	0
KENTON 1X	23	$1,097,247	$1,764,215	$666,968	27,429	1	73	1
VANWERT 1X	24	$1,086,344	$3,087,247	$2,000,903	48,172	3	76	0
ADA 1X	25	$1,084,730	$3,085,634	$2,000,903	47,242	3	79	1
NORTH NEWARK 5X	26	$1,080,323	$3,081,227	$2,000,903	41,217	3	82	0
SHANNON 1X	27	$1,062,368	$3,439,705	$2,377,336	51,981	4	86	0
ST. CLAIR 2X	28	$1,043,898	$3,305,010	$2,261,112	66,695	4	90	1
ROBERTS 3X	29	$965,404	$3,270,106	$2,304,702	60,244	4	94	0
ROCKHILL 1X	30	$940,420	$1,571,071	$630,651	23,858	1	95	0
BIXBY 4X	31	$892,479	$3,484,696	$2,592,216	71,018	4	99	0
HILLIARD 4X	32	$874,909	$2,626,769	$1,751,859	38,352	3	102	0
UPSANDUSK 4X	33	$856,958	$2,857,861	$2,000,903	43,288	3	105	1
MARION ROAD 15E1-5Y	34	$825,927	$1,931,574	$1,105,647	34,403	2	107	0
KARL ROAD 3X	35	$820,667	$3,004,296	$2,183,629	44,896	4	111	0
DUBLIN (#0023) 2X 3X	36	$811,417	$5,275,501	$4,464,085	104,433	8	119	2
HESS STREET (#0054) 1X 2X	37	$811,265	$4,159,329	$3,348,063	94,110	6	125	0
BERKSHIRE 1X	38	$805,941	$2,285,157	$1,479,216	38,474	2	127	0

Candidate	Rank	NPV	PV Benefits	PV Costs	Reduced CO2	Circuits	Total	OHA
CALCUTTA 1X	39	$803,640	$2,282,856	$1,479,216	32,998	2	129	0
N.COSHOCT 3X	40	$791,146	$2,792,050	$2,000,903	39,538	3	132	1
N.MCCONNE 1X	41	$768,275	$1,725,797	$957,523	25,154	1	133	0
WILSON ROAD 1Y	42	$765,737	$2,977,031	$2,211,294	44,000	4	137	0
JUG STREET 1X	43	$751,862	$2,231,078	$1,479,216	65,730	2	139	0
SAWMILL 4X	44	$745,366	$2,497,226	$1,751,859	35,055	3	142	0
SOUTH COSHOCTON 4X	45	$742,461	$2,743,364	$2,000,903	40,816	3	145	0
PLEASANTS 1X	46	$729,318	$2,621,271	$1,891,953	38,380	3	148	0
W.LOGAN 1X	47	$725,174	$2,204,391	$1,479,216	31,134	2	150	1
KARL ROAD (#0009) 1X 2X	48	$713,257	$4,534,607	$3,821,350	67,038	7	157	0
SOUTH NEWARK 2X	49	$711,980	$1,973,282	$1,261,302	26,746	2	159	0
ASTOR (#0046) 1X 2X	50	$711,260	$4,885,325	$4,174,065	82,599	7	166	0
MILL CREEK 4X	51	$706,073	$2,457,933	$1,751,859	45,396	3	169	1
KENNY ROAD (#0003) 1X 2X	52	$700,490	$3,490,543	$2,790,053	78,238	5	174	2
GREELY 2X	53	$697,305	$2,176,521	$1,479,216	33,226	2	176	0
W.WOOSTER 1X	54	$697,153	$2,176,369	$1,479,216	37,457	2	178	0
BEXLEY 3Y	55	$688,015	$3,236,641	$2,548,626	51,553	4	182	0
MORSE ROAD 3X	56	$668,728	$1,766,598	$1,097,869	29,485	2	184	0
GLENMOOR 1X	57	$667,930	$2,147,146	$1,479,216	28,018	2	186	0
DUBLIN 1X	58	$660,108	$2,892,150	$2,232,042	54,895	4	190	1
EAST WILLARD 1X	59	$647,739	$1,387,347	$739,608	20,738	1	191	0
HILLIARD (#0021) 1X 2X	60	$638,021	$3,836,375	$3,198,354	57,153	4	195	0
WILSON ROAD 2Y	61	$634,571	$2,580,555	$1,945,984	52,272	3	198	1
LEIPSIC 2X	62	$615,898	$1,282,866	$666,968	24,036	1	199	0
SUGRCRTRM 1X	63	$613,725	$2,092,941	$1,479,216	43,826	2	201	0
BRIDGEVILLE 1X	64	$609,932	$2,610,836	$2,000,903	53,591	3	204	0
ADDISON 1X	65	$605,662	$2,606,565	$2,000,903	44,768	3	207	0
LANCASTER JUNCTION 2X	66	$600,567	$1,861,868	$1,261,302	27,949	2	209	1
LANCASTER JUNCTION 1X	67	$595,583	$1,856,885	$1,261,302	27,118	2	211	1
SHARON VALLEY 1X	68	$592,790	$2,593,693	$2,000,903	36,920	3	214	0
NEWPHILA 4X	69	$584,787	$1,251,755	$666,968	17,031	1	215	0
DELPHOS 1X	70	$581,498	$1,321,106	$739,608	21,466	1	216	0
HYATT 2X	71	$573,799	$3,096,403	$2,522,604	47,090	4	220	0
AVONDALE 2X	72	$560,074	$1,299,682	$739,608	18,724	1	221	0
LIVINGSTON AVE (#0025) 1X 2X	73	$559,623	$2,560,527	$2,000,903	42,303	3	224	0
MARION ROAD W2	74	$551,102	$2,497,086	$1,945,984	34,822	3	227	0
KIRK 1X	75	$548,864	$2,028,080	$1,479,216	31,208	2	229	1
MAPLE GROVE 1X	76	$536,023	$2,015,239	$1,479,216	30,198	2	231	0
BOLIVAR 1X	77	$517,656	$1,996,872	$1,479,216	32,483	2	233	0
CORWIN 1X	78	$510,537	$1,844,472	$1,333,936	26,093	2	235	0
ROSEMOUNT 2X	79	$500,661	$1,240,269	$739,608	19,137	1	236	0
MOUND (#0030) 1X 2Y	80	$499,788	$4,353,306	$3,853,518	88,665	6	242	3
MARTINSBURG ROAD 1X	81	$485,732	$2,486,635	$2,000,903	51,450	3	245	0

Candidate	Rank	NPV	PV Benefits	PV Costs	Reduced CO2	Circuits	Total	OHA
LINCOLN STREET (#0218) 1X 2X	82	$482,339	$2,483,242	$2,000,903	39,600	3	248	0
EAST NEWARK 1X	83	$469,542	$2,470,445	$2,000,903	32,402	3	251	0
NORTH ZANESVILLE 2X	84	$464,895	$1,726,197	$1,261,302	24,636	2	253	1
TWORIDGES 1X	85	$453,802	$1,933,018	$1,479,216	28,187	2	255	0
FRAZEYSBURG 1X	86	$448,081	$1,405,603	$957,523	18,780	1	256	0
CLINTON 3X	87	$443,169	$2,926,422	$2,483,253	41,832	4	260	0
SOUTH POINT 7X	88	$442,906	$1,073,557	$630,651	13,849	1	261	0
CANAL STREET (#0013) 1X 2X	89	$430,831	$5,615,264	$5,184,433	91,714	8	269	3
BIXBY 3X	90	$422,733	$3,302,463	$2,879,730	54,906	4	273	0
W.NEWPHIL 4X	91	$404,280	$1,738,216	$1,333,936	22,238	2	275	0
BANNOCKRD 1X	92	$401,686	$1,880,903	$1,479,216	25,539	2	277	0
EASTOWNRD 1X	93	$391,639	$2,174,641	$1,783,002	34,323	3	280	0
ETNA 2X	94	$383,902	$1,050,870	$666,968	15,139	1	281	0
GRANVILLE 1X	95	$374,189	$2,375,092	$2,000,903	29,597	3	284	0
EASTONSTR 2X	96	$366,864	$1,584,589	$1,217,724	28,713	2	286	0
DELAWARE 3X	97	$352,697	$1,492,938	$1,140,241	26,362	2	288	1
CIRCLEVILLE 1X	98	$346,879	$2,129,881	$1,783,002	34,092	3	291	1
S.VANWERT 2X	99	$343,465	$2,344,369	$2,000,903	41,475	3	294	1
CLARK STREET 2X	100	$323,208	$2,106,210	$1,783,002	34,913	3	297	0
HESS STREET (#0054) 3X 4X	101	$319,664	$4,242,756	$3,923,091	68,759	6	303	1
WOOSTER 3X	102	$314,777	$1,793,993	$1,479,216	30,987	2	305	0
BILLIAR 2X	103	$312,941	$1,052,549	$739,608	15,613	1	306	0
ELK 2X	104	$311,749	$1,573,051	$1,261,302	21,985	2	308	0
GROVES ROAD (#0038) 7X 8X	105	$307,898	$3,349,161	$3,041,263	45,841	5	313	0
BEALLAVEN 3X	106	$305,824	$2,306,727	$2,000,903	38,955	3	316	0
ACADEMIA 1Y	107	$298,290	$1,777,506	$1,479,216	26,882	2	318	1
MARION ROAD 15W1-4Y	108	$295,234	$1,953,704	$1,658,470	39,970	3	321	0
SHANNON 2X	109	$292,018	$1,480,686	$1,188,668	20,887	2	323	0
MEIGS 1X	110	$277,974	$1,017,582	$739,608	13,929	1	324	0
CARROLLTON 2X	111	$271,148	$1,532,450	$1,261,302	22,462	2	326	1
RIO 1X	112	$269,122	$1,603,057	$1,333,936	22,187	2	328	0
SUGARHILL 1X	113	$265,247	$1,744,464	$1,479,216	22,046	2	330	0
WILSON ROAD 3Y	114	$263,608	$2,762,416	$2,498,808	39,997	4	334	0
STEUBENVI 1X	115	$261,618	$2,262,522	$2,000,903	37,582	3	337	1
S.CAMBRID 3X	116	$252,356	$1,209,878	$957,523	20,212	1	338	0
CLINTON 3Y	117	$248,207	$2,731,460	$2,483,253	36,731	4	342	0
MILLBROPA 6X	118	$245,262	$1,724,478	$1,479,216	24,339	2	344	0
HAVILAND 2X	119	$240,572	$1,198,095	$957,523	14,326	1	345	0
ETNA ROAD 2X	120	$239,415	$1,715,597	$1,476,182	24,022	2	347	0
UTICA 1X	121	$238,360	$1,717,577	$1,479,216	23,903	2	349	0
SCIOTO TRAIL 2X	122	$236,344	$1,715,560	$1,479,216	31,665	2	351	0
GALLOWAY 1X	123	$234,265	$1,710,447	$1,476,182	26,411	2	353	0
DOGWOOD RIDGE 1X	124	$233,742	$2,234,645	$2,000,903	28,385	3	356	0

Candidate	Rank	NPV	PV Benefits	PV Costs	Reduced CO2	Circuits	Total	OHA
E.DOVER 1X	125	$233,173	$1,190,695	$957,523	16,385	1	357	0
BEXLEY 2Y	126	$226,292	$791,570	$565,278	16,268	1	358	0
RARDEN 2X	127	$224,884	$964,492	$739,608	14,207	1	359	0
GROVES ROAD 7Y	128	$223,736	$1,325,236	$1,101,500	19,135	2	361	0
COOLVILLE 1X	129	$218,496	$958,104	$739,608	14,827	1	362	0
S.E.LOGAN 1X	130	$213,254	$1,170,776	$957,523	17,830	1	363	0
BELLVILLE 1X	131	$205,791	$1,163,314	$957,523	17,673	1	364	0
EAST PROCTORVILLE 1X	132	$201,925	$868,893	$666,968	10,426	1	365	0
SHAWNEERD 1X	133	$200,394	$2,201,298	$2,000,903	36,027	3	368	0
EASTONSTR 1X	134	$194,941	$2,021,528	$1,826,586	29,747	3	371	0
FINDLAY 2X	135	$193,911	$860,879	$666,968	13,706	1	372	0
CRESTWOOD 1X	136	$182,673	$2,183,577	$2,000,903	43,509	3	375	0
CORNERSTONE 2X	137	$168,312	$1,429,613	$1,261,302	23,967	2	377	0
ASHAVENUE 1X	138	$165,475	$2,166,379	$2,000,903	33,404	3	380	0
SMITHFIEL 1X	139	$161,310	$1,118,832	$957,523	13,458	1	381	0
WILLISTON 1X	140	$157,866	$2,158,770	$2,000,903	28,464	3	384	0
SUNNYSIDE 6X	141	$157,275	$2,158,178	$2,000,903	33,100	3	387	0
W.GALION 1X	142	$157,169	$1,636,386	$1,479,216	23,352	2	389	0
MARION ROAD E2	143	$153,079	$1,811,549	$1,658,470	38,200	3	392	0
NEWPHILA 3X	144	$146,877	$1,480,813	$1,333,936	20,385	2	394	0
W.MILLERB 1X	145	$142,767	$1,100,290	$957,523	18,866	1	395	0
LINDEN AVENUE 2X	146	$140,359	$2,141,262	$2,000,903	30,265	3	398	1
LOUISVILL 1X	147	$136,667	$2,137,571	$2,000,903	29,096	3	401	0
GENOA 1Y	148	$130,361	$1,048,525	$918,165	16,597	1	402	0
BARNESVIL 1X	149	$129,827	$2,130,731	$2,000,903	29,066	3	405	1
PARSONS (#0057) 2X 3X	150	$118,199	$2,640,803	$2,522,604	45,777	4	409	0
THORNVILLE 1X	151	$115,126	$1,594,342	$1,479,216	19,941	2	411	0
RIVERVIEW 2X	152	$113,617	$2,114,520	$2,000,903	35,207	3	414	2
CENTER STREET 1X	153	$110,208	$2,111,111	$2,000,903	29,676	3	417	0
PLEASANTS 2X	154	$108,110	$738,761	$630,651	8,538	1	418	0
BYESVILLE 1X	155	$106,601	$2,107,504	$2,000,903	31,288	3	421	0
COOLVILLE 2X	156	$105,376	$844,984	$739,608	10,992	1	422	0
VIGO 1X	157	$96,267	$1,575,483	$1,479,216	19,484	2	424	0
N.WILLARD 1X	158	$96,237	$2,097,140	$2,000,903	32,071	3	427	0
SEAMAN 1X	159	$92,974	$2,093,877	$2,000,903	27,902	3	430	1
CLIFTMONT AVE 1X	160	$91,068	$1,048,590	$957,523	16,173	1	431	0
DELPHOS 2X	161	$87,179	$826,787	$739,608	12,587	1	432	0
SUNSETBOU 1X	162	$84,315	$2,085,218	$2,000,903	29,450	3	435	1
N.W.LIMA 1X	163	$80,137	$2,602,740	$2,522,604	38,177	4	439	0
HEBRON 1X	164	$78,959	$1,036,481	$957,523	14,042	1	440	0
MEMORIALD 1X	165	$78,598	$2,601,201	$2,522,604	38,651	4	444	1
LANCASTER 4X	166	$78,516	$1,557,733	$1,479,216	23,573	2	446	0
BLUFFTON 1X	167	$77,294	$1,556,510	$1,479,216	26,866	2	448	1

Candidate	Rank	NPV	PV Benefits	PV Costs	Reduced CO2	Circuits	Total	OHA
WEST GRANVILLE 1X	168	$69,557	$1,027,080	$957,523	17,066	1	449	0
MCCOMB 1X	169	$67,056	$632,334	$565,278	8,515	1	450	0
W.NEWPHIL 3X	170	$62,826	$729,794	$666,968	11,832	1	451	0
18 ST.HTS 2X	171	$60,418	$800,026	$739,608	10,306	1	452	0
SMITHVILL 1X	172	$59,548	$1,017,070	$957,523	15,582	1	453	0
E.LOGAN 1X	173	$53,883	$2,054,786	$2,000,903	29,186	3	456	0
SOUTH NEWARK 1X	174	$52,766	$1,314,068	$1,261,302	19,537	2	458	0
WHEELERSB 1X	175	$52,071	$1,009,594	$957,523	13,816	1	459	0
GROVES ROAD 3X	176	$51,534	$3,643,547	$3,592,013	50,518	6	465	0
SLATE 1X	177	$48,172	$1,527,389	$1,479,216	21,183	2	467	0
NORTH HEBRON 1X	178	$47,289	$1,526,505	$1,479,216	23,364	2	469	0
ETNA ROAD (#0070) 1X 3X	179	$38,682	$2,703,532	$2,664,850	53,154	4	473	1
STRASBURG 1X	180	$35,845	$1,515,061	$1,479,216	23,208	2	475	0
EAST UNION 1X	181	$30,486	$1,509,703	$1,479,216	22,502	2	477	0
MILL ST 1X	182	$27,513	$985,035	$957,523	17,834	1	478	0
ELK 1X	183	$22,270	$1,283,572	$1,261,302	19,992	2	480	0
DUCK CREEK 1X	184	$18,780	$2,019,683	$2,000,903	36,703	3	483	0
FOREST 3X	185	$15,506	$755,114	$739,608	8,877	1	484	0
RIO 2X	186	$11,688	$678,655	$666,968	11,527	1	485	0
GROVES ROAD 8Y	187	$11,071	$1,400,085	$1,389,014	21,227	2	487	0
BILLIAR 1X	188	$7,711	$747,320	$739,608	11,588	1	488	0
S.DELPHOS 1X	189	$7,219	$1,486,436	$1,479,216	23,834	2	490	0
S.FINDLAY 2X	190	$3,025	$1,220,749	$1,217,724	23,374	2	492	1
MILES AVE 1X	191	($1,782)	$1,999,121	$2,000,903	29,751	3	495	1
BEAVER 1X	192	($5,081)	$1,474,135	$1,479,216	17,030	2	497	0
E.SPARTA 2X	193	($5,496)	$661,472	$666,968	9,391	1	498	0
JEFFERSON (#0145) 1X 2X	194	($14,600)	$1,986,303	$2,000,903	26,286	3	501	0
WAKEFIELD 1X	195	($19,177)	$1,460,039	$1,479,216	17,690	2	503	0
DENNISON 4X	196	($23,414)	$934,108	$957,523	14,519	1	504	1
NORTH END FOSTORIA 2X	197	($28,534)	$1,305,402	$1,333,936	17,350	2	506	0
MCCOMB 2X	198	($28,831)	$536,447	$565,278	16,307	1	507	0
BLENDON 1Y	199	($33,611)	$1,184,113	$1,217,724	15,136	2	509	0
NORTH BALTIMORE 1X	200	($38,490)	$1,440,727	$1,479,216	19,946	2	511	0
SCIOTOVIL 1X	201	($41,263)	$1,437,953	$1,479,216	16,925	2	513	0
ROSEMOUNT 1X	202	($43,589)	$696,020	$739,608	9,624	1	514	0
PACKARD 1X	203	($46,819)	$1,954,084	$2,000,903	28,980	3	517	0
CORNERSTONE 1X	204	($47,625)	$1,213,677	$1,261,302	15,688	2	519	2
TORONTO 1X	205	($51,007)	$1,428,209	$1,479,216	20,379	2	521	0
BELPRE 1X	206	($51,825)	$1,209,476	$1,261,302	18,706	2	523	0
CIRCLEVILLE 2X	207	($59,378)	$1,723,624	$1,783,002	27,588	3	526	0
W.ALIKANN 1X	208	($63,816)	$893,706	$957,523	13,328	1	527	0
COLERAIN 1X	209	($70,884)	$886,639	$957,523	11,274	1	528	0
OERTELS 1X	210	($73,130)	$1,406,086	$1,479,216	16,042	2	530	0

Candidate	Rank	NPV	PV Benefits	PV Costs	Reduced CO2	Circuits	Total	OHA
ROCKBRIDG 1X	211	($83,113)	$1,396,103	$1,479,216	17,391	2	532	0
SOUTH GRANVILLE 1X	212	($86,027)	$1,393,189	$1,479,216	28,490	2	534	0
HIGHLAND AVENUE 1X	213	($87,690)	$1,913,214	$2,000,903	27,969	3	537	0
E.FREMONT 1X	214	($92,653)	$1,386,563	$1,479,216	24,303	2	539	0
MINFORD 1X	215	($94,895)	$1,384,322	$1,479,216	17,699	2	541	0
SMYRNA 1X	216	($102,440)	$855,083	$957,523	10,351	1	542	0
E.LANCAST 1X	217	($107,999)	$631,609	$739,608	8,436	1	543	0
COLUMBIA 1X	218	($108,388)	$1,658,342	$1,766,730	24,814	2	545	0
N.CANTON 1X	219	($108,408)	$2,414,196	$2,522,604	40,059	4	549	0
MILLWOOD 1X	220	($108,873)	$1,892,031	$2,000,903	24,512	3	552	0
WALNUT CR 1X	221	($110,498)	$847,024	$957,523	16,173	1	553	0
TILTONSVI 2X	222	($116,479)	$1,362,737	$1,479,216	20,812	2	555	0
PARK 1X	223	($116,619)	$1,362,597	$1,479,216	25,450	2	557	0
ADAMS 2X	224	($117,056)	$1,362,160	$1,479,216	18,023	2	559	0
DILLONVAL 1X	225	($121,892)	$835,630	$957,523	10,652	1	560	0
STONESTREET 3X	226	($124,666)	$1,876,238	$2,000,903	30,819	3	563	1
ST. CLAIR 3X	227	($124,780)	$1,571,054	$1,695,834	29,697	3	566	0
MARTINSFE 1X	228	($134,817)	$1,344,399	$1,479,216	19,467	2	568	1
LEESVILLE 2X	229	($135,720)	$603,888	$739,608	6,788	1	569	0
SUPERIOR 1X	230	($136,602)	$820,920	$957,523	10,826	1	570	0
WEST PHILO 1X	231	($140,642)	$816,881	$957,523	10,455	1	571	0
ROZELLE 1X	232	($141,385)	$1,337,832	$1,479,216	17,350	2	573	0
CROOKSVILLE 3X	233	($142,438)	$815,085	$957,523	10,860	1	574	0
NEGLEY 1X	234	($143,014)	$1,857,889	$2,000,903	41,486	3	577	0
BERLIN 1X	235	($143,629)	$1,335,587	$1,479,216	23,649	2	579	0
NEFFS 1X	236	($147,116)	$810,407	$957,523	10,067	1	580	0
RENO 1X	237	($150,424)	$1,328,792	$1,479,216	27,363	2	582	0
PLY.HGTS. 1X	238	($152,889)	$804,634	$957,523	12,625	1	583	0
BLISSPARK 1X	239	($154,782)	$1,846,121	$2,000,903	27,889	3	586	2
SHAWNEE 1X	240	($157,051)	$1,322,165	$1,479,216	14,958	2	588	0
BLOOM ROAD 1X	241	($157,837)	$799,685	$957,523	11,953	1	589	0
BUCYRUS 1X	242	($158,268)	$1,842,636	$2,000,903	30,945	3	592	0
CENTERBURG 1Y	243	($158,279)	$508,689	$666,968	6,634	1	593	0
BATEVILL 1X	244	($161,412)	$796,111	$957,523	9,312	1	594	0
LEXINGTON 1X	245	($162,566)	$1,316,650	$1,479,216	19,432	2	596	0
N.WOOSTER 1X	246	($166,737)	$790,786	$957,523	10,391	1	597	1
HIGHLAND TERRACE 1X	247	($168,631)	$788,891	$957,523	9,144	1	598	0
EAST OTTAWA 1X	248	($172,001)	$1,307,215	$1,479,216	22,428	2	600	0
EAST WILLARD 2X	249	($173,599)	$566,009	$739,608	13,748	1	601	0
MADISON 1X	250	($174,913)	$1,304,304	$1,479,216	27,917	2	603	0
S.CANTON 2X	251	($181,219)	$776,303	$957,523	11,391	1	604	0
EASTOWNRD 2X	252	($181,771)	$1,601,232	$1,783,002	24,225	3	607	1
AUGLAIZE 1X	253	($184,532)	$555,076	$739,608	5,970	1	608	0

Candidate	Rank	NPV	PV Benefits	PV Costs	Reduced CO2	Circuits	Total	OHA
N.IRONTON 1X	254	($185,688)	$771,835	$957,523	9,905	1	609	0
N.SPENCVI 1X	255	($186,049)	$1,293,167	$1,479,216	20,028	2	611	0
RUHLMAN 1X	256	($188,027)	$2,334,577	$2,522,604	33,560	4	615	2
BUCYRUSCT 2X	257	($188,232)	$1,812,671	$2,000,903	31,185	3	618	1
S.GREENWI 1X	258	($191,683)	$765,839	$957,523	10,275	1	619	0
BELPRE 2X	259	($197,221)	$1,064,080	$1,261,302	15,687	2	621	0
COL.GROVE 1X	260	($199,285)	$758,238	$957,523	9,596	1	622	0
CAIRO 1X	261	($205,626)	$751,896	$957,523	10,560	1	623	0
MOUNT STERLING 1X	262	($207,992)	$749,531	$957,523	8,425	1	624	0
MEIGS 2X	263	($209,407)	$530,201	$739,608	6,155	1	625	0
SUMMERHIL 1X	264	($211,922)	$1,267,295	$1,479,216	21,454	2	627	0
GINGER 1X	265	($213,210)	$1,266,006	$1,479,216	15,878	2	629	0
W.LAFAYET 1X	266	($214,243)	$1,264,973	$1,479,216	16,213	2	631	0
PITTSBURGH AVENUE (#4204) 1X 2X	267	($219,937)	$1,780,966	$2,000,903	23,335	3	634	0
FREMONTCT 2X	268	($221,633)	$735,889	$957,523	11,190	1	635	0
E.TIFFIN 1X	269	($223,148)	$1,256,068	$1,479,216	19,222	2	637	0
IDAHO 1X	270	($233,574)	$1,245,643	$1,479,216	16,580	2	639	0
S.VANLUE 1X	271	($241,274)	$716,248	$957,523	8,558	1	640	0
CORNER 1X	272	($245,385)	$1,755,519	$2,000,903	22,691	3	643	0
COOPERMILL 2X	273	($251,224)	$706,298	$957,523	8,524	1	644	0
ROBERTSVI 1X	274	($254,343)	$703,179	$957,523	9,257	1	645	0
AUGLAIZE 2X	275	($258,204)	$481,404	$739,608	6,715	1	646	0
CAMBRIDGE 1X	276	($262,003)	$1,217,213	$1,479,216	18,310	2	648	0
CADIZ 1X	277	($263,776)	$1,215,441	$1,479,216	17,028	2	650	1
CORWIN 2X	278	($265,762)	$401,205	$666,968	5,539	1	651	0
ST.CLAIRA 1X	279	($271,122)	$1,729,781	$2,000,903	22,031	3	654	1
MOUNT VERNON 1X	280	($298,203)	$1,181,014	$1,479,216	18,829	2	656	1
FINDLAY CENTER 2X	281	($301,863)	$655,660	$957,523	8,729	1	657	0
ANCHOR-HOCKING 2X	282	($302,817)	$654,705	$957,523	8,250	1	658	0
GAMBIER 1X	283	($312,375)	$1,166,841	$1,479,216	17,405	2	660	0
CARROLLTON 1X	284	($312,701)	$948,601	$1,261,302	13,535	2	662	0
KALIDA 3X	285	($315,522)	$1,163,694	$1,479,216	23,008	2	664	0
CLARK STREET 1X	286	($316,604)	$1,466,398	$1,783,002	29,764	3	667	1
MADISONBURG 2X	287	($320,512)	$1,680,392	$2,000,903	27,758	3	670	1
BEXLEY 3X	288	($322,271)	$243,006	$565,278	7,036	1	671	0
BREMEN 1X	289	($323,751)	$633,771	$957,523	7,648	1	672	0
MONROESTR 1X	290	($326,676)	$1,674,227	$2,000,903	22,422	3	675	1
MAHONINGR 1X	291	($326,942)	$1,673,961	$2,000,903	26,794	3	678	0
TIFFINTAP 2X	292	($328,085)	$1,151,131	$1,479,216	21,327	2	680	0
OAKWOOD 1X	293	($331,676)	$2,190,927	$2,522,604	33,007	4	684	0
18 ST.HTS 1X	294	($332,242)	$407,366	$739,608	8,409	1	685	0
LOCK 1X	295	($333,473)	$1,145,743	$1,479,216	15,407	2	687	0
SOUTH SOMERSET 1X	296	($336,229)	$621,294	$957,523	8,174	1	688	0

Candidate	Rank	NPV	PV Benefits	PV Costs	Reduced CO2	Circuits	Total	OHA
S.FINDLAY 1X	297	($338,567)	$1,488,020	$1,826,586	24,495	3	691	0
W.HICKSVI 1X	298	($344,426)	$613,096	$957,523	8,317	1	692	0
SAVANNAH AVENUE 4X	299	($348,627)	$1,130,589	$1,479,216	15,871	2	694	0
HOWARD 3X	300	($350,548)	$1,128,668	$1,479,216	13,508	2	696	0
RARDEN 3X	301	($355,634)	$383,974	$739,608	4,540	1	697	0
HOPEDALE 1X	302	($358,093)	$599,429	$957,523	7,474	1	698	0
COSHOCTON 1X	303	($359,646)	$1,641,257	$2,000,903	20,777	3	701	1
CENTERBURG 1X	304	($361,050)	$972,885	$1,333,936	23,461	2	703	0
CALIFORNIA 1X	305	($362,964)	$2,159,639	$2,522,604	32,110	4	707	0
E.N.CONC. 1X	306	($363,810)	$1,115,406	$1,479,216	18,835	2	709	0
BIGPRAIRI 1X	307	($369,341)	$588,181	$957,523	7,214	1	710	0
DERWENT 1X	308	($373,443)	$584,080	$957,523	7,559	1	711	0
ROSEFARM 1X	309	($378,904)	$578,618	$957,523	6,588	1	712	0
MILL CREEK 2X	310	($380,433)	$203,520	$583,953	8,946	1	713	1
REEDURBAN 1X	311	($381,589)	$2,141,015	$2,522,604	33,767	4	717	0
REYNOLDS 1X	312	($385,806)	$1,093,410	$1,479,216	16,215	2	719	0
POSTON 3X	313	($386,192)	$571,331	$957,523	10,054	1	720	0
HEMLOCK 1X	314	($387,788)	$1,091,428	$1,479,216	14,612	2	722	0
LEESVILLE 1X	315	($388,332)	$351,276	$739,608	4,312	1	723	0
W.TORONTO 1X	316	($392,809)	$1,086,407	$1,479,216	14,090	2	725	0
OTWAY 1X	317	($394,901)	$562,622	$957,523	6,866	1	726	0
ASHLEY 1X	318	($395,430)	$1,083,786	$1,479,216	13,105	2	728	0
APPLECREE 1X	319	($396,892)	$560,631	$957,523	9,461	1	729	0
DRESDEN 1X	320	($397,078)	$1,082,139	$1,479,216	14,398	2	731	0
MINERVA 1X	321	($399,154)	$1,601,749	$2,000,903	26,164	3	734	0
OAKLAND 1X	322	($403,695)	$1,597,208	$2,000,903	22,978	3	737	0
N.WELSVIL 1X	323	($404,864)	$1,074,352	$1,479,216	13,837	2	739	0
LANSING 1X	324	($410,408)	$547,114	$957,523	6,261	1	740	0
SOUTH BELMONT 1X	325	($413,326)	$1,065,890	$1,479,216	13,674	2	742	0
ST. CLAIR 2Y	326	($414,875)	$1,280,958	$1,695,834	25,078	3	745	0
CRIDERSVI 1X	327	($419,669)	$1,059,548	$1,479,216	14,359	2	747	1
PEKIN 2X	328	($424,493)	$533,030	$957,523	8,524	1	748	0
WILKESVILLE 1X	329	($426,054)	$531,469	$957,523	6,228	1	749	0
PAYNE 1X	330	($428,899)	$1,050,317	$1,479,216	13,491	2	751	0
E.MT.CORY 1X	331	($436,409)	$521,114	$957,523	6,144	1	752	0
SHADYSIDE 1X	332	($439,279)	$1,039,938	$1,479,216	13,330	2	754	0
E BUCYRUS 1X	333	($442,371)	$1,036,845	$1,479,216	14,322	2	756	0
BLOOMVILL 1X	334	($444,343)	$513,179	$957,523	5,790	1	757	0
FRIENSHIP 1X	335	($446,951)	$1,032,265	$1,479,216	12,771	2	759	0
TORREY 5X	336	($448,647)	$1,030,569	$1,479,216	16,094	2	761	0
AVONDALE 1X	337	($449,158)	$290,450	$739,608	3,296	1	762	0
FINDLAY 1X	338	($459,424)	$874,512	$1,333,936	13,595	2	764	0
PLEASANTV 1X	339	($459,503)	$1,019,713	$1,479,216	13,394	2	766	0

Candidate	Rank	NPV	PV Benefits	PV Costs	Reduced CO2	Circuits	Total	OHA
NORTH END FOSTORIA 1X	340	($460,495)	$206,472	$666,968	4,755	1	767	0
HILLVIEW 1X	341	($461,151)	$1,018,065	$1,479,216	14,811	2	769	0
SALINEVIL 1X	342	($468,462)	$489,061	$957,523	5,533	1	770	0
PENNSVILL 1X	343	($472,660)	$1,006,556	$1,479,216	10,879	2	772	0
E.LANCAST 2X	344	($475,460)	$264,148	$739,608	3,427	1	773	1
SULPH.SPR 1X	345	($476,030)	$1,003,187	$1,479,216	12,059	2	775	0
RACINE 1X	346	($484,095)	$473,428	$957,523	5,929	1	776	0
PLEASANGR 1X	347	($485,798)	$471,724	$957,523	5,987	1	777	0
PROCTORVL 3X	348	($487,834)	$991,382	$1,479,216	12,524	2	779	0
DELANO 1Y	349	($491,099)	$1,509,805	$2,000,903	37,267	3	782	2
N. CROWN CITY 1X	350	($492,018)	$465,505	$957,523	4,873	1	783	0
STANTONST 2X	351	($500,818)	$978,398	$1,479,216	13,626	2	785	0
N.CAMBRID 1X	352	($505,666)	$451,857	$957,523	8,559	1	786	1
NORTH WALDO 2X	353	($506,507)	$972,709	$1,479,216	13,037	2	788	0
CARROTHER 1X	354	($511,757)	$445,766	$957,523	5,032	1	789	0
WEST CANTON 1X	355	($523,040)	$1,854,296	$2,377,336	29,520	4	793	0
N.FREMONT 1X	356	($527,871)	$1,473,032	$2,000,903	24,600	3	796	0
COPELAND 1X	357	($534,473)	$1,466,430	$2,000,903	20,042	3	799	1
KENNY ROAD (#0003) 1Y 2Y	358	($541,095)	$3,940,007	$4,481,102	68,281	7	806	3
E.SPARTA 1X	359	($543,082)	$790,853	$1,333,936	11,439	2	808	0
SARDINIA 1X	360	($544,074)	$935,142	$1,479,216	12,463	2	810	0
SCIO 1X	361	($547,648)	$931,568	$1,479,216	11,986	2	812	0
MUNGEN 1X	362	($550,612)	$406,911	$957,523	4,554	1	813	0
RAVEN 1X	363	($550,659)	$928,557	$1,479,216	12,363	2	815	0
W.OAKWOOD 1X	364	($552,192)	$405,330	$957,523	4,730	1	816	0
NORTH HICKSVILLE 2X	365	($556,047)	$705,255	$1,261,302	9,904	2	818	1
LAFAYETTE 1X	366	($560,984)	$918,232	$1,479,216	12,398	2	820	0
ARBOR ST 1X	367	($561,680)	$917,537	$1,479,216	13,182	2	822	1
OLDWASHIN 1X	368	($561,875)	$395,647	$957,523	4,733	1	823	0
KILLBUCK 1X	369	($562,713)	$394,810	$957,523	5,306	1	824	0
GEORGESRU 1X	370	($570,948)	$908,269	$1,479,216	12,259	2	826	0
PADEN CITY 2X	371	($571,762)	$385,761	$957,523	5,513	1	827	0
SHREVE 1X	372	($577,200)	$902,017	$1,479,216	12,491	2	829	0
SO.MORRAL 1X	373	($577,369)	$380,153	$957,523	4,408	1	830	0
FULTON 1X	374	($579,020)	$900,196	$1,479,216	10,053	2	832	0
JONES CITY 1X	375	($579,053)	$378,469	$957,523	4,295	1	833	0
S.MAR.FER 1X	376	($582,391)	$1,418,513	$2,000,903	19,300	3	836	0
AMSTERDAM 1X	377	($585,742)	$893,475	$1,479,216	10,502	2	838	0
BROADACRE 1X	378	($587,827)	$891,389	$1,479,216	12,438	2	840	0
POMEROY 3X	379	($587,839)	$891,377	$1,479,216	11,134	2	842	0
W.MALTA 1X	380	($596,055)	$883,162	$1,479,216	10,317	2	844	0
BROKEN SWORD 1X	381	($601,692)	$877,524	$1,479,216	10,116	2	846	0
ZOARVILLE 1X	382	($605,595)	$873,621	$1,479,216	10,360	2	848	0

Candidate	Rank	NPV	PV Benefits	PV Costs	Reduced CO2	Circuits	Total	OHA
LEIPSIC 1X	383	($612,433)	$721,502	$1,333,936	9,302	2	850	0
BENTONVILLE 1X	384	($612,436)	$866,780	$1,479,216	13,242	2	852	0
ISLETA 1X	385	($615,003)	$342,519	$957,523	3,907	1	853	0
FOREST 2X	386	($623,451)	$116,158	$739,608	2,499	1	854	0
ARLINGTON 1X	387	($652,643)	$826,573	$1,479,216	10,498	2	856	0
E.DELPHOS 1X	388	($663,486)	$815,730	$1,479,216	13,245	2	858	0
CONESVILL 1X	389	($667,789)	$289,733	$957,523	3,603	1	859	0
BEAVERDAM 1X	390	($668,405)	$810,811	$1,479,216	11,020	2	861	0
STCLAIRSV 1X	391	($674,055)	$283,468	$957,523	3,359	1	862	0
BUCKSKIN 1X	392	($676,598)	$1,324,306	$2,000,903	16,451	3	865	0
DECLIFF 1X	393	($676,676)	$802,540	$1,479,216	9,796	2	867	0
SENECAVILLE 1X	394	($691,336)	$266,186	$957,523	2,767	1	868	0
CROTON 1X	395	($691,700)	$265,823	$957,523	2,964	1	869	0
CONTINETL 1X	396	($692,949)	$786,268	$1,479,216	9,715	2	871	0
OTTOVILLE 1X	397	($693,406)	$785,810	$1,479,216	10,720	2	873	0
KIMBOLTON 1X	398	($693,723)	$263,800	$957,523	2,702	1	874	0
HILLNDALE 1X	399	($703,208)	$776,008	$1,479,216	11,141	2	876	0
BELLAIRE 1X	400	($714,093)	$765,124	$1,479,216	12,043	2	878	1
E.HAVERHI 1X	401	($725,190)	$754,027	$1,479,216	10,315	2	880	0
S.CONVOY 1X	402	($729,740)	$749,477	$1,479,216	10,631	2	882	0
WINTERSVI 1X	403	($729,937)	$1,270,966	$2,000,903	18,776	3	885	0
NORTH HICKSVILLE 1X	404	($732,756)	$528,546	$1,261,302	7,366	2	887	1
WILDCAT 1X	405	($733,486)	$745,730	$1,479,216	9,268	2	889	0
MACKSBURG 2X	406	($736,489)	$221,033	$957,523	2,660	1	890	0
HIGHSTREE 1X	407	($747,528)	$731,688	$1,479,216	15,492	2	892	1
GLENWOOD 1X	408	($751,456)	$727,760	$1,479,216	8,076	2	894	0
S.CADIZ 1X	409	($759,531)	$197,991	$957,523	3,168	1	895	1
DUNKIRK 3X	410	($762,452)	$716,764	$1,479,216	8,195	2	897	0
BEARTOWN 1X	411	($772,461)	$706,755	$1,479,216	8,099	2	899	0
W.MOULTAN 1X	412	($781,240)	$176,282	$957,523	2,114	1	900	0
NEWCOMERS 1X	413	($786,912)	$692,305	$1,479,216	10,419	2	902	0
BROOM ROAD 1X	414	($789,292)	$1,211,611	$2,000,903	16,252	3	905	0
BRIDGEPORT 1X	415	($804,809)	$674,407	$1,479,216	8,901	2	907	0
MILL CREEK 3X	416	($810,668)	$941,191	$1,751,859	16,615	3	910	2
PANDORA 1X	417	($812,428)	$666,788	$1,479,216	10,059	2	912	0
STONYHOLL 1X	418	($824,085)	$1,176,819	$2,000,903	17,430	3	915	0
RUTLAND 1X	419	($827,477)	$130,046	$957,523	1,374	1	916	0
WARSAW 1X	420	($830,123)	$649,093	$1,479,216	6,988	2	918	0
WILLARD 1X	421	($834,521)	$644,695	$1,479,216	7,472	2	920	0
OHIOCITY 1X	422	($834,736)	$122,787	$957,523	1,418	1	921	0
N.MIDDLPT 1X	423	($854,454)	$624,762	$1,479,216	8,776	2	923	0
ANTWERP 1X	424	($859,566)	$619,650	$1,479,216	7,247	2	925	1
N.FREDERI 1X	425	($874,955)	$604,261	$1,479,216	8,474	2	927	0

Candidate	Rank	NPV	PV Benefits	PV Costs	Reduced CO2	Circuits	Total	OHA
ROBYVILLE (#5007) 1X 2X	426	($884,372)	$594,844	$1,479,216	6,476	2	929	0
KOSSUTH 1X	427	($889,654)	$67,869	$957,523	328	1	930	0
FLUSHING 1X	428	($908,193)	$571,024	$1,479,216	6,358	2	932	0
FLAG CITY 1X	429	($910,491)	$1,612,112	$2,522,604	22,377	4	936	0
NEELYSVIL 1X	430	($914,499)	$1,086,405	$2,000,903	13,286	3	939	0
HARMAR HILL 1X	431	($941,254)	$1,581,349	$2,522,604	23,477	4	943	0
SHERWOOD 1X	432	($944,180)	$535,036	$1,479,216	6,070	2	945	0
LOWELL 1X	433	($960,473)	$518,743	$1,479,216	6,011	2	947	0
COALGROVE 1X	434	($964,210)	$515,006	$1,479,216	5,343	2	949	0
N.UPSANDU 1X	435	($974,359)	$504,857	$1,479,216	6,797	2	951	0
E.FINDLAY 1X	436	($998,211)	$481,005	$1,479,216	6,397	2	953	0
LATTY 1X	437	($1,011,026)	$468,190	$1,479,216	5,308	2	955	1
RAY 1X	438	($1,081,092)	$398,124	$1,479,216	5,253	2	957	0
MCDERMOTT 1X	439	($1,112,867)	$366,350	$1,479,216	3,862	2	959	0
COMMERCE 1X	440	($1,122,201)	$357,015	$1,479,216	6,818	2	961	0
NEW MATAMORAS 1X	441	($1,124,712)	$354,505	$1,479,216	3,979	2	963	0
OTTAWA 1X	442	($1,125,638)	$875,265	$2,000,903	12,328	3	966	0
E.SPRING 1X	443	($1,176,051)	$303,165	$1,479,216	2,958	2	968	0
WEST TRINWAY 1X	444	($1,191,742)	$287,474	$1,479,216	5,241	2	970	0
BLOOM 1X	445	($1,310,629)	$690,274	$2,000,903	8,318	3	973	0

6.3 Financial and Other Assumptions

Table 12
Financial Assumptions

Financial Evaluation Criteria	Value
After-Tax Weighted Average Cost of Capital	7.80%
Combined Federal & State Income Tax Rate	21.88%
Local Property Tax Rate	3.05%
Basis for Determining Property Tax	Net Book

Depreciation of Capitalized Infrastructure	Tax Dep	SL Dep
Substation (DACR and VVO) [20, 21]	SLD 45	SLD 45
Distribution (DACR and VVO) [20, 21]	SLD 32	SLD 32
Smart Meters (AMI) [21]	SLD 15	SLD 15
Communication [21]	SLD 15	SLD 15
Information Technology	SLD 5	SLD 5

Operations & Maintenance Category	Value
T&D Infrastructure O&M - % of Plant:	3.0%
Com Infrastructure O&M - % of Plant:	3.0%
Info Tech Infrastructure O&M - % of Plant:	3.0%

Annual Escalation Variables	Value
Substation & Distribution Costs	1.5%
Communication Costs	1.5%
Information Technology Costs	1.5%
Annual O&M Expenses	1.5%
System Load Growth	1.0%
Meter Population Growth	0.5%
Retail Power Costs	1.5%
LBNL cost of interruptions	1.5%

[20] Digital controls and related appurtenances have a much shorter service life than their associated substation and distribution devices such as breakers, reclosers, voltage regulators, switched capacitor banks, or other equipment. Because of their shorter service life, these controls and appurtenances may eventually be segregated into separate plant accounts and depreciated sooner than their associated substation or distribution devices.

[21] Any digital equipment such as substation and distribution device controls, their related appurtenances, smart meters, or digital radios, etc. that are anticipated or planned to be replaced prior to being fully depreciated is assumed in this Phase 3 report to be sold or disposed of at book value or exchanged with a similar asset that results in no accounting gains or losses.

Other Assumptions and Notes:

1. Cisco™ field radios required for DACR and VVO installed is anticipated to be replaced every 10 years. Scheduled capital replacement of all Cisco™ field radios is included within all the DACR and VVO business cases.
2. All DACR and VVO business cases include capital costs and O&M costs associated Cisco's field network directory ("FND"). These costs may decrease if other AEP business units or operating companies choose to deploy Cisco's FND.
3. Itron-SSN field radio access points and relays required for AMI is assumed to be operated until they fail in-service. The cost to replace failed SSN access points and relays is included within the AMI business case.
4. DACR controller hardware and software is anticipated to be replaced every 10 years. Scheduled capital replacement of this IT infrastructure is included within all the business cases for each DACR scheme candidate.
5. VVO controller hardware and software is anticipated to be replaced every 8 years. Scheduled capital replacement of this IT infrastructure is included within all the business cases for each VVO bus candidate.
6. The business case for each VVO bus candidate assumes that AMI is deployed and software licenses are purchased for the VVO vendor's AMI module, which enables voltage reduction be increased from 3 percent to 4 percent to achieve greater energy savings.
7. The business case for each DACR scheme candidate assumes that outage frequency (SAIFI) is reduced 15.8 percent and CAIDI is unchanged.
8. Reduced CO_2 emissions over 15 years assume AEP Ohio's electricity CO_2 emission factor of 0.88 metric tons per MWh remains unchanged over the 15 year business case for each VVO bus candidate.
9. Reduced CO_2 emissions over 15 years associated with vehicles is based on the gasoline CO_2 emission factor of 19.60 lbs. of CO2 per gallon.
10. The topology and baseline reliability of all distribution circuits and DACR scheme candidates remains unchanged over the 15 year study period.
11. The topology of distribution circuits and VVO bus candidates remains unchanged over the 15 year study period.