NATIONAL ENERGY TECHNOLOGY LABORATORY

West Virginia Smart Grid Implementation Plan

Revision 1

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U.S. DEPARTMENT OF ENERGY

West Virginia
Smart Grid Implementation Plan

20 August 2009

Revision 1

Submitted to:

The Honorable Joe Manchin III, Governor, State of West Virginia

Submitted by:

West Virginia Division of Energy

National Energy Technology Laboratory

US DOE Office of Electricity Delivery and Energy Reliability

Research and Development Solutions (RDS)

Allegheny Power

American Electric Power

West Virginia University

Disclaimer

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1.0 Executive Summary

1.1 Key Findings

The West Virginia Smart Grid team examined the current state of the West Virginia (WV) electricity grid and the likely future state of that grid necessary to support the development of the 21st century economy in WV. This examination revealed several gaps that must be addressed in order to establish a resilient and reliable energy infrastructure supportive of West Virginia's future economic development. The transition to the Smart Grid is an important step in supporting that future. Today,

- WV averages more than $450M per year in capital spend on electric infrastructure
- WV is well below the national average in grid reliability
- WV does not have the regulatory framework to:
  - incentivize grid intelligence as a way of solving reliability, efficiency, and economic weaknesses
  - encourage consumer participation in demand reduction and applying their distributed energy resources to the grid

All stakeholders will need to participate in closing the technology, regulatory, consumer and R&D gaps to ensure the success of the WV Smart Grid. The required effort will be great, but the reward is greater.

- The business case shows the benefits far outweigh the costs
- The Smart Grid capital and operating expense will be less than today's historical spend in the WV utilities
- The selected solutions are available today for demonstration
- The majority of the benefit of a Smart Grid accrues to the WV consumer and WV society
- The implementation of the Smart Grid in WV will take eight years and can begin as early as 2010

The major technology contributors are addressed in terms of their penetration, their costs and their benefits. These major solutions are discussed below as enablers to the Smart Grid characteristics that will support the 21st century economy in WV.

1.2 West Virginia Smart Grid Overview

Table 1-1 outlines the WV Smart Grid Solutions (details may be found in section 6.3). These solutions are consistent with the DOE Modern Grid Strategy recommendations (details may be found in section 3.0).

TABLE 1-1: WEST VIRGINIA SMART GRID SOLUTIONS

Solution	Scope
Advanced Meter Infrastructure (AMI)	All residential, commercial and industrial Customers represented by 998,317 meters
IT Integration (IT)	A CIS Upgrade to accommodate AMI and DR functionality & Outage Management
Demand Response (DR)	The aggregated sum of 104 MW of DR from Residential, Commercial and Industrial Customers
Distribution Management System (DMS)	The automated fault clearing & restoration of service, circuit monitoring and control of the Distribution System to include 707 circuits of 1107 total circuits
Distributed Energy Resources (DER)	100MW of Base Generation, 800 MW of Peak Generation, 250 MW of Advanced Storage and 100 MW of Wind Resources all capable of being dispatched on demand

Table 1-2 shows the present value (PV) cost and benefit of each solution while Table 1-3 shows the benefit values delivered by the solutions to each of the beneficiaries.

TABLE 1-2: WEST VIRGINIA SMART GRID SOLUTION COSTS AND BENEFITS

	PV 20-yr Cost and Benefits	
Solution	**Cost**	**Benefits**
AMI	$399	$1,649
IT	$170	$1,308
DR	$22	$1,091
DMS	$454	$3,288
DER	$832	$5,289
Total	**$1,878**	**$12,625**

TABLE 1-3: WEST VIRGINIA SMART GRID SOLUTION BENEFITS BY BENEFICIARY

	PV 20-yr Benefits by Beneficiaries			
Solution	**Consumer**	**Operational**	**WV Society**	**US Society**
AMI	$630	$439	$308	$271
IT	$563	$136	$326	$283
DR	$23	$614	$240	$214
DMS	$2,909	$73	$303	$2
DER	$3,368	$2	$301	$1,618
Total	**$7,493**	**$1,263**	**$1,479**	**$2,389**

Table 1-4 shows the benefit categories and their estimated values.

TABLE 1-4: WV SMART GRID BENEFITS (ANNUAL)

Key Success Factors	Benefits	Annual Benefits ($M) (All Beneficiaries)
Reliability	Reduced Consumer Losses	$898
	Reduce Power Quality Events	$131
Economic	Reduce Price of Electricity	$399
	Job Creation	$215
	Consumer Sales of DER Resources	$175
	Increased Energy Sales as Exports	$7
	Reduced Transmission Congestion	$1
	Increased Transportation Fuels Business	$5
	Consumer Conservation	$20
	Operational Savings	$194
Environmental	Reduced Emissions	$7
Security	Reduced Blackout Probability & Dependence on Foreign Oil	$13
Safety	Reduce Hazard Exposure	$1

It is important to note that the business case and implementation plan developed in this project are based on the assumption that the solutions are rolled-out in a coordinated fashion, not independently. Treating the solutions as separate cases will increase the cost and reduce the benefit to consumers and society.

1.3 Summary of Results

The business case results in a total PV benefit to all beneficiaries of slightly more than $12 billion over the next 20 years for a PV cost of ~$2 billion as shown in Figure 1-1. The net present value (NPV) or benefit net of cost is ~ $10 billion.

The specific benefit to West Virginia consumers, society, and utilities is over $10 billion over the next 20 years for the cost of ~$2 billion as shown in Figure 1-2. The benefit net of cost is ~ $8 billion. The results are presented in present value (PV) for costs and benefits, and racked to show the overall net present value (benefit net of cost). **In all racking charts in this report, the costs are shown as negative cash flows and the benefits are shown as positive cash flows.**

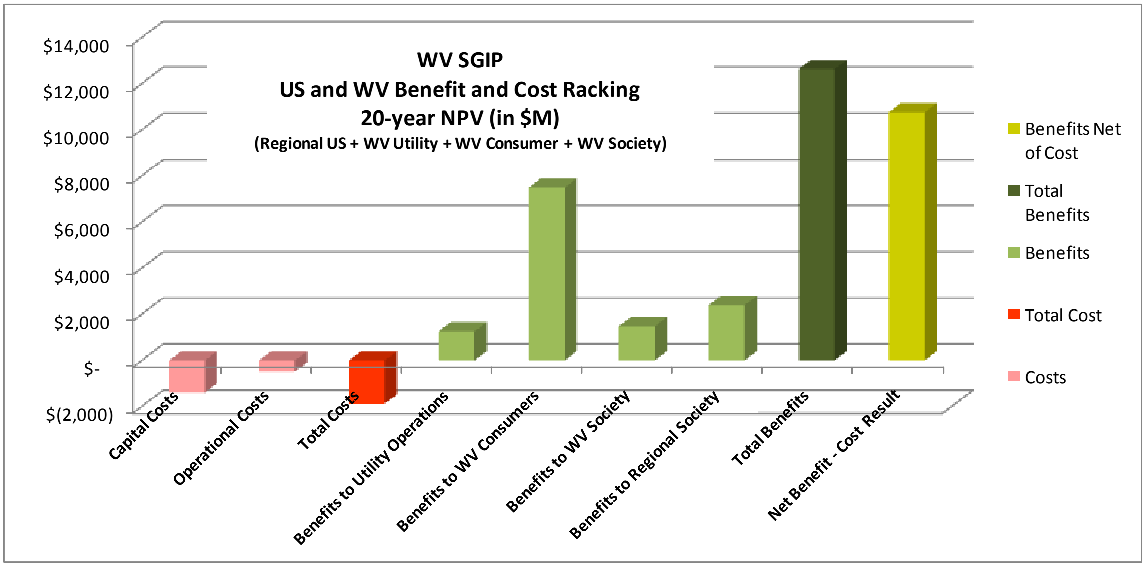


FIGURE 1-1: TOTAL WEST VIRGINIA BENEFIT AND COST RACKING

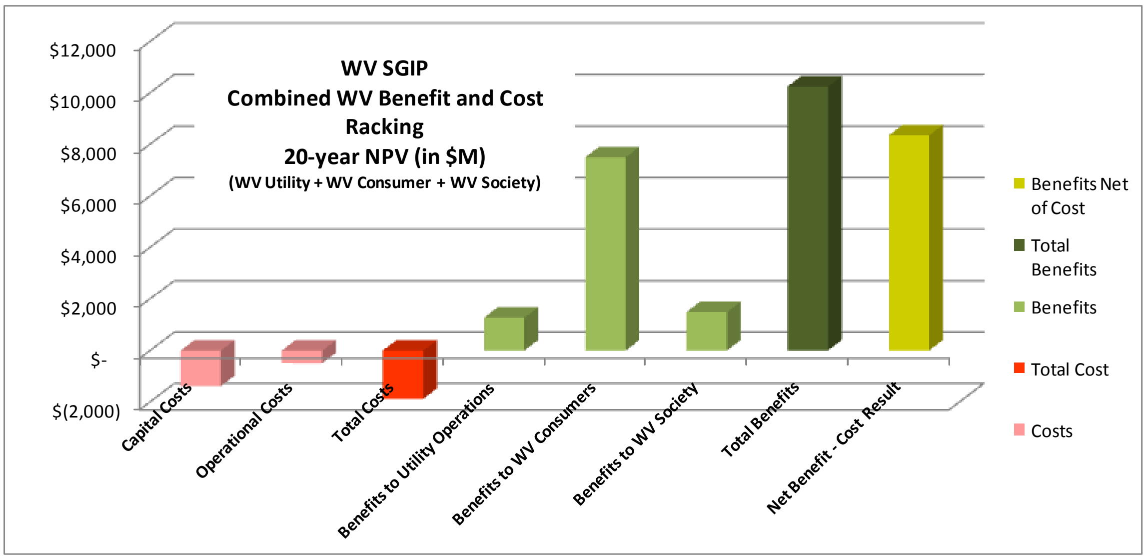


FIGURE 1-2: TOTAL WEST VIRGINIA BENEFIT AND COST RACKING

Explaining Figure 1-1 and 1-2, the total present value cost ($1.9 billion) is the sum of the capital costs and operational costs and is presented as a negative since it is cash outflow. The total present value benefit is the sum of the benefits generated across the beneficiaries (e.g. $10.2 billion in Figure 1-2), and the NPV (benefit net of cost) is the total benefit minus the total cost yielding $8.3 billion (ref. Figure 1-2).

1.4 Recommendations

Table 1-5 and Figure 1-3 shows the implementation plan for the Solutions. The time shown between the start year and the field year in Table 1-5 is the time needed to develop and deploy pilots, develop systems, and implement foundational systems like integrated communications. These actions help prepare for a rapid and low risk field deployment across the state.

TABLE 1-5: IMPLEMENTATION SOLUTIONS SCHEDULE AND DURATION

Solution	Start Year	Field Start	Duration (yrs)
AMI	2010	2012	6
IT	2010	2013	4
DR	2013	2016	5
DMS	2011	2014	7
DER	2013	2015	5

ID	Task Name	Start	Finish	Duration
1	AMI	1/1/2010	12/29/2011	104w
2	AMI Field	1/2/2012	12/25/2015	208w
3	IT Systems	1/1/2010	12/27/2012	156w
4	IT Systems Field	1/1/2013	12/30/2013	52w
5	DR	1/1/2013	12/28/2015	156w
6	DR Field	1/1/2016	12/28/2017	104w
7	DMS	1/3/2011	12/27/2013	156w
8	DMS Field	1/1/2014	12/26/2017	208w
9	DER	1/1/2013	12/29/2014	104w
10	DER Field	1/1/2015	12/27/2017	156w

FIGURE 1-3: WV SMART GRID IMPLEMENTATION PLAN

The WV Smart Grid Implementation Plan includes research, development and deployment (RD&D) projects (further described in section 8.4) to accelerate the implementation plan and reduce risk for the following applications:

- AMI pilot
- DR pilot
- DMS pilot
- DER pilot

These RD&D projects should start immediately and attempt to take advantage of the federal Smart Grid Matching Grant program authorized by the Energy Independence and Security Act of 2007, Title XIII and appropriated under the federal American Recovery and Reinvestment Act of 2009.

Finally, some will find the results and recommendations surprising because the approach is non-traditional. However, the solutions are using lower cost technological improvements and leveraging information with existing capital assets to make more effective use of those assets. That is, finding ways to extract more value from existing (paid for) assets instead of building new capital assets.

Ultimately, the issue will be the cultural acceptance of Smart Grid technologies and processes in the regulatory treatment in place of traditional boilers, turbines, poles, transformers, and wires solutions.

2.0 Introduction

2.1 Approach / methodology

The overall approach for the project employs an expanded gap analysis and follows the structure illustrated in Figure 2-1. This approach has been applied to several successful Smart Grid implementation assessment and planning efforts over the last 5 years. This approach employs an expanded gap analysis.

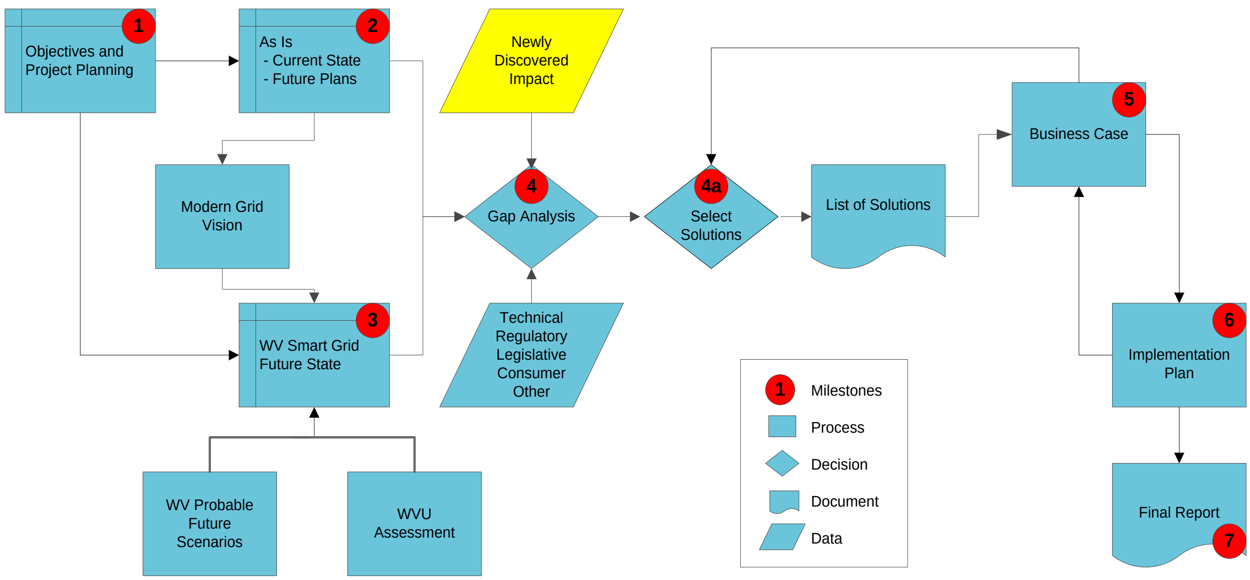


FIGURE 2-1: SMART GRID IMPLEMENTATION PLAN APPROACH

Milestone 1 –sets the agreed upon objectives of the work and establishes an overall plan to accomplish the project.

Milestone 2 – develop an understanding of the current state of the grid in West Virginia (WV) in relation to the stakeholder values associated with electric services in WV. This includes an assessment of the current state using the Smart Grid Characteristic Maturity Model.

Milestone 3 – develop an understanding of the probable future state in WV given the objectives of the state, the national Smart Grid vision from the Modern Grid Strategy team, inputs from the Probable Future State Scenarios, and inputs from the West Virginia University (WVU) consumer and stakeholder focus groups. This also includes an assessment of the probable future state using the Smart Grid Characteristic Maturity Model.

The information from Milestones 2 and 3 provide the essential information for the Gap Analysis or Milestone 4.

Milestone 4 – analyze the gap between the current state and the probable future state in the context (dimensions) of technology, regulatory / policy, and consumer needs.

Milestone 4a – determine the solutions that best address the gaps identified in the gap analysis. This forms the Solution Set for running the business case and implementation planning.

Milestone 5 – develop the business case to analyze the costs to implement the solutions, and the benefits to utility operations, WV consumers, WV society, and regional US society. This milestone is iterated with Milestone 4a to refine the scope of each solution to provide the most compelling business case for WV.

Milestone 6 – from the solution set optimized by the business case, develop an implementation plan that is practical and deliverable. The implementation plan is iterated with Milestone 5 as sequencing and duration of each solution's implementation can affect the business case. This sequencing processing continues until a practical feasible solution is revealed or until all solutions are exhausted and the plan is deemed infeasible. At this point a final report results.

Milestone 7 – develop a report that documents the results of the process, the outcomes in the form of the business case and implementation plan, and presents the results to key stakeholders.

2.2 Assumptions

The assumptions used in the West Virginia Smart Grid Implementation Plan (WV SGIP) are a result of a hierarchical approach to data quality for the analysis. The goal is to minimize assumptions used in the analysis. The data priority used is:

- Specific WV state data
- Specific WV utility data
- National business and electric system data that can be tailored or rationalized to WV
- Industry-wide data that can be tailored or rationalized to WV
- Specific vendor technical information
- Assumptions from expert elicitation processes with documented reasoning
- Assumptions from general team experience

Assumptions are tested in a sensitivity analysis to see their effects on the outcome of the business case. If the business case shows a high sensitivity to a particular assumption, more analysis is done to reduce the uncertainty of the assumption and attempts are made to uncover additional data sources. If the business case shows low sensitivity to a particular assumption, then the risk to the business case is very low.

For the WV SGIP, the sensitivity analysis showed that the business case had very low sensitivity to the few assumptions used.

The WV SGIP uses 27 assumptions, and more than 380 documented data elements. The team believes this is a good foundation for a quality business case and implementation plan.

2.3 Interpretation of Results

The WV SGIP team has interpreted the results of the gap analysis, business case, and implementation plan. These interpretations which are based on the vast experience of the team are presented in the subsequent sections of this report. Additionally, there is sufficient detail in the gap analysis, business case, and implementation plan for readers to form their own interpretation of the results.

2.4 Organization of Report

This report is organized to flow consistent with the approach taken and described above, starting with a general overview of a Smart Grid to set the stage for understanding the various chapters that follow:

- 3.0 Overview of the Smart Grid
- 4.0 Current State of the Smart Grid in WV
- 5.0 WV Future Probable State for Smart Grid
- 6.0 Gap Analysis
- 7.0 Business Case
- 8.0 Implementation Plan
- 9.0 Summary of Conclusions and Recommendations

3.0 Overview of the Smart Grid

The Smart Grid is a digitally-enhanced version of the traditional electric grid, employing an intelligent overlay of advanced communications, electronics and computing technologies that enable its seven modern characteristics to support the 21st century economy. It is a "system of systems" and is transactive in nature. That is, the Smart Grid will provide the infrastructure to support financial, informational, and electrical transactions among consumers, assets, and those users who have authorized access.

The Modern Grid Strategy team conducted a systems analysis of the electric grid and determined that stakeholders find value in a Smart Grid in the following areas:

- Safety – protection for line workers and the public
- Reliability - reduced outage frequency and duration, adequate power quality (PQ), and consumers satisfied with their electricity delivery service
- Security – reduced vulnerability to attack and natural events
- Economics – downward pressure on future electricity prices, opportunities and options for consumers
- Efficiency – energy conservation by consumers, reduced system losses and reductions in operations, maintenance and capital expenditures
- Environmental friendliness – enablement of intermittent renewables

From these values (which the team later referred to as key success factors), the systems analysis derived the functionality necessary to deliver these values. This functionality is described as the principal characteristics of a Smart Grid.

3.1 Smart Grid Characteristics

Seven principal characteristics provide the foundation of the Smart Grid:

- Enables Active Consumer Participation
- Accommodates All Generation & Storage Options
- Enables New Products, Services and Markets
- Provides PQ for the Digital Economy
- Optimizes Asset Utilization & Operates Efficiently
- Anticipates and Responds to System Disturbances
- Operates Resiliently Against Attack and Natural Disaster

Collectively these characteristics define the vision for the Smart Grid infrastructure. It includes the end-to-end value chain beginning at the generator output, the transmission system, the distribution system and the connected loads and resources of consumers that are enabled to participate in the operation of the grid.

Enables Active Consumer Participation

In today's power grid, consumers see a price signal after the fact and then only on a monthly basis. This delay between the usage of electricity and its associated costs creates economic inefficiency and a lack of awareness of the impact consumers have on the electric system. Such a lack of timely information, combined with an inability to interact with the system, leaves consumers with few options or incentives to be an active participant in the system.

A smart grid will provide the communications infrastructure to allow timely information to be passed back and forth between all consumers, suppliers, and grid operations personnel. This will allow for the creation of new value added services by utilities, load aggregators or other interested parties to provide options and/or services that empower customers to easily interact with suppliers and grid managers, and to tailor services that meet consumer expectations in a more effective and transparent manner. Consumers will be integral to the power system; helping to balance supply and demand and to increase reliability by the way they purchase and use electricity. The technologies that enable customer interaction (two-way communications, consumer portals and agents, real-time pricing, and smart metering) will also provide the infrastructure needed for widespread use of such load leveling applications as Plug-In Hybrid Electric Vehicles (PHEV).

Consumer participation will take a variety of forms, including selection of a particular real time pricing (RTP) plan or by allowing the utility to directly control certain aspects of the load. Consumers will have access to new information, control and options to engage in electricity markets. This will allow for better management of energy costs and allow a cost comparison of energy efficiency devices and measures. Finally, this new connected system will enable the consumer to engage in a two-way energy market where they buy and sell energy resources.

Operating within predefined limits established by the consumer, the utility will be able to exert control based upon conditions on the grid at the system level, the regional level or even at the individual circuit or service entrance level. This increased controllability of an integral element of the electric system, the load, will enable improved utilization of grid assets as well as reduced electrical losses. This control also facilitates reliability and more rapid outage restoration.

Accommodates All Generation and Storage Options

A smart grid will enable the deployment of diverse, distributed generation (DG) and storage sources. It will also simplify their interconnection by creating the ability for standardized grid-to-generation interaction similar in nature to the concept of "Plug and Play" for software interaction in modern computer systems. While all forms of generation and storage can and will be accommodated, distributed generation resources will likely be much more common than they are today. The many environmental and financial benefits that flow from broad application of distributed resources like wind, solar, combined heat and power (CHP) and storage will drive their expanded use in a new and improved system that is capable of maximizing these applications. The widespread deployment of distributed generation creates new grid challenges, due to their more variable nature and their less stable performance characteristics (e.g. less ability to ride through faults and voltage depressions). These challenges can be accommodated through the smart grid's use of increased information, two-way communications, more intelligent control and the proper blending of DG, storage and demand response.

The broad application of DER at the distribution level presents many new opportunities and challenges for feeder design and operation. The primary challenge is the conversion of radial feeders to accommodate multiple sources spread across the circuit. New communications and protective systems will allow safe and reliable operation with these new configurations. The opportunities fall in such areas as reduced electrical losses, improved reliability and power quality, increased asset utilization, higher process efficiency (e.g. CHP efficiency of 80% from production to consumption versus perhaps 45% for central generation), reduced emissions through more renewable generation, etc. A highly diversified generation structure is also far more resilient to all forms of attack, both natural and man-made.

Enables New Products, Services and Markets

In order for a market to be successful its participants should be sensitive to the right information at the right time, i.e. consumer prices must be linked to the real time prices in the wholesale market in some manner. A smart grid will be able to utilize its vast array of sensors, networked communications, and data sources to link buyers and sellers down to the consumer level, creating new or expanded markets in which "smart loads" and distributed resources can readily participate. Increased transmission capacity, enhanced by both conventional and smart grid technology, will help facilitate these markets. The purchase, sale and scheduling of electricity creation, transmission, and use can be linked from the level of the RTO down to an individual consumer's home. This allows electricity to become fully commoditized, with open-access markets created across the country. Suppliers at all levels in new or classic markets will be seamlessly integrated. Generation resources will be dispersed throughout load areas, mostly to minimize transportation costs, and many will be much smaller in electrical size.

All loads will have some measure of intelligent control associated with new demand-response (DR) markets. Distributed generation, energy storage, demand-response strategies and new ways to effectively manage voltage will emerge to cope with a more volatile operating environment. Highly interactive and user-friendly interfaces will allow participants at many different levels to participate in markets for spinning reserve, volt/VAR support, demand response, renewable energy credits, or other markets.

The increased role of markets will alter historic load patterns as seen at both transmission and distribution levels. Greatly expanded real time monitoring and alarming will keep system operators abreast of conditions at each level and advanced controls will allow appropriate intervention when reliability is threatened.

Provides Power Quality for a Digital Economy

A smart grid will provide the capability to differentiate electricity delivery service by offering different grades of power quality at different price levels. It will provide real-time monitoring, diagnostics and rapid response to power quality events. In today's grid an engineer or technician is needed to independently evaluate and diagnose each individual PQ event. Often this will require a visit to each site. In a smart grid the time and need for a site visit can be reduced or eliminated and the problem may be controlled automatically through the use of dynamic control systems and algorithms. This would include both protecting consumers from events that originate in the electrical grid and also protecting the grid from erratic and harmful distortions that are caused by consumer electrical loads. The level of delivered power quality can range from "standard" to "premium", depending on the individual consumers' requirements.

The provision of differing grades of power quality will require a new focus on momentary disturbances to the grid. The creation of PQ parks for example will entail feeders that are better protected from lightning and less exposed to abnormal events. The installation of compensation devices that buffer loads from perturbations on the grid will be required in many cases. Micro grids will also have an important role. And the application of new re-closer schemes that prevent closing into faults will be valuable as a way to reduce the number of voltage sags and, at the same time, to reduce grid exposure to damaging fault currents. Finally, since many PQ events are caused by the failure of grid components, the improved monitoring of equipment health and superior maintenance practices will reduce this factor.

In total, PQ events today can cost consumers money and frustration and cost utilities time and money to diagnose and correct them. The smart grid offers the ability to quickly determine the cause and origin of PQ events and allow the ability to dynamically or autonomously correct the problem quickly and efficiently.

Optimizes Assets and Operates Efficiently

The smart grid will integrate ubiquitous grid information with asset management and operational processes to significantly improve the utilization and efficiency of the grid. It will use dynamic ratings on equipment and sensor data to optimize the capacity of transmission and distribution assets and to lower the probability of failure. It will reduce system losses, minimize waste and idle capacity, and reduce capital and maintenance costs by optimizing the use of resources to supply and deliver power and by shaping load curves to accommodate these objectives. The ability to "shave" or reduce the peak load will be enabled through the use of demand side management (DSM), energy efficiency programs, distributed energy resources (DER), and demand response (DR).

Transmission congestion will be reduced or eliminated, transmission electric losses will be minimized and line reliability will be improved via such technological tools as dynamic line rating, flow control (FACTS), advanced protection systems, wide area monitoring and High Temperature Superconducting (HTS) cable.

Knowledge of conditions on the distribution grid will be increased by orders of magnitude. This information will result in the prevention of most outages and much more rapid restoration when outages do occur. It will also ensure that power quality problems (sags, surges, imbalances, and harmonics) are quickly identified, resulting in lower electrical losses and reduced equipment failure rates. Planners and engineers will have the knowledge they need to build what is needed when it is needed, extend the life of assets, repair equipment before it fails unexpectedly and more effectively manage the work force. Improved knowledge also implies improved safety for both the public and utility workers. And it means maintenance can be based on equipment condition rather than simply the passage of time.

Anticipates and Responds to System Disturbances

A smart grid will have the ability to act proactively to deal with changing system conditions. It will be able to detect and address emerging problems on the system before they affect service.

This will be accomplished through the use of automated switching, intelligent systems controls, alternative supply options, and advanced operator information and visualization tools. The Smart Grid's advanced capabilities will allow it to handle problems too complex or fast-moving for human intervention.

A self-healing grid will utilize various data inputs from an array of sensors and a networked design linking multiple energy sources, including circuit ties to other feeders or to distributed energy resources (DER). It will also extend the idea of reconfiguration to another level and introduce the concept of dispersed and independent electrical islands or micro-grids. These micro-grids will consist of a collection of distributed energy resources, loads, and small distribution networks, which can disconnect from the main grid during outages or other emergency situations and continue to operate independently until the grid can be restored.

The realization of self healing is dependent upon rapid, reliable communications between the many distribution devices that will allow the grid to detect a problem and then instantly reconfigure itself so as to mitigate that problem. This in turn requires standardization of interfaces to these many diverse devices, combined with the establishment of a communications platform that accommodates these stringent requirements and is hardened against malicious attack. One challenge is to find the communications platform(s) that can accommodate not only the substantial demands of self healing, but rather the full set of smart grid applications.

This will be achieved through better system control and the diversity of distributed generation resources that are located near the loads.

Operates Resiliently Against Attack and Natural Disaster

A smart grid is designed to be resistant to attack, both physical and cyber. With access to massive amounts of real time information and analysis, as well as instantaneous control capability, it is able to deter, detect, mitigate, and respond to security threats that the current grid cannot. Every element of the smart grid must be designed with security in mind, from the communications, control equipment and sensors, to the training of grid operations personnel.

The smart grid addresses security from the outset, making it a requirement for all its elements and ensuring an integrated and balanced approach across the system. The threat of attack is minimized by concealing or masking high value targets, dispersing vulnerable systems or equipment, and reducing the number of single points of failure. In addition, the integration of widespread distributed energy resources enhances the reliability of the overall system by providing multiple sources of energy and allowing for the creation of islanded systems.

The smart grid is less vulnerable to natural disasters and can lessen their impact. In the current grid the loss of a single major transmission line can create serious consequences for large numbers of customers over a wide geographic area. This is due to the inability of the grid to move the power from large centralized power plants to widely dispersed loads or to intelligently re-route power among the remaining transmission or distribution lines. The ability of a smart grid to dynamically monitor and control the grid, the use of demand response and distributed generation sources will all lessen the impact of natural disasters as well as coordinated attacks on the grid's infrastructure.

This principal characteristic is, to some extent, a byproduct of the others. More information about grid conditions, diversity in generation, the ability to influence load shapes and to rapidly reconfigure the grid, the use of highly secure communications, the ability to rapidly restore power and to diagnose the cause of outages—all these discourage intentional attacks and to minimize their impact.

3.2 Steps to the Smart Grid

How do we get to the smart grid? We need a pathway or a "roadmap" to get from here to there. One way to do this is to break the smart grid down into a handful of functional pieces. These functional pieces are the milestones (suggested by DOE/NETL Modern Grid Strategy) that must be reached in order to get to the final destination of a smart grid. The four milestones are Consumer Enablement, Advanced Distribution Operations, Advanced Transmission Operations, and Advanced Asset Management.

Consumer Enablement (CE)

The CE milestone is primarily aimed at the consumer side of the Smart Grid by providing them with information, control and options, mainly involving advanced metering infrastructure (AMI) and demand response (DR). AMI includes smart meters for advanced measurement, an integrated two-way communications infrastructure, and an active interface to give consumers and their home area networks access to information, and a meter data management system to process the vast amount of new data. Additionally, AMI provides information about conditions on the grid and interfaces with other utility enterprise systems that can benefit from its functionality. AMI's communication infrastructure, data, and interfaces with other enterprise systems are all critical links to the other three milestones. The general solution set for achieving this milestone includes:

- Smart meters that record interval energy usage, power quality parameters, other system operating parameters, and are equipped with remote connect/disconnect capability
- Two-way integrated communication system with adequate throughput and acceptable latency to support the exchange of data and information among consumers, other Smart Grid users, and all appropriate Smart Grid processes, technologies and applications.
- Consumer portal that supports a wireless home area network and in-home display that enables consumers to easily set preferences, control their smart devices, and interface with the Smart Grid
- Meter data management system that intelligently processes the vast amount of data produced by the smart meters, converts the data to information and integrates with other smart grid processes and technologies
- Time based prices that reflect the real cost of electricity provided to consumers at frequencies needed to support market transactions
- Upgrades to utility legacy processes, technologies and applications needed to support the integration of other Smart Grid applications. For example, legacy Customer Information Systems and Information Technology architectures might need modification to support

the increased transactional load and cross-functional nature inherent in the Smart Grid vision.

- Customer educational programs to assist consumers in their understanding of the benefits of the Smart Grid and how they can take advantage of the new opportunities and options it provides to them.
- Demand response programs that incent consumers to participate in demand reducing activities
- Consumer owned Distributed Energy Resources that are interconnected, dispatchable by grid operators and provide financial incentives to the owners

Advanced Distribution Operations (ADO)

The ADO milestone is primarily aimed at the utility side of the Smart Grid, providing the increased information and granularity of control needed for a self-healing grid. ADO includes a distribution management system with advanced and ubiquitous sensors and distributed intelligence, advanced outage management capability, and distribution automation technologies. It enables effective and efficient operation of a grid that employs extensive distributed generation of all types and sizes including perhaps millions of Plug-in Hybrid Electric Vehicles and various types of micro-grids. It is also deeply integrated with a distribution geographical information system (GIS). The ADO milestone supports the Advanced Transmission Operations milestone. The general solution set for achieving this milestone includes:

- Ubiquitous deployment of smart sensors that monitor distribution system operating parameters at all key locations
- High level of granularity of smart switches enabling the distribution to be sectionalized into optimum size parts when needed
- Distribution Management System (DMS) equipped with advanced analysis and control algorithms to enable two-way power flow on the distribution system. DMS is used to take advantage of the ubiquitous system information and control capability to optimize operation and provide self healing capability
- Distribution Automation that autonomously reconfigures the distribution system to minimize the impact of disruptions
- Advanced Outage Management System which integrates ADO with Consumer Enablement to detect and diagnose local outages leading to a rapid dispatch of crews to repair the trouble. Customer calls to report trouble will no longer be needed to determine location and source of the trouble.
- Geographic Information System (GIS) to provide the "where" dimension needed to support ADO and CE
- Micro-grid operation integrated with DMS and consumer's HAN to identify when micro-grids should be operating in parallel or islanded mode.

- Advanced protection and control systems (e.g. voltage regulation, VAR support, distribution automation, fault current interruption) that adapt and support two-way power flow

Advanced Transmission Operations (ATO)

The ATO milestone is primarily aimed at improving transmission reliability and efficiency, while managing congestion on the transmission system. ATO also integrates certain aspects of distribution system operations with transmission operations. It enables the security constrained economic dispatch models used by some regional transmission organizations (RTO) to more effectively utilize the distribution system as a "resource". ATO includes substation automation, advanced protection and control, modeling, simulation and visualization tools, advanced grid control devices and materials, and the integration of all these tools with markets and RTO operations and planning functions. The general solution set for achieving this milestone includes:

- Substation Automation that collects information and control capabilities at each substation and communicates with other substations to ensure that broader system conditions are shared among these assets.
- Integration with Regional Transmission Organizations (RTO's) and its processes to ensure linkage among ATO, ADO and ultimately with CE.
- Wide Area Measurement System (WAMS) that are integrated with transmission operation centers to increase operator's situational awareness. WAMS will also reduce the time needed for key transmission algorithms to solve giving operators' new tools to better understand existing and projected conditions
- Ubiquitous deployment of smart sensors that monitor transmission system operating parameters at all key locations
- Modeling and simulation tools to enable operators to perform "what-if" scenarios and understand future operating risks
- Advanced materials and power electronics devices to improve asset utilization, voltage management, power quality and flow control of large blocks of power
- Advanced protection systems that adapt to system operating conditions

Advanced Asset Management (AAM)

The AAM milestone is primarily aimed at improving the utilization of transmission and distribution (T&D) assets at the operational level and more effectively managing these assets from a life cycle perspective. AAM depends on the ubiquity of smart sensors that provide both operational and asset condition information that it acquires from the other three milestones. The deep integration of that information significantly improves the effectiveness of enterprise asset management systems such as T&D capacity planning, condition based maintenance, resource and work management, engineering design and construction and others. The general solution set for achieving this milestone includes:

- Ubiquitous deployment of smart sensors that monitor asset condition and health for all critical assets
- Dynamic ratings of assets to optimize their utilization
- Condition monitoring algorithms that optimize when assets should be removed from service for maintenance and maximize their useful life
- Integration of smart grid intelligence with key asset management processes including system planning, maintenance, engineering, customer service, work and resource management

The milestones described above can be used as a roadmap to help guide the creation of the smart grid. The final realization of a smart grid is a system that demonstrates all seven of the principal characteristics (see Figure 3-1).

Smart Grid Characteristic	CE	ADO	ATO	AAM
Enables Active Consumer Participation	✓	✓		
Accommodates All Generation & Storage Options	✓	✓	✓	
Enables New Products, Services and Markets	✓	✓	✓	
Provides PQ for Digital Economy	✓	✓	✓	✓
Optimizes Assets & Operates Efficiently	✓	✓	✓	✓
Anticipates and Responds to System Disturbances	✓	✓	✓	✓
Operates Resiliently Against Attack and Natural Disaster	✓	✓	✓	

FIGURE 3-1: THE SMART GRID – PRINCIPAL CHARACTERISTIC - MILESTONE MAP

By using the milestone "roadmap" we can plan an ordered and cost effective strategy to get to the smart grid while keeping the "end in mind." It is possible to use each milestone to develop a business case and then integrate these four business cases together to determine the most productive transformation plan for a given region with its own limitations, priorities, and cost concerns. In a general sense, properly sequencing the milestones can aid in the implementation and maximizing the benefits (see Figure 3-2 below).

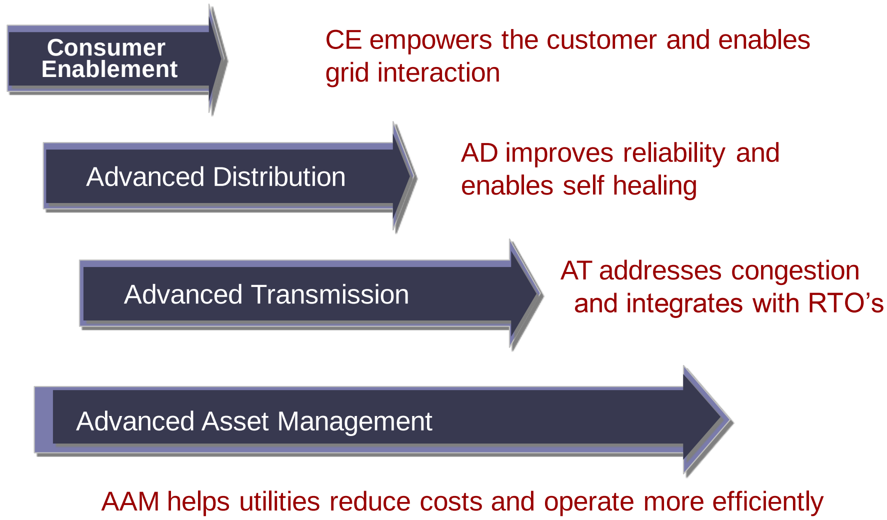


FIGURE 3-2: SEQUENCING THE MILESTONES

A general layout of the key Smart Grid applications consistent with the Milestones discussed above is shown in Figure 3-3. The DOE/NETL Modern Grid Strategy team commonly refers to this as the Smart Grid "Big Picture".

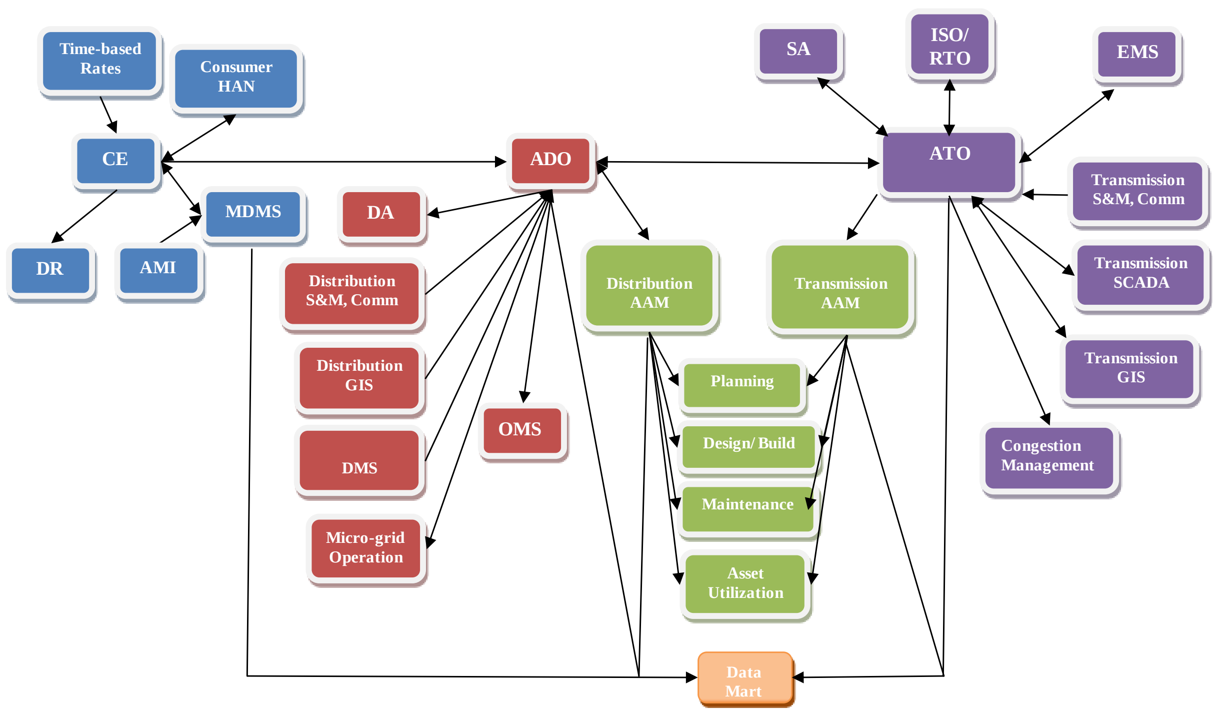


FIGURE 3-3: SMART GRID APPLICATIONS BY MILESTONE

3.3 Smart Grid Key Technology Areas (KTA)

In order to achieve a smart grid we must realize each of the four milestones: CE, ADO, ATO, and AAM. There are various changes that have to be made in the processes, culture, regulation and technologies that are in place today. The changes necessary to the current technologies can be addressed by five key technology areas. These key technology areas (Figure 3-4) have been proven in other industries and are essential to meet the goals established by the principal characteristics, and realizing the Smart Grid vision:

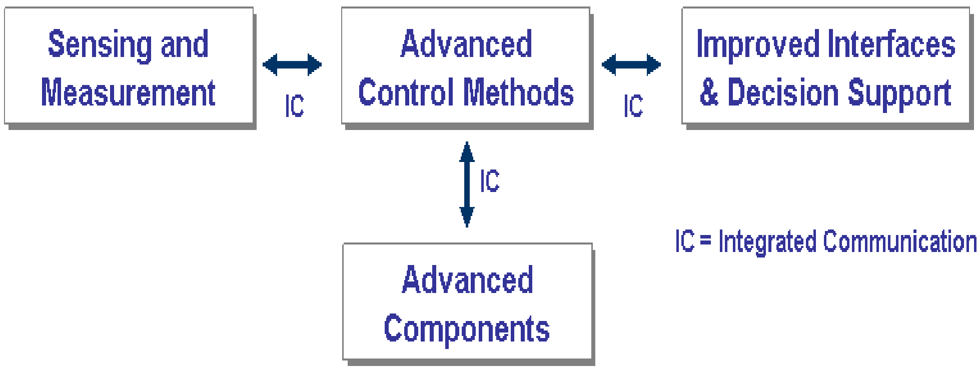


FIGURE 3-4: SMART GRID KEY TECHNOLOGY AREAS

Integrated Communications

High-speed, fully integrated, two-way communication technologies will make the Smart Grid a dynamic, interactive "mega-infrastructure" for real-time information and power exchange. Open architecture will create a plug-and-play environment that securely networks grid components to talk, listen and interact. Integrated Communications is the glue that binds together the four other key technology areas (KTA).

An effective, fully-integrated communications infrastructure is an essential component of the Smart Grid.

Sensing and Measurement

These technologies will enhance power system measurements and enable the transformation of data into information. They evaluate the health of equipment and the integrity of the grid and support advanced protective relaying; they eliminate meter estimations and prevent energy theft. They enable consumer choice and demand response, and help relieve congestion.

Some examples:

- Smart meters
- Smart system sensors that measure operating parameters
- Asset condition monitors
- Wide area monitoring systems (WAMS)
- Advanced system protection relays

- Dynamic sensing of transmission lines

Advanced Components

Advanced components play an active role in determining the grid's behavior. The next generation of these power system devices will apply the latest research in materials, superconductivity, energy storage, power electronics, and microelectronics. This will produce higher power densities, greater reliability and power quality, enhanced electrical efficiency producing major environmental gains and improved real-time diagnostics.

Some Examples:

- Next generation FACTS/PQ devices
- Advanced distributed generation and energy storage
- PHEV
- Fault current limiters
- Superconducting transmission cable & rotating machines
- Micro-grids
- Advanced switches and conductors

Advanced Control Methods

New methods will be applied to monitor essential components, enabling rapid analysis and diagnosis and timely, appropriate response to any event. They will also support market pricing and enhance asset management and efficient operations.

These will include broad application of computer-based algorithms that:

- Collect data from and monitor all essential grid components
- Analyze the data to diagnose and provide solutions from both deterministic and predictive perspectives
- Determine and take appropriate actions autonomously or through operators (depending on timing and complexity)
- Provide information and solutions to human operators
- Integrate with enterprise-wide processes and technologies

Improved Interfaces and Decision Support

In many situations, the time available for operators to make decisions has shortened to seconds. Thus, the Smart Grid will require wide, seamless, real-time use of applications and tools that enable grid operators and managers to make decisions quickly. Decision support with improved interfaces will amplify human decision making at all levels of the grid.

Some Examples:

- Data reduction
- Visualization
- Speed of comprehension
- Decision support
- System operator training

The integrated suites of technologies needed to support the achievement of the principal characteristics will emerge from these key technology areas. Whether building a Smart Grid for a region, city, or community, the process of determining which suite of technologies serve the principal characteristics will also drive the best integrated fit.

The DOE/NETL Smart Grid vision was used as the overarching vision and starting point for determining a Smart Grid vision for West Virginia. A probable future state analysis was then conducted to determine to what extent each Smart Grid Characteristic and hence milestone should be implemented in West Virginia. The resultant West Virginia Smart Grid vision broken down by Characteristic was utilized in the gap analysis which ultimately led to the optimum Smart Grid solution set for West Virginia.

4.0 Current State of the Smart Grid in WV

4.1 General Discussion

In WV today the lines, transformers, circuit breakers and other components that make up the electric grid are aging and being used in ways that increase the equipment stress resulting in undue wear and tear on the equipment or unexpected failure. This makes the whole system more vulnerable to natural disasters, critical failures, or deliberate attack. Loads are at risk due to a system that delivers power from large centralized power generation facilities to consumers over an aging infrastructure that lacks dynamic system re-configuration and distributed resources. Since outages on the distribution system must still be identified by sending crews into the field in response to customer calls it takes an extended period of time to identify the failure and restore service to customers.

American Electric Power (AEP) and Allegheny Power (AP) are the main utilities in West Virginia serving about 98% of the customers. The distribution system is composed primarily of overhead radial feeders protected by electromechanical relays, reclosers, and fuses. Less than half of the distribution substations have fully functional SCADA connectivity and there are very few intelligent sensors or monitoring devices installed. While the transmission system is more advanced and has a greater ability to respond to disturbances, it has few intelligent devices and sensors, there are no FACTS devices installed and only a few Wide Area Measurement System (WAMS) devices exists. AEP has Phasor Monitoring Units at Amos, Culloden, and Kanawha River.

There is no integrated communication system in place that allows for bidirectional information flow between the consumers and the utilities. Where communications do exist there is not widespread coverage, typically not enough bandwidth to use for any advanced applications, and no connectivity to most residential and commercial customers.

In WV today there are consumer-owned back-up generators located at sites throughout the state, but they are incapable of operating in a grid connected mode and utilities may not even be aware of their existence. Not only are no incentives in place to entice customers, utilities are not prepared to utilize these resources. There are a minimal number of CHP facilities and little, if any, distributed generation. The transmission and distribution system was designed and built to deliver power in one direction only, moving MWs from large centrally dispatched power plants to customer loads throughout the state and across state lines. For wide penetration of distributed generators, the protection systems would need to be re-calibrated or re-designed. If the grid could accommodate distributed energy resources (DER), the Public Service Commission and utilities would need to provide the proper incentives and interconnection rules to make DER feasible. Interconnection standards were designed primarily for large central power plants or small back-up generators; there has been no concerted effort to establish a standard that considers the widespread connection of customer owned distributed generation and storage technologies that are connected to the grid. While there are newly established net metering rules in WV they are for generation limited in size (no greater than 25 kW) using a renewable fuel source. It only allows the generation owner to earn credits towards their bill and does not allow for any payments to the generation owner.

Power Quality is a problem in WV today because there is no capability for proactive response to power quality issues. Utilities in WV respond to customer complaints of power quality problems and dispatch work crews to do physical inspections which can be costly.

There are few, if any, power quality, temperature, weather, or asset health monitors deployed in the distribution system. Both major WV utilities have a GIS system but it is not well integrated with other planning, operation, or customer service applications and processes. Since there is no distribution or substation automation deployed, grid operations and control is a centralized process. Operators in these centralized control rooms lack enough system data, visualization tools, modeling or simulation tools to optimize the system and maximize equipment capabilities.

Dynamic ratings of critical assets are not currently being used and the monitoring and sensing capability does not exist to implement dynamic ratings. Time-based maintenance is predominant, with maintenance schedules determined primarily by manufacturer recommendations, prior history of performance and equipment failure. Equipment condition is determined by physical inspection and localized trouble shooting since no intelligent sensor systems exist to monitor equipment.

WV consumers are not active participants in the electric grid since there are no competitive retail markets for electricity, few policies or incentives to encourage participation, and the consumer lacks awareness and understanding of the nature and benefits of smart grid technology. Deployment of AMI and the associated communications infrastructure has not begun in WV. The rate structure is very straight forward in WV. Current rates are differentiated by customer or usage type but there are almost no time-of-use (TOU) or dynamic rates in place. No real-time price or usage information is available to consumers in WV and coupled with inadequate or non-existent regulatory policies, and very little consumer awareness, there are no demand response programs, no end use devices, and no home area networks deployed in the state.

4.1.1 Technical aspects

Understanding the current state of West Virginia's assets, technologies, applications and processes is a key input to the gap analysis and the ultimate determination of the solution sets needed for achieving the West Virginia Smart Grid vision. The following sections describe the current state in each of these categories.

Generation

West Virginia is a major producer of electric power in the Eastern United States and is physically located near the many metropolitan load centers in New York, Pennsylvania, Delaware, Maryland, and Virginia (see Tables 4-1 and 4-2 and Figures 4-1 and 4-2). Coal-fired plants account for nearly all of West Virginia's electricity generation, and natural gas plants and hydroelectric facilities account for most of the remaining production.

TABLE 4-1: WEST VIRGINIA GENERATION (MW)

WV Generation Capacity in MWs	
	MWs
Total Operating Capacity	16,503
Total Planned Capacity	2,177
Total Retired Capacity	411
Total Cancelled Capacity	5,293

TABLE 4-2: WEST VIRGINIA GENERATION (BY FUEL TYPE)

Total WV Generation Capacity by Fuel		
	MWs	**Percentage of total capacity**
Coal Generation Operating Capacity	14765	89.5%
Natural Gas Generation Operating Capacity	1132	6.9%
Wind Generation Operating Capacity	230	1.4%
Hydro Generation Operating Capacity	376	2.3%

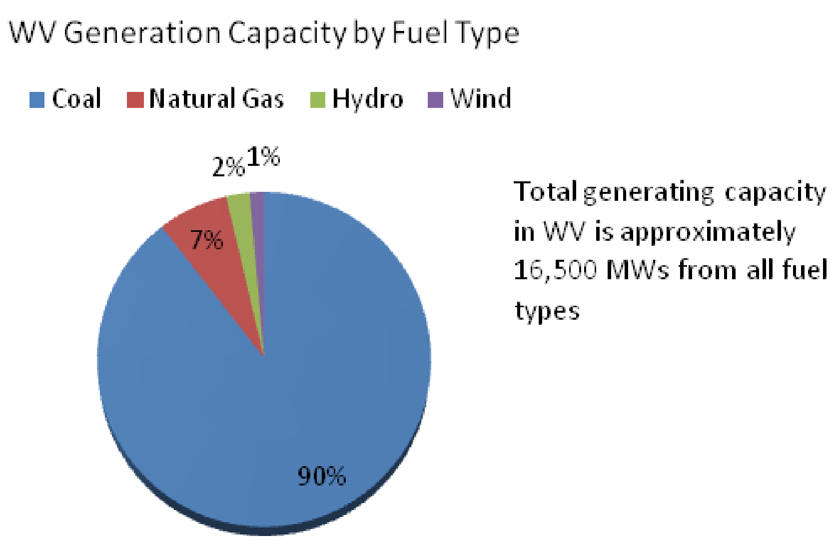


FIGURE 4-1: WV GENERATING CAPACITY BY FUEL TYPE

Currently, the Energy Information Agency (EIA) reports that West Virginia is the largest net exporter of electricity in the United States. West Virginia leads the Nation in electricity exports because of several factors. First, the abundance of coal, water, and other resources allow the production of much more electricity than is needed for consumption within the state. Second, since all utilities and merchant generators in WV are members of PJM, the inexpensive energy from abundant coal-fired generation can be easily sold into PJM's wholesale electricity markets to supply these nearby metro load pockets located on the east coast. This combination of factors has made West Virginia a major exporter of electric power.

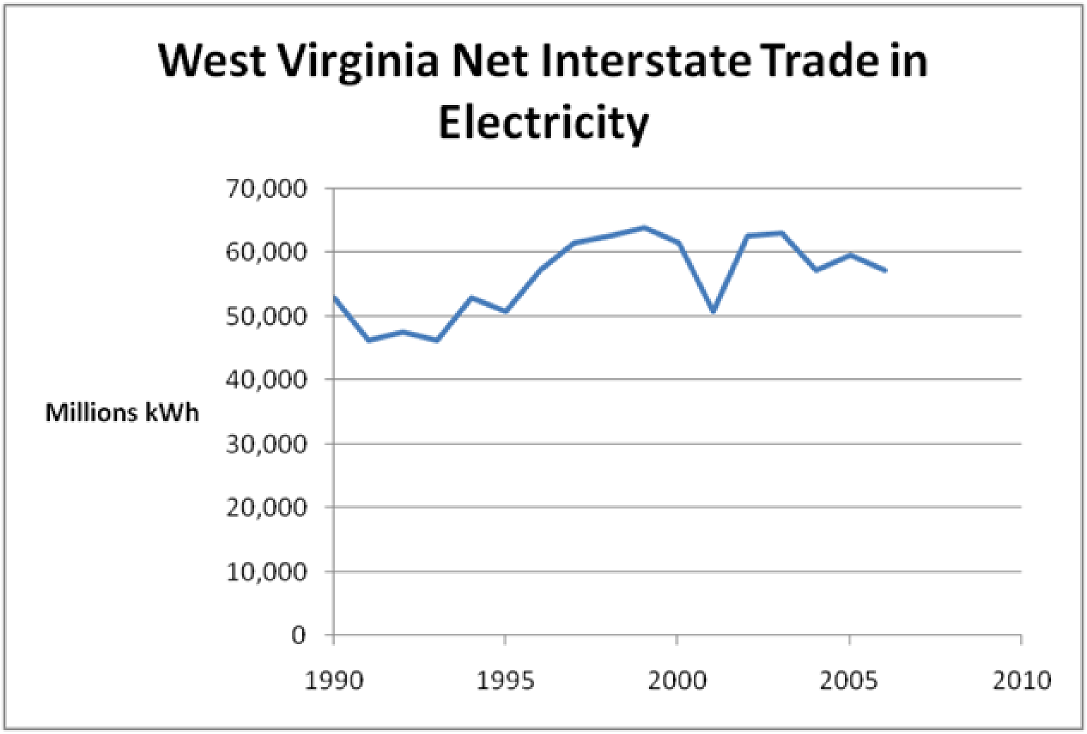


FIGURE 4-2 HISTORICAL WV ELECTRICITY INTERSTATE TRADE FROM EIA STATE ENERGY PROFILE DATA

Transmission

The majority of the transmission network in West Virginia is owned and operated by American Electric Power and Allegheny Energy companies. Allegheny Energy transmission system in WV consists primarily of 500 kV and 138 kV lines. American Electric Power transmission system in WV is composed of 138 kV, 345 kV, and 765 kV transmission lines with approximately 361 miles of 69 kV; 495 miles of 115 kV; 3003 miles of 138 kV; 605 miles of 345 kV; 686 miles of 500 kV; 777 miles of 765 kV transmission lines. There are three hundred and sixty four (364) transmission substations from 69 kV up to 765 kV, most of which are monitored by SCADA (Supervisory Control and Data Acquisition) system.

The state of West Virginia is located within the RFC (Reliability First Corporation) NERC reliability region (see Figure 4-3). The North American Electricity Reliability Corporation (NERC) helps to monitor and analyze the bulk power system as well as developing and enforcing standards to transmission planning, design, and operation. The various NERC reliability regions can be seen in the figure below.

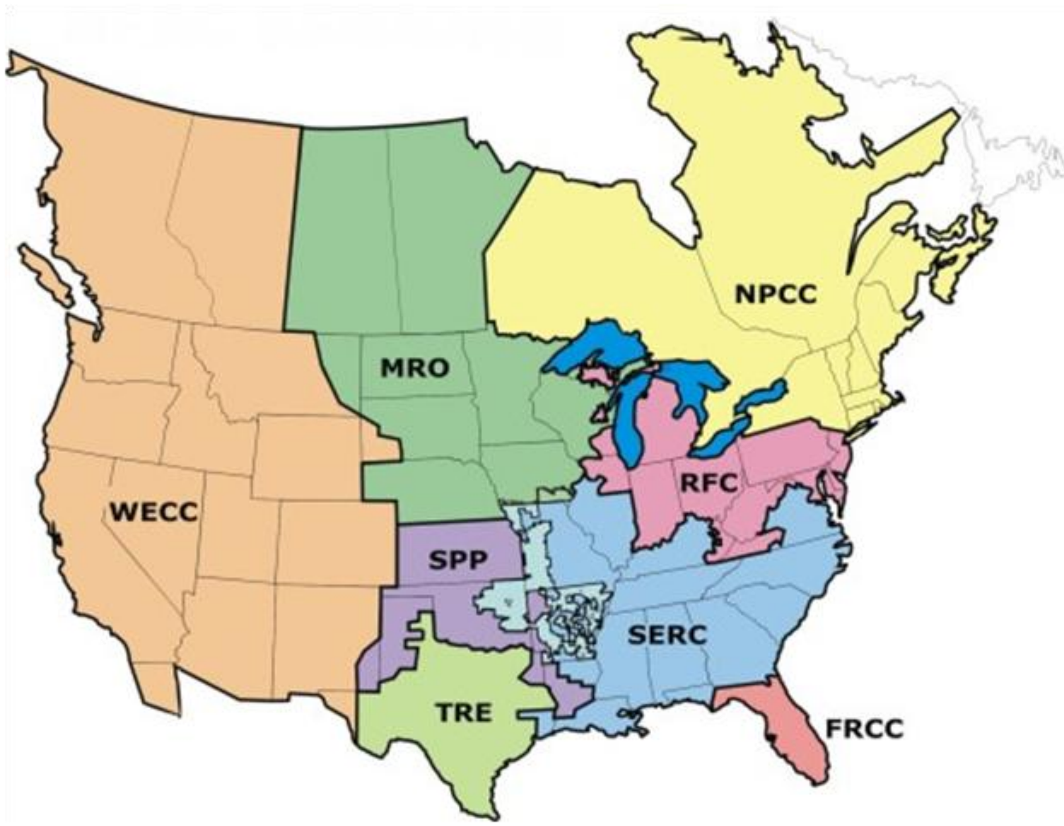


FIGURE 4-3 NERC RELIABILITY REGIONS

AEP and Allegheny Energy are both members of PJM. PJM is a Regional Transmission Operator (RTO) that covers thirteen (13) states, including WV. The function of the RTO is to manage a real-time wholesale power market, maintain real-time reliability, and develop long term transmission plans. A map of PJM along with the major transmission backbone network can be seen below in Figure 4-4.

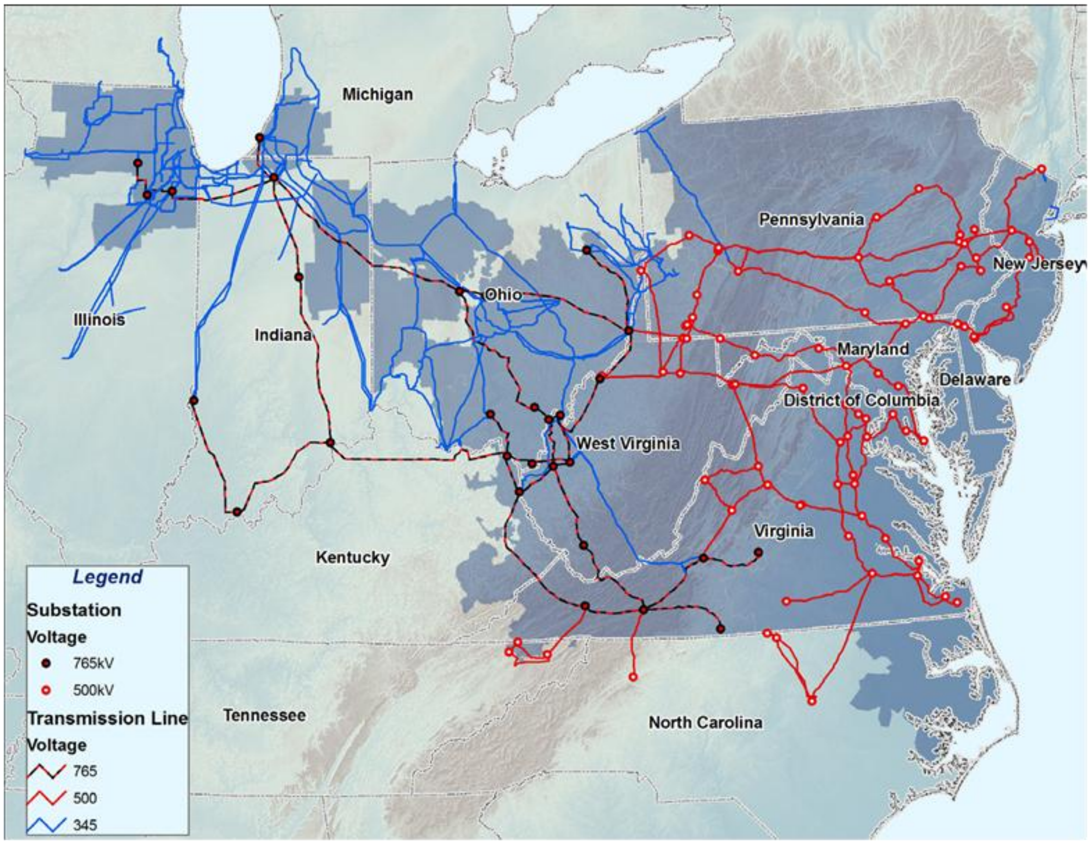


FIGURE 4-4: PJM REGION ALONG WITH MAJOR TRANSMISSION BACKBONE. FROM THE PJM RTEP ANNUAL REPORT FOR 2008

Distribution

The distribution system in WV is primarily composed of AEP and Allegheny Power assets. The distribution system of AEP in WV consists of approximately 21,150 miles of primarily 12 kV and 34 kV systems that are stepped down to the customer supply voltage at or near the customer point of delivery with about 22 customers per mile on average in AEP's service territory. The distribution system of Allegheny Power in WV consists of approximately 26,163 miles of primarily 13 kV and 34 kV circuits that are stepped down to the customer supply voltage at or near the customer point of delivery with nearly 18 customers per mile on average in Allegheny Power's service territory.

Reliability Data for the State of WV

Reliability is tracked in terms of indices established by IEEE 1366. The national average for customer interruption duration is 106 minutes per year. Recent results are shown in Table 4-3.

SAIDI (System Average Interruption Duration Index) - minutes of average sustained outage duration for each customer served in a year.

CAIDI (Customer Average Interruption Duration Index - SAIDI / SAIFI) – the average outage duration that any given customer would experience in a year. CAIDI can also be viewed as the average restoration time.

SAIFI (System Average Interruption Frequency Index) – average number of sustained outages interruptions that a customer would experience in a year.

TABLE 4-3: RECENT WEST VIRGINIA RELIABILITY METRICS

Zone	SAIDI	CAIDI	SAIFI
AP – WV 2008 w/o Major storms	324.14	203.39	1.593577
AEP-WV 2008 w/o Major storms	435.4	198.4	2.194
AP-WV 2007 w/Major Storms	377.32	219.40	1.720916
AEP-WV 2007 w/Major storms	457.6	181.0	2.592
AP-WV 2007 w/o major storms	353.15	210.37	1.679140
AEP-WV 2007 w/o Major storms	439.7	177.3	2.479
AP-WV 2006 w/Major Storms	279.12	186.92	1.494469
AEP-WV 2006 w/Major storms	533.8	211.8	2.52
AP-WV 2006 w/o major storms	252.39	178.12	1.417972
AEP-WV 2006 w/o Major storms	380.7	168.3	2.263

Substations

In the state of WV there are a total of 813 substations. As previously mentioned, 364 of the substations are classified as transmission. The remaining four hundred and forty nine (449) substations are part of the distribution system. Less than half of the distribution substations are monitored by SCADA (Supervisory Control and Data Acquisition) systems.

Metering

Table 4-4 summarizes the customer count (meter count) in West Virginia.

TABLE 4-4: WEST VIRGINIA CUSTOMER COUNT

Customer Count by Type	APCO	WPCO	MP	PE	WV
Residential	372,261	35,615	327,713	112,510	**848,099**
Commercial	64,280	5,331	45,465	15,536	**130,612**
Industrial	2,433	273	7,368	1,898	**11,972**
Other	785	153			**938**
Total	**439,759**	**41,372**	**380,546**	**129,994**	**992,559**

Some notes on the table above. APCO is Appalachian Power Company and WPCO is the Wheeling Power Company. These are operating companies of American Electric Power. MP is Monongahela Power Company and PE is the Potomac Edison power company. These are operating companies of Allegheny Energy. If we consider only the operating companies of the two major utilities in West Virginia we are looking at nearly one million meters or customers.

All of AEP's installed meters are Automated Meter Reading (AMR) type meters. This means that some technology is placed in the meter that allows some form of automated data collection. This data can then be transferred to a central database for billing, customer service, and planning. This has the potential to reduce labor costs, save employee trips, and reduce the number of trucks on the road. An additional benefit is that customer bills can be based on actual consumption rather than on estimates derived from previous consumption. AEP began installing AMR meters with a radio frequency (RF) pilot in 2004. The process continued with deployments of various AMR types until completion in 2008. Currently all meters in AEP territories are AMR meters of one type or another. For the residential customers, AEP has installed a mix of radio frequency based AMR meters that report KWh readings using drive-by technology, power line carrier (PLC) based AMR meters that report KWh and cell phone based AMR meters that read KWh and interval data. The different meters are deployed based on the environment, network topology, customer type, and safety concerns. For commercial and industrial customers AEP deployed RF based AMR meters that report KWh, KW and some KVAr using drive-by technology, power line carrier based AMR meters that report KWh and KW readings and cell phone based AMR meters that report KWh, KW, on and off peak KW, KVAr and interval data using cell phone technology.

Allegheny Power began installing AMR meters with an RF module in 2004 on hazardous or hard-to-read locations. To date, approximately 2% of all meters are read using antennas on hand-held units in a walk-by scenario. Beginning in 2003, Allegheny Power installed some AMR meters with PLC modules (<1%) on locations that were considered very costly to read. These accounts are read automatically by a central-based system. For large commercial and industrial customers (<1%), Allegheny Power has utilized telephone lines and cellular carriers to remotely collect kWh and kVArh readings and interval data since 1998.

Communications

American Electric Power has several different types of communications mediums in service throughout the electrical system in West Virginia. Most of the communications is provided by fixed voice telephone (analog PBX and VOIP phones) lines. In addition, there are 144 substations that are served with a combination of leased line, private microwave at 6 GHz and fiber. There is a 900 MHz, “MDS-entraNET” point to multi-point SCADA with a data rate of 106 kbps installed at 10 substations. Three substations are linked via Satellite using VSAT 12 to 14 GHz at a data rate of 128 kbps. Leased Frame Relay at 56 kbps is in service at 32 substations

A Mobile Workforce Voice and Data system (an 800 MHz, enhanced digital access communications system (EDACS) trunked radio system) is in service in WV using 40 towers. The system is configured in a Star topology into the city of Charleston using multisite controller. Much of the equipment is over 15 years old.

Allegheny Energy also uses a combination of communication technologies throughout its territory. The overwhelming majority of substation SCADA communications is through leased analog 9600 bps data circuits. The SCADA and dispatch (voice) radio are primarily back-hauled over the microwave system. It consists primarily of 2 GHz and 6 GHz analog equipment, about 20 years old. Some of the 2 GHz links are currently being upgraded to 6 GHz digital. Seven substations in West Virginia presently have 768 kbps frame relay connectivity. Five substations in West Virginia either have plans to connect or are presently connected with fiber.

The Allegheny Energy voice dispatch radio system in West Virginia is currently an analog system. In the Monongahela Power operating company territory (the bulk of AE’s West Virginia territory), it is primarily a repeated UHF system, operating in the 450 MHz frequency band. In the portions of West Virginia that are part of the Potomac Edison territory, it is a VHF high band system, operating in the 150 MHz band. In a small portion of the Monongahela Power territory, it is a VHF low band system operating around 48 MHz. Plans are in process to upgrade the UHF and VHF high band systems to a VHF high band digital trunked system by the end of 2012.

4.1.2 Regulatory/Legislative Environment

The existing regulatory policies and legislation in WV do not support a smart grid deployment. There are net metering rules but they do not provide adequate incentives for the widespread interconnection of consumer owned generation. The net metering rules approved in WV only apply to generating systems up to 25 kilowatts (kW) in capacity that generate electricity using wind, photovoltaics (PV), hydropower, biomass, landfill gas, or fuel cells. The generated electricity in excess of demand can be applied as a kilowatt-hour (kWh) credit to a customer-generator's next bill and can be carried over for up to 12 months. A merchant generation owner can be paid directly for generated KWh's. The net-metering tariffs must be identical in rate structure, retail-rate components, and monthly charges, to the normal tariff for customers without their own generation. In addition, there is a provision that each net-metered customer-generator must carry a minimum of $100,000 in liability insurance. The equipment requirements for net metering are a single, bi-directional meter that the customer must pay for if one is not already in place and a means to disconnect from the grid in accordance with standard interconnection agreements.

There are almost no time of use (TOU) rates or dynamic pricing in WV at this time. The necessary technology, communications, and processes are not in place to accomplish this on a statewide basis. The lack of various dynamic rate designs does not provide an incentive for consumers to become involved.

There are no depreciation rules in place that allow utilities to recover costs for equipment that are not at the end of their functional lifetimes but need to be replaced to facilitate the deployment of a smart grid. This may serve to delay smart grid implementations. There are no clear policies in place that provide the necessary cost-recovery and incentives for utilities to make the large initial investments required to implement a smart grid. Without the appropriate incentives and the ability to include consumer and societal benefits in a rate case filing it may not be possible for utilities to justify smart grid investments since they cannot get a return on their investment.

4.1.3 Consumer Environment

There is little consumer participation in West Virginia since there are no competitive retail markets for electricity, few policies or incentives to encourage involvement, and the consumer lacks awareness of the current electrical grid structure and understanding of the nature and benefits of a smart grid. At the present time most interaction between consumers and the grid is through the utility billing departments. Since the smart technologies and enabling regulatory policies are not in place in WV, consumers have no real-time information or interaction with the system and have few choices as to electricity suppliers, differentiated service levels, or use of grid connected devices. Consumers are almost exclusively using standard tariffs that have no time of use or dynamic component and there are no demand response programs available. If consumers cannot interact with their local utility then they are cut-off from participation in the larger regional, wholesale or ancillary services markets.

While this would seem to paint a bleak picture for the consumer/supplier relationship in WV customer satisfaction surveys seem to show the opposite picture. In Table 4-5 below the American Customer Satisfaction Index (ACSI) indicates that the two major utilities in WV scored well in comparison to energy utilities around the country. This could be due in large part to the fact that the retail electric rates in WV are well below the national average. According to the Energy Information Administration the average retail price of electricity in WV in November 2008 was 5.52 cents/kWh (7.26 cents/kWh for residential only). This was the third lowest rate of all 50 states and well below the U.S. average retail price of 9.73 cents/kWh (11.47 cents/kWh for residential only). The positive relationship between electricity consumers and suppliers in WV can be seen in other ways besides high ratings in customer satisfaction surveys. The state of WV recently approved the construction of the West Virginia segment of the Trans-Allegheny Interstate Line (TrAIL) Project, a 500 kV high voltage transmission line. In 2007, PJM approved construction of a new 275 mile 765 KV transmission line from southwestern West Virginia (Amos Substation in Putnam County, WV) to central Maryland (proposed Kemptown Substation southeast of New Market, MD), designed to maintain the reliability of the regional transmission system. Allegheny Energy and American Electric Power (AEP) have announced a joint venture to build the Potomac-Appalachian Transmission Highline (PATH). The project also includes a new Welton Spring Substation along the proposed route in northwest Hardy County, W.Va.

Figure 4-5 shows how West Virginia's retail electricity rates compare to the rest of the US.

TABLE 4-5: UTILITY CUSTOMER SATISFACTION SCORES

Energy Utility	2001	2002	2003	2004	2005	2006	2007	2008
Allegheny Energy, Inc.	**79**	**80**	**76**	**75**	**74**	**80**	**79**	**NM**
PacifiCorp	72	71	76	NM	NM	NM	NM	NM
Southern Company	80	81	82	81	79	80	82	81
Sempra Energy	67	74	77	77	79	75	80	80
PPL Corporation	80	80	80	79	80	81	81	78
FirstEnergy Corp.	72	77	76	69	71	75	76	77
Progress Energy, Inc.	76	77	75	78	75	77	77	77
Duke Energy Corporation	79	79	77	78	78	80	79	76
FPL Group, Inc.	73	71	73	76	74	68	73	76
American Electric Power	**76**	**75**	**74**	**75**	**74**	**75**	**73**	**76**
CenterPoint Energy, Inc.	NM	NM	NM	NM	73	72	74	75
Energy East Corporation	73	73	71	70	73	74	70	75
Edison International	60	66	69	71	75	78	74	75
Public Service Enterprise Group Incorporated	75	76	76	73	74	75	73	75
Dominion Resources, Inc.	65	70	72	67	71	70	73	75
Entergy Corporation	69	74	71	73	75	70	73	74
CMS Energy Corporation	75	76	78	71	74	72	73	74
Xcel Energy Inc.	65	74	73	70	68	70	71	73
Reliant Energy, Inc.	67	74	70	68	69	69	65	72
All Others	68	74	72	74	74	70	72	72
DTE Energy Company	74	68	72	71	68	65	70	72
National Grid plc	NM	NM	73	75	69	72	65	71
National Grid USA	NM	73	75	69	72	65	71	71
PG&E Corporation	49	58	66	66	67	68	72	70
NiSource Inc.	67	68	66	68	68	66	72	70
Pepco Holdings, Inc.	NM	NM	77	72	73	71	70	69
Exelon Corporation	66	69	71	71	71	70	68	69
Energy Future Holdings Corp.	71	75	74	74	72	65	63	68
Northeast Utilities	76	72	73	68	74	72	69	68
Consolidated Edison, Inc.	66	74	72	68	68	68	69	66
Ameren Corporation	78	76	77	74	75	74	57	64
TXU Corp.	76	71	75	74	74	72	65	63
KeySpan Corporation	68	72	71	74	70	71	74	#
Cinergy Corp.	NM	NM	NM	74	75	71	#	

Scores can be downloaded from http://www.theacsi.org/index.php?option=com_content&task=view&id=147&Itemid=155&i=Energy+Utilities. These scores were downloaded on 19 February 2009.

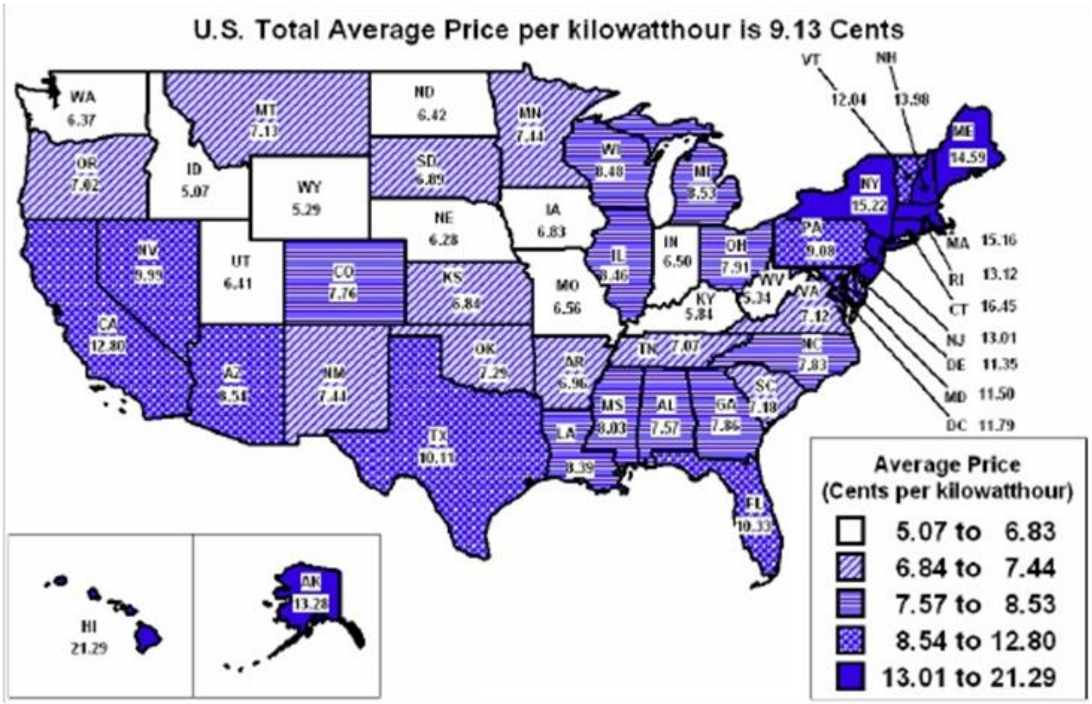


FIGURE 4-5 U.S. RETAIL ELECTRICITY RATES FROM ENERGY INFORMATION ADMINISTRATION, FORM EIA-861, "ANNUAL ELECTRIC POWER INDUSTRY REPORT."

The West Virginia Public Services Commission (PSC) does track consumer complaints about electric utilities, looking at the number and types of complaints as well as the trends over time, may provide some insight into the consumer/utility interaction. The data shown in Table 4.6 was taken from work done by APERC at West Virginia University. It is noted that this data does include complaints caused by severe weather conditions. The full report entitled "APERC Report on Customer Complaints to WV PSC about Electric Power Service" can be seen in Appendix 10.3 at the end of this report.

TABLE 4-6 ELECTRICITY SERVICE PROBLEMS IN WEST VIRGINIA

	POOR QUALITY OF PRODUCT		**UTILITY OUTAGE**		**TOTAL COMPLAINTS**
Year	Inadequate or Excessive Voltage Problems	Telephone Reception or Transmission Problems	Customer Reported Problems	Utility Reported Problems	
1998	24	2	21	0	47
1999	39	1	25	0	65
2000	19	0	33	1	53
2001	38	0	20	0	58
2002	37	0	37	2	76
2003	34	0	33	1	68

2004	42	1	37	0	80
2005	32	0	14	0	46
2006	35	0	13	1	49
2007	65	0	35	1	101
2008	55	2	52	8	117
Avg	38.2	0.5	29.1	1.3	69.1
Totals	420	6	320	14	760
Percent	55%	1%	42%	2%	

There appears to be a slight general trend upwards in the number of complaints over time. The data from this Table 4-6 can be seen graphically in Figure 4-6 below. Notice that there were approximately twice as many complaints in 2008 as there were a decade ago.

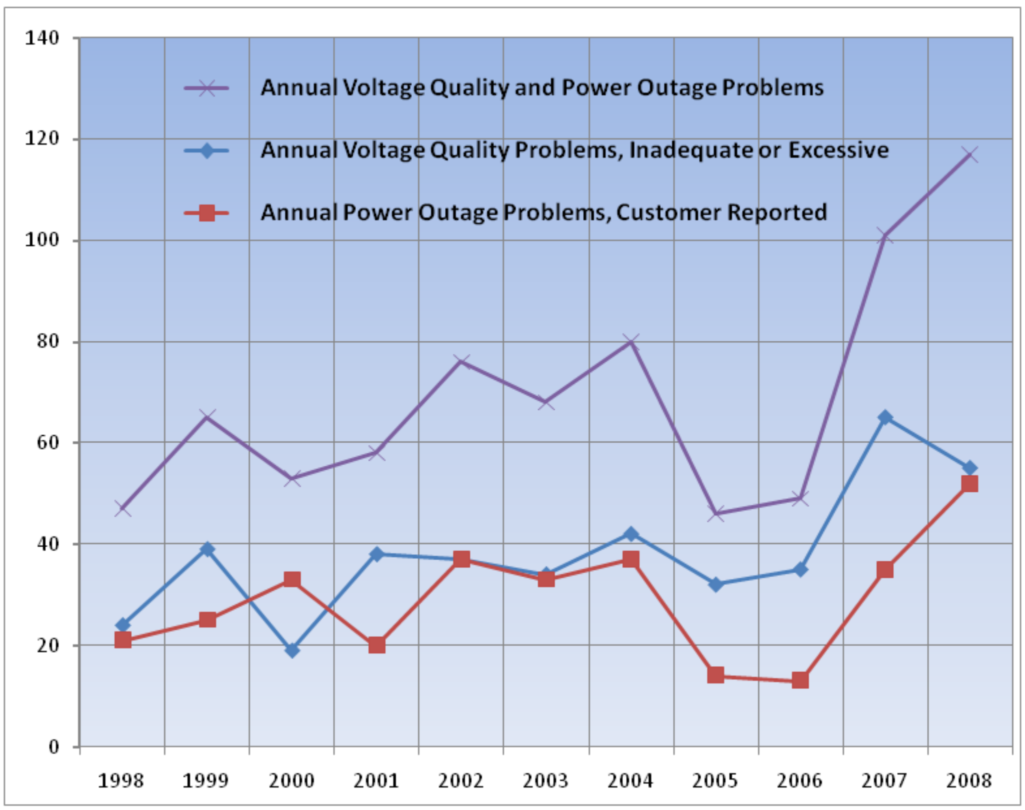


FIGURE 4-6 CHART OF ELECTRICITY SERVICE PROBLEMS IN WV. SOURCE: WV PSC.

4.1.4 Other

The entire state of WV is located within the Appalachian Mountain range, making all areas of the state mountainous and covered with rugged terrain. Being highly mountainous and heavily forested can pose problems for widespread communications deployments, particularly with wireless technologies.

The most recent Census Bureau figures show WV with a Population of 1.8 million people. Out of this total population there is a civilian labor force of 0.8 million. According to the US Census Bureau, in 2004 West Virginia's personal per capita income was $23,995. This is the third lowest in the nation. WV median household income data for 2004 to 2007 shows that WV ranked last in the nation in 2004 but due to the largest percent increase of all states over this time period (8.3%) WV now ranks 46th. Having a small and relatively poor population that is predominantly in suburban or rural areas could make the cost of installing advanced distribution automation technologies prohibitive.

One of the state's major resources is coal. Coal is a major export in raw form and also as a fuel for electricity exports. Most of the electricity generation in WV is from coal-fired power plants. According to the Energy Information Administration, WV exports more electricity than any other state in the nation. Any changes to the electric supply and delivery system in the state of WV could have a dramatic impact on the coal industry and must be carefully considered.

4.2 Smart Grid Maturity Model for Current State

4.2.1 Process Description

In an attempt to be as objective as possible in describing the current state of the electric grid in West Virginia and to better facilitate the gap analysis it was decided that a maturity model that placed a numerical value on each principal characteristic would be very effective and could be easily repeated for different geographic areas. The matrix was evaluated by several different parties and the results shared among the entire team. The purpose was to try and get the perspective of utilities, regulators, legislators, consumers, and as many other involved parties as possible from the state of WV. The matrix was evaluated by representatives from both major WV utilities, Allegheny Energy and American Electric Power, to get the utility perspective. West Virginia University conducted research into the views of WV consumers and this information was used to evaluate the maturity model from the standpoint of consumers. In addition, each team member evaluated the maturity model independently and then shared the results as well as their justifications with the team. In addition, three of the experts applied the Smart Grid Characteristic Maturity Model assessment tool which formulates a score based on answers to assessment questions. The next step was to establish a consensus view of the maturity level of each Characteristic based on the individual evaluations, the team discussion, and the available data to justify each decision.

4.2.2 Results

The results of the maturity model evaluation are shown in Table 4-7.

TABLE 4-7: SMART GRID MATURITY MODEL ASSESSMENT OF WV CURRENT STATE

	Expert Team Assessment			Consensus Result	SGMM Tool
Smart Grid Characteristic	**Average**	**High**	**Low**		**Average**
Enables active consumer participation	1.38	2	1	**1.5**	1.70
Accommodates all generation and storage options	1.09	1.75	1	**1**	1.77
Enables new products, services and markets	1.58	2	1	**1.5**	1.71
Provides PQ for 21st century needs	1.41	2	1	**1.5**	1.65
Optimizes assets and operates efficiently	1.66	2	1	**1.5**	1.67
Anticipates and responds to disturbances	1.39	2	1	**1.5**	1.74
Operates resiliently against attack and natural disaster	1.19	2	1	**1.5**	1.68

The Consensus Results generally suggest a Traditional / Initiating current state of the grid in West Virginia. This means the grid today is a capital equipment-centric network typical of those designed 50 - 70 years ago, plus a few investigative projects looking at new technologies and processes. This can be seen in the graphical representation in Figure 4-7.

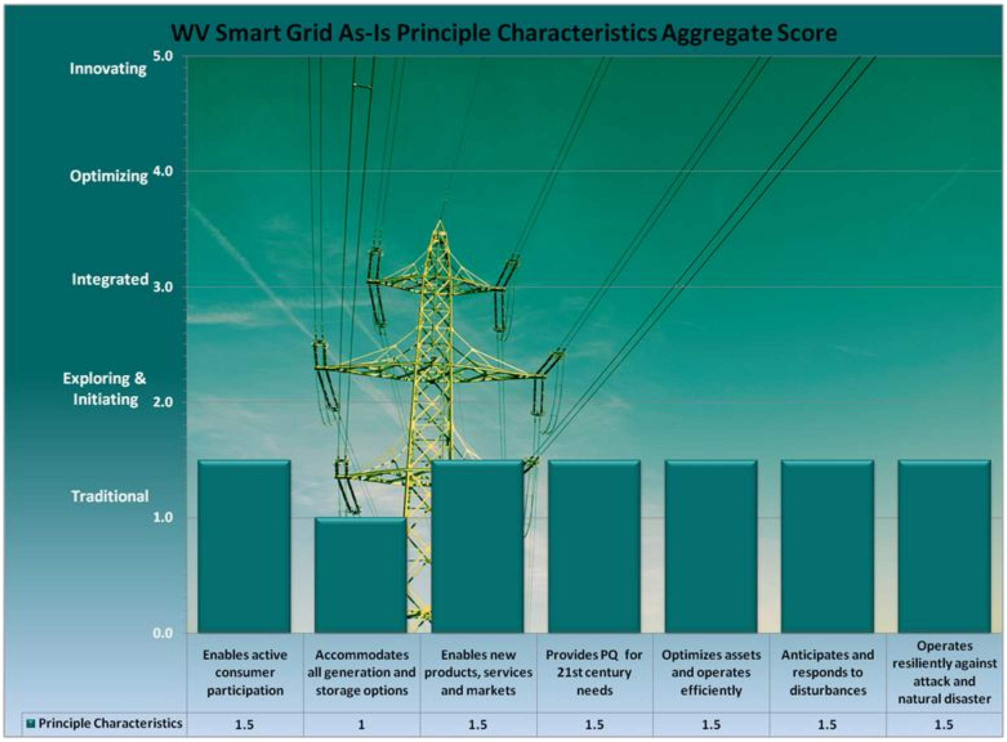


FIGURE 4-7 WV AS-IS MATURITY MODEL SCORE

5.0 West Virginia Probable Future State for Smart Grid

5.1 General Discussion

The probable future state of West Virginia's power grid is not a single state, but a collective of probable states given external influences, trends in consumers, economy, regulatory treatment, and environment. The team evaluated the probable future state from existing future energy plans by utilities, regulators, and legislators for WV, as well as other higher level trends, consumer views, and expert future state workshops. In addition, the team "scored" the future WV grid maturity using the Smart Grid Maturity Model. This team evaluation attempted to define "where WV expects to be in the future regarding implementation of a Smart Grid" from several different perspectives.

From the initial workshop on Probable Future States, the team explored several key questions in detail for West Virginia:

- What issues are important to the people of West Virginia?
- What will West Virginia be like in ten years?
- What will West Virginia be like in 2030?

This lead to a summary of the characteristics that could describe the state of West Virginia in 2018 and 2030:

- Energy-centric
- Great place to live and work
- Increasing "green" focus
- Robust infrastructures
- Energy independency, state independency, and individual independency matters
- State energy conversion nature
- Increasing mix of generation diversity
- Increasing energy exports
- Supportive regulatory policies (i.e. how energy regulation is handled)

From these discussions and characteristics, the team analyzed and established six Future State scenarios (see Figure 1):

1. Traditional Regulatory Measures-A future state dominated by traditional PUC rate-making that provides rater recovery for prudent investments that are deemed least cost to the consumer. Consumer and societal benefits are not strictly considered in this state which is consistent with the regulated rates approach of the last 50 years.
2. Consideration of Broad Regulatory Measures-A future states dominated by flexible rate structures (wholesale and retail) that encourage or incentivize Smart Grid strategies such

as demand response, dispatch of consumer-owned generation resources, and time of use rates.

3. Limited Access to Opportunities and Resources-A future state dominated by few options for jobs and resources, but good availability of recreational lands consistent with the long term desires of the residents.
4. Broad Access to Opportunities and Resources-A future state dominated by many, various jobs and careers, as well as use of natural resources for energy, business, and recreation consistent with the long term desires of the residents.
5. Limited Energy Development-A future state dominated by traditional coal for electricity generation.
6. Broad Use of Energy Resources for National Benefit-A future state dominated by innovative uses of coal, biomass, and other domestic resources for electricity, heating, and transportation fuels for residents as well as for sale to others.

Process

Figure 5-1 represents the summary of the workshop and subsequent analysis.

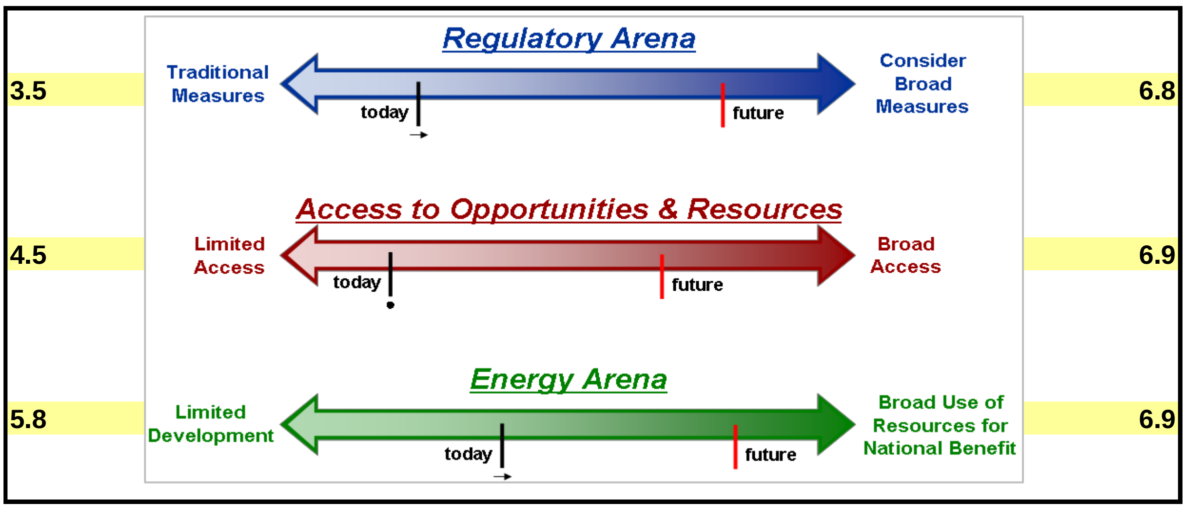


FIGURE 5-1: WV PROBABLE FUTURE STATES DIAGRAM

The black vertical bars on the large arrows that represent the future scenarios are the team's assessment of the current situation in West Virginia. For example, the regulatory arena is mainly represented by traditional regulatory measures, but moving toward broader measures.

The red vertical bars on the scenarios are the team's initial collective desired future situation in West Virginia. This was part of the original workshop brainstorming. For example, the team saw the energy arena in the future as mainly represented by broadened use of West Virginia resources to benefit the nation, while also stimulating the expansion of in-state industries.

The numbers to the left and right of the dimensions represent the scenario scores from the Probable Future States Analysis. The likelihood of each scenario existing a decade from now is scored on a scale of 1 to 10, with 10 being most likely. These scores are constructed from a process that evaluates the many drivers that ultimately influence each scenario. For example, the drivers that affect a change in electric load are given below in Table 5-1. And a change in electric load is an external influence on some or all of the six scenarios. Therefore, it was important that the team determine the three-way relationship between the drivers, external influences, and scenarios.

TABLE 5-1: SMART GRID MATURITY MODEL ASSESSMENT OF WV FUTURE STATE

Drivers Affecting a Change in Electric Load
Weather
Manufacturing (chemical, polymer)
Culture/people profile
In-migration from PA / DC
PHEV / EV
Economic development
Change in Federal presence
Change in infrastructure
Business Profile
Solar roofs (WC)
Transportation fuels business
DR/ conservation
State GDP

From this developed three-way relationship, each scenario can be built. In short, the likelihood of a particular Scenario is a result of how External Influences affect it. Likewise, External Influences are made up of key Drivers and their trends.

Why do this? It is because key drivers, and their respective trends, are elements that can be much more easily assessed for impact as near-independent variables. This brings an element of objectivity to assessing the Probable Future States that West Virginia will see 10 to 20 years from now.

Thus, based on the scores, for example, a Consideration of Broad Regulatory Measures (6.8) scenario is much more likely than a Traditional Regulatory Measures (3.5) scenario to exist 10 years from now.

Results and Lessons

Collecting the most impactful drivers for the three top scenarios provides a clear picture of how the scenarios will likely develop.

These impactful drivers would tend to create tension that would move a state to modify its regulatory policy to address these drivers. Thus, West Virginia is more likely to adopt broad regulatory measures when there is:

- Carbon tax and climate change in the shorter term
- Shifting from central to distributed generation in an increasing manner
- Increasing interest/participation by consumers in Demand Response and conservation
- Increasing availability of plug-in hybrid electric vehicles and electric vehicles in use
- Increasing number of solar roofs (residential and commercial) in use
- A more proactive stance on Renewable Portfolio Standards (RPS)
- A more proactive stance on saving green space
- Continued acceptance of production tax credits (PTC)
- Increasing use of new tariff structures (time of use, critical peak pricing, etc)
- A longer term stance on market incentives (PJM wholesale pricing)
- A more proactive stance on use of incentives to drive goals
- Increasing consumer involvement in the future
- Increasing amount of communications infrastructure

West Virginia is more likely to provide broad access to opportunities and resources when there is:

- Increasing interest/participation by consumers in Demand Response and conservation
- Increasing availability of plug-in hybrid electric vehicles and electric vehicles in use
- Increasing emphasis and production of coal to liquid fuels
- Increased in-migration of people from Pennsylvania and Washington DC
- Increasing number of solar roofs (residential and commercial) in use
- A more proactive stance to growing the transportation fuels business
- A more proactive stance on use of incentives to drive goals
- A more proactive stance to supporting Clean Coal technology deployment
- Shifting from central to distributed generation in an increasing manner

In contrast to the above two scenarios, the energy scenarios show less of a scoring gap (5.8 vs. 6.9). The relatively high score (5.8) under Limited Energy Development suggests that West Virginia will continue to aggressively pursue coal export as a main staple of its economics.

But West Virginia will be more likely to support broad use of energy resources for national benefit when there is:

- Carbon tax and climate change in the shorter term
- Increasing number of plug-in hybrid electric vehicles and electric vehicles in use
- Increasing number of solar roofs (residential and commercial) in use
- A more proactive stance to supporting Clean Coal technology deployment
- A more proactive stance toward adoption of Kyoto or other climate change treaties
- Increasing use of advanced storage in the electric system
- Increasing emphasis and production of coal to liquid fuels
- Increasing new DG development (e.g. fuel cells, new solar technology, etc.)

- A more proactive stance to growing the transportation fuels business
- Shorter term economic development goals
- Increasing participation by consumers in Demand Response and conservation
- A more proactive stance on the policies of the new President
- A more proactive stance on Renewable Portfolio Standards (RPS)
- Increasing use of new tariff structures (time of use, critical peak pricing, etc)
- Application and use of the EISA 2007 (appropriations under the American Recovery and Reinvestment Act of 2009 (ARRA)) – incentives for grid investment
- The longer term deployment of wind turbines
- Changes that lead to decreasing gasoline use
- Shifting from central to distributed generation in an increasing manner
- Increasing R&D funding and new interests on campus

From Figure 5-2, West Virginia is today a significant exporter (80%) of energy (predominantly coal) to the rest of the nation. This aggressive supply orientation is a key reason that West Virginia is one of seven states in the financial black. In addition, TransGas Development and CONSOL Energy have significant projects to build coal to liquids plants in West Virginia. This is directly in line with the state's goals to develop alternatives to its petroleum imports and develop additional lines of business in energy export to the rest of the nation.

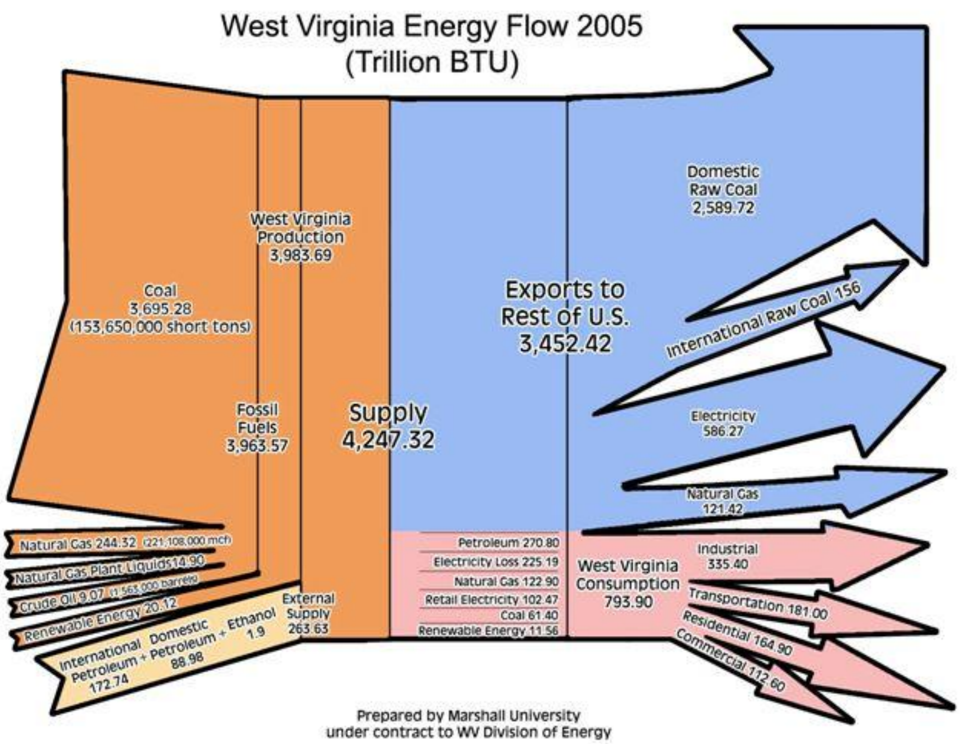


FIGURE 5-2: WEST VIRGINIA ENERGY BALANCE

In addition, several West Virginia energy companies are developing new natural gas extraction and production facilities, as well as addressing carbon management and clean coal technologies. Plus, the West Virginia Hydrogen Coalition is developing a hydrogen fueling station at the Yeager Airport in Charleston using the Arizona Public Service hydrogen station design which is widely held up as the model in the nation. These initiatives are an important recognition that the burning of coal will continue to come under increasing political pressure and that new ways are needed to utilize WV's most abundant natural asset.

About 75% of WV energy export is domestic raw coal. This may decrease as carbon emissions rules are enacted. The resulting "coal surplus" will need to find new markets or disappear. As with the above examples, coal to liquid could provide one such new market. New clean coal power plants could be another new market. But these and other markets will have long development times, while carbon rules will likely be upon us much sooner. This suggests a possible drop in WV gross domestic product (GDP) in the near term.

An offsetting factor could be increased sale of raw coal to China and others, which was less than 5% of exports in 2005.

Conclusions

The Future State of West Virginia shows a very strong balance between Regulation, Access to Opportunities and Resources, and Energy, with each of these measures undergoing moderate to substantial change (rightward movement) from today. This future balance is different from today's emphasis on natural beauty and fostering an economy built predominantly on exporting coal.

This future will balance the protection of natural resources with the use of natural resources for job creation. It also means more aggressive regulatory support to develop energy businesses that create jobs or provides similar benefit to the people of West Virginia. And it means more creative energy export lines of business that use domestic resources responsibly in balance with benefits to the people and businesses of West Virginia.

A Smart Grid implementation in West Virginia should fit within this balanced approach to the future:

- Consideration of Broad Regulatory Measures – flexible and wide ranging measures that work with the other scenarios in balance.
- Broad Access to Opportunities and Resources – multiple and creative uses that support environmental, and life style goals in balance with economic growth.
- Broad Use of Energy Resources for National Benefit – diverse and growing lines of energy businesses that keep West Virginia in an energy supply/development leadership role in the nation. This should include attracting industry to WV by, among other things, providing lower cost energy and the power quality they require. These two elements, combined with outstanding natural features, can be a magnet for new jobs.

Smart Grid technologies and processes that support these three scenarios in balance will fit West Virginia's future. This places additional importance on consumer side and societal benefits in the development of the business case.

5.1.1 Technical Perspective

The Smart Grid vision developed by the DOE/NETL Modern Grid Strategy team is a starting point for developing an intelligent grid in WV that meets the Smart Grid Characteristics described in section 3.1, as well as the enabling technologies described in section 3.3. To this, is added the significant West Virginia energy goals of providing transportation fuels from domestic WV resources and ever increasing energy exports from the state as a primary form of gross domestic product (GDP) for the state.

Plus, as seen from the results of the Probable Future State Scenario assessment, WV will have a strong emphasis on technology solutions in the grid that enable deeper penetration of new energy resources (wind, solar, storage, electric vehicles, demand response, and DG).

In addition, it will be important to determine optimal penetration rates for the Smart Grid technologies that result (solution set) from the gap analysis. Determining the optimal penetration rates is part of the business case and implementation planning for the solution set.

5.1.2 Regulatory/Legislative Environment

The key word is "balance" in the future regulatory and legislative environment. As West Virginia seeks to develop new energy resources and expand existing ones for national benefit, the regulatory / legislative environment will need to become more broad and flexible with wide ranging treatment strategies that operate simultaneously.

5.1.3 Consumer Perspective

Polynomial trend lines were added to the three graphs of electricity service problems shown previously in Figure 4.6 to extrapolate customer complaint data from the PSC into the future. These trend lines and their second order polynomial equations are shown in Figure 5.3.

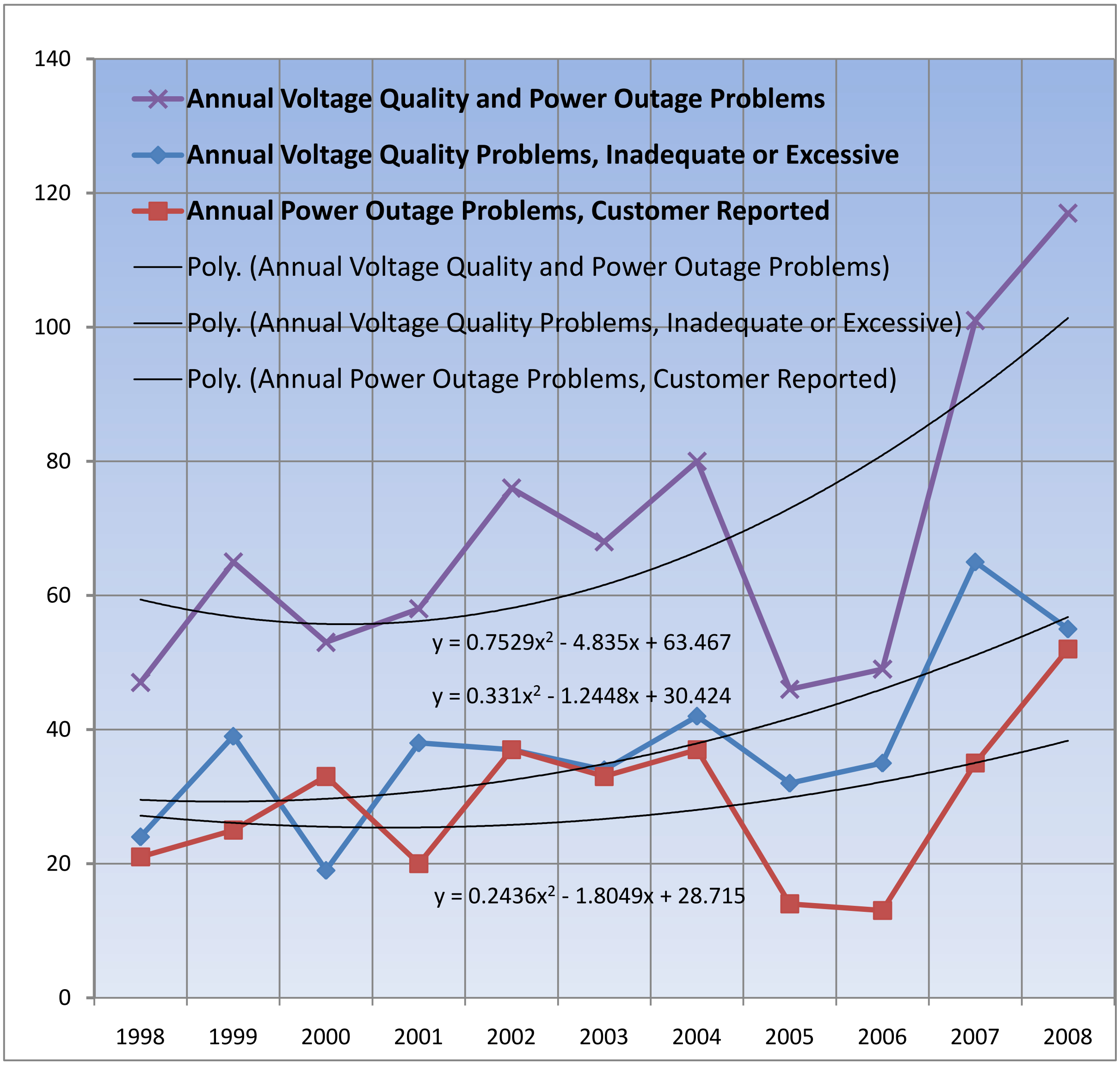


FIGURE 5.3: TREND LINES FOR CUSTOMER COMPLAINT DATA

These three polynomial equations were used to compute to the year 2030 the total number of annual power outage complaints, voltage quality complaints and total complaints before Smart Grid, as shown in Column 2, Column 3 and Column 4 in Table 5.2. The Extrapolated Total Complaints data for Column 4 in Table 5.2 is shown plotted as the top curve in Figure 5.4.

TABLE 5.2: NUMBERS OF COMPLAINTS BEFORE AND AFTER SMART GRID

Year	Power Outage Complaints before Smart Grid	Voltage Quality Complaints before Smart Grid	Extrapolated Total Complaints before Smart Grid	Revised Total Complaints before Smart Grid	Projected Total Complaints after Smart Grid

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
1998	27	30	59	59	59
1999	26	29	57	57	57
2000	25	30	56	56	56
2001	25	31	56	56	56
2002	26	32	58	58	58
2003	27	35	62	62	62
2004	28	38	67	67	67
2005	30	42	73	73	73
2006	32	46	81	81	81
2007	35	51	90	90	90
2008	38	57	101	101	101
2009	42	63	114	114	114
2010	46	70	128	128	128
2011	51	78	143	143	134
2012	56	86	160	158	137
2013	62	95	179	173	139
2014	68	105	199	188	139
2015	75	115	220	204	138
2016	82	126	243	219	136
2017	90	138	268	234	134
2018	98	150	294	249	131
2019	107	163	322	263	128
2020	116	177	351	277	125
2021	126	191	381	291	122
2022	136	206	413	304	119
2023	146	222	447	317	116
2024	158	238	482	330	114
2025	169	255	518	342	111
2026	181	273	556	354	109
2027	194	291	596	365	107
2028	207	310	637	376	105
2029	220	330	680	386	103
2030	234	350	724	396	102

The extrapolated curve for complaints before the Smart Grid was considered to show a growth in total complaints that was not realistic into the future. Thus, the data in Column 5 of Table 5.1 was generated as a revised Total Complaints before Smart Grid column. This Revised Total Complaints data is shown plotted as the middle graph in Figure 5.2.

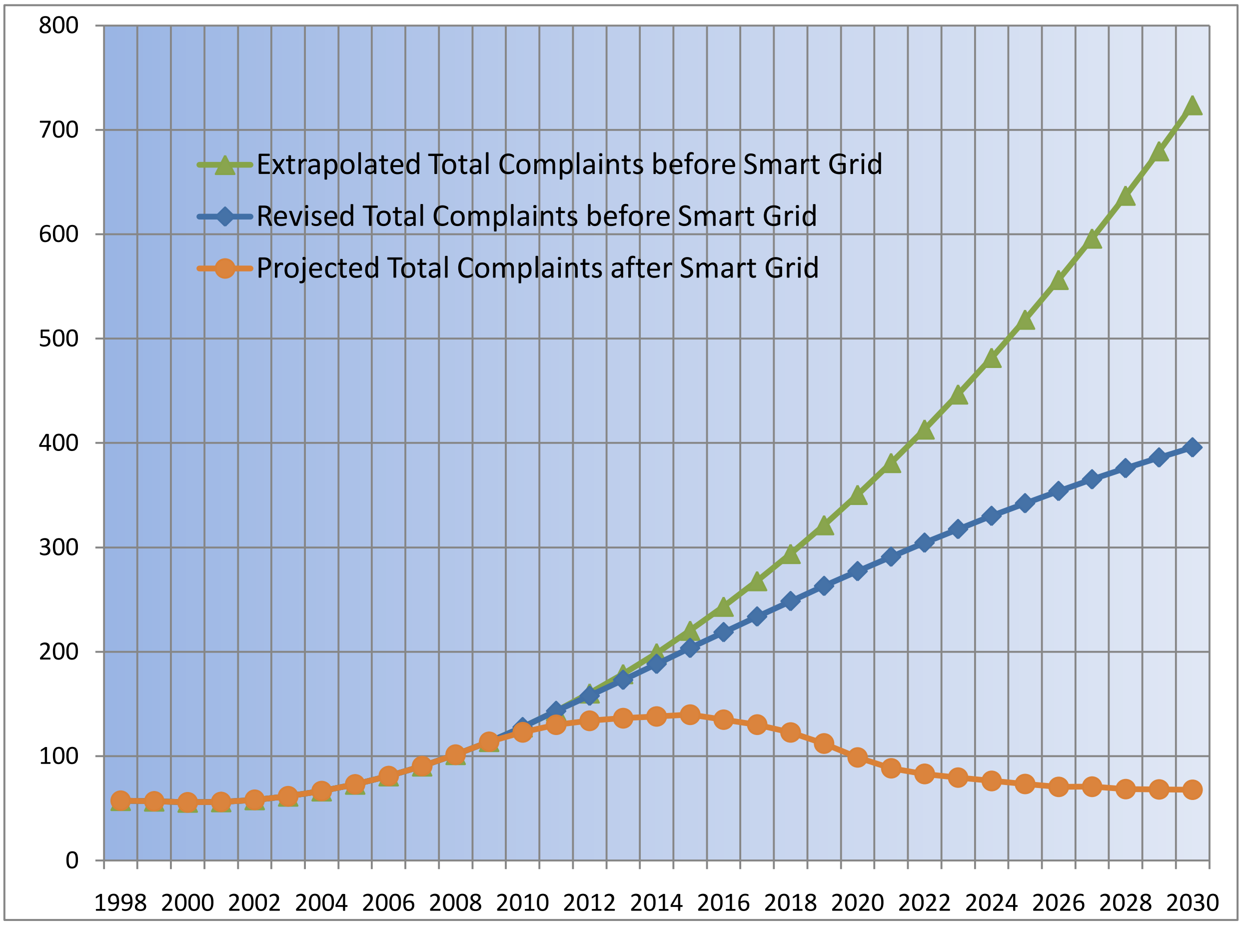


FIGURE 5.2: CHART OF TOTAL CUSTOMER COMPLAINTS BEFORE AND AFTER SMART GRID

Projected Total Complaints after Smart Grid

A 'Business Case' model has been developed as part of the WV SGIP Project. This model permits the computation of both the benefits for a 'business as usual' case as well as the computation of the specific benefits for implementing various smart grid solutions in West Virginia.

The three most important ways to assess whether customer complaints will be reduced after implementation of smart grid technologies is to consider 1) the distinct benefits to customers relative to the specific utility and the general society, 2) the benefits to customers from implementation of specific smart grid technologies (AMI, DA, DG, DR, …, and Storage) in the grid and 3) the benefits to customers with respect to the specific time phases (first, second, …, and later) for implementing the smart grid.

First, the computation of the benefits from implementing the proposed smart grid on the WV grid indicates that about 70% of the benefits will serve the customers, about 20% of the benefits will serve society and about 10% of the benefits will serve the power utility company. Thus, it can be projected that at least two-thirds of the smart grid solutions when implemented will serve to lower customer complaints.

Second, these computations also indicated that about three-fourths of the computed benefits would result from installation of DA (Distribution Automation), AMI (Advanced Meter Infrastructure), PHEV (Plug-in Hybrid Electric Vehicles), DG (Distributed Generation), Advanced Storage, and other systems. Hence, it can be projected that these solutions will serve to lower customer complaints.

Third, it is also shown by the February 13, 2009 computations that if initiation is begun for the four specified phases of implementation between 2010 and 2015, then by 2025 those implemented solutions that benefit the customer as mentioned in the above two paragraphs can be projected to lower customer complaints.

An idealized outcome of this smart grid implementation plan project for West Virginia would be that the number of customer complaints after the project were completed would be zero. However, based on the business case explanation described in the above three paragraphs, it could be proposed that when implemented, the computed benefits from this project would perhaps lower the total number complaints made by customers of electric power to the WV PSC by about 70%.

However, for this project, a realistic projection of the total number of customer complaints to the WV PSC will be that the total number of complaints will increase from about 130 per year in 2010 to about 140 per year in 2015, and then will gradually decrease by about 50% to around 70 complaints per year in 2030. This result is shown plotted as the bottom graph in Figure 5.2.

Summary

In summary, it is projected that implementation of the smart grid in West Virginia will potentially improve the electricity service to customers in 2030 by decreasing the number of complaints from a projected total of about 400 per year to about 70 per year.

5.1.4 Other Key Insights

There were three key insights into the future state of WV that are unique.

First, the topography of the state will affect the communications and grid topology which might limit implementation of the DOE/NETL MGS Smart Grid vision (e.g., cost effectiveness of reaching very rural areas).

Second, the state economy is strongly tied to the WV coal industry as an exporter, thus the major input to the state GDP. Therefore, a WV Smart Grid needs to be supportive of this state strategy.

Third, the state has an aggressive strategy to reduce its energy import (mainly transportation fuels) and develop a domestic changeover to a significant in-state transportation fuels business.

5.2 Smart Grid Maturity Model Describing Probable Future State

5.2.1 Process Description

The process was the same as that described in section 4.2.1; however the context was the Probable Future State of WV instead of the Current State assessed before.

5.2.2 Results

The results of the maturity model evaluation are shown in Table 5-2.

TABLE 5-2: SMART GRID MATURITY MODEL ASSESSMENT OF WV FUTURE STATE

	Expert Team Assessment			Consensus Result	SGMM Tool
Smart Grid Characteristic	**Average**	**High**	**Low**		**Average**
Enables active consumer participation	4.13	5	3	**4**	3.98
Accommodates all generation and storage options	4.04	5	2.5	**4**	3.90
Enables new products, services and markets	4.11	5	3	**4**	3.84
Provides PQ for 21st century needs	3.72	5	2	**3.5**	3.74
Optimizes assets and operates efficiently	4.29	5	3	**4**	3.81
Anticipates and responds to disturbances	3.80	5	3	**4**	3.92
Operates resiliently against attack and natural disaster	4.09	5	2.5	**3.5**	3.95

The Consensus Results generally suggest an Optimizing future state of the grid in West Virginia. This means that the nature of the grid in the future will be continuously seeking a more optimized state, and have the sophistication to achieve this.

Comparing the maturity model results to the probable future state scenarios of section 5.1, we obtain the following overall picture (Table 5-3 through 5-9) of the future grid in West Virginia.

TABLE 5-3: WV FUTURE STATE – CONSUMER PARTICIPATION

Smart Grid Characteristic:	Maturity Description:
Enables active consumer participation	• **AMI deployment completed in specific regions** • **DR in place with smart meters** • **consumers active in deploying smart appliances, PHEV, DG, and home area networks** • **activity with RTO underway to link to consumer** • **dynamic real time rate structures in place**
Related Probable Future State: **In the future, West Virginia is more likely to adopt broad regulatory measures to (1) shift from central to distributed generation in an increasing manner, (2) increase interest/participation by consumers in Demand Response and conservation, (3) increase use of Plug-in hybrid electric vehicles and electric vehicles, (4) increase the number of solar roofs (residential and commercial), (5) increase use of new tariff structures (time of use, critical peak pricing, etc), (6) take a longer term stance on PJM LMP and market incentives, (7) take a more proactive stance on use of incentives to drive goals, and (8) increase the amount of communications infrastructure to support all of the above. This should lead to increased direct consumer benefit to residents and businesses.**	

TABLE 5-4: WV FUTURE STATE – GENERATION AND STORAGE

Smart Grid Characteristic:	Maturity Description:
Accommodates all generation and storage options	• **new tariffs incent DER deployment** • **integrated operation of multiple DER devices and micro-grids on a single feeder** • **DER coordination at substation or higher system level**
Related Probable Future State: **In the future, West Virginia is more likely to adopt broad regulatory measures and support broad use of energy resources for national benefit to (1) shift from central to distributed generation in an increasing manner, (2) increase use of new tariff structures (time of use, critical peak pricing, etc), (3) increase the amount of communications infrastructure to support DER and microgrid strategies, (4) take a more proactive stance on Renewable Portfolio Standards (RPS), (5) take a more proactive stance to supporting Clean Coal technology deployment, (6) increase use of advanced storage in the electric system, (7) increase new DG development (e.g. fuel cells, new solar technology, etc.), and (8) support the longer term deployment of wind turbines. This should lead to increased system flexibility, efficiency, and reliability which adds system and consumer benefits.**	

TABLE 5-5: WV FUTURE STATE – NEW PRODUCTS, SERVICES, AND MARKETS

Smart Grid Characteristic:	Maturity Description:
Enables new products, services and markets	• **access to RTO markets available in specific regions** • **value of consumer involvement well understood, transactions occur among consumers, utilities, and RTO's in real time** • **AMI communications infrastructure can support multiple HAN applications** • **DR, DER and energy efficiency programs in place** • **transmission congestion greatly reduced**
Related Probable Future State: **In the future, West Virginia is more likely to adopt broad regulatory measures and support broad use of energy resources for national benefit to (1) increase use of new tariff structures (time of use, critical peak pricing, etc), (2) increase the amount of communications infrastructure to support consumer access to markets, (3) take a more proactive stance on Renewable Portfolio Standards (RPS), (4) take a longer term stance on PJM LMP and market incentives, (5) use the EISA 2007 appropriations – incentives for grid investment, and (6) increase new DG development (e.g. fuel cells, new solar technology, etc.). This should lead to increased system flexibility, efficiency, and energy export which adds system and consumer benefits.**	

TABLE 5-6: WV FUTURE STATE – POWER QUALITY

Smart Grid Characteristic:	Maturity Description:
Provides PQ for 21st century needs	• **minimally acceptable PQ levels for all customers established** • **PQ metrics established and performance trends tracked** • **advanced technology deployments include: remote PQ Sensing, static VAr compensation, power electronic PQ devices, spike and harmonic filters, and PQ parks**
Related Probable Future State: **In the future, West Virginia is more likely to adopt broad regulatory measures to (1) increase use of new tariff structures (time of use, critical peak pricing, etc), (2) increase R&D funding and new interests on campuses, (3) take a more proactive stance on use of incentives to drive goals, (4) support shorter term Economic Development goals, and (5) increase the amount of communications infrastructure to support PQ parks. This should lead to increased direct consumer benefit to residents and businesses.**	

TABLE 5-7: WV FUTURE STATE – ASSETS AND EFFICIENCY

Smart Grid Characteristic:	Maturity Description:
Optimizes assets and operates efficiently	• **regionally deployed health and condition sensors integrated with AMI and GIS to enable at least one of the following processes - system planning, condition based maintenance, outage management, system loss reduction, work management, customer service, engineering,** • **modeling, simulation and visualization tools enable operators to perform "what if" analyses** • **enterprise-wide level visualization system deployed and integrated with AMI, GIS, OMS, DA, DR, DER, work management, etc.**
Related Probable Future State: **In the future, West Virginia is more likely to adopt broad regulatory measures and support broad use of energy resources for national benefit to (1) shift from central to distributed generation in an increasing manner, (2) increase use of new tariff structures (time of use, critical peak pricing, etc), (3) increase the amount of communications infrastructure to support DER and microgrid strategies, (4) increase emphasis on and production of coal to liquid fuels, (5) increase the number of solar roofs (residential and commercial) in use, (6) increase use of advanced storage in the electric system, (7) increase new DG development (e.g. fuel cells, new solar technology, etc.), and (8) increase participation by consumers in Demand Response and conservation. This should lead to increased system flexibility, efficiency, and flatten the energy profile which adds system and consumer benefits.**	

TABLE 5-8: WV FUTURE STATE – ANTICIPATE DISTURBANCES

Smart Grid Characteristic:	Maturity Description:
Anticipates and responds to disturbances	• **System Integrity Protective Systems (SIPS) ensure regional reliability, adaptive relaying deployed** • **system-wide controls installed to process extensive system real time data, including WAMs inputs, and take instantaneous actions when manual operator action would be too slow** • **DER and DR integrated with DA and feeder backup is underway** • **islanding services available to customers** • **all critical system assets are monitored in real time (SCADA fully deployed)**
Related Probable Future State: **In the future, West Virginia is more likely to adopt broad regulatory measures to (1) shift from central to distributed generation in an increasing manner, (2) increase interest/participation by consumers in Demand Response and conservation, (3) increase use of Plug-in hybrid electric vehicles and electric vehicles, (4) increase the number of solar roofs (residential and commercial), (5) increase use of new tariff structures (time of use, critical peak pricing, etc), (6) increase use of**	

advanced storage in the electric system, (7) take a more proactive stance on use of incentives to drive goals, (8) increase consumer involvement in the future and (9) increase the amount of communications infrastructure to support all of the above. This should lead to increased direct consumer benefit to residents and businesses.

TABLE 5-9: WV FUTURE STATE – RESILIENCE AGAINST ATTACK

Smart Grid Characteristic:	Maturity Description:
Operates resiliently against attack and natural disaster	• **AMI penetration growing, providing tool for more rapid service restoration** • **service restoration faster where AMI deployed** • **regional advanced detection, diagnosis, and autonomous corrective action in place** • **cyber security standards are well defined and incorporated in new designs** • **more than half of consumers have back-up power** • **local micro-grids emerge**

Related Probable Future State:

In the future, West Virginia is more likely to adopt broad regulatory measures to (1) shift from central to distributed generation in an increasing manner, (2) increase interest/participation by consumers in Demand Response and conservation, (3) increase use of Plug-in hybrid electric vehicles and electric vehicles, (4) increase the number of solar roofs (residential and commercial), (5) application and use of the EISA 2007 appropriations – incentives for grid investment, (6) increase use of advanced storage in the electric system, (7) take a more proactive stance on use of incentives to drive goals, (8) increase consumer involvement in the future and (9) increase the amount of communications infrastructure to support all of the above. This should lead to increased direct consumer benefit to residents and businesses.

6.0 Gap Analysis

6.1 Process

A gap analysis identifies the actions which are needed to achieve a Smart Grid in WV. The Project Team examined the important differences between the Current State and Future State in relation to "business-as-usual" BAU and "Accelerated Smart Grid" scenarios. The BAU scenario uses existing historical energy trends and data and projects a future state from this. The Accelerated Smart Grid (Smart Grid) scenario uses the Gap Analysis to determine the direction in technology, regulatory, and consumer perspectives necessary for the future state. The Gap Analysis was performed in the following dimensions:

- Technology implementation/deployment
- Regulatory and legislative policy
- Consumer systems

Figure 6-1 shows the steps leading to the gap analysis and essential elements of the analysis.

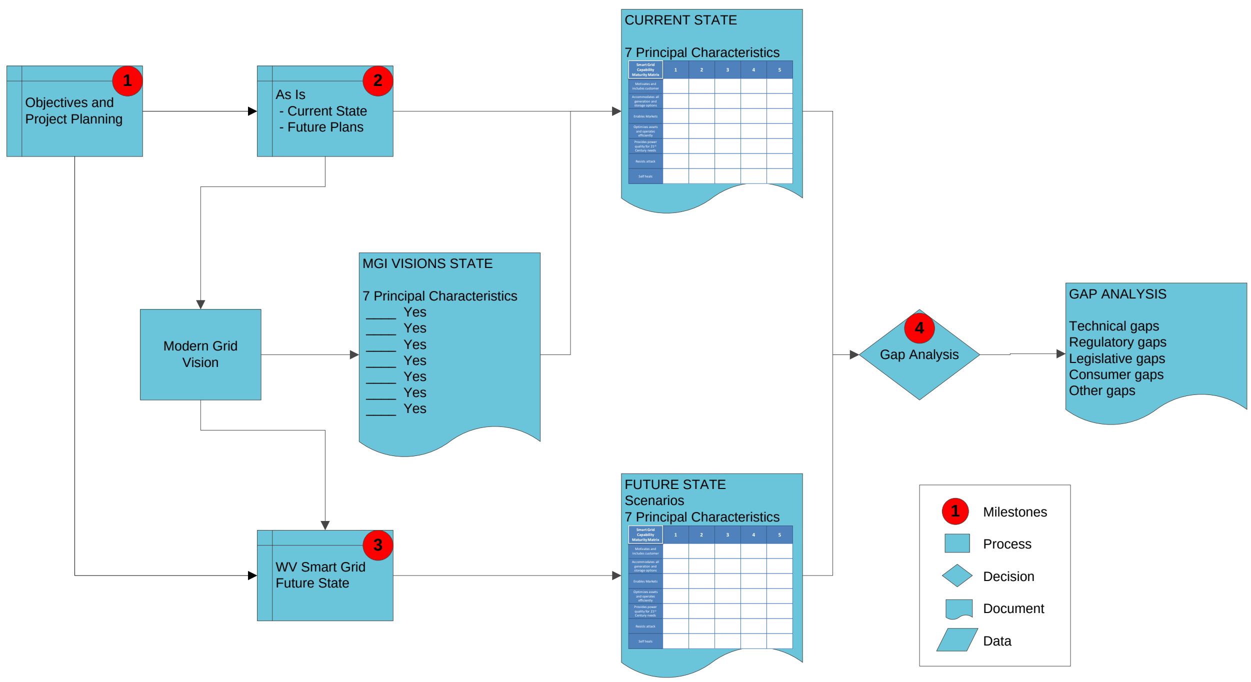


FIGURE 6-1: SMART GRID PROCESS FROM OBJECTIVES TO GAP ANALYSIS

Once the gap analysis is complete, the result is a set of solutions that closes each of the gaps identified in the analysis. This forms the basis for the initial cost analysis in the business case, as well as the basis for the initial implementation plan.

The gap analysis used the newly formed Smart Grid Maturity Model mechanism described in Appendix 10.1. The maturity model provides a mechanism to evaluate progress on each of the seven principal characteristics of a smart grid. The study team determined where on the model's scale WV would fall today and where it believes the state should be ten years from now. It concluded that West Virginia is today at the very beginning (Level 1) of this evolution and that in ten years it should be at an advanced level (between 3.5 and 4). Moving beyond that advanced level to the most mature case (level 5) would be expected to take an additional decade. The following Table 6-1 shows the team's maturity assessment regarding each principal characteristic.

TABLE 6-1: WV MATURITY ASSESSMENT BY SMART GRID CHARACTERISTIC

Principal Characteristic	Current State	**Situation a Decade from Now**
Enables active consumer participation	• Dumb meters • Varying amount of AMR • Traditional rates, monthly bills • Little price visibility, few choices **Rating = 1.5**	**• Regulatory climate supports advanced rates.** **• Deployment of AMI completed in specific regions, consistent with value.** **• DR in place with smart meters.** **• Consumers active in deploying smart appliances, PHEV, and DG.** **• Consumers accept value of Smart Grid, leading to wide deployment of home area networks.** **• Activity with RTO underway to link to consumer.** **Rating = 4**
Accommodates all generation and storage options	• Little or no grid connected distributed resources • Interconnection standards are expensive and complex • Unaccommodating grid design **Rating = 1.0**	**• Wide penetration of DER; new tariffs incent DER deployment.** **• Distribution circuit communications, control and protection schemes accommodate two way power flows.** **• Integrated operation of multiple DER devices and micro-grids on a single feeder.** **• Central DER coordination at substation or higher system level.** **Rating = 4**
Enables new products, services and markets	• Consumer has no system interaction with utility or RTO • Limited wholesale markets **Rating = 1.5**	**• Market access available in specific regions; value of consumer involvement well understood.** **• Transactions occur between consumers and utility in real time.** **• Demand Response and energy efficiency programs in place.** **• Transmission congestion greatly reduced** **Rating=4**

Provides PQ for 21st Century needs	• Reactive response to customer PQ complaints • Adversarial discussions over who is responsible for fix. **Rating = 1.5**	• **PQ monitoring systems installed.** • **Utility investment planning processes include consideration of PQ.** • **Establishment of minimally acceptable PQ for all customers backed up with system designs/investments that deliver this level.** • **Companion strategy to provide price differentiated PQ consistent with consumer needs.** • **PQ metrics established and performance trends tracked.** • **Advanced technology deployments include: remote PQ sensing, static VAR compensation, power electronic PQ devices, spike and harmonic filters, and PQ parks.** **Rating = 3.5**
Optimizes assets and operates efficiently	• Limited grid information available to operators, planners, engineers, and maintenance personnel • Time-based maintenance is predominant. **Rating = 1.5**	• **Asset management a priority, including condition based maintenance, dynamic rating of assets, and system loss reduction.** • **DR employed to improve asset utilization.** • **AMI reduces energy theft and identifies electrical losses due to poor PQ.** • **Asset condition and health sensors deployed for critical assets system-wide.** • **Large amount of new data transformed to information that feeds GIS and other enterprise wide processes - system planning, maintenance, outage management, work management, customer service, engineering, etc.** • **Modeling, simulation and visualization tools enable operators to perform "what if" analyses.** **Rating = 4**

Anticipates and responds to disturbances	• Reactive protection of assets. • Tripping of protective circuit breakers after fault occurrence. • Limited monitoring of equipment health to warn of impending failures. • Run to failure strategy. **Rating = 1.5**	• **Existing monitoring technology (e.g. PMUs, transformer gas analysis) deployed broadly, with research initiated to develop new methods (e.g. EMI analysis) of health assessment.** • **Digital relays replace electromechanical relays and are networked through a digital communications platform.** • **Adaptive relaying deployed.** • **Advanced operator visualization tools installed at system and regional centers, combined with extensive RT data collection.** • **System Integrity Protective Systems (SIPS) insure regional reliability.** • **System-wide controls installed to process extensive system real time data, including WAMs inputs, and take instantaneous actions when manual operator action would be too slow.** • **Automation deployed across entire distribution level.** • **DER and DR integrated with DA and feeder backup.** **Rating = 4**

Operates resiliently against attack and natural disaster	• Centralized model with stressed and aging assets makes the grid vulnerable to attack and natural disaster.
	• Service restoration slow and based on customer call-in
	
	Rating = 1.5
		• **Cyber security a prime consideration in the design and deployment of all Smart Grid technologies.**
		• **Strong utility support for decentralized generation and storage (DER).**
		• **AMI fully deployed, making service restoration far faster.**
		• **Consumer-installed distributed generation and storage technologies.**
		• **Self healing technologies widely deployed**
		    o **Assets monitored to detect challenges.**
		    o **Increased grid intelligence and advanced visualization technologies give operators an increased situational awareness.**
		    o **Advanced detection, diagnosis and autonomous corrective action technologies in place.**
		
		Rating = 3.5

6.2 Identified Gaps by Principal Characteristic

Each of the seven principal characteristics were analyzed to identify the gap between its current state and its probable future state, as well as to identify the actions required to close that gap. The results of these analyses are discussed below:

6.2.1 Enables Active Consumer Participation

Current State: West Virginia's consumer involvement with the electric grid is today very limited. There are no retail markets for electricity, few policies or incentives to encourage consumer participation, and a general lack of consumer awareness or understanding of the nature and benefits of smart grid technologies. In West Virginia today there is widespread deployment of AMR meters and this process is continuing to take place. But neither smart meters nor the communications infrastructure needed to leverage smart grid technologies have been deployed. Some pilot projects are planned in WV to deploy smart meters capable of two-way communication; however, they will only be done on a local and limited basis.

WV rate structures are conventional and straight forward. Rates are differentiated by customer or usage type but there is very little in the way of time-of-use or dynamic rates. Energy usage information is provided as part of the customer's monthly bill, along with a monthly charge based on fixed prices; no real-time pricing or hourly consumption information is made available.

Consistent with the lack of infrastructure, inadequate or non-existent regulatory policies, and very little consumer awareness, there are no demand response programs, and little or no distributed generation or home area networks deployed in the state. Only a rudimentary net metering rate structure is in place, for customer generation rated up to 25 kilowatts (kW) if that generation utilizes photovoltaics (PV), wind, biomass, landfill gas, hydropower or fuel cells.

Probable Future State: The desired situation, ten years from now, is quite different. This future state of consumer participation in West Virginia will be an active one, in which consumers interact with electricity markets, employing new smart grid technologies and programs. Consumer education initiatives that help customers understand the value and opportunities the Smart Grid provides will have been highly effective. Widespread deployment of consumer-enabling AMI and an associated integrated communications infrastructure will have occurred. Lessons learned in past pilot projects will have helped shape smart grid technology development and application deployments, as well as demonstrating economic and technical feasibility to policy makers. The future rate structure in WV will include time-of- use rates and dynamic pricing that is based on the current wholesale price of energy and capacity. Sensible net metering rate structures and supportive policies will be in place to drive demand response programs and the ownership of newly effective distributed generation and storage resources. Most customers will know their energy usage and pricing options on a real-time basis. Incentives and consumer price-awareness will stimulate customer's use of energy efficient appliances, distributed energy resources, home area networks, plug-in hybrid electric vehicles and other advanced technologies and applications.

Functionality Needed:

- Consumers have access to new information, control and options to engage in electricity markets
    - Energy management
    - Investment in DER and PHEV
    - Offer resources to market
- Grid operators have new resource options
    - Reduce peak load and prices
    - Improve grid reliability
- E-bay level of activity (e.g. millions of transactions per day)

Technology Gap:

Active consumer participation requires real-time linkages with service providers and other market participants. This will require the appropriate communications infrastructure, new IT applications and processes and smart metering devices to measure key parameters and provide or support an interface for consumer interaction. In addition, demand response technology is needed as the basic mechanism for consumers to react to pricing signals. This includes home area networks that make it easy for consumers to respond to changing prices by simply entering the appropriate settings (i.e. their consumption/price sensitivity pattern) into a programmable agent.

Expanded participation will be further enabled when the consumer has the added ability to store, generate and deliver his own electric energy. Thus, economical, user friendly energy storage and distributed generation technologies will be needed (PHEVs represent the most obvious and promising opportunity to do this). And a grid that can accommodate these many new sources - one that enables both two-way communication and two-way power flows - will also be required, as described elsewhere in this report.

In addition, programs that can predict consumer response to price signals (elasticity of electrical supply and demand) will be needed. RTOs will need to learn how to use this tool as one more way to achieve the required continuous energy balance. These new tools will have a valuable role in complementing the variable nature of increasing amounts of centralized renewable generation.

Regulatory Gap:

At a minimum, regulators will have to allow utilities to earn a fair return on investments that enable consumer participation. These investments include replacing (with allowed write offs, cost recovery, depreciation, securitization, etc) functional traditional ("dumb") meters with smart meters that can talk to consumers and service providers. It also includes installing an appropriate two-way communications platform that supports two-way power flow and can convey pricing information whenever and wherever needed to support consumer energy management strategies. Investments include modernization of IT systems that can process supply and demand information, develop appropriate price points, convey pricing information to all market participants and collect energy and demand information to support a more sophisticated market clearing and billing process. Of course, rate structures that allow for greater consumer risk and reward are fundamental to this paradigm and will have to be available.

Beyond simply approving utility requests for such investments, regulators can accelerate this transition by encouraging desired behavior. This can be done by offering incentive rates of return and by making it clear that this is the preferred direction that must be considered ahead of more traditional approaches.

An even more proactive regulatory stance would be to eliminate the disincentives in the present regulatory model. Decoupling profitability from increased energy sales volume would be one such step.

These are progressively difficult challenges to traditional utility regulation that will require a new mind set and bold action. Those regulators who understand the resultant full set of benefits to all of society (not just to the utility) will be most willing to take these steps.

Consumer Gap:

Today's consumer has little understanding of power system economics or technologies. Consumers know the lights come on when a switch is flipped, but not why that happens, what it costs, how it affects the environment, or how they could influence any of these areas. As energy costs rise, as environmental concerns grow, and as finances become tighter, consumers will want a greater say in these matters. Their receptivity to, or even demand for, tools and information that help them manage this vital product will increase. These are the kinds of tools that a new computer-savvy generation wants and expects. Yet, left to its own, this shifting consumer attitude will likely be too slow to drive the desired ten year transformation. Hence extensive consumer education regarding how their participation with the Smart Grid can provide many opportunities to address these issues is needed. A full understanding of the benefits of Consumer Participation, as well as how the other six principal characteristics of a Smart Grid will support consumer interaction, is needed to create a public outcry for change.

Gap Closing Solutions:

- AMI, DR, HANs, Consumer Agents
- Integrated communications
- IT integration
- DER
- Two way distribution circuits
- Inclusion of related investments in rate base*
- Recovery of smart grid-driven early write-offs
- Supportive rate structures
- Consumer education regarding the role they can play

* Note: these investments typically support multiple principal characteristics

RD&D Needs:

- Econometric models of consumer response to prices
- Coordination with intermittent central generation

- Decoupled rate design

6.2.2 Accommodates All Generation and Storage Options

Current State: The electric infrastructure in WV does not currently accommodate all generation and storage options. In WV today there are back-up generators at hospitals and other critical facilities but they are not used in a grid-connected mode. There are minimal numbers of CHP facilities, very little distributed generation (and what does exist is located only at major industrial sites- not at residential customers), and virtually no demand response programs. The transmission system was designed and built to deliver power that is generated at large centrally-dispatched coal plants, with no consideration of distributed resources.

The distribution system was not designed to accommodate two-way power flow. Conductors, insulators, and circuit breakers are not adequate for wide penetration of DER and the protection systems were not designed with DER in mind. In addition, there are no communications or control systems in place to allow effective control, dispatch, or even just monitoring of DER.

Interconnection standards were designed primarily for large central power plants or small back-up generators. There has been no concerted effort to establish a standard that considers the widespread connection to the grid of customer-owned distributed generation and storage technologies. While there are newly established net metering rules in WV, they are only for limited size generation (no greater than 25 kW) using a renewable fuel source. And these rules only allow generation owners to earn credits towards their bill; they do not allow for any payments to the generation owner.

While there is a pilot project underway that will incorporate demand response and demonstrate the benefits of using various types of distributed generators and storage technologies, it will take widespread changes to make these deployments possible on a larger scale.

Probable Future State: The future state of generation and storage in WV will involve a mix of large centrally dispatched power plants and distributed generation and storage technologies, all being intelligently dispatched to optimize the available grid assets, mitigate congestion, and maximize the economic benefits of the different resources. There will be wide deployment of distributed resources across the state, tariffs and connection standards to encourage this deployment and a sufficiently re-designed electric infrastructure to support and control these new resources.

New tariffs will encourage the installation of distributed resources for the mutual benefit of grid operators and grid users. New regulations will remove dis-incentives to consumer-owned generators including insurance requirements, small-scale applications, etc. Interconnection standards will allow for a wide range of different technologies and interconnections while maintaining system security and net metering rules will make DER economically viable.

The distribution grid will accommodate and control the two way flow of power. The protection system will monitor and, if necessary, interrupt power that can be flowing in two directions. Advanced sensing and measurement technologies will be deployed and integrated into new applications. Distribution automation technologies will be used to dynamically reconfigure the system to minimize interruptions to all connected resources and loads. Distribution Automation

(DA) will allow the creation and control of advanced micro grids utilizing DER and new control algorithms to connect and disconnect from the grid without loss of service to connected load.

Smart meters, smart sensors, and the communications networks necessary to aggregate and transmit information back and forth across the grid will enable advanced applications that can monitor, coordinate, control, and even dispatch distributed resources and integrate these with energy efficiency or demand response programs to provide a comprehensive means to serve the load in the most efficient and economically sensible manner.

Functionality Needed:

- Distribution circuits that accommodate two-way power flow.
- Seamless integration of DER of all sorts, particularly at the distribution level.
- Coordinated operation of all central generation, distributed generation, distributed storage and demand response.
- Application of distribution DER to also support transmission operation

Technology Gap:

Fundamental to this principal characteristic is the ability of distribution circuits to support two-way power flow. Since most distribution circuits are of a radial design, they assume power will only flow from the substation to the loads. New protection and control schemes will be needed to make two-way power flow capability a reality. Both protection and control schemes will require secure communications among the various distributed devices located along the circuit -- devices that will often be widely separated. Additional switching devices, as part of expanded distribution automation (DA) programs, will also be needed to enable circuit reconfiguration and the islanding of DER, providing the ability to serve load that is dynamically matched to the island's available power supply.

Optimal operation of a new mix of storage and distributed generation devices will require advanced algorithms for coordination between devices as well as with circuit loading capacity and patterns. Communications from control points to control centers will be needed to enable this coordination. Modification of loading patterns in real time will need to be accomplished through demand response tools. In addition, the variability of some central generation sources, such as wind and solar farms, will need to be partially offset through control algorithms that continuously modulate distributed energy resources as well as DR.

Storage devices will come in a variety of types and sizes, ranging from hundreds of megawatts installed at power stations to tens of kilowatts installed at customer sites, possibly in the form of PHEVs. These new storage and generation technologies require additional development. Improved DER to grid interfaces, employing power electronics technology that is more efficient, less expensive, more flexible and longer-lived, will be needed to enhance the economics and accelerate the penetration of a more distributed energy model.

The interconnection and coordinated operation of this new assortment of grid connected devices will require the creation of new technical and operational standards that recognize the inherent potential of DER as well as the grid’s ability to accommodate it. At meaningful levels of penetration, DER resources spread across the distribution infrastructure can become a significant transmission resource, providing improved voltage control and reduced congestion of the high voltage system. New business entities that aggregate the assortment of distributed devices, and offer an integrated set of products to RTOs and others, will then emerge.

Regulatory Gap:

At a minimum, regulators need to allow utilities to earn a fair return on investments that let the grid accommodate all generation and storage options. These investments include replacing functional "dumb" meters with smart meters that can accommodate demand response. They also include installing an appropriate communications platform that can enable a two way distribution grid and can convey pricing information so consumers can participate in new storage and generation markets. And they include modernization of IT systems that support the reliable and economic operation of a distributed energy model.

Of course, rate structures that embody greater consumer risk and reward are fundamental to this paradigm. Net metering rules for all sizes and types of generation or storage should be established. Owners of such facilities should be allowed to receive payments, not just credits, for electricity fed into the grid. These are the kinds of regulatory actions that will encourage broad deployment of DER. Regulators should also promote the development of interconnection standards that address the widespread connection of customer-owned distributed generation and storage technologies.

Beyond simply approving utility requests for related investments, regulators can accelerate progress by encouraging desired behavior. This can be done by offering incentive rates of return and by making it clear that there is a preferred direction to be considered ahead of more traditional approaches. Incentives can also encourage early adoption and improved cost competitiveness of new DER technologies. Formulation of appropriate programs can be done effectively at the federal level, without preempting additional incentives that individual states may introduce to spur renewable resources.

These are progressively difficult challenges to traditional utility regulation that will require a new mind set and bold action. Those regulators who recognize the resultant full set of benefits to all of society (not just to the utility) will be most willing to take these steps. Their business case, done from a societal perspective, explicitly evaluates externalities such as cleaner air benefits, enhanced national security, job creation, and other factors of interest. These considerations also help formulate related issues such as tariffs, reliability, distribution company obligations as a provider of last resort, and liability considerations.

Consumer Gap:

Today's consumer has little to no understanding of power system economics, operations or technology. As energy costs rise, as environmental concerns grow, and as finances become tighter, consumers will want a greater say, and some will want to participate actively, in the emerging market opportunities created by DER. Their receptivity to, or even demand for, tools and information that help them navigate these new waters will grow.

Consumers' interest will be further stimulated as they become increasingly aware of emerging technologies, such as PHEVs and HANs, that can provide them with economic and life style benefits. Hence extensive consumer education programs regarding this, as well as the other six principal characteristics of a smart grid will be needed to create a public desire for change.

Gap Closing Solutions:

- Secure communications between distributed DER devices
- DA to allow DER switching and control
- AMI to support DR coordination with DER
- HANs to facilitate consumer participation
- Distribution circuit upgrades for two-way flow
- Inclusion of related investments in rate base
- Tariffs that support consumer participation in DER and DR
- DER interconnect standards
- Regulator buy-in and encouragement
- Federal and state funding of related R&D
- Consideration of decoupling
- Decisions based on societal business case
- Consumer education

RD&D Needs:

- DER enhancements
- DER dispatch algorithms
- Distribution circuits that accommodate two-way power flow
- Tariff design
- Marriage of intermittent generation with storage and DR
- Dynamic islanding

6.2.3 Optimizes Assets and Operates Efficiently

Current State: In West Virginia today there is very little capability to maximize asset optimization or realize the potential operational efficiencies that can be obtained with a smart grid. There are few, if any, power quality, temperature, weather, or asset health monitors deployed in the system. SCADA is not fully deployed in the distribution system and where SCADA is deployed its full functionality is not always used. In many cases only alarm conditions and equipment status is passed to the control center from the station. This lack of adequate sensor deployment and monitoring capability limits information available to operators, planners, engineers, and maintenance personnel. Both major WV utilities have a GIS system but it is not well integrated with other planning, operation, or customer service applications and processes. Since there is no distribution or substation automation deployed, grid operations and control is a centralized process. Operators in these centralized control rooms lack enough system data, visualization tools, modeling or simulation tools to optimize the system and maximize equipment capabilities. Outage management processes are not automated and still rely on customer calls to initiate action, and operators in centralized control centers to coordinate action among various parties. Outage causes must still be determined primarily by field personnel. No dynamic ratings are currently being used and the monitoring and sensing capability does not exist to implement dynamic ratings. Time-based maintenance is predominant, with maintenance schedules determined primarily by manufacture recommendations, prior history of performance and equipment mis-operation. Equipment condition is determined by physical inspection and localized trouble shooting since no intelligent sensor systems exist to monitor equipment.

Probable Future State: In the future, assets deployed in the electric grid in West Virginia will be utilized efficiently and to their utmost capability. This ability to optimize asset usage will be achieved through the use of intelligent, autonomous and distributed processes and technologies that allow for automatic and de-centralized control actions and a comprehensive and proactive maintenance program that allows problems to be addressed before failures occur on the system. There will be widespread deployment of power quality, temperature, weather, or asset health monitors in the system. SCADA will be fully deployed in the distribution system and incorporated into substation automation processes. Large amounts of new data from sensor deployment and monitoring capability will be transformed to information that feeds GIS and other enterprise-wide processes.

This new wealth of information will be incorporated into advanced visualization tools and simulation programs to allow operators, planners, engineers, and maintenance personnel to make better decisions. These advanced and integrated applications will create the potential for studying "what-if" scenarios on the distribution system, predicting potential outages or equipment failures, or responding to real-time system conditions in the most appropriate fashion. Dynamic ratings will be used to allow equipment to be operated according to real-time conditions. As a result, assets will be used in an efficient manner, both by increasing capacity and by preventing undue wear and tear. Condition-based maintenance will be predominant, with maintenance schedules determined by advanced analytic tools that monitor inputs from equipment sensors, track historic trends, perform risk analysis, and determine potential system impacts from failure. Smart meters will be used to provide power quality and equipment condition information, as well as reducing energy theft. Distributed energy resources will be deployed and intelligently used by utilities to maximize asset utilization.

Functionality Needed:

- Operational improvements
  - Improved load factors and lower system losses
  - Improved PQ
  - Integrated outage management
  - Risk assessment
- Asset Management improvements
  - The knowledge to build only what is needed
  - Improved maintenance processes
  - Improved resource management processes
  - More power through existing assets
- Reduction in utility costs (O&M and Capital)

Technology Gap:

The deep penetration of intelligent electronic sensors, the ability to control critical assets (including broadly-deployed DER), the integration of communication systems that connect these assets and the advanced algorithms that analyze and diagnose their condition will all be needed for this characteristic to be achieved. Optimal grid management implies a deep knowledge of its state at all times. This will need to be provided by AMI, equipment health sensors, and a communications infrastructure that delivers information to the right place at the right time. IT tools will be needed to distribute, process and integrate this information with the various systems that contribute to overall optimization. Decisions made through this process will determine the best way to actuate everything from condition-based maintenance to power flow redistribution, to load shaping by DR and DER, to adaptive setting of protective relays. These and many other areas will need to be optimized through the measurement, analysis, integration and actuation of the many options made possible by a smart grid.

More specifically, eight areas of optimization will require technological advances:

Asset utilization – Advanced distribution management and enhanced transmission flow control will be needed to give grid operators the information and control needed to optimally load assets. Improved power quality (discussed elsewhere in this report) will also be needed to extend equipment life by reducing damaging surges and heat-producing harmonics.

System losses and congestion – Widespread deployment of distributed generation and storage, combined with new market products and an enabled consumer (all discussed elsewhere in this report) will be needed to give grid operators additional ways to reduce electrical losses and congestion. In addition, improved reactive power management will be needed for transmission lines to operate at or near unity power factor, thereby reducing losses associated with reactive power flow.

Capacity planning – AMI will be needed to provide complete, historical, time-stamped information, leading to a more accurate projection of future peak loads, overloads and voltage constraints. The result will be more effective solutions and a more accurate timeframe on when solutions will be needed. New tools like fault current limiters will also be needed to extend the useful life of circuit breakers and other power system equipment. And the new role of DR and DER will need to be factored into all system planning studies.

Maintenance programs – Asset condition information will be needed, as will new condition-based maintenance programs that can predict when failures are likely to occur. Using these tools, the lifetimes of critical assets will be extended and the costs, dangers and inconveniences will be reduced.

Outage management – Advanced outage management systems (OMS) will be needed to minimize the time to detect, locate and diagnose outages, allowing system dispatchers to focus on marshalling the resources needed to correct the problem and restore service more quickly. AMI will be needed to provide the real-time outage information required by OMS and distribution automation (DA) will be needed to allow the most rapid restoration of service. The role of DER will also need to be addressed, from both a safety perspective and from its ability to reduce outage size and duration.

Engineering, customer service, and work management – Operating and asset condition information will be needed to improve design standards and to give customer service staffs the information they need to better satisfy customers. Access to the distribution communication system and its interface with geographical information systems (GIS) will also be needed to enable a more efficient mobile work force management program.

Modeling and simulation – Operating and asset condition information coupled with new modeling and simulation tools will be needed to allow both distribution and transmission operators to better manage risk. New monitoring tools such as wide area monitoring systems (WAMS) using phasor measurements will be needed to allow operators to anticipate emerging problems and take corrective actions.

Asset power density – Advanced materials, such as HTS cable, will be needed to allow higher capacity ratings. New intelligent electronic sensors and communication methods will be needed to support accurate dynamic ratings for transmission lines and other assets.

In summary, the broad areas of technology required to optimize assets and operate efficiently are:

- Deep penetration of intelligent electronic sensors that measure both operating and asset condition parameters. These sensors must be capable of monitoring at the consumer level (e.g. smart meters), distribution level and transmission level (e.g. phasor measurement units).
- Switching devices and systems that can be controlled by grid operators. Intelligent controls that enable automatic grid reconfiguration will also be needed to address rapidly-changing events.
- An integrated communication system to communicate the needed information to the users and systems responsible for optimizing the operation and management of the assets. These communication systems should also be interoperable with other enterprise wide processes such as GIS, mobile work force management, engineering and records management.
- Process integration among all applicable users and systems to allow operating and asset condition information to be leveraged. In particular, an interface with the RTO will be needed to ensure that the optimization of operations and asset management is not limited to the distribution system.
- Advanced applications and algorithms that take advantage of the vast increase in new information and control options. Real-time dynamic rating applications, condition-based maintenance applications, advanced protection and control systems (particularly as related to the broad application of DER) and more sophisticated modeling and simulation tools are examples that can greatly enhance efficiency and reduce operating risks. Tools to help operators assimilate all this new information will also be required.

Regulatory Gap:

At a minimum, regulators will need to allow utilities to earn a fair return on investments that optimize assets and operate efficiently. And they include modernization of IT systems that support the reliable and economic operation of a distributed energy model.

Beyond simply approving utility requests for related investments, regulators can accelerate progress by encouraging desired behavior. This can be done by offering incentive rates of return and by making it clear that there is a preferred direction to be considered ahead of more traditional approaches. Incentives can also encourage early adoption and improved cost competitiveness of new technologies.

Consumer Gap:

Smart Grid investments that enable grid operators to improve asset utilization and operate more efficiently will also help lower future capital costs and O&M expenses. Operating more fiscally efficient through the use of such Smart Grid investments will keep downward pressure on future electricity prices, a potentially significant benefit to consumers and society. Consumer education that provides this understanding is needed to create a public desire for change.

Gap Closing Solutions:

- Integrated communications platform
- Deep penetration of sensors, WAMS and AMI
- Optimization and control (voltage and flow) algorithms
- DER and DR deployment
- DA
- Back office IT system integration
- Simulation tools
- Inclusion of related investments in rate base
- Consumer education regarding the role they can play

R&D Needs:

- Equipment health sensors and diagnostics
- Current limiting devices
- HTS cable
- Visualization tools

6.2.4 Anticipates and Responds to Disturbances

Current State: The electrical grid in WV today does not have the capability to anticipate disturbances and respond to them in a truly dynamic or autonomous way. The distribution system protection equipment is generally restricted to electromechanical relays and reclosers, there is almost no distribution substation automation, no dynamic feeder reconfiguration, no intelligent sensors or monitoring devices, and less than 50% of distribution substations have SCADA. While the transmission system is more advanced and has a greater ability to respond to disturbances, it also lacks the intelligent devices, sensors and controls necessary to allow the system to autonomously react and reconfigure itself in response to current or anticipated problems. In addition, there is a lack of health monitoring sensors to predict impending equipment failures, and an absence of proactive maintenance strategies to repair or replace equipment that is near failure.

Probable Future State: In the future the electrical grid in WV will be much more advanced than it is today. It will be proactive rather than reactive and will be better able to detect, analyze and respond to disturbances. Advanced health sensors will be placed in the field or incorporated into grid components and health monitoring equipment will be used to track and aggregate sensor data. There will be a proactive maintenance strategy that incorporates health sensor data, advanced methods of equipment health assessment, and risk analysis. This will allow system operators to determine where and when equipment is likely to fail, analyze potential impacts, and repair or replace equipment to prevent unexpected outages or failures. The electromechanical relays and reclosers that make up the protection system will be upgraded with electronic reclosers and adaptive relays. Distribution automation and dynamic feeder reconfiguration technologies will be used to respond to disturbances and adjust the system to minimize interruptions. A Wide Area Measurement System (WAMS) utilizing Phasor Measurement Units and other advanced sensor technologies will be deployed on the transmission grid for early detection of stability problems, voltage depressions, or potential cascading outages. Demand side and distributed resources will be integrated with advanced distribution technologies and incorporated into the broader system level control strategy that will utilize transmission and distribution level resources to operate the entire Grid reliably. Finally, system operators will have access to cutting edge applications and visualization tools to help them turn data into information and information into intelligent operating decisions.

Functionality Needed:

- Perform continuous self-assessments
- Detect, analyze, respond to, and restore grid components or network sections
- Handles problem too large or too fast-moving for human intervention
- Self heal - act as the grid’s “immune system”
- Support grid reliability, security, and power quality

Technology Gap:

This principal characteristic, frequently referred to as self-healing, represents the grid's immune system. It detects any threat to grid health (requires AMI and advanced sensors), analyzes how best to address that threat (requires IT systems integrated across multiple functions and offering advanced visualization), initiates timely actions (requires DA, DER, DR, flow control, grid friendly appliances and digital protection and control) to remove or mitigate the threat, and failing that, provides for the fastest possible recovery (requires DA) from any residual effects. This is the most challenging PC and the one that has been integral to the grid from its inception. Powerful communications, monitoring, IT analysis, operator visualization aides, and protection and control methods will be needed to help self-healing evolve to new levels. And while these silicon-based tools will offer huge enhancements, it will also be necessary to have adequate conventional copper and steel capacity to complement them.

Achieving the self-healing characteristic, at both transmission and distribution grid levels, will require integration of advanced capabilities in the following areas:

Look ahead features – Analytical computer programs, using accurate and near real-time state estimation results, will be needed to identify challenges to the system, both actual and predicted, and take immediate automatic corrective action. These algorithms will also need to provide options for system operators to take manual action in evolving situations where time allows. Probabilistic risk assessment, done in near real time, will be needed to identify threats to the system associated with a wide range of contingencies.

Monitoring features – Command and control centers, at the regional level for transmission operations and at local levels for distribution operations, will need to serve as hubs for the new self-healing technologies. State estimators, that utilize advanced sensing and data acquisition methods and more powerful computers, will be needed to evaluate problems within seconds. Advances in communication technology will be needed, along with many new, low-cost smart sensors, providing a significantly larger volume of various types of data, such as wide-area phasor measurements and dynamic line rating information. This dramatic increase in real-time data will, in turn, create a need for advanced visualization techniques that consolidate and present information in easily understood formats, giving system operators an accurate picture of the power delivery system's health. New tools will also be needed for analyzing equipment health parameters, including high frequency signatures, acoustic emissions and gas evolution patterns. These condition-monitoring technologies will provide additional perspectives on the risk of potential equipment failures.

Protection and control features – Advanced relaying will be needed that can adapt to real-time grid conditions. High-speed communications between digital devices will need to go beyond single element protection, enabling area and even regional protection. High-speed switching, throttling, modulating, and fault-limiting power electronics devices will be required to dynamically alter grid patterns, including faster isolation and sectionalizing as well as rapid control of real and reactive power flows, in response to changing system conditions. And, intelligent control devices, such as grid friendly appliances, will be needed to modulate load accordingly.

Distributed technology features – Transformation of the distribution system from a one-way, radial design to an intelligent two-way network (as described elsewhere in this report- -through the addition of more circuit-to-circuit ties and the application of advanced communication, control, and protection technology) will be required to achieve a self-healing distribution grid. Distributed generation and energy storage technologies will then need to be broadly deployed on that grid, and dispatched to help meet system-wide needs. The deep penetration of Plug-in Hybrid Electric Vehicles (PHEVs) will be needed to enhance both self-healing and environmental efforts. DR programs will need to be widely expanded to assist in the coordinated management of local and system overloads, peaks, and voltage problems. DA will need to be further expanded and integrated with widespread DER/DR programs, as well as in conjunction with new operating tools and micro-grids to enable successful dynamic islanding.

Many of these needs are also requirements of other principal characteristics. In summary, specific areas that will need to be more fully developed and deployed include:

- Integrated high-speed communications platforms.
- Intelligent electronic devices (both front end sensors and back end control devices)
- Distribution automation schemes to provide distribution level self-healing capabilities, to accommodate all forms of DER and to act as an asset to the transmission system.
- Cost-effective environmentally acceptable DER, including energy storage devices capable of coexisting among residential populations.
- DR systems using real-time pricing.

These advances in technology, taken together, will be needed to create a sophisticated self-healing capability that will dramatically improve overall reliability, efficiency, safety, and security.

Regulatory Gap:

The business case for a self-healing grid is good, particularly if it includes societal benefits. But, regulators will need to be convinced that these harder-to-quantify benefits will materialize, and be valued by the public, before they will authorize major investments. And, even if they do, the industry may not have the financial capacity to fund these new technologies and will need the aid of government incentives.

Early retirement of equipment may be another regulatory issue. Some older functional equipment will need to be replaced, if it is incompatible with the requirements of self-healing. This may present a problem for utilities and regulators since keeping equipment through, and even beyond, its depreciated life minimizes capital costs to consumers. Regulators will need to accept this new requirement.

Net metering rules for all sizes and types of generation or storage should be established. Owners of such facilities should be allowed to receive payments, not just credits, for electricity fed into the grid. These are the kinds of regulatory actions that will encourage broad deployment of the DER which contribute substantially to the self-healing feature of a smart grid. Regulators should also promote the development of interconnection standards that address the widespread connection of customer-owned distributed generation and storage technologies.

Consumer Gap:

Consumers' interest will be further stimulated as they become increasingly aware of the value of a self-healing grid in terms of significantly improving grid robustness and reliability. Consumer education programs demonstrating how the investment in a modern self-healing grid will produce benefits beyond just keeping the lights on will be needed. Consumers who understand and support this concept can press regulators to approve the associated investments in the grid.

Gap Closing Solutions:

- AMI, WAMS
- DER,DA,DR
- Two-way distribution circuits
- IT integration
- Operator decision-support tools

- FACTS, Grid Friendly Appliances
- Integrated Wide Band Communications Platform
- T&D KVA capacity to accommodate contingencies
- Inclusion of related investments in rate base*
- Recovery of security-driven early write-offs
- Supportive rate structures
- Consumer education regarding the role they can play

* Note: these investments typically support multiple principal characteristics

R&D Needs:

- Advanced digital protection and control
- Contingency analysis based on expanded real time data availability
- Advanced visualization programs
- Advanced equipment health sensors
- Fault current limiters

6.2.5 Enables New Products, Services and Markets

Current State: The current state of markets and services for grid related products in WV is quite limited, providing access to only large wholesale market participants such as utilities and merchant power plants. While these wholesale markets are fairly robust, retail markets are non-existent. Since the smart technologies and enabling regulatory policies are not in place in WV, consumers have no real-time information or interaction with the system and have few choices as to electricity suppliers, differentiated service levels, or use of grid-connected devices. Since consumers cannot interact with their local utility, they are cut-off from participation in the larger regional, wholesale or ancillary services markets.

WV is currently a large exporter of electricity to metropolitan load centers on the eastern seaboard from Virginia to New York. Growing regional congestion may prevent the export of this excess generation.

Probable Future State: A statewide AMI deployment will provide consumers with smart interactive meters and a high-speed, two-way communications infrastructure. These technologies, combined with regulatory policies that define rules and provide incentives for retail markets, will give consumers the opportunity to see and act upon real-time prices and other grid related information. This information will provide consumers the knowledge to make intelligent investment decisions regarding energy efficiency, demand response, advanced end-use devices, and distributed generation.

Expanded retail markets and wider market interaction with RTOs will give consumers new opportunities to become active market participants. Increased awareness and participation by consumers will lead to the wide deployment of home area networks, home energy management systems, and consumer owned distributed generation and storage devices. Enhancing consumers' ability to easily interact with the grid and providing more and better energy management options will be realized.

Advanced transmission applications, such as dynamic line ratings, flow control, and advanced digital protection, will help mitigate transmission congestion, as will the addition of new lines where necessary. Integration of DER and demand response as dispatchable resources will enable peak load reduction and provide additional congestion relief, virtually eliminating congestion as an issue.

Functionality Needed:

- Links buyers and sellers
- Consumer to RTO
- Supports the creation of new electricity markets
- PHEV and vehicle to grid
- Brokers, integrators, aggregators, etc.
- New commercial goods and services
- Provides for consistent market operation across regions

Technology Gap:

Markets in the future will need to integrate many diverse technologies and control functions, including the following:

- Seamless integration into various markets of all generating unit sizes (from 10kw to 1,300MW)
- Various forms of consumer decision software to aid participation in markets
- Intelligent control of loads, enabling new demand-response (DR) markets

One of the best ways to expand markets is to facilitate the transfer of product (typically MWHs) from sellers to buyers. This will require a power transmission and distribution delivery system that is both uncongested and has room for increasing transactions. A variety of new technologies will be needed to enhance the existing power delivery system's ability to do this, while new lines will have to be added when existing capacity is fully consumed. Included in the new technology category are FACTS devices to better control real power flow patterns, reduce reactive power flows and support voltage to prevent collapse, and new control and protection systems that include phasor measurement systems and dynamic rating of transmission lines to allow optimal line loading.

At the distribution level, DER/DR will be needed to provide voltage support and increase available transmission capacity by reducing peaks and serving more internal load from local sources. A distribution grid that can accommodate many new devices - one that enables both two-way communication and two-way power flows - will also be required, as described elsewhere in this report. Integration of these features requires a robust communications platform combined with new IT tools that include advanced operator visualization aides. These improvements free-up capacity that can then be applied to marketplace transactions.

Given the ability to readily transfer products between buyers and sellers, the development of new markets needs real-time linkages between all market participants, including RTOs, aggregators and the vast numbers of participating consumers. This requires standardizing the communication of market information through equipment, software processes and protocols. Any consumer should have information access through non-proprietary equipment. An appropriate secure, communications infrastructure will be needed, as will new IT applications, AMI, DR and other processes that support market interactions. New market elements can then be built on this foundation, including:

- Expansion of the ancillary services market offerings
- Introduction of renewables, carbon trading, and other specialty markets
- Inclusion of DER market operations and other consumer-rich markets at the wholesale and retail levels.

Given the ability to readily transfer products, along with new markets that accommodate their application, many new products will need to (and most naturally will) arise from the growing ability at all levels to store, generate and modify consumption of electric energy. New load management tools as well as economical, user-friendly energy storage and distributed generation technologies (PHEVs represent the most obvious and promising opportunity) will have to be part of this evolution. This includes home area networks that make it easy for consumers to respond to changing prices by simply entering the appropriate settings (i.e. their consumption/price sensitivity pattern) into a programmable agent.

In addition, programs that can predict consumer response to price signals (elasticity of electrical supply and demand) will be needed. RTOs will have to learn how to use these new market tools, which will then have a valuable role in complementing the intermittent nature of more and more centralized renewable generation (often from independent power producers), as yet another way to achieve the required continuous energy balance of a power system.

Regulatory Gap:

Today, FERC regulates interstate wholesale markets and state and local agencies regulate retail markets. For the Smart Grid to provide seamlessly integrated markets, it must include interstate wholesale markets, regionally-based retail markets, and a new intermediate market that joins them at the distribution level. Both federal and state regulations will be required to support full-scale integrated markets to fulfill the needs of all consumers. The regulators of low energy cost states may be reluctant to have their low cost energy sent out of state to the detriment of their consumers. The regulators of high energy cost states may feel pressure to keep out low cost energy providers. Yet both will need to support the electricity market’s development while insuring independent monitoring and review to assure fairness and reliability of the grid.

Market participants must be reasonably certain their investment will be profitable, given the large commitment needed to set up, operate, and monitor the market.

Regulators will need to modify existing and create new policies and regulations that remove economic and political barriers to integrated markets, while incentivizing capital investment. It will take a systems view and, most likely, federal directives to align policies toward integrated markets that benefit all consumers. Regulators who wish to have access to competitive markets to lower prices, may still be reluctant to authorize investments that spread benefits outside their regulatory jurisdiction. Options for resolution include cost sharing, benefit sharing or some combination of the two.

Consumer Gap:

The stage is set for a win-win scenario in which the consumer takes a more active role, joins with other consumers into coalitions and sells products in the marketplace at a fair price.

Access by all consumers, wholesale and retail, to the electrical market will be needed to expand commerce for future services and products that support their needs for lower cost energy. Providing widespread market education to all stakeholders, especially distribution level consumers, is necessary to draw this critical mass of participants into the market. An educated consumer is required to effectively operate in any market.

Gap Closing Solutions:

- AMI, DR, HANs, Consumer Agents
- Integrated communications
- Standardized transfer of market information
- IT integration
- DER that is plug and play
- Two way distribution circuits
- Inclusion of related investments in rate base*
- Recovery of early write-offs
- Supportive rate structures
- Cooperation between state regulators and with federal regulators to support seamlessly integrated markets
- Consumer education regarding the role they can play
- Access by all consumers, wholesale and retail, to the electrical market

* Note: these investments typically support multiple principal characteristics

R&D Needs:

- Advanced digital protection and control
- Econometric models of consumer response to prices
- Decoupled rate design

6.2.6 Provides Power Quality for 21st Century Needs

Current State: In WV today, utilities are trying to understand and deal with power quality issues, but the current state of field-deployed equipment in WV does not allow any proactive response to these issues. Due to the lack of advanced sensors, intelligent devices, and data aggregation and integration, the only real response to PQ problems is to respond to customer complaints of power quality problems. Generally PQ complaints require physical inspection and can be costly. No “early warning system” or automated system of detection exists. There are a few PQ monitors deployed in the state of WV that are being used to try and benchmark system power quality events but there are not enough sensors to provide widespread coverage. Another issue is the lack of a well-defined and widely accepted standard for power quality or the availability of rate structures that offer differentiated levels of power quality at different prices.

Probable Future State: The future state of Power Quality (PQ) in WV will be much different than it is today. Rather than reacting to power quality problems or customer complaints there will be a proactive system-wide response to power quality issues. Utilities will install power quality monitoring systems, track performance trends, and develop metrics and applications to help detect, analyze, diagnose, and even predict power quality problems. Standards will be developed to define the minimally acceptable PQ for all customers and price-differentiated Power Quality levels will be offered that are consistent with different consumer needs. The quality of delivered power will be part of the long term planning and system design processes.

Advanced technologies will be deployed on the transmission system and the distribution system, especially near sensitive loads, to both mitigate power quality events in the power delivery system and protect end users' sensitive electronic equipment. At the transmission level, FACTS devices and other power semiconductor devices will be installed to mitigate voltage sags and other momentary power disturbances. On the distribution system, similar advanced power electronic devices will be used to mitigate problems, while advanced sensors, smart meters, and ubiquitous communications will be used to detect, identify, and track disturbances and provide input for advanced power quality diagnostic applications. Distributed generation and storage will be used along with advanced controls to provide local and clean power to sensitive loads. The combination of intelligent devices, new sensor technologies, distributed energy resources, and dedicated and redundant underground feeders will be used to create premium power parks for customers seeking high quality power.

Functionality Needed:

- Tariffs that offer differing PQ levels for different prices.
- Customer acceptance of different levels of delivered PQ that is priced accordingly.
- Grid designs that provide an acceptable base level of PQ.
- PQ enhancement tools and strategies that enable superior PQ for those willing to pay a premium.

Technology Gap:

A fundamental technical requirement is gaining the ability to measure the quality of power throughout the grid and delivered to end users. AMI, with its smart meters that also measure PQ, will be needed at the customer interface and at selected locations throughout the grid. This will help identify the source of PQ problems and provide timely verification that premium power customers (a concept discussed more fully below) are getting what they pay for. New data processing tools will also be needed to quickly identify likely causes of poor PQ and required corrective actions.

It will also be necessary to mitigate PQ events that originate in the transmission and distribution levels of the power system. Advanced control and monitoring systems will be needed to enable rapid sensing and instantaneous correction of PQ events. Voltage dips that last less than 100 milliseconds can have the same effect on an industrial process as an outage that lasts several minutes or more.

Grid operators will need to treat PQ as a subset of reliability that must be approached with similar diligence, including the establishment of performance metrics. PQ criteria will need to be included in planning and operating procedures. Deployment of appropriate technologies to ensure an acceptable level of PQ will need to be provided to all customers. And a superior level of PQ will need to be made available to those who are willing to pay a premium.

Regulatory Gap:

Today, there is a continuing debate about who should bear the costs of PQ improvement; the utility or the consumer.

The development of PQ minimum standards and premium power quality tariffs will be needed. For those customers who could suffer significant harm due to PQ events, a premium power product can be a good solution for both buyer and seller.

Regulators also need to push for the development of standards that will make loads less vulnerable. This needs to include the monitoring and enforcement of standards that limit the level of harmonics a consumer load is allowed to produce. Standards are needed to help guide the development of power quality tariffs which consumers can choose from according to their needs.

Cost/benefit analyses need to be conducted, taking into account the full range of benefits that improved PQ delivers. Because PQ problems can originate anywhere along the electricity path, regulators may need to become more involved in determining how to allocate costs of PQ solutions.

Consumer Gap:

The power quality solution not only includes grid technologies that improve and maintain power quality, but also those that make customer loads more tolerant of PQ events. Within the customer's facility, advanced devices and techniques, including proper wiring and grounding practices, often offer solutions to PQ-sensitive load problems. Programs to provide PQ education should be developed and broadly publicized. Customers need to be better educated about the PQ issue so their facilities can be designed to accommodate PQ imperfections.

Harmonics caused by customer equipment can cause power quality problems for other utility customers. Customers will need to understand that they can be held accountable for harmonic currents they produce, if those currents interfere with the power system and other customers.

Residential customers also have varying power quality needs, depending on the sophistication of their home electronics. Here, much rests with the vendors of consumer products, which need to be designed to tolerate common PQ events.

Gap Closing Solutions:

- PQ treated by utilities and regulators as equal in importance to reliability, with associated metrics to evaluate performance.

- Extensive PQ monitoring (using AMI and other instrumentation), combined with analytical tools to identify PQ problems and sources.
- Increased availability of more economical PQ enhancing devices, including many that employ power electronics.
- DER that is designed to both deliver energy and contribute to improved PQ.
- Inclusion of related investments in rate base
- Definition of, and education about, minimum acceptable PQ levels and load sensitivity standards.
- Enforcement of rules regarding customer's harmonic pollution of the grid.
- Development of PQ parks for special needs customers.

R&D Needs:

- Development of low cost power electronics.

6.2.7 Operates Resiliently Against Attack and Natural Disaster

Current State: In WV, as in most states today, the electric grid is composed of stressed and aging assets that are vulnerable to cascading problems when subject to natural disasters, critical failures, or deliberate attack. Loads are always at risk due to a system that delivers power from large centralized power generation facilities to consumers over an aging infrastructure that lacks dynamic system re-configuration and distributed resources. Without enough distributed resources and self-healing technologies there will always be single points of failure. Once an outage or other equipment failure occurs it takes a long time to identify the failure and restore service to customers. This is because outages on the distribution system must still be identified by sending crews into the field in response to customer calls.

Probable Future State: In the future, the electrical grid in WV will be planned, designed, and operated in such a way as to be much more resistant to attack and natural disaster. This means that a suite of comprehensive self healing technologies will be widely deployed across the transmission and distribution grids. There will be a wide array of sensors and measurements devices installed to monitor assets and detect system changes or disturbances. Intelligent devices will be in place throughout the system to aggregate and analyze sensor data, troubleshoot or predict potential problems, and even autonomously act to prevent failures, cascades, or loss of load. In the control rooms, data from all these new intelligent devices will be fed into advanced modeling and visualization tools to drive decision support systems or create actionable information for system operators.

There will also be regulatory policies and utility interconnection agreements that support or incent consumer-installed distributed generation and storage technologies. The widespread availability of distributed generation, as well as greatly increased demand response programs will provide alternative and local generation sources, reducing the number of single points of failure, and providing a more robust system. A fully deployed AMI system will increase the ability to operate the system and all its centralized and distributed resources in an effective manner while also improving the entire service restoration process. These smart meters can help to quickly locate and identify outages, problems or equipment failures, improving the utility response and greatly reducing the time to restore service.

Cyber security will be a formal component of all system planning and design considerations. The security and bandwidth requirements will be determined for all smart grid technologies and the interactions between different technologies and applications will be continually monitored and analyzed to maintain system wide protection.

This combination of local sources of power, intelligent and reconfigurable system components, surveillance monitoring of critical assets, as well as adequate and secure communications, will provide a much more robust system that can ride through disturbances, minimize loss of load and system "down time", and operate more resiliently against traumatic system events, whether caused by weather or coordinated attacks.

Functionality Needed:

- System-wide solution to physical and cyber security
- Reduced threat, vulnerability, and consequences
- Deter, detect, mitigate, respond, and restore
- Fortress image
- Decentralization and self-healing enabled

Technology Gap:

Given the Smart Grid's dependency on digital technologies and advanced communication systems, it will be necessary to place heavy emphasis on cyber security, in addition to the more conventional physical security focus. Smart Grid designers will need to address security from the outset, making it a requirement for all the elements of the grid and ensuring an integrated and balanced approach across the system.

It will be important to assume that a dedicated, well-planned, and simultaneous attack against several parts of the system (likely cyber) will be attempted. Application of existing security technologies, such as encryption and the widespread use of routine security procedures will help, but more advanced techniques will be required to defeat sophisticated, modern terrorists. It will be necessary to replace control devices in use on today's grid that do not have the bandwidth and processing power to allow cyber protection.

Multiple Smart Grid strategies will be needed to increase the physical robustness of the grid- -robustness that deters and combats terrorist actions. For example:

- Moving to a more de-centralized design and operating model will be needed to reduce vulnerability to the loss of "targets" (e.g. large central power plants and major transmission lines) that could result in significant consequences
- Increasing the situational awareness of both the transmission and distribution grid, through the deployment of extensive monitoring and advanced decision support technologies, will be needed to give system operators a better chance to detect potential security breaches

- Increasing the intelligence and control granularity of the distribution and transmission system through "self-healing" technologies will be needed to enable the grid to respond more effectively and recover more efficiently from a natural or man-made event.
- A Smart Grid communications platform having the reliability and bandwidth required to accommodate sophisticated encryption methods will be needed
- An image of extreme robustness will be needed so that terrorists are deterred from even considering an attack in the first place.

Regulatory Gap:

At a minimum, regulators will need to allow utilities to earn a fair return on investments that protect against attacks of all sorts. When examined independently, the costs and benefits of security investments can seem unjustifiable. Therefore, it will be important to make clear the fact that these investments are frequently the same ones that also enable many other principal characteristics.

The case for a hardened grid is sound, particularly when it includes all the resulting societal benefits. But, regulators will need to be convinced that these security benefits will materialize, and be valued by the public, before they will authorize major investments.

Federal, state, and local officials will need to work with individual utilities to address acceptable risk, possibly with support from DOE and Homeland Security officials. Planning for manmade threats will need to consider not only single, but also multiple points of failure. Government and industry will need to jointly conduct exercises that will improve the security aspects of the Smart Grid, as well as its design and operation. Metrics will be needed to gauge success and guide improvements. But industry as a whole will need a standard approach to conducting these assessments, understanding consequences, and valuing security upgrades.

Regulators will also need to ensure that Smart Grid designs and investments address critical cyber security issues from the outset, making security a requirement for all the elements of the grid. The increasing use of open systems will need to be met with industry approved and adopted standards and protocols that enhance system security. Advanced cyber security systems will need to be integrated with standards to ensure that new Smart Grid technologies are "hack-proof" and that existing technologies such as SCADA, protective relaying and communication systems are upgraded to provide the same level of advanced cyber security.

Consumer Gap:

Consumer education programs are needed to communicate the importance and value of deploying Smart Grid technologies that improve the security of the grid.

Gap Closing Solutions:

- Security-focused grid designs
- Cyber-secure communications platform
- Broad deployment of DER and DR
- Extensive real-time monitoring/surveillance (AMI, WAMS, cameras…)
- Self –healing grid designs

- Operator decision-support tools
- Inclusion of related investments in rate base*
- Recovery of security-driven early write-offs
- Supportive rate structures
- Consumer education regarding the role they can play
- Government-Industry grid security drills

* Note: these investments typically support multiple principal characteristics

R&D Needs:

- Advanced cyber security applications for Smart Grid communications
- Advanced modeling and visualization tools

6.3 Proposed Solutions

In addition to providing adequate conventional T&D capacity, new combinations of technology, regulatory and consumer solutions will be required to achieve the full set of principal characteristics needed to meet the probable future state of WV. Most individual solutions are applicable to multiple characteristics, as described in the preceding sections. The following solutions will need to be applied in concert in order to realize the full set of Smart Grid benefits.

TABLE 6-2: WEST VIRGINIA SMART GRID SOLUTION SETS

Gap Dimension	Solutions
Technology	• AMI • IT Integration (back office, integrated cyber-secure wideband communications platform, interoperability standards, etc) • Demand Response • Distribution management systems • DER that is plug and play and supports generation, storage and PQ • *Transmission management systems**
Regulatory / Governmental	• Inclusion of Smart Grid investments in rate base • Rate structures that encourage DER, DR and differentiated PQ • Federal and state funding of related R&D • Change in regulatory policy to create incentives and remove dis-incentives for investment (e.g. decoupling as new regulatory model) • Decisions based on societal business case • Recovery of Smart Grid-driven early write-offs
Consumer	• Consumer Education (role they can play, PQ issues; Security issues) • Access by all consumers to the electrical market • DER interconnect standards • HANs and consumer agents • Standardized transfer of market information

* There are two significant transmission projects in the region (including West Virginia) that will help address gaps in transmission system performance for the foreseeable future. The 500kV Trans-Allegheny Interstate Line (TrAIL) project and the 765kV Potomac-Appalachian Transmission Highline (PATH) project will help sustain transmission reliability and reduce regional congestion. For these reasons and to avoid confusion, the WV Smart Grid Implementation Plan team chose not to develop additional analyses and business cases for transmission systems.

6.3.1 Technology Solution Descriptions

The technology solutions are described more fully below:

AMI

This category encompasses the deployment of AMI technologies; including Smart Meters with remote connect/disconnect capability, two-way communications ability and Meter Data Management Systems that transform data into actionable information. It makes use of the full set of AMI technologies and provides the necessary applications to manage demand response. This assumes time differentiated rates are available. It also provides support for such applications as Consumer Agents, GFAs (Grid Friendly Appliances) and HANs (Home Area Networks) that facilitate the management of load from both utility and consumer perspectives. These include various in-premise interfaces that allow consumers to take full advantage of consumption/pricing information and control options.

Back office IT system integration

This category includes the upgrading of utility IT systems to employ a Service Oriented Architecture (SOA), using a Common Information Model (CIM) and a common, interoperable information bus.

Existing IT systems were not designed to support the new functionalities demanded by smart grid applications. Enhancements to existing IT technologies will be needed along with additional IT infrastructure hardware. An SOA allows different applications to exchange data with one another. This architecture provides a foundation for the integration of all future smart grid applications, both among themselves and with existing legacy systems such as MDMS, CIS, planning, maintenance, work management, and AM/FM/GIS.

The Common Information Model (CIM), an international standard, provides the only power system information model available covering the power system from the customer meter to the transmission system. Accompanied by the associated Generic Interface Definition (GID) standard, the CIM allows a utility to add new or upgrade old applications while providing long-term data exchange capabilities within a system (e.g., an EMS), between systems (e.g., EMS to DMS to CIS), or between utilities.

Integrated, cyber-secure, wide-band communications platform

This category provides the foundation for all smart grid applications, both now and for decades to come. It provide the reliability and speed (in terms of redundancy, bandwidth and latency) to accommodate increasingly complex security techniques, as well as differentiated performance to match the varying needs of a multiplicity of smart grid applications (ranging from AMI, to DER control, to System Integrity Protection Systems for the transmission grid). It supports interoperability of all smart grid devices and applications, and it accommodates a wide range of geographic territories by employing appropriate media that operate in a seamlessly integrated way.

Demand Response

This category includes those programs and systems that enable consumer and utility response to increasing prices for energy demand particularly during peak times. The programs engage the consumers and their systems (appliances, business and building systems, etc) in voluntary and direction load control ways. These programs may be established individually, or aggregated by the utility or third-party to provide a more definitive load response to a critical demand situation. The typical result of engaging a demand response program is a flattening of the load profile.

Distribution Management Systems

This category includes multiple enhancements to the distribution system and full integration with the communications and IT platforms described above. These enhancements are sufficiently refined to allow two-way power flow on distribution circuits, thereby accommodating the DER described below. It includes distribution and substation automation, employing data collection, control and switching applications, to cost-effectively improve reliability and power quality while reducing electrical losses. Deployment of smart meters and sensors that provide extensive information regarding operational parameters, power quality and grid health is also needed. Networks of communicating smart switches provide advanced protection and control at distribution levels. Advanced outage management systems utilize AMI's loss of power messages to minimize the time to detect, diagnose and repair outages, leading to significantly improved SAIDI and CAIDI. And it includes enhanced Distribution Management Systems (DMS) that integrate all these functions, providing operators with a more complete view of the entire distribution system along with the ability to directly interact with its elements.

DER deployment

This category covers the broad area of distributed generation and storage. Tomorrow's improved Distributed Energy Resources, with plug and play capability, will see rapid deployment by consumers, utilities and other new entrants. Virtual power plants and micro-grids will supplement central generation to an increasing extent and increased use of CHP will be facilitated. The above solutions will provide the ability to optimally integrate and dispatch these units, which can offer VAR support and PQ enhancement, as well as KW and KWH services.

The ability to accommodate PHEVs provides new transportation options that reduce dependence on imported fuels, while also supporting the grid as a new form of environmentally-friendly DER. This category also includes the integration of existing consumer-owned backup generators that are retrofitted with the necessary technologies to allow low-emission, parallel operation. The cost to integrate existing customer-owned generation can be substantially lower than that of today's DER.

Transmission Management Systems (not included in the business case – see Table 6-3)

This category includes multiple enhancements to the transmission system and full integration with the communications and IT platforms described above. It includes new monitoring and diagnostic tools, such as WAMS and dynamic line ratings, to enable system operators to better simulate and visualize the state of the system as well as the risks to its stable operation. It includes the application of digital communications, sensing, protection and control technologies, combined with the application of power electronics, to improve reliability and power quality while reducing electrical losses and increasing asset utilization. And it includes enhanced Energy Management Systems (EMS) that integrate all these functions, including the ability to take advantage of new distribution tools like DER and DR, so as to insulate the system from a wide variety of contingencies while also achieving high levels of efficiency.

In addition to technology solutions, regulators and consumers have a major role to play.

6.3.2 Regulatory / Governmental Solution Descriptions

Of course, regulator buy-in is a requirement that spans all of the solutions and this buy-in will be achieved only when regulators make decisions based on the societal business case for a smart grid. For example, one such decision relates to write-off allowances on equipment that meets its original purpose, but cannot accommodate a smart grid (metering being a prime example). Cooperation among state regulators and with federal regulators will be needed on a wide range of issues. It will be necessary to establish supportive tariffs that encourage DER, DR and differentiated PQ. And most fundamental will be the inclusion of smart grid investments in rate base. The work of the FERC/NARUC Smart Grid Collaborative and the recent ARRA appropriations for funding Smart Grid investments will help drive the urgency and priority for modifying regulatory policy where needed and appropriate.

6.3.3 Consumer Solution Descriptions

The consumer is the other key stakeholder in the application of a smart grid. But today's consumer is not knowledgeable when it comes to the complications involved in generating, transmitting, delivering and even using electricity. Therefore, a major program of consumer education will be required help them understand how each of the principal characteristics benefits them and how they can play an important role in achieving these characteristics. In addition, systems will be required to facilitate consumer participation in the smart grid. DER interconnection standards, market access and standardized information transfer will all help ease the entry of the consumer.

Substantial R&D is also needed to provide the tools that enable many of these gap-closing solutions. Needless to say, federal and state funding will significantly accelerate the achievement of these solutions.

6.3.4 R&D Solution Needs

Technology

In the area of technology, the following R&D has been identified, with the highest priority items shown first:

- Top priority
  - DER enhancements

  - Integrated communications solutions
  - Distribution circuits that accommodate two-way power flow
  - Equipment health sensors and diagnostics
  - Development of low cost power electronics.
  - Advanced modeling and visualization tools
- Also needed
  - DER dispatch algorithms
  - Data handling and reduction to extract value; including data transmission by exception
  - Marriage of intermittent generation with storage and DR
  - Dynamic islanding
  - HTS cable
  - Advanced digital protection and control
  - Contingency analysis based on expanded real time data availability
  - Fault current limiters
  - Coordination with intermittent central generation
  - Advanced cyber security applications for Smart Grid communications

Regulation

In the area of regulation, the following R&D is required:

- Tariff redesign

Consumer

In the area of consumers, the following R&D is required:

- Time-of-use or real time pricing experiment (voluntary) to determine consumer interest

6.3.5 The Smart Grid Relationship to the Coal Industry

The coal energy industry is in the national and international news almost daily since the new US administration took office. This may be indicative of a growing threat to the West Virginia coal energy industry, and thus a major contributor to the state gross domestic product (GDP). The question becomes what new business and environmental models will influence the coal energy industry future? Whether there is a continuation of the coal firing energy processes or new coal-to-gases and coal-to-liquids businesses emerge, the Smart Grid provides some support. As the Smart Grid improves efficiency in the WV electric system, the losses will be reduced which allows more coal energy export. However, this is not a net increase in coal production; simply a change from in-state customers to out-of-state customers.

The Smart Grid does promote a coal to transportations fuels business future, but not extensively.

Both coal and the Smart Grid are domestic West Virginia resources which in concert leads to improved energy independence in the state.

The Smart Grid promotes combined heat and power (CHP) integration for energy efficiency which could lead to a new line of smaller, CHP-based clean coal generation strategies. West Virginia could take the lead in exploring this strategy for the nation.

6.4 Gap Analysis Conclusions

In summary, there are many gaps that must be addressed in order to move to a smart grid. All stakeholders will need to participate in closing the technology, regulatory, consumer and R&D gaps. The required effort will great, but the benefits will far exceed the cost, as explained in the next section of this report.

In this next section, the major technology contributors are addressed in terms of their penetration, their costs and their benefits. These major items include AMI, IT Integration, DR, DMS, and DER. Integrated communications and IT interfacing are also included as enablers of these (as well as most other) smart grid features. While additional technology opportunities exist their deployment is beyond the scope of this report.

7.0 Business Case

The objective of the Business Case was to develop a conservative financial picture of the cost and benefits associated with implementing Smart Grid technologies in West Virginia. Multiple scenarios were designed and compared to the base case of "business as usual" to demonstrate the potential net benefits resulting from the implementation of these technologies. The following three scenarios were used in the analysis:

A. Smart Grid Implementation using Operational, Consumer, West Virginia Societal and US Societal Benefits
B. Smart Grid Implementation using Operational, Consumer and WV Societal Benefits
C. Smart Grid Implementation using Operational Benefits only

The business case began with the identification of smart grid technology solutions as defined in the gap analysis. Hardware, software, and process elements were defined in the context of implementation plans for these Smart Grid technology solutions. The integration of advanced technologies such as advanced storage units and AMI in conjunction with estimates of their implementation dates (start date and years to complete the project) were used to develop timing for the costs and benefits.

Cost equations were developed for the technology solutions for both the capital investment and the annual operation and maintenance (O&M) expenses.

Annual benefits were identified and quantified for each key success factor. Algorithms were developed to derive and to annualize benefits when direct values were not available. The annualized benefits were classified by key success factor, category, and beneficiary (operations, consumer, and society). Overlapping benefits were allocated among the technology solutions via a sharing matrix developed by the project team given the complexity associated with segregating joint benefits. A Delphi method was employed whereby the benefits were discussed and a consensus reached on the contributing value of those benefits to each technology solution.

The benefits and costs were incorporated in an annualized cash flow model using the following assumptions:

1. Benefits in a given year were based upon the percent completion of capital expended for the solution that yields that benefit divided by the total capital investment for that solution. Thus, in year one, no benefits occur and full annual benefits occur one year after the project was completed.
2. Yearly capital costs were derived by dividing the total capital expense by the number of years required to complete the project. Amortization and depreciation were simplified into the discount rate as the project duration was considered short compared to the life of the systems being added.
3. Annual (O&M) expenses were based upon the percent completion of capital expended for each solution divided by the total capital investment required to implement that solution. Thus, in year one, no (O&M) expenses occur and the full annual (O&M) expense occur only after project completion.

Four annual cash flows were calculated for use in the scenario analysis,

1. All benefits including operations, consumer, WV societal and US societal and costs
2. WV benefits including operations, consumer and WV societal and costs
3. WV benefits with beneficiaries treated separately and costs
4. Benefits and costs for business as usual (BAU)

The financial metrics used to evaluate the scenarios were net present value (NPV), benefit to cost ratio, years to positive cash flow and the internal rate of return (IRR). Multiple metrics were used to address the informational needs of the diverse audiences this report is intended to serve.

A sensitivity analysis was performed on the NPV's to illustrate the affect the choice of discount rate had in each scenario. NPV's were graphed using differing interest rates in one percent increments from five to fifteen percent. The benefit to cost ratio, years to positive cash flow and IRR were single value financial metrics, presented to provide additional insight into economic feasibility of a WV Smart Grid.

To aid in understanding the depth of this project, summaries for each scenario were developed as well as a comparison summary of all scenarios. The scenario summaries depict the financial metrics for individual solutions as well as the total of the integrated components that comprise the overall solution. It should be understood that individual solutions are highly interdependent; therefore, the business case should not be used to select an individual solution for implementation without understanding the synergy of the system as a whole. Graphics of discounted cash value, capital spending by year, cumulative cash flow and the PV of the Net Benefit by Solution Option were included for thoroughness. Cost rollups for Capital and O&M were captured on separate sheets. Cash flow details are shown in Appendix 10.4.

7.1 Solutions Included

The following Table 7-1 identifies the Technology Solutions considered in the Business Case.

TABLE 7-1: WEST VIRGINIA SMART GRID SOLUTIONS

Solution	Solution Long Name	Scope of Work
AMI	Advanced Meter Infrastructure	All Residential, commercial and Industrial Customers represented by 998,317 meters
IT	IT Integration	A CIS Upgrade to accommodate AMI and DR functionality & Outage Management
DR	Demand Response	The aggregated sum of 104 MW of DR from Residential, Commercial and Industrial Customers
DMS	Distribution Management System	The automated fault clearing & restoration of service, circuit monitoring and control of the Distribution System to include 707 circuits of 1107 total circuits (64%)
DER	Distributed Energy Resources	100MW of Base Generation, 800 MW of Peak Generation, 250 MW of Advanced Storage and 100 MW of Wind Resources all capable of being dispatched on demand

7.2 Calculation of Costs

The basic equation for calculating Capital and O&M costs used in the business case was unitized installed cost multiplied by volume of units to be installed. The implementation plan for each of these solutions identified the volumes. Table 7-2 summarizes the estimated expenditures by solution.

TABLE 7-2: WV SMART GRID SOLUTION COSTS (NPV)

Solution	Capital PV Expenditure ($M)	O&M Annual Expenditure ($M) (not PV)	O&M 20-yr PV Expenditure ($M)
AMI	$379	$3.6	$22
IT	$137	$5.0	$33
DR	$19	$0.8	$3
DMS	$385	$14.0	$69
DER	$473	$77.5	$359
Total	$1,392	$101	$486

7.3 Calculation of Benefits

The benefits described in the Business Case were derived from the Smart Grid key success factors that were developed by the DOE/NETL Modern Grid Strategy team.

Each benefit was calculated as a function of incorporating multiple data elements in an algorithm that represents specific benefit generation. Each data element and assumption is documented.

The assumptions underpinning the basis of the benefits include:

1. Markets are accessible to the consumers who can buy or sell power at market prices
2. Market Aggregators can assemble demand response into a capacity or energy resource
3. Generator interconnection agreements will allow customers to feed their supply of power into the distribution grid
4. An efficient broadband communications system is available to enable dispatching of both DER and DR Resources as well as communicating among distribution automation switches to minimize fault areas and restore power to customers as quickly as possible.

Table 7-3 summarizes the values of the major benefits associated with implementing the WV Smart Grid. This is the same as Table 1-4 in the Executive Summary.

TABLE 7-3: WV SMART GRID BENEFITS (ANNUAL)

Key Success Factors	Benefits	Annual Benefits ($M) (All Beneficiaries)
Reliability	Reduced Consumer Losses	$898
	Reduce Power Quality Events	$131
Economic	Reduce Price of Electricity	$399
	Job Creation	$215
	Consumer Sales of DER Resources	$175
	Increased Energy Sales as Exports	$7
	Reduced Transmission Congestion	$1
	Increased Transportation Fuels Business	$5
	Consumer Conservation	$20
	Operational Savings	$194
Environmental	Reduced Emissions	$7
Security	Reduced Blackout Probability & Dependence on Foreign Oil	$13
Safety	Reduce Hazard Exposure	$1

Each of these benefits is briefly described below:

Reduced Consumer Losses – Residential, commercial, and industrial costs are reduced by suffering less outages leading to price reductions in goods and services to consumers by improving reliability through AMI and distribution.

Reduce Power Quality Events – Improvements in PQ due to AMI PQ detection and diagnosis technologies lead to an improvement in power quality which reduces the losses suffered by C&I consumers. This results in a reduction in the prices of goods and services.

Reduce Price of Electricity – Peak shaving and load flattening through DER and DR reduces prices for all consumers as well as provides financial incentives (opportunities) for individual consumers.

Job Creation – Improved reliability, PQ and Smart Grid features that benefit businesses attract new jobs and increase GDP in WV.

Consumer Sales of DER Resources – Distributed energy resources (DER) deployed and owned by consumers can earn revenue in power markets made available by the Smart Grid.

Increased Energy Sales as Exports – The profits of exports are directly applied to reduce the electric rates in West Virginia.

Reduced Transmission Congestion – Use of WV Smart distribution grid as an asset for transmission will reduce transmission congestion.

Increased Transportation Fuels Business – The Smart Grid enables more coal to be available for fuel conversion.

Consumer Conservation – AMI provides energy usage and prices to consumers enabling them to be more effective conserving, commonly referred to as the Prius Effect.

Operational Savings – These savings are a result of being more efficient and include staff reductions, reduced response time, reduced equipment wear, increased asset utilization etc.

Reduced Emissions – Increased use of combined heat and power (CHP) as DER, reduced emissions due to reduced losses, EE and efficiencies, and incremental capability of WV Smart Grid to integrate intermittent renewables results in improved environment, benefitting society.

Reduced Blackout Probability and Dependency on Foreign Oil – Deployment of DER and Distribution Automation technologies will enable microgrid operation and dynamic islanding. This feature will reduce the probability that large sections of the WV grid will be "blacked out".

Reduced Hazard Exposure – Keeping traffic lights in service longer as well as reducing line patrols and remote meter reading will reduce hazard exposure.

Distribution automation (DA) plays a major role in improving reliability and hence reducing consumer losses. Deployment of DA on approximately 64% of the circuits was calculated to be optimal penetration given the disperse population within the state. This level of penetration minimizes the cost and maximizes the reduction in consumer losses by deploying DA where the majority of C&I consumers are served. This penetration was conservatively assumed to improve reliability to 90% of the C&I customers.

The following Table 7-4 and Figure 7-1 summarizes the benefits by Solution.

TABLE 7-4: WV SMART GRID SOLUTION BENEFITS (ANNUAL & PV)

Solution	Annual Benefits ($M) (All Beneficiaries)	20-yr PV Benefits ($M) (All Beneficiaries)	% of Total
AMI	$234	$1,649	12%
IT Integration	$178	$1,308	10%
DR	$196	$1,091	11%
DMS	$556	$3,288	26%
DER	$903	$5,289	41%
Total	$2,065	$12,625	100%

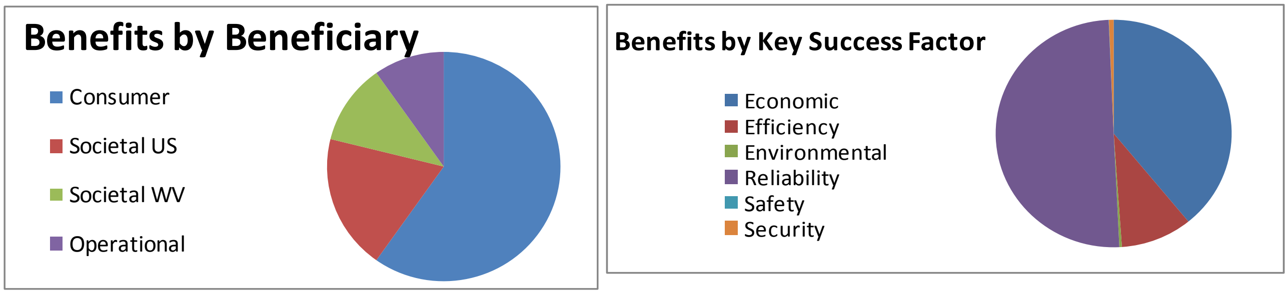


FIGURE 7-1: TOTAL BENEFITS BY BENEFICIARY AND KEY SUCCESS FACTOR

7.4 Summary of Results

Significant differences were found in the results of the cash flow scenarios (see Figure 7-3). The present value of benefits against costs range from negative $600M for net operational benefits to over + $10 billion for benefits to all beneficiaries. Benefit to cost ratios (figure 7-2) range from under one to over five.

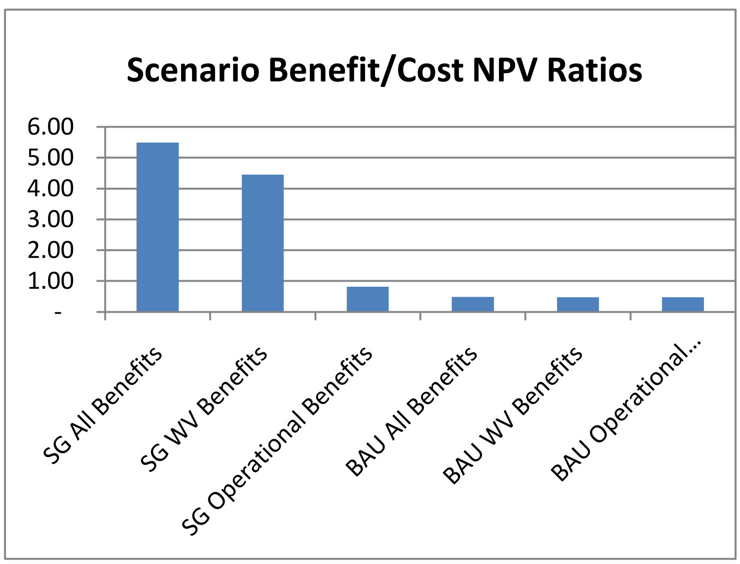
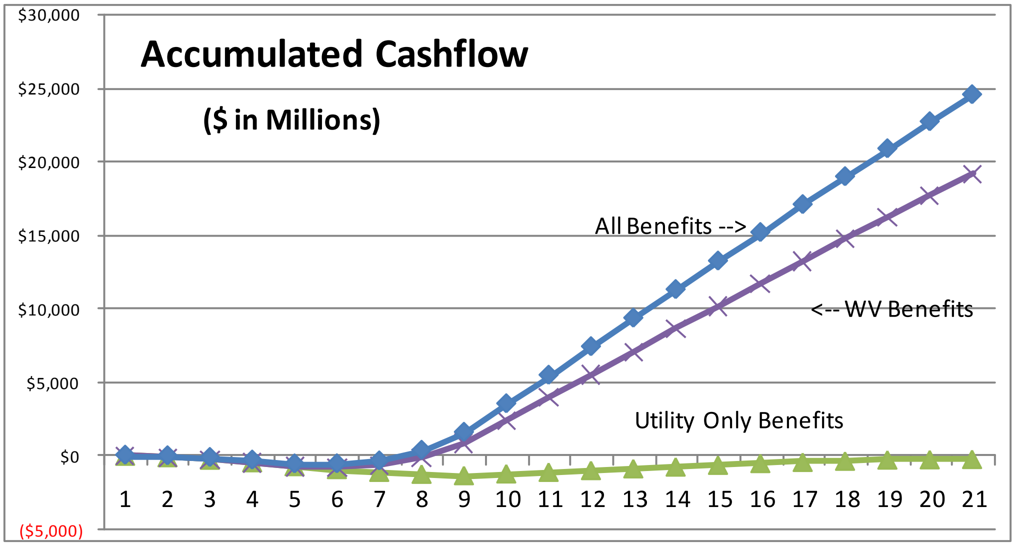


FIGURE 7-2: BENEFIT COST RATIOS FOR SMART GRID AND BUSINESS AS USUAL (BAU) SCENARIOS



* The Utility Only Benefits case does not include return on investment. For the purpose of this report it was considered part of the cost of implementing the Smart Grid solutions.

FIGURE 7-3: THREE SCENARIO ACCUMULATED CASH FLOWS

One concise way of presenting business case results is with a racking chart where the present value costs and benefits are "racked up" on the same chart showing the relative size and net effect. For example, Figure 7-4 below is the Benefit and Cost Racking for All Beneficiaries broken out by the benefit from each solution.

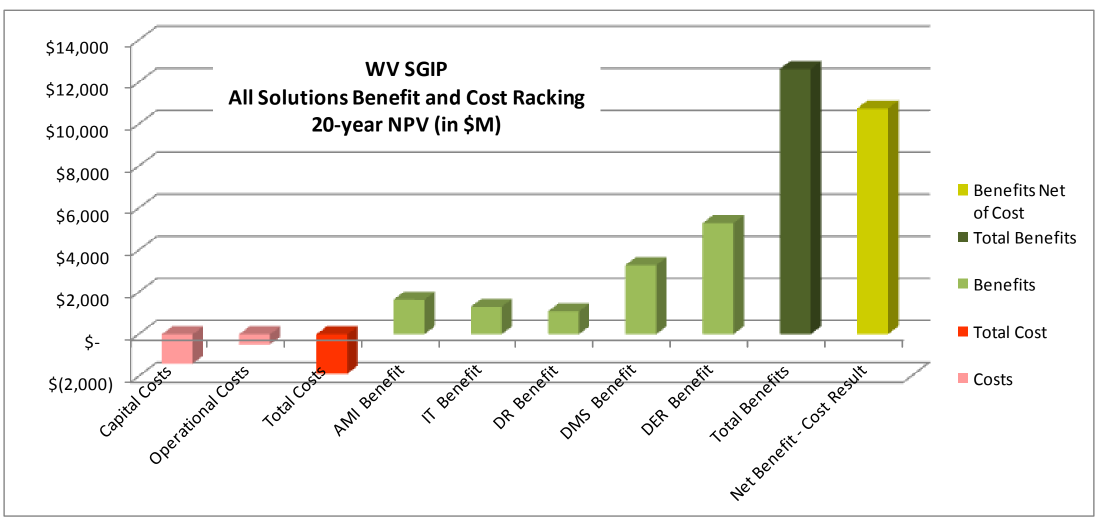


FIGURE 7-4: SOLUTION BENEFIT AND COST RACKING (ALL BENEFICIARIES)

As described in the following sections, there are significant differences in the level of benefits for the various scenarios. From the utility's perspective there is little financial incentive to implement a Smart Grid based on operational benefits alone. However, when expanding the analysis to include all benefits, there appears to be adequate incentive to move forward with a Smart Grid in WV. The key to unlocking the benefits of the Smart Grid resides in finding ways to compensate utilities for Smart Grid expenditures they make for the benefit of consumers and society not currently captured by rate structure or that accrue to individuals or institutions outside the market. This is normally done through the rate case process, however, a Smart Grid rate case is not a traditional case. Therefore a mechanism must be developed to capture these non-traditional benefits and provide a return to utilities sufficient to justify Smart Grid investments.

The business-as-usual Business Case Scenario (section 7.4.4) is based solely on maintaining the status quo. It offers no improvements outside the routine replacement of obsolete plant and equipment. This business case model did not go to great lengths to attempt to accurately model the complete financial workings of public utilities. Rather, it estimated benefits using the same Smart Grid key success factor categories that were used to develop the scenarios. This method provided a modest return on investment consistent with the annual reports of the participating utilities. The business-as-usual case spends less on capital and O&M expenses and offers four to six billion dollars less in net present value over 20 years than the Smart Grid scenarios.

7.4.1 Scenario A –Smart Grid Implementation Plan Using Operational, Consumer, WV and US Societal Benefits

The scenario (shown in Figure 7-4 above) uses all operations, consumer and societal benefits to reach a positive cash flow in eight years and in 20 years reaches more than ten billion dollar accumulated benefit to all beneficiaries net of costs. The business case is sound, but the issue is "who pays for the investment"? If all the benefits accrued to the utility, the utilities would already be taking steps to implement Smart Grid technologies. This is a very important issue because consumer and societal benefits make up the majority of benefits in this business case.

In Figure 7-5 (benefits by beneficiary), the WV consumer and society benefits plus the operational benefits that accrue to the utility show a compelling business case. In addition, the US region around WV (mainly the PJM territory) also benefits from investments in WV.

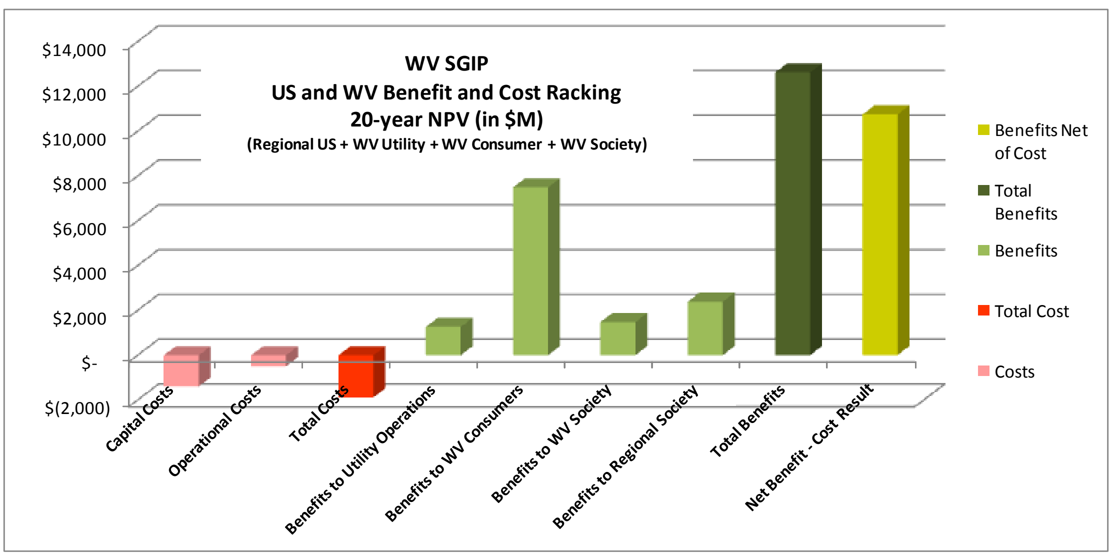


FIGURE 7-5: TOTAL BENEFIT AND COST RACKING BY BENEFICIARIES

While this scenario is the most favorable, there are impediments to be resolved. Since the utilities are typically the driver for change and seek consumer investment through rate cases, the utilities are not the stakeholders who stand to gain an adequate benefit alone. Therefore, it is the collective stakeholders of West Virginia who need to understand that they are the ones that stand to benefit the most from the Smart Grid and therefore must be willing to compensate the utilities for the implementation of a Smart Grid in WV. This will require a comprehensive effort to educate all stakeholders on the benefits and costs of the Smart Grid.

7.4.2 Scenario B - Smart Grid Implementation Plan Using Operational, Consumer and West Virginia Societal Benefits

This scenario uses operational benefits, consumer benefits and only those societal benefits that pertain to the people of West Virginia (see Figure 7-6), ignoring the "spillover" of benefits that would accrue to consumers outside the state in the PJM territory. In this case, a positive cash flow is achieved in nine years. In 20 years, it achieves an estimated accumulated net benefit of over eight billion dollar. Once again, the issue of who pays for the implementation of the Smart Grid is critical.

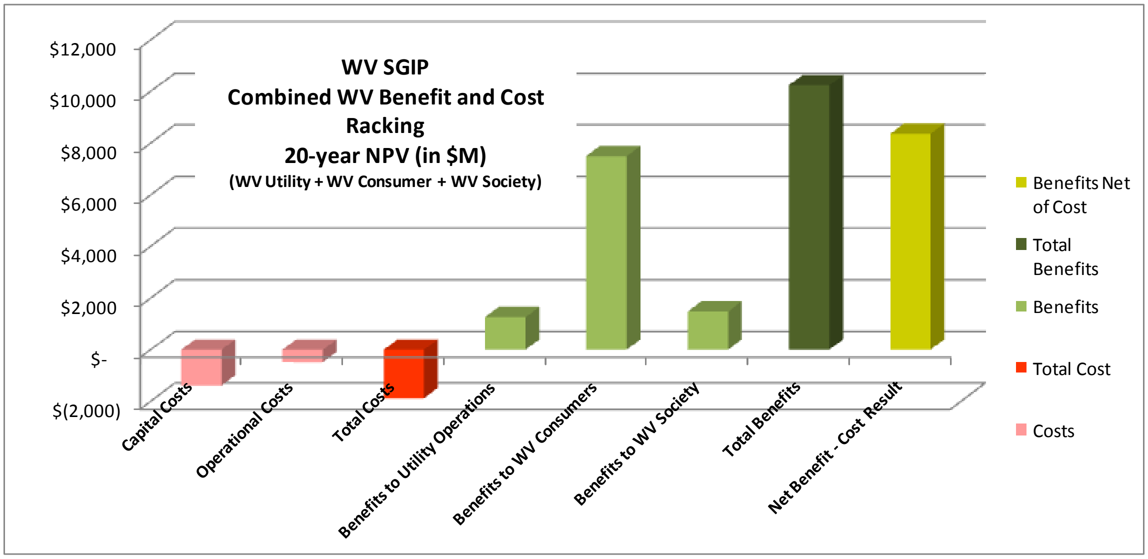


FIGURE 7-6: TOTAL WEST VIRGINIA BENEFIT AND COST RACKING

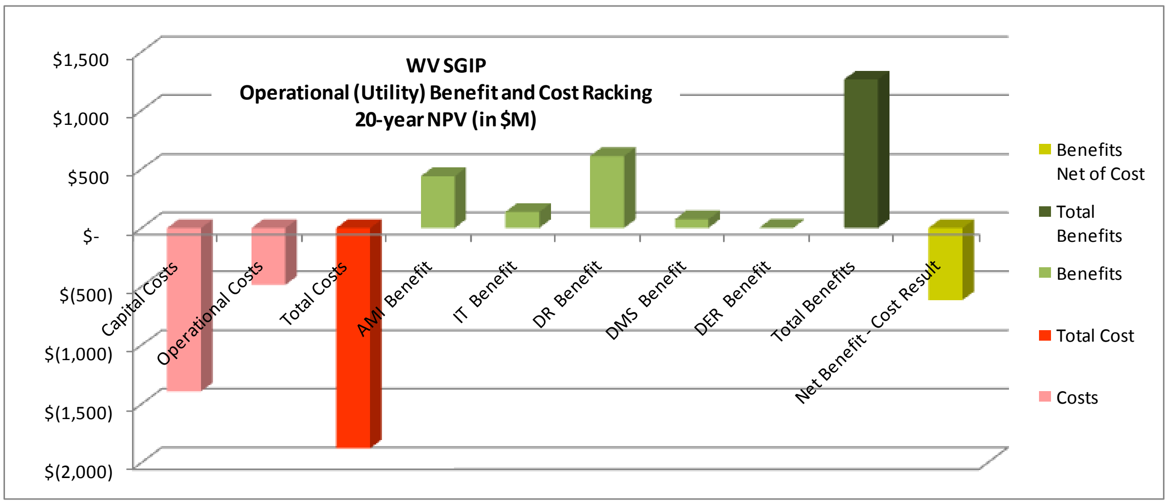
The main difference between Scenario A and Scenario B occurs in the peak shaving that occurs at the regional US level (PJM territory). If West Virginia uses its Smart Grid resources to reduce the peak in West Virginia, the region around WV also benefits from the reduced peak load on the transmission system. While WV benefits from this action, it gets only a portion of the benefit. It receives a prorated load share of the total benefit generated, whereas the other PJM participants receive the majority of the benefit from the West Virginia effort. The team's experience from previous Smart Grid implementation plans shows that the first implementations create the greatest benefit in peak shaving and that subsequent benefits decrease as more Smart Grid implementations occur. This means that the first states to implement will realize more benefit than states who implement a Smart Grid later.

7.4.3 Scenario C - Smart Grid Implementation Plan Using Operational Benefits Only

This scenario examines the costs and benefits solely for WV utilities (racked in Figure 7-7). This business case reaches an estimated negative cash flow of ~$600M over 20 years. In this scenario the costs of the Smart Grid implementation is assigned through traditional rate treatment. It is not financially viable as a utility revenue requirements (only) model even though the total WV benefits are relatively large. This is due to the rate structures which fail to compensate the utilities for generating these benefits.

In this scenario, the operational benefits do not support the level of investment required to implement the Smart Grid technologies. Traditionally, this is normal for technology projects with revenue requirements based rate treatment. Without rate recovery for the costs to deliver the larger consumer and societal benefits, the utility lacks incentive to invest.

Without some recovery means, the utility will not make such an investment based solely on operational benefits. The sound investment return generated across West Virginia by implementing a Smart Grid should be considered a state initiative. The most straight-forward method to achieve the benefit is to treat the costs associated with implementing the Smart Grid as a special rate case because WV consumers and society benefit most.



* The Utility Only Benefits case does not include return on investment. For the purpose of this report it was considered part of the cost of implementing the Smart Grid solutions.

FIGURE 7-7: WV OPERATIONAL-ONLY BENEFIT AND COST RACKING

If the consumer bears all the capital and operational expenses for the entire Smart Grid program (~$1.9B from Figure 7-6) in an effort to generate the consumer benefit (~$7.5B from Figure 7-6), it appears they would have nearly a 4:1 benefit to cost ratio. Adding the WV societal benefit into this analysis yields a 4.7:1 benefit to cost ratio. This provides a compelling argument for the investment for the WV consumer and society.

7.4.4 Scenario D – The Business Case for Business as Usual (BAU)

The old saying is that "if you keep doing what you've always done, you'll always get what you've always got." is an appropriate analogy for the business as usual case. The infrastructure in West Virginia and in the vast majority of the country is old and aging at a faster rate than it is being replaced. While this is true for most utilities, West Virginia is well below average on the grid reliability spectrum and that in itself is an impediment to economic development. The BAU business case does not provide for any benefits from the upgrade of the obsolescent infrastructure since the reliability performance of the WV grid would remain the same.

In Figure 7-8, the net benefit to continuing a business as usual approach to grid infrastructure is far more costly and generates far less benefits than the Smart Grid Implementation Plan presented in this report. The BAU costs were projected from the historical average capital $450M/yr) and operation annual ($181M/yr) spends of Allegheny Power and American Electric Power in West Virginia. The benefit shown is primarily driven by the return on investment.

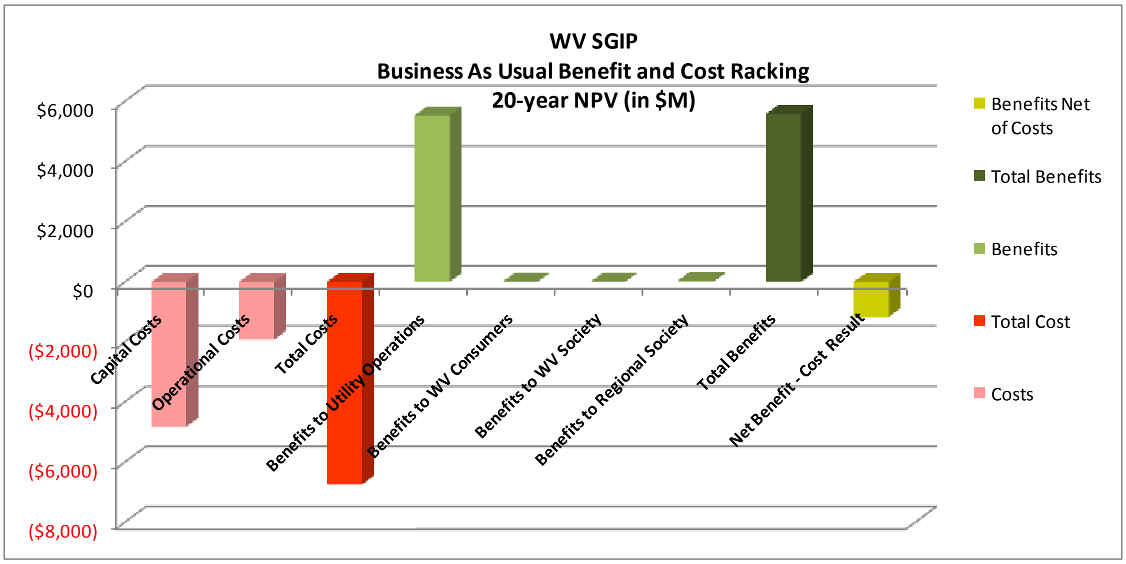


FIGURE 7-8: WV OPERATIONAL BENEFIT AND COST RACKING

7.4.5 Solution Set Benefit and Cost Results

The racking charts (Figures 7-9 through 7-13) are provided to illustrate the potential benefits and costs of each proposed Smart Grid solution.

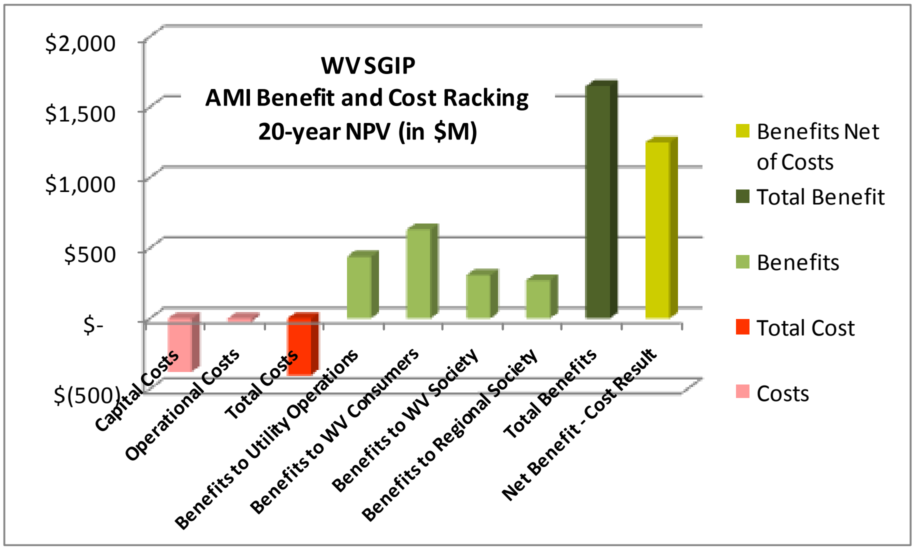


FIGURE 7-9: ADVANCED METERING INFRASTRUCTURE BENEFIT AND COST RACKING

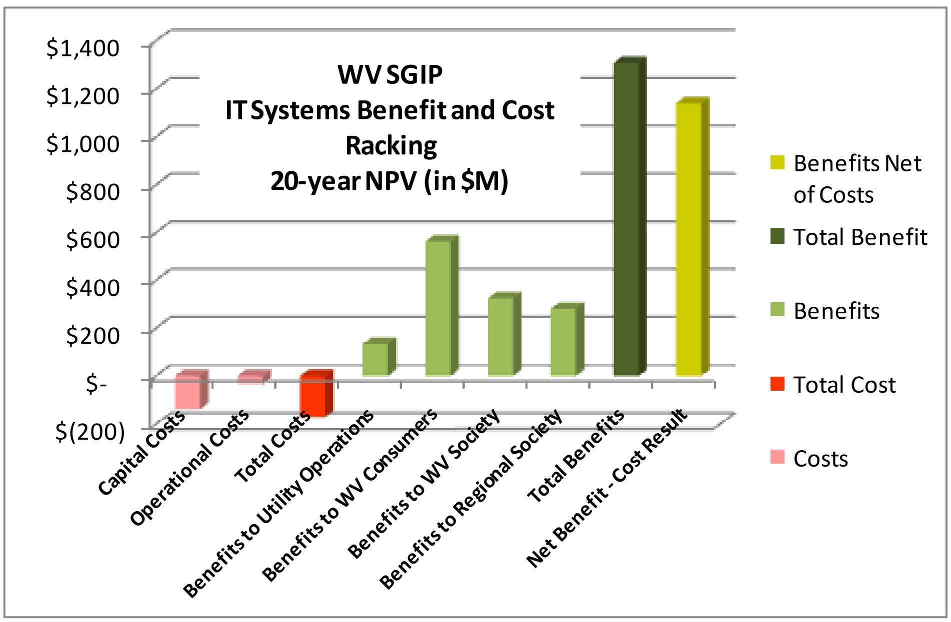


FIGURE 7-10: IT SYSTEMS BENEFIT AND COST RACKING

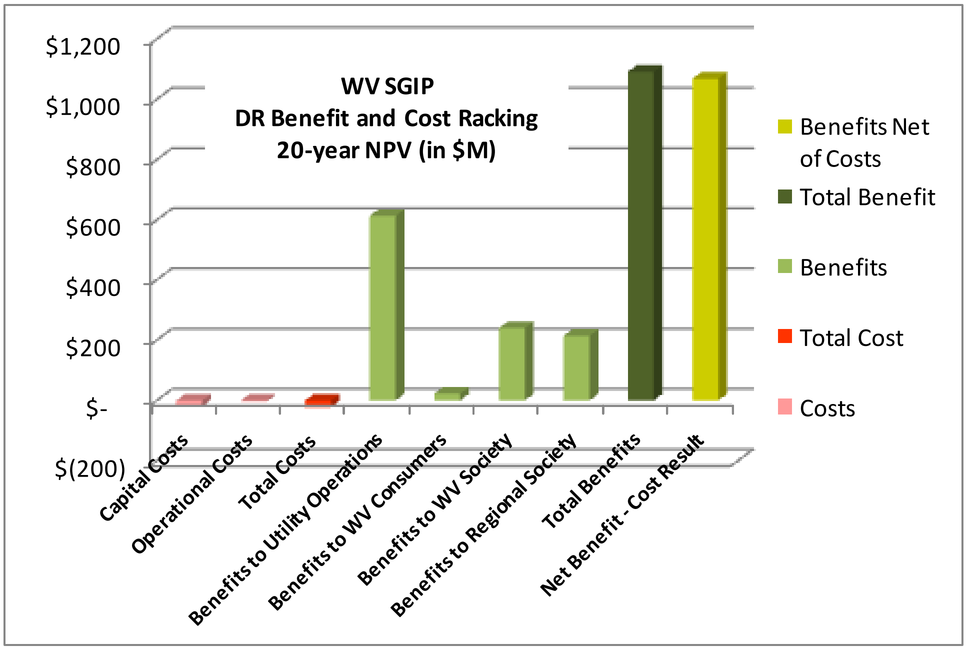


FIGURE 7-11: DEMAND RESPONSE BENEFIT AND COST RACKING

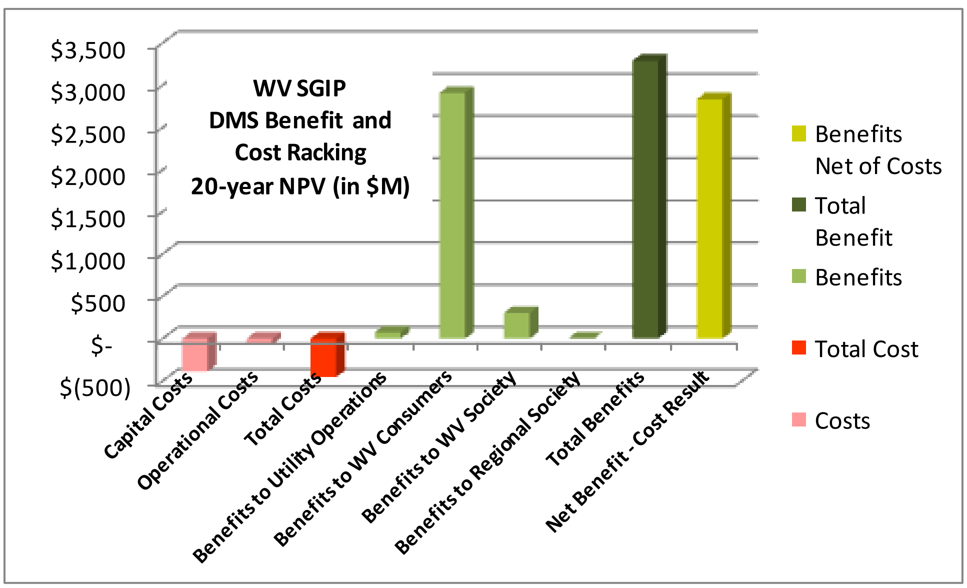


FIGURE 7-12: DISTRIBUTION MANAGEMENT SYSTEM BENEFIT AND COST RACKING

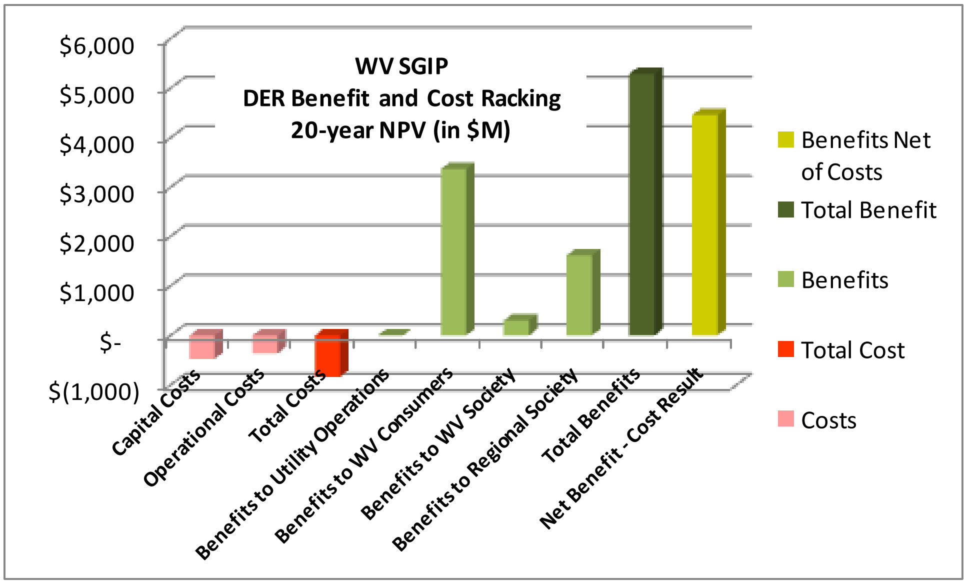


FIGURE 7-13: DISTRIBUTED ENERGY RESOURCES BENEFIT AND COST RACKING

The combination of benefits and costs for all Smart Grid solutions was previously presented in Figure 7-4. Although costs and benefits are provided for individual Smart Grid solutions in the above figures, each solution should not be considered as a stand-alone solution in a business case. The set of five solutions presented have several interdependencies that require an integrated approach to implementation. The costs efficiencies and benefits analysis incorporate these interdependencies. Therefore, taking each solution in isolation as an investment strategy will raise the cost and reduce the benefits of each. It is therefore not advisable to do this.

7.5 Business Case Conclusions

From the business case perspective using all benefits, the implementation of the Smart Grid appears to be a viable scenario and could bring substantial benefits to West Virginia in the form of more reliable power and enhanced economic growth. If the cost of the implementation is placed solely upon the utilities under the current tariff structure in WV, no compelling case can be made because utilities would be able to recoup their investment since there is no cost recovery. It is important to recognize that utilities fund infrastructure improvements to serve the WV consumer and reduce operational costs which also serve the WV consumer. With a Smart Grid, society benefits from the creation of jobs and from increases in state and regional incomes as well as providing electric services with a lesser impact on the environment. It is appropriate for those who benefit from such programs to invest in such programs. A recovery mechanism which provides a sufficient return to the utility for the benefits that consumers and society would receive would encourage Smart Grid investments.

Scenario Scenario Benefit Type	Smart Grid All Benefits	Smart Grid WV Benefits	Smart Grid Operational Benefits	Business as Usual All Benefits
Total CapEx->	$ 1,719,762	$ 1,719,762	$ 1,719,762	$ 11,275,000
Annual Op Ex ->	$ 100,958	$ 100,958	$ 100,958	$ 181,000
Operational Benefits/Yr	$ 203,471	$ 203,471	$ 203,471	$ 337,194
Consumer Benefits/Yr	$ 1,236,383	$ 1,236,383		$ -
WV Societal Benefits/Yr	$ 233,839	$ 233,839		$ -
US Societal Benefits/Yr	$ 392,002			$ 4,360
Total Benefits/Yr	$ 2,065,696	$ 1,673,694	$ 203,471	$ 341,554
Benefit/Cost NPV Ratio	5.49	4.45	0.82	0.48
Simple Payback (years)	0.83	1.03	8.45	33.01
NPV @ 8%	$ 8,600,720	$ 6,557,266	$ (565,622)	$ 547,689
Internal Rate of Return	58%	45%	-2%	19%

TABLE 7-5: SUMMARY OF BUSINESS CASE SCENARIOS

The All Benefits (Figures 7-3 and 7-4) and All WV Benefits (Figure 7-5) Business Cases appear to be economically viable and would create solid returns if the following actions occur:

- Markets are brought to West Virginia consumers.
- Utilities are compensated for their Smart Grid investments.
- Consumers can join a market aggregator for their demand response loads.
- Generator Interconnection agreements will allow for Distributed Energy Resources to feed their supply into the distribution grid.

It is worthy to note that in examining the business case, it shows that every year of delay in the implementation of a Smart Grid causes a drop of about $750 million in Net Present Value due to foregone benefits and implication of the time value of money on these benefits. The benefits from a delay in a cash generating process cannot be recovered. The value of the lost benefits becomes a lost opportunity.

Upon delivery of a Smart Grid infrastructure in West Virginia, the following benefits are expected:

- Interruptions will significantly decrease and power quality will increase to the benefit of WV businesses.
- There will be downward price pressure on electricity from the use of Smart Grid solutions to shave the peak and flatten to load profile in West Virginia.
- The state will attract new businesses, creating new jobs.
- West Virginia utilities will operate more efficiently and increase the asset utilization of existing resources.

Figure 7-14 illustrates the relative spending profiles for the BAU and Smart Grid scenarios. In the short term, to limit the total capital investment, the team recommends that as capital increases to support Smart Grid implementation the traditional capital spend be reduced accordingly. As Smart Grid solutions are implemented and their benefits are realized future BAU spending might be substantially reduced due to these benefits. By redeploying some of the capital spending planned in the BAU case during Smart Grid implementation, the overall impact to capital spending in the short term can be mitigated.

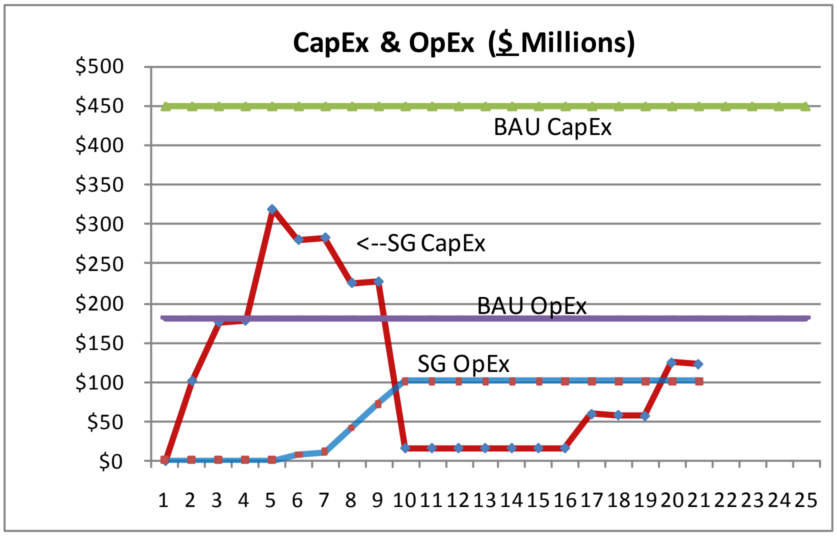


FIGURE 7-14: CAPITAL AND OPERATING EXPENSE COMPARISON

Some will find this surprising because the approach is non-traditional. However, the solution is using lower cost technology improvements and leveraging information about existing capital assets to make more effective use of assets. That is, finding ways to extract more value from existing (paid for) assets instead of building new capital assets.

Ultimately, the issue will be the acceptance of Smart Grid technologies and processes in the context of regulatory treatment.

8.0 Implementation Plan

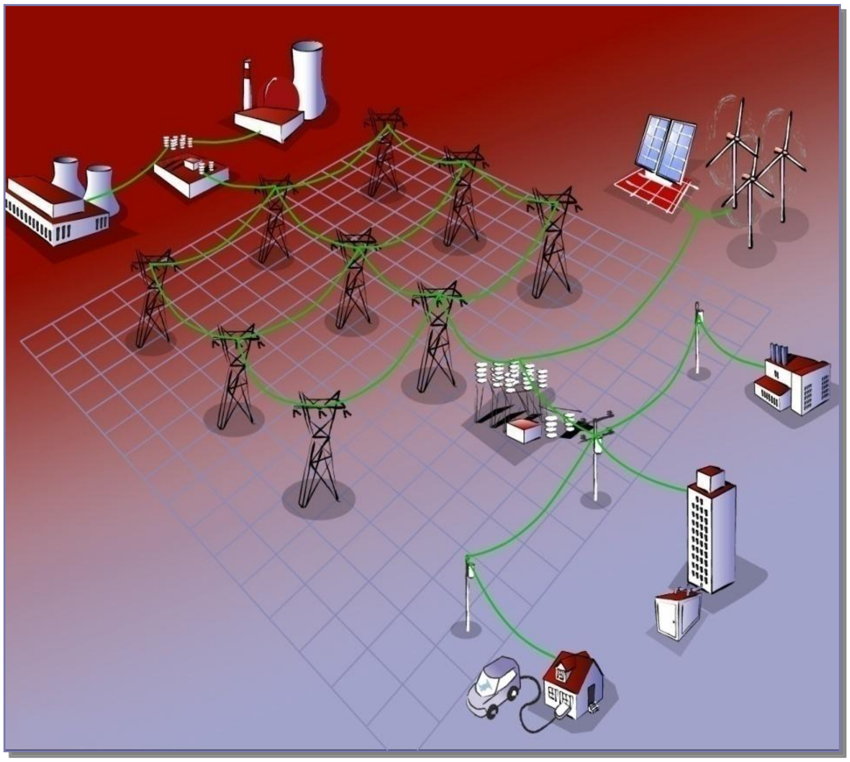


FIGURE 8-1: THE SMART GRID IMPLEMENTED

The DOE/NETL Modern Grid Strategy team's business case analysis demonstrates that a Smart Grid could yield enough benefits to West Virginia to justify further consideration. The project team developed an implementation plan that comprises three parts:

- Smart Grid Implementation Solutions – smart grid components that provide specific functionality required to meet the desired maturity for the seven modern grid principal characteristics described in Section 3.1. This section provides some background information, a schedule, and a work breakdown structure for each implementation solution.
- Pathway to a West Virginia Smart Grid – the implementation solutions are sequenced as building blocks, always adding capabilities to the grid as the project progress. The implementation pathway addresses system dependencies and builds a schedule of all the solutions in the optimal staging order to support the business case.
- Recommended RD&D Projects – Since implementation of the Smart Grid is a significant undertaking, it is prudent to consider developing and executing several research, development and demonstration projects that are smaller in scope but that test the concept of a component as part of the overall Smart Grid Implementation Plan solutions.

8.1 Process

The West Virginia Smart Grid Implementation Plan team used assumptions to calculate many of the benefits used in the cost-benefit analysis in the business case model. To increase the relevancy and applicability of information used, the project team selected values from other studies, drew from the significant experiences of the DOE/NETL Modern Grid Strategy team, and extrapolated from national averages. In addition, the team conducted a sensitivity analysis on each assumed value whereby each assumed value was doubled and halved recording the internal rate of return (IRR), the percent change in total benefits and the percent change in net present value (NPV). The optimal business case is one which maximizes IRR and NPV.

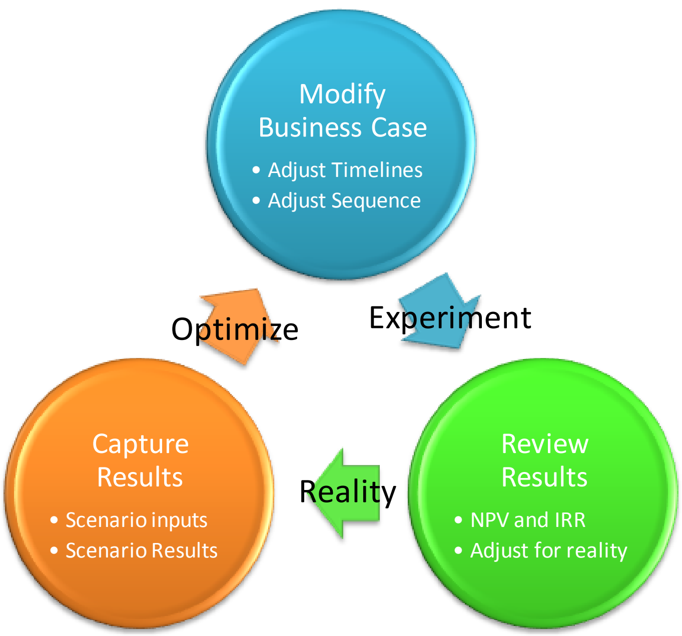


FIGURE 8-2: ITERATIVE DEVELOPMENT OF SOLUTION IMPLEMENTATION PLAN

Once the business case model was configured and evaluated for correctness, an iterative process of applying the five implementation solutions over different timelines and sequences began. Common sense and modern grid strategy team experience were used in determining reasonable timelines and dependencies. It took several iterations before coming to the implementation timeline and sequencing conclusions presented in this document.

8.2 Implementation Plan Results

The West Virginia Smart Grid Implementation team analyzed the implementation solutions used in the business case which provide the optimal enablement of the industry-recognized principal characteristics of a smart grid. Table 8-1 below shows the smart grid implementation solutions developed by the team. Each of the solutions provides support for most of the seven modern grid principal characteristics. All of the solutions described in this document provide high value smart grid capabilities.

TABLE 8-1: IMPLEMENTATION SOLUTIONS VS. MODERN GRID PRINCIPAL CHARACTERISTICS

	AMI	IT	Demand Response	Distributed Energy Resources	Distribution Management System
Enables active consumer participation	✓	✓	✓	✓	
Accommodates all generation and storage options	✓	✓	✓	✓	✓
Enables new products, services and markets	✓	✓	✓	✓	
Provides PQ for 21st century needs	✓	✓	✓	✓	✓
Optimizes assets and operates efficiently	✓	✓	✓	✓	✓
Anticipates and responds to disturbances	✓	✓	✓	✓	✓
Operates resiliently against attack and natural disaster	✓	✓	✓	✓	✓

The team prioritized the implementation solutions and accounted for the most desirable business case strategy, as well as how the systems must be integrated to achieve the desired results. The highest priorities and initial solutions create a foundation for implementing projects later in the rank order. In addition, technology maturity, capital requirements, and length of deployment also affected whether an improvement project appeared high or low in the rank order (see Table 8-2). The integrated planning is very important to make sure that priority projects are not held up by lesser priority projects, hence the importance of the pathway.

TABLE 8-2: IMPLEMENTATION SOLUTIONS SCHEDULE AND DURATION

Solution	Start Year	Field Start	Duration (yrs)
AMI	2010	2012	6
IT	2010	2013	4
DR	2013	2016	5
DMS	2011	2014	7
DER	2013	2015	5

Most of the implementation solutions assume an electrical network communications infrastructure that provides broadband or near broadband capabilities from the utilities to the distribution endpoints. In other words, electrical network communication dependency is universal across all the implementation solutions, except the IT solution. Also, three of the five solutions (AMI, Demand Response, and Distributed Energy Resources) have the further dependency requirement of smart meters. Since the AMI system implementation solution provides the infrastructure requirements for both communications and smart meters, it is the natural lead solution for establishing a smart grid in West Virginia. More on this subject will be discussed in the risk assessment section.

ID	Task Name	Start	Finish	Duration
1	AMI	1/1/2010	12/29/2011	104w
2	AMI Field	1/2/2012	12/25/2015	208w
3	IT Systems	1/1/2010	12/27/2012	156w
4	IT Systems Field	1/1/2013	12/30/2013	52w
5	DR	1/1/2013	12/28/2015	156w
6	DR Field	1/1/2016	12/28/2017	104w
7	DMS	1/3/2011	12/27/2013	156w
8	DMS Field	1/1/2014	12/26/2017	208w
9	DER	1/1/2013	12/29/2014	104w
10	DER Field	1/1/2015	12/27/2017	156w

FIGURE 8-3: WV SMART GRID IMPLEMENTATION PLAN

8.3 Smart Grid Implementation Solutions and Integrated Solution Pathway

8.3.1 Advanced Metering Infrastructure

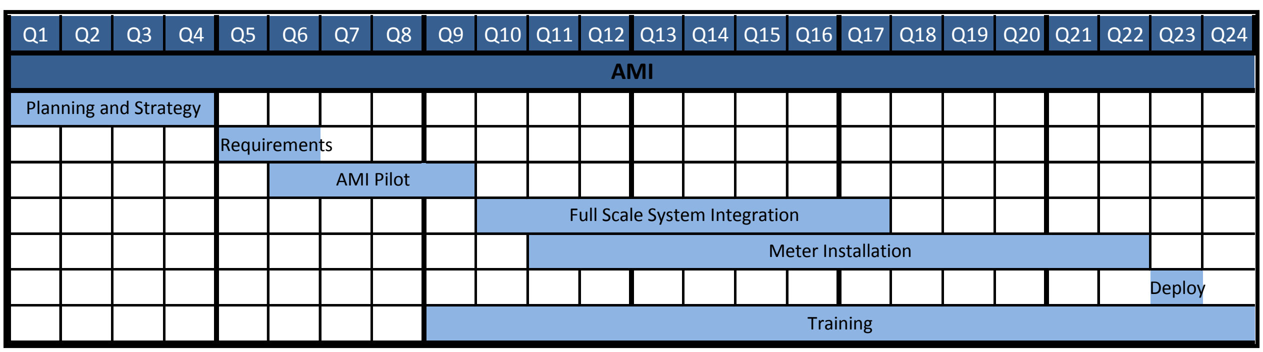


FIGURE 8-4: AMI SCHEDULE

The schedule (Figure 8-4) reflects the Advanced Metering Infrastructure smart grid implementation solution for West Virginia. The schedule reflects a six (6) year project duration with seven (7) primary tasks, which includes a RD&D pilot program near the beginning to test requirements compliance on a small scale. Table 8-3 below shows a high-level work breakdown structure (WBS) for the AMI project.

TABLE 8-3: AMI HIGH-LEVEL WORK BREAKDOWN STRUCTURE

WBS	Number	Duration
Planning and Strategy	**1.0**	**12 mo**
Kickoff	1.1	
Develop Project Plan	1.2	
Develop Detailed Implementation Schedule	1.3	
Develop Communications Plan	1.4	
Develop Risk Management Plan	1.5	
Technology, Integration, and Process Strategy	1.6	
Regulation Strategy	1.7	
Customer Relationship Management Strategy	1.8	
Develop Business Case	1.9	
Requirements and Vendor Selection	**2.0**	**6 mo**
Develop AMI/Communication Requirements Document	2.1	
Develop Security Requirements	2.2	
Develop RFPs	2.3	
Evaluate RFP Responses	2.4	
Select Vendors, Technologies, Meters, and MDMS	2.5	
Procure Pilot Hardware and Software	2.6	
AMI Pilot	**3.0**	**12 mo**
Develop AMI Pilot Project Plan	3.1	
Develop Pilot Detailed Schedule	3.2	
Integrate MDMS	3.3	
Install Communications and Meters	3.4	
Install Collectors, Substation Hardware, and Head End	3.5	
Perform Minimal Integration	3.6	
Test, Validate, and Verify	3.7	
Full Pilot Deployment	3.8	
Capture Lessons Learned and Re-baseline (if necessary)	3.9	
Full Scale System Integration	**4.0**	**24 mo**
Integrate MDMS	4.1	
Integrate CIS	4.2	
Integrate ERP	4.3	
Integrate Field Services	4.4	
Integrate GIS	4.5	
Integrate Other Enterprise Systems	4.6	

Unit Testing	4.7	
System Testing	4.8	
Operational Readiness Review	4.9	
Meter Installation	**5.0**	**36 mo**
Install Communications and Meters	5.1	
Install Collectors, Substation Hardware, and Head End	5.2	
Unit and System Testing	5.3	
Evaluation and Acceptance	5.4	
Operational Readiness Review	5.5	
Deploy	**6.0**	**3 mo**
Operational Readiness Review	6.1	
Deploy	6.2	
Test	6.3	
Assess	6.4	
Tune	6.5	
Training	**7.0**	**48 mo**
Training Planning and Development	7.1	
System Operator Training	7.2	
Organizational Change Management	7.3	
Customer Education and Awareness	7.4	
System Training	7.5	

8.3.2 Information Technology Transformation

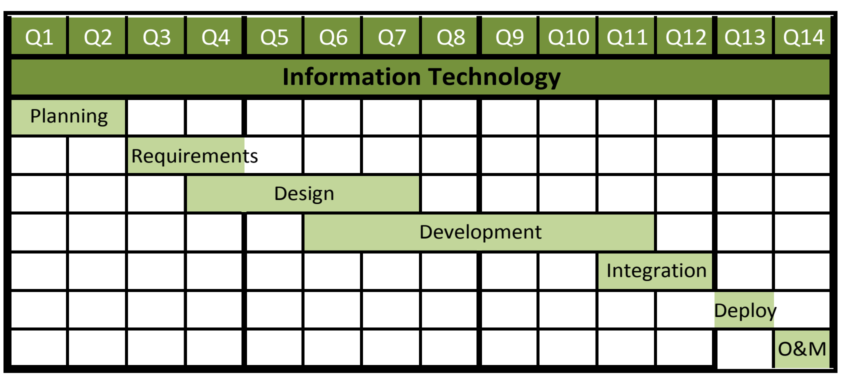


FIGURE 8-5: INFORMATION TECHNOLOGY TRANSFORMATION SCHEDULE

Interoperability, ease of system integration, and standardized sets of integration rules (or governance) are key aspects for ensuring system future-proofing and the ability to add, remove, and modify business processes without complete system re-works. Service Oriented Architecture (SOA) has become the common approach by most major utilities attempting to transform their business into a smart grid philosophy. As new smart grid systems emerge and mature, SOA provides the rules, interoperability, and system integration methods for minimizing the impact and effort on the business. It also provides the capability of automating and providing intelligence for business rules and business processes. The IT transformation schedule (Figure 8-5) reflects the adoption and implementation of a service-based integration strategy.

The schedule reflects a three and a half (3.5) year project duration with seven (7) primary tasks, which includes a significant effort prior to performing any development. Table 8-3 below shows a high-level WBS for the IT transformation project.

TABLE 8-4: IT TRANSFORMATION HIGH-LEVEL WORK BREAKDOWN STRUCTURE

WBS	Number	Duration
Planning	**1.0**	**6 mo**
Kickoff	1.1	
Develop SOA Strategy	1.2	
Develop Project Plan	1.3	
Develop Detailed Implementation Schedule	1.4	
Develop Communications Plan	1.5	
Develop Risk Management Plan	1.6	
Requirements	**2.0**	**6 mo**
Develop Requirements Document	2.1	
Develop SOA Governance and Rules	2.2	
Develop Security Requirements	2.3	
Design	**3.0**	**12 mo**
Develop Reference Architecture	3.1	
Develop Pilot Design	3.2	
Select Technologies and Software	3.3	
Establish Development and Test Systems	3.4	
Procure Software	3.5	
Design Interfaces, Components, Services	3.6	
Design Automated Business Processes	3.7	
Development	**4.0**	**18 mo**
Implement Vendor Software (ESB)	4.1	
Develop Interfaces, Components, Services	4.2	
Build Business Processes	4.3	
Interface, Components, Services Validation	4.4	
Unit Testing	4.5	
Integration	**5.0**	**6 mo**
Integrate Interfaces, Components, Services	5.1	

System Testing	5.2	
Evaluation and Acceptance	5.3	
Deploy	**6.0**	**3 mo**
Operational Readiness Review	6.1	
Deploy	6.2	
Test	6.3	
Assess	6.4	
Tune	6.5	
Operational Maintenance and Improvement	**7.0**	**3 mo**
Identify and Prioritize Systems to Integrate	7.1	
Design	7.2	
Develop	7.3	
Integrate	7.4	
Test	7.5	
Deploy	7.6	

8.3.3 Demand Response and Distributed Energy Resources

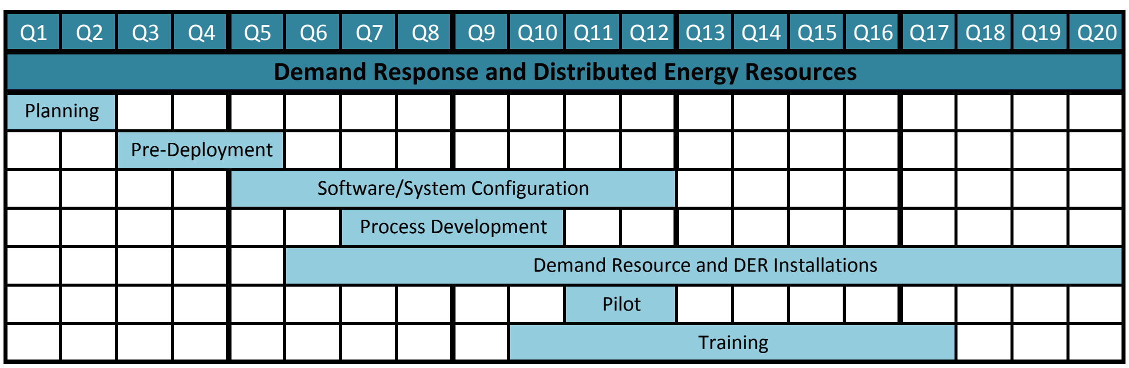


FIGURE 8-6: DEMAND RESPONSE AND DER SCHEDULE

Demand Response (DR) and Distributed Energy Resources (DER) have long been discussed as the real reason for implementing an AMI solution. DR and DER provide the means for managing energy efficiency, increasing electric reliability, and providing the ability for consumers to participate in the grid's economic market.

Some recent studies in California indicate that DR and DER look the same to a utility. DR provides load shedding/increasing capabilities, while DER provides generation increasing/decreasing capabilities. Both are driven by business rules around reliability and economics. Both are manageable, dispatchable resources that can be communicated with when grid or economic conditions require an increase/decrease in load or an increase/decrease in generation. Both can be managed by a single system, or demand response management system (DRMS). With this understanding, we have combined the DR and DER implementation solutions into a single implementation project.

The schedule (Figure 8-6) reflects the Demand Response and Distributed Energy Resource smart grid implementation solution for West Virginia. The schedule reflects a five (5) year project duration with seven (7) primary tasks, which includes a RD&D pilot program to test requirements compliance on a small scale. Table 8-5 below shows a high-level WBS for the DR and DER projects.

TABLE 8-5: DR AND DER HIGH-LEVEL WORK BREAKDOWN STRUCTURE

WBS	Number	Duration
Planning and Strategy	**1.0**	**6 mo**
Kickoff	1.1	
Develop Project Plan	1.2	
Develop Detailed Implementation Schedule	1.3	
Develop Communications Plan	1.4	
Develop Risk Management Plan	1.5	
Develop Requirements Document	1.9	
Pre-Deployment Preparation	**2.0**	**9 mo**
Technology and product selection	2.1	
Negotiate and sign contracts	2.2	
Develop Participant Programs	2.3	
System Integration	2.4	
Cyber Security	2.5	
Change Management	2.6	
Customer Awareness	2.7	
Procurement	2.8	
Software/System Configuration (same as DER systems)	**3.0**	**24 mo**
DRMS	3.1	
MDMS	3.2	
Other Systems (CRM, WFM, etc.) needing integration	3.3	
Legacy Load Control and AMI Communications	3.4	
Interactive Customer Website	3.5	
SOA and ESB	3.6	
Security	3.7	
Process Development	**4.0**	**12 mo**
Standards Identification and Compliance	4.1	
Business Processes and Rules	4.2	
Exceptions Management	4.3	
Workflow Processes	4.4	
Demand Resource Installation	**5.0**	**36 mo**

Participant Recruitment and Sign-up	5.1	
Installations	5.2	
Pilot	**6.0**	**6 mo**
Plan	6.1	
Configure	6.2	
Deploy	6.3	
Test	6.4	
Assess	6.5	
Tune	6.6	
Training	**7.0**	**24 mo**
Training Planning and Development	7.1	
Process and Workflow	7.2	
Systems	7.3	
Organizational Change Management	7.4	
Customer Education and Awareness	7.5	

8.3.4 Distribution Management System

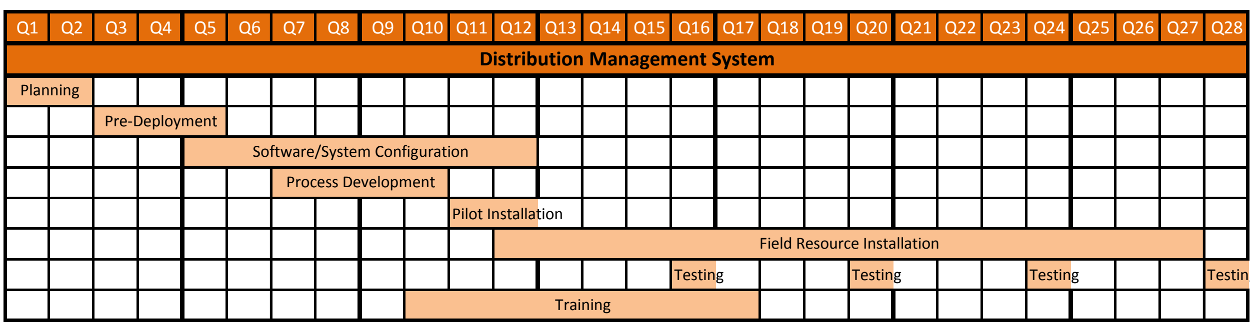


FIGURE 8-7: DISTRIBUTION MANAGEMENT SYSTEM SCHEDULE

The schedule (Figure 8-7) reflects the Distribution Management System (DMS) smart grid implementation solution for West Virginia. The DMS schedule is the longest duration smart grid implementation solution. The schedule reflects a seven (7) year project duration with eight (8) primary tasks, which includes iterative testing efforts as field resources are installed as well as a RD&D pilot program to test requirements compliance on a small scale. Table 8-6 below shows a high-level WBS for the DMS project.

TABLE 8-6: DMS HIGH-LEVEL WORK BREAKDOWN STRUCTURE

WBS	Number	Duration
Planning and Strategy	**1.0**	**6 mo**
Kickoff	1.1	

Develop Project Plan	1.2	
Develop Detailed Implementation Schedule	1.3	
Develop Communications Plan	1.4	
Develop Risk Management Plan	1.5	
Develop Requirements Document	1.9	
Pre-Deployment Preparation	**2.0**	**9 mo**
Architecture, technology, and product selection	2.1	
Negotiate and sign contracts	2.2	
Model the device/sensor penetration	2.3	
System Integration	2.4	
Cyber Security	2.5	
Change Management	2.6	
Customer Awareness	2.7	
Procurement	2.8	
Software/System Configuration	**3.0**	**24 mo**
DMS	3.1	
Distribution Automation	3.2	
Other Systems (GIS, CIS, OMS) needing integration	3.3	
Integrated Communications	3.4	
Advanced OMS	3.5	
Distribution Operations Center	3.6	
Security	3.7	
Process Development	**4.0**	**12 mo**
Standards Identification and Compliance	4.1	
Business Processes and Rules	4.2	
Exceptions Management	4.3	
Workflow Processes	4.4	
Pilot Installation	**5.0**	**6 mo**
Plan	5.1	
Configure	5.2	
Deploy	5.3	
Test/Commission	5.4	
Assess	5.5	
Tune	5.6	
Field Resource Installation	**6.0**	**48 mo**
Field Services Provisioning	6.1	
Installations	6.2	

Testing and Commissioning	**7.0**	**3 mo**
Subsystem testing	7.1	
System testing	7.2	
Commissioning	7.3	
Training	**8.0**	**24 mo**
Training Planning and Development	8.1	
Process and Workflow	8.2	
Systems	8.3	
Organizational Change Management	8.4	
Customer Education and Awareness	8.5	

8.3.5 Combined Roadmap

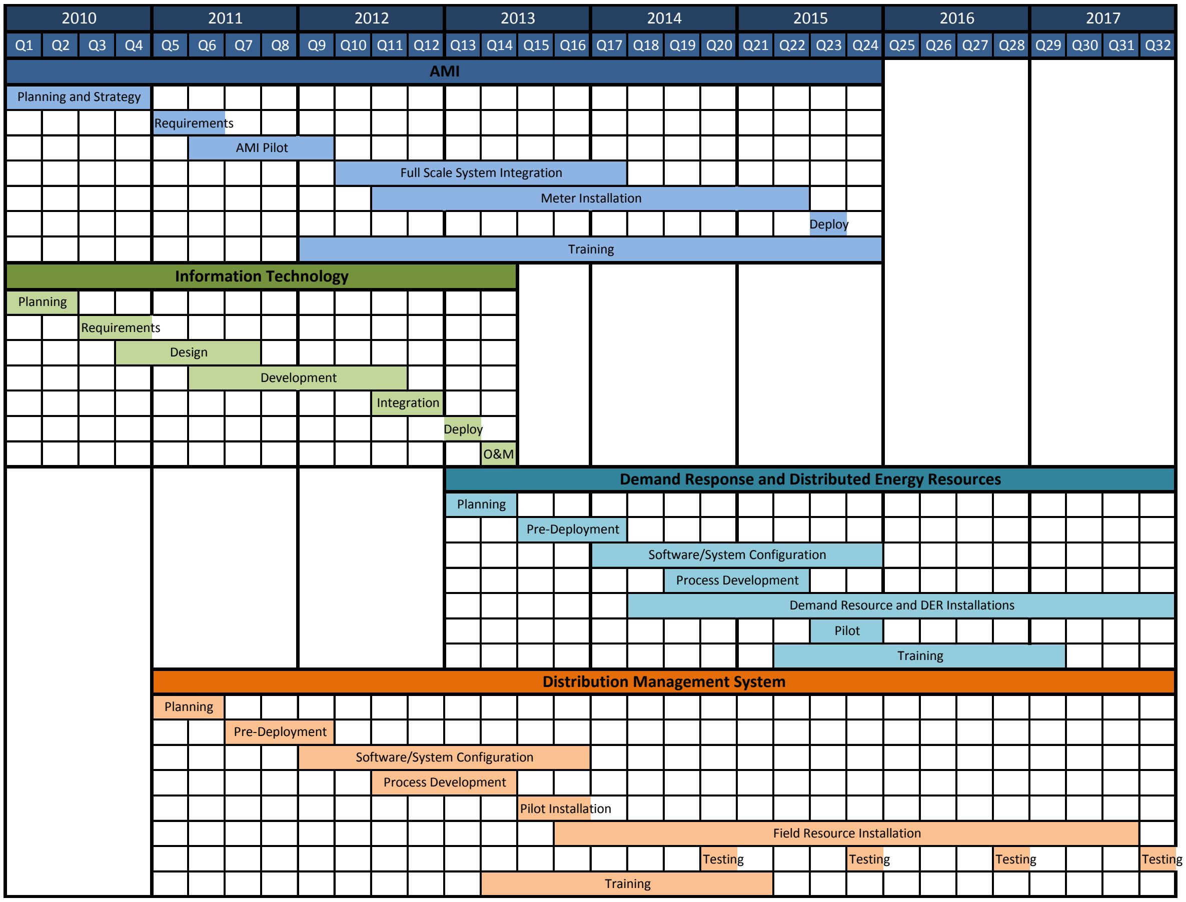


FIGURE 8-8: COMBINED IMPLEMENTATION SOLUTION SCHEDULE

Figure 8-8, above, shows the minimal amount of time necessary to implement the five (5) smart grid implementation solutions.[1] The AMI and Information Technology solutions provide a lot of the necessary communication infrastructure, system interoperability, and governance that are needed for the other smart grid solutions. These two solutions initiate the WV smart grid transformation. The combined schedule assumes an initial start date of January 2010. The Distribution Management System implementation solution is the longest duration, and is the last to complete. As already discussed, it includes an iterative approach with the field service installations and testing. The Demand Response and DER solutions are complex and require the AMI infrastructure for communications to Demand Resources and DER devices. These solutions are also simpler to implement once the IT discipline, market systems, and Service Oriented Architecture are in place.

[1] Demand Response and Distributed Energy Resource implementation schedules were combined since they use the same management software and infrastructure.

8.4 Recommended RD&D Projects

A West Virginia Smart Grid implementation is a significant effort. Several research, development and demonstration (RD&D) projects (or pilots) have been identified that test the component parts of the overall Smart Grid solutions. The Smart Grid solutions could require additional guidance that best comes from a smaller pilot project that explores risks of new technologies and complexities of integration before introducing them at large to the operating grid. The project team identified four (4) such demonstration projects and included them in the implementation plan.

1. AMI – the AMI pilot begins once planning and the initial requirements have been identified. It exercises a small number of AMI meters from the chosen vendor using the Meter Data Management System (MDMS) in a minimally-integrated role. The pilot allows the utility to test the communication infrastructure, messaging, and data collection against the system requirements.
2. Demand Response – the DR pilot begins once the advanced meters have been installed from the AMI project and the Demand Response Management System (DRMS) and test business processes have been configured. A small number of load management Demand Resources are deployed and tested. The pilot allows the utility to test DR program rules, business rules for load management, economic and reliability message requests and their load management results, expected vs. actual load management results, in home device results, and participant behavioral patterns.
3. Distributed Energy Resource – similar to the DR pilot discussed above, the DER pilot allows the utility to test generation management (rather than load management) and occurs during a similar timeline in the overall DR and DER implementation solution schedule.
4. Distribution Management System – the DMS pilot begins once business process development has completed and is used to help complete the software configuration and testing. With the DMS system, it is likely that several different devices and strategies will be used over time. The pilot is not anticipated to test everything, but rather provide a simple, baseline system that allows the DMS enterprise systems an opportunity for testing and experimentation. There are adjustments in the schedule to allow for iterative testing of multiple strategies and devices during the full deployment effort.

8.5 Risk Assessment

8.5.1 Future Proofing

The most obvious potential risk with all of the different smart grid implementation solutions is the maturity and future-proofing related to the solution technologies. What happens as the technologies mature? Will something better come along down the road? Could these technologies become stranded costs? Are there smart grid solutions we haven't identified yet?

These are all valid questions and concerns. In fact, it is anticipated that these solutions will continue to mature and evolve, and other solution opportunities will present themselves in the future. The risk comes in balancing West Virginia's, AEP's, and Allegheny Energy's need to stay current (or ahead) of other states and utilities and the potential problem of jumping on the smart grid bandwagon too soon.

Fortunately, smart grid solutions have progressed dramatically in the past six years. Vendors recognize the revenue opportunities with smart grid technologies and products, and competition has created stronger solutions that support different state, utility, and consumer needs. Vendors also recognize that the landscape continues to change, so their products reflect the ability to be upgraded and provide interoperability between other smart grid technologies and competitor products. Government and societal interest in better energy efficiency and grid reliability also help drive standards development, innovation, and investment in smart grid technology maturation.

A major help in future proofing the system is the use of an integrated communications system to support all the aspects of the Smart Grid. The integrated communications system provides flexibility to deploy smart grid technologies in steps and allow key additions later once they are mature. In addition, Information Technology advances (one of the smart grid implementation solutions discussed in this document), and Service Oriented Architecture, in particular, also provide a better means for integrating systems and products, automating business processes, and making changes to systems and products without completely disrupting other systems and processes.

All of these risk mitigation efforts and the actual need right now for smart grid solutions in West Virginia outweigh the argument for just doing nothing. In fact, there is more risk in doing nothing since it will put WV at a competitive disadvantage in providing incentives for corporations and skilled workers to either remain or relocate here. Better electric reliability and efficiency are very real catalysts for growing the 21st century economy in WV. Since WV is an energy export state, there are immediate market-related WV benefits from using the smart grid to improve efficiencies inside the state which leads to more exports of electricity to neighboring states on the RTO market.

8.5.2 Change Management at the Utilities

The amount of change required at the utilities as a result of implementing the smart grid solutions described in this document should not be underestimated. This is a dramatic transformation from a mid-20th century operating mentality to a high tech, very modern operation. In the future, the Smart Grid utility will not simply make more money by selling more electricity and adding more capacity. Instead, it will be profitable through innovation, intelligent and efficient management of dispatchable resources, and market participation. West Virginia has incredible profitability opportunities for utilities because of the vast and readily-accessible resources (coal, especially) and a surplus of electrical generation.

Change management within the utility during this transformation should be a high priority. Finding skilled personnel will be challenging. Structured, comprehensive training and a top-down, dedicated commitment to preparing personnel for the smart grid way of doing business will be critical to the utility's success.

8.5.3 Delaying AMI

One of the deployment strategies discussed and analyzed was the idea of moving the DMS solution to the front, delaying the AMI solution implementation and the other dependent solutions due to AEP's recently completed AMR program in WV. The WV Smart Grid Implementation Plan team also evaluated starting the AMI implementation at the same time as the DMS, but stretched it to 10 years in order to allow a DMS priority. The result indicated that this business case is not optimal. In fact, the stretched AMI implementation caused a two year delay in the DR and DER solutions, showing a PV of Net Benefits decline of about $2 billion.

The team recognized that the positive business case for AMI alone does not drive the complete Smart Grid value; however, it does provide the baseline infrastructure required for other high-value solutions, especially Demand Response and Demand Energy Resources. It is not prudent to delay or extend the AMI solution in order to focus on the DMS solution.

9.0 Summary of Conclusions and Recommendations

A summary of the main conclusions and recommendations that were determined by this project are tabulated in this section. These conclusions and recommendations evolved from the Gap Analysis performed in Section 6.0, the Business Case explained in Section 7.0, and the Implementation Plan described in Section 8.0, and are summarized below.

9.1 Gap Analysis

The fundamental gaps that exist between the current state of the electric grid in West Virginia and its proposed future state were identified thorough a gap analysis. Then a list of proposed solutions were identified that if implemented would enable these gaps to be eliminated or reduced so that a smart grid could be functional in West Virginia before 2020. The identified gaps and their proposed solutions are shown in Table 9-1.

TABLE 9-1: MAIN GAPS AND SMART GRID SOLUTIONS (REF TABLE 6-3)

Main Gaps for Smart Grid	Proposed Solutions for Implementing a Smart Grid
Technology	• Advanced Meter Infrastructure • Information Technology Integration • Demand Response • Distribution Management Systems • Distributed Energy Resource that is plug and play and supports generation, storage and PQ • Transmission Management Systems*
Regulatory / Governmental	• Inclusion of Smart Grid investments in rate base • Rate structures that encourage DER, DR and differentiated PQ • Federal and state funding of related R&D • Change in regulatory policy to create incentives and remove dis-incentives for investment (e.g. decoupling as new regulatory model) • Decisions based on societal business case • Recovery of Smart Grid-driven early write-offs
Consumer	• Consumer Education (role they can play, PQ issues; Security issues) • Access by all consumers to the electrical market • DER interconnect standards • HANs and consumer agents • Standardized transfer of market information

* Transmission projects such as TrAIL and PATH are already in progress and provide the technology solution needed at the transmission level. Because of this, the team decided to focus on the distribution and consumer solutions.

All of the critical stakeholders who need to partner together to achieve this smart grid endeavor will have to be participants in order to accomplish the needed Technology, Regulatory/Governmental and Consumer solutions.

One of the major contributors to implementing a successful smart grid will be eliminating the technology gap. Thus, this project devoted considerable effort to addressing each of the main contributors to closing the technology gap in terms of its penetration, its costs and its benefits. The five main technology contributors to the successful implementation of a smart grid in West Virginia were AMI, IT Integration, DR, DMS and DER. A tabulation of these main contributors and the scope of their proposed implementation are shown in Table 9-2.

TABLE 9-2: TECHNOLOGY CONTRIBUTORS FOR A SMART GRID (REF TABLE 7-1)

Technology Contributor	Long Name for Technology Contributor	Scope of Implementation needed to Close Main Technology Gap in West Virginia
AMI	Advanced Meter Infrastructure	The installation of smart meters will for all 998,317 residential, commercial and industrial customers in West Virginia.
IT	Information Technology Integration	An upgrade of computer information system by utility companies in West Virginia in order to accommodate AMI and DR functionality and outage management.
DR	Demand Response	An aggregated sum of 104 MW of new DR from residential, commercial and industrial customers in West Virginia.
DMS	Distribution Management System	The automated fault clearing and restoration of service, circuit monitoring and control of the distribution system for 707 circuits of the 1107 total circuits in West Virginia.
DER	Distributed Energy Resources	The addition of 100 MW of base generation, 800 MW of peak generation, 250 MW of advanced storage and 100 MW of wind resources in Wet Virginia, all capable of being dispatched on demand.

The scope of implementation stated for each of the five technology contributors listed in Table 9.2 evolved as part of the assessment performed during the gap analysis, during extensive benefit and cost studies performed during the business case phase, and during an optimization of the schedule performed during the implementation plan phase. Also, a set of research, development and deployment (RD&D) projects that would accelerate the implementation plan and reduce risk were identified. In addition, the interfacing of integrated communications and information technology that could also be enablers of the smart grid implementation was incorporated (see Section 9.3).

While other technology solutions do exist, such as the use of high-temperature superconducting cables and fault current limiters, their deployment was deemed outside the scope of this project.

9.2 Business Case

The business case utilized estimates for the capital and O&M costs for the identified solutions and estimates of the benefits that would be enjoyed by utility operations, WV consumers, WV society, and for the regional US society. These costs and benefits are plotted in the chart shown in Figure 9-1. As shown, capital costs are the largest expense in order to implement the smart grid, while the largest benefit would belong to the WV consumers.

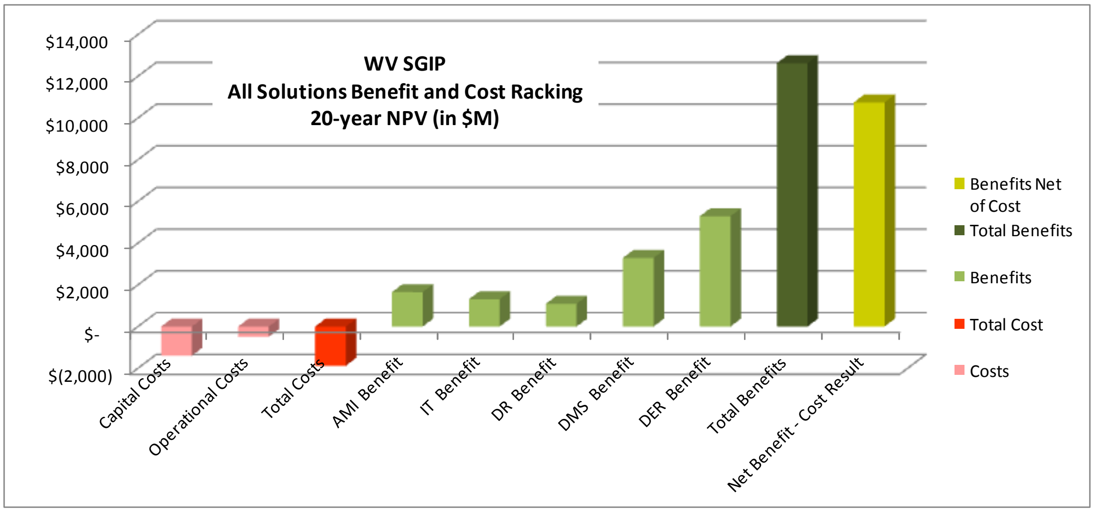


FIGURE 9-1: COSTS AND BENEFITS FROM IMPLEMENTING SMART GRID (REF FIG 7-4)

In summary, an investment of about $1.9 Billion will result in about $10.7 Billion in benefits yielding a benefit to cost ratio of approximately 5:1 over the next 20 years.

Figure 9-2 illustrates the benefits shared among WV utilities, WV consumers and WV society.

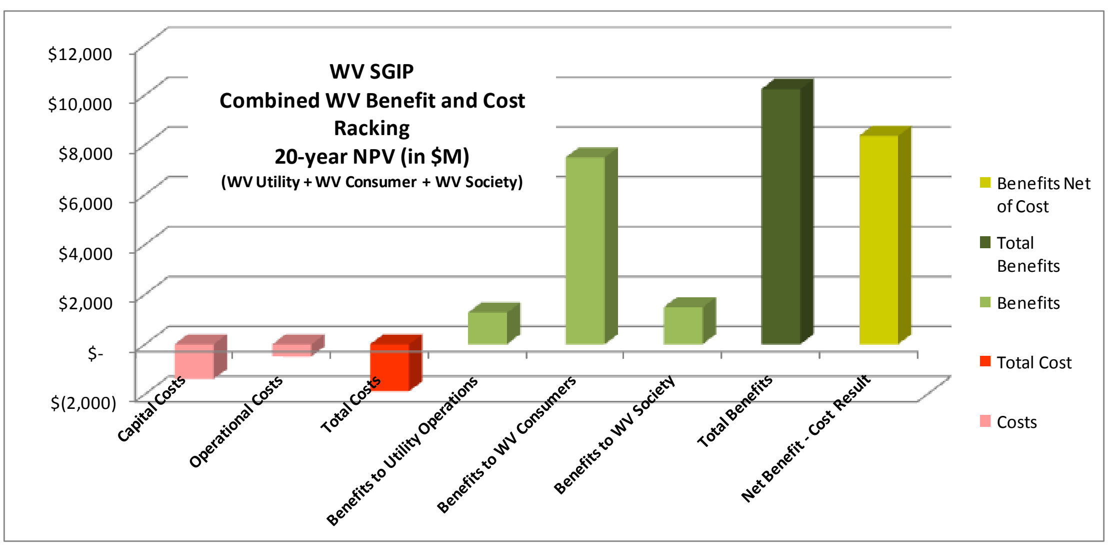


FIGURE 9-2: TOTAL WEST VIRGINIA BENEFIT AND COST RACKING (REF FIG 7-6)

9.3 Implementation Plan

The results summarized in Section 9.2 are based on a specific implementation schedule that has been optimized to minimize costs and maximize benefits. Table 9-3 outlines the phasing of the technology contributors that will realize the most benefit for the least cost to WV.

TABLE 9-3: SCHEDULE FOR IMPLEMENTATION OF TECH CONTRIBUTORS (REF TABLE 8-2)

Technology Contributor	Start Year	Field Year	Years for Implementation
AMI	2010	2012	6
IT	2010	2013	4
DR	2013	2016	5
DMS	2011	2014	7
DER	2013	2015	5

The time shown between the start year and the field year is needed to conduct RD&D pilot projects and to implement foundational systems, such as the required integrated communication systems. The main pilot projects are an AMI pilot project, a DR pilot project, a DMS pilot project and a DER pilot project. See Section 8.4 for descriptions of these projects.

The incorporation of such pilot projects and communications systems will accelerate the smart grid implementation plan and will reduce the risks. They are integral to a successful field deployment of the smart grid across the state.

10.0 Appendices

Appendix	Description
10.1	Smart Grid Characteristic Maturity Model
10.2	West Virginia University Stakeholder Assessment
10.3	West Virginia University Consumer Complaints Assessment
10.4	Business Case Details

10.1 Smart Grid Characteristic Maturity Model

	1 Traditional	2 Exploring and Initiating	3 Integrated	4 Optimizing	5 Innovating
Enables active consumer participation	•"Dumb" meters •varying amount of AMR, no AMI • traditional rates, monthly bills, little price visibility •minimal consumer involvement, few choices	•AMR, TOU rates being discussed, considering AMI •little or no DR in place (none using smart meters) •consumers questioning value of Smart Grid	•AMI pilots in progress, consumers interested in new options •regulatory climate supports advanced rates, utility security concerns are satisfied •limited deployment of home area networks.	•AMI deployment completed in specific regions •DR in place with smart meters •consumers active in deploying smart appliances, PHEV, DG, and home area networks •activity with RTO underway to link to consumer •dynamic real time rate structures in place	•Full deployment of integrated Demand Response and AMI system • Ubiquitous access to markets, extensive consumer participation,"E-bay" level of activity •deep integration of consumer status with OMS • AMI becomes a platform for new consumer-side applications in the home.
Accommodates all generation and storage options	•Little or no grid connected distributed resources •interconnection standards are expensive and complex •grid design does not support "plug or play"	•Minimal deployment of DG and storage •integration limited due to inability of distribution feeders to accommodate two-way power flow •simplified but safe interconnection standards available.	•Wide penetration of DER as distribution circuit conductors, communications and control and protection schemes are upgraded to accommodate two-way power flow •emerging opportunities for integrated DG and energy storage.	•New tariffs incent DER deployment •integrated operation of multiple DER devices and microgrids on a single feeder •central DER coordination at substation or higher system level.	•Wide deployment of DER, PHEV's and storage •full plug and play capability •ubiquitous two-way power flow from DER, centrally coordinated for optimal grid operations •virtual power plants are created by aggregating DER that is controlled as a single entity •generation planners consider DER an equal to central generation •DER owners earn revenue by providing ancillary services to RTO.
Enables new products, services and markets	•No consumer interaction with utility or RTO •limited wholesale markets	•Limited Demand Response and energy efficiency programs are in place •Demand Response pilots/experiments are in progress •utility is market participant at RTO •energy prices based on time of use.	•Combined DR and AMI technologies emerging to change customer conservation behavior •Home Energy Management systems are deployed in some areas •market tariffs for ancillary services emerge to incent consumer participation.	•Access to RTO markets available in specific regions •value of consumer involvement well understood, transactions occur among consumers, utilities, and RTO's in real time •AMI communications infrastructure can support multiple HAN applications •DR, DER and energy efficiency programs in place •transmission congestion eliminated.	•RTO's are nationally integrated •consumers offer their resources to the utility and RTO for reliability and market benefits •widespread deployment of "grid-aware" consumer products in home •consumer involvement has significant impact on grid operations
Provides PQ for 21st century needs	•Reactive response to customer PQ complaints •adversarial discussions over who is responsible for fix.	•PQ monitoring systems installed proactively •PQ unit created within utility •utility investment planning processes include consideration of PQ.	•Minimally acceptable PQ levels for all customers established, backed up with system designs/investments that deliver this level •companion strategy to provide price differentiated PQ consistent with consumer needs.	•PQ metrics established and performance trends tracked •Advanced technology deployments include: remote PQ Sensing, static var compensation, power electronic PQ devices, spike and harmonic filters, and PQ parks.	•PQ objectives included in management performance evaluations • Identification and resolution of PQ issues are a priority • Levels of PQ established for different prices supported by customers, regulators and utility.
Optimizes assets and operates efficiently	•Limited grid information available to operators, planners, engineers, customer service reps and maintenance personnel •Time-based maintenance is predominant •Traditional energy efficiency programs available to consumers	•Asset management program is a priority at utility, increasing interest in condition based maintenance, dynamic ratings of assets, and reducing system losses •limited deployment of sensors for monitoring asset health and condition •Increased focus on more aggressive energy efficiency programs	•Asset condition and health sensors being deployed for critical assets system wide •capability exists to process the large amount of new data to information •limited integration with GIS and other enterprise wide processes •DR employed to improve asset utilization •AMI reduces energy theft and identifies electrical losses • Utility enterprise-wide systems are being integrated using Service-oriented Architecture technologies (SOA).	•Regionally deployed health and condition sensors integrated with AMI and GIS to enable at least one of the following processes - system planning, condition based maintenance, outage management, system loss reduction, work management, customer service, engineering, •Modeling, simulation and visualization tools enable operators to perform "what if" analyses •Enterprise-wide level visualization system deployed and integrated with AMI, GIS, OMS, DA, DR, DER, work management, etc.	•High level of granularity of grid intelligence available •operating and asset health data deeply integrated with operating and asset management applications •dramatic improvement in enterprise wide processes - GIS, system planning, maintenance, outage management, work management, customer service, engineering •improved load factors allow existing assets to be fully utilized.
Anticipates and responds to disturbances	•Reactive protection of assets, circuit breaker trips after fault occurrence •limited monitoring (grid sensors and SCADA) of equipment status and health to warn of degraded conditions •run to failure strategy.	•Increased monitoring, control and visualization technologies deployed (e.g. SCADA, PMUs, transformer gas analysis), with research initiated to develop new methods (e.g. EMI analysis) of monitoring asset health •digital relays replace electromechanical ones •DA pilots initiated on a small scale	•Digital relays networked through a digital communications platform •advanced operator visualization tools and real time data collection (SCADA) installed at system control centers •automation deployed where appropriate across entire distribution level AMI integrated with distribution OMS •DA deployment strategies developed and deployments are underway	•System Integrity Protective Systems (SIPS) ensure regional reliability, adaptive relaying deployed •system-wide controls installed to process extensive system real time data, including WAMs inputs, and take instantaneous actions when manual operator action would be too slow •DER and DR integrated with DA and feeder backup is underway •islanding services available to customers • all critical system assets are monitored in real time (SCADA fully deployed).	•Ubiquitous digital communications platform integrates multiple self healing technologies •deep deployment of grid sensors, distributed generation and storage, feeder backup and control devices enable early detection and resolution of degraded conditions •outage and restoration times minimized, disturbances prevented through autonomous control.
Operates resiliently against attack and natural disaster	•Centralized model with stressed and aging assets make the grid vulnerable to attack and natural disaster •Service restoration slow and based on customer call-in	•Cyber security is a prime consideration •utility support for decentralized generation and storage (DER) exists •aging assets are replaced with new, more intelligent and robust technologies.	•AMI penetration growing, providing tool for more rapid service restoration •some distributed generation, storage technologies, self healing technologies deployed •most assets monitored to detect challenges • increased grid intelligence •advanced visualization technologies that provide increased situational awareness under evaluation	•Service restoration faster due to fully deployed AMI •regional advanced detection, diagnosis, and autonomous corrective action in place •cyber security standards are well defined and incorporated in new designs •more than half of consumers have back-up power •local micro-grids emerge.	•Advanced visualization tools integrated with enterprise-wide technologies to optimize situational awareness and reduce reaction times •System-wide grid intelligence is used to deter, detect, mitigate, and rapidly restore from deleterious impacts •majority of consumers have back-up power •micro-grids deployed in all critical areas.

10.2 WVU Stakeholder Assessment

West Virginia Smart Grid Implementation Plan (WV SGIP) Project

APERC Report on Assessment of As-Is Grid by Non-Utility Stakeholders

Ali Feliachi, Muhammad Choudhry, John Saymansky and Ed Sneckenberger

February 15, 2009

Report is attached.

10.3 WVU Consumer Complaints Assessment

West Virginia Smart Grid Implementation Plan (WV SGIP) Project

APERC Report on Customer Complaints to WV PSC about Electric Power Service

Ali Feliachi, Muhammad Choudhry, John Saymansky and Ed Sneckenberger

February 16, 2009

Report is attached.

10.4 Business Case Details

The cash flows of the various Smart Grid Scenarios and technology solution options will be highlighted in this appendix. In Figure 10-1 below, the discounted cash flow is shown for interest rates from 5% to 15% in one percent increments.

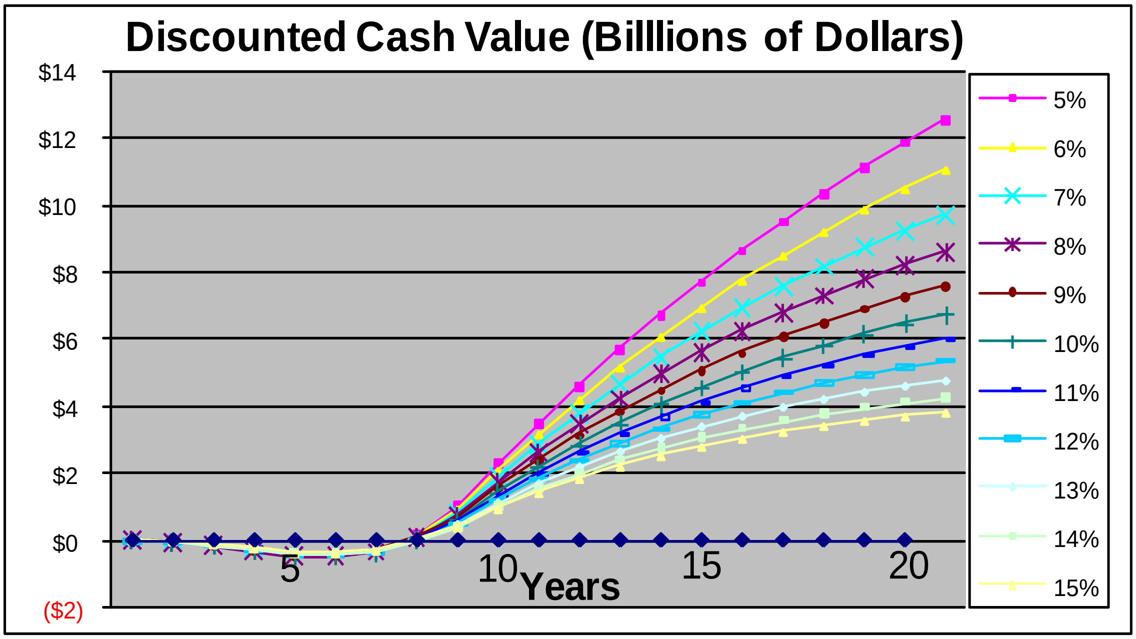


FIGURE 10-1: BUSINESS CASE DISCOUNTED CASH VALUE USING ALL BENEFITS

The graph shows that in 8 years, regardless of interest rate, a positive cash flow will result. It shows the potential to reap billions of dollars in benefits in the decade following the point of positive cash flow. This graph uses all benefits to include societal, consumer and operational benefits combined with the capital and O&M expenditures to arrive at the overall cash flow values. A discounted cash flow graph showing such positive returns is indicative of a sound business case and is worthy of investment.

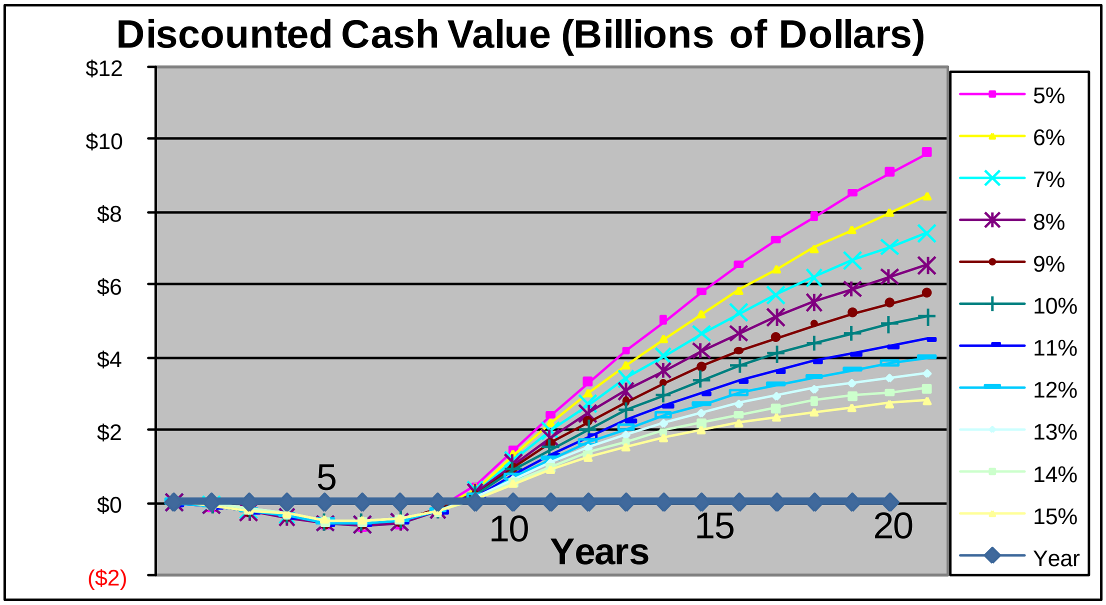


FIGURE 10-2: BUSINESS CASE DISCOUNTED CASH VALUE USING WV BENEFITS

Figure 10-2 displayed above shows a 9 year lag to positive cash flow regardless of interest rate and the potential to reap billions in over the decade after that. This graph includes the societal benefits that apply only to West Virginia, the West Virginia consumer benefits and the operational benefits that apply to the West Virginia utilities. A discounted cash flow graph showing such positive returns is indicative of a sound business case and is worthy of investment.

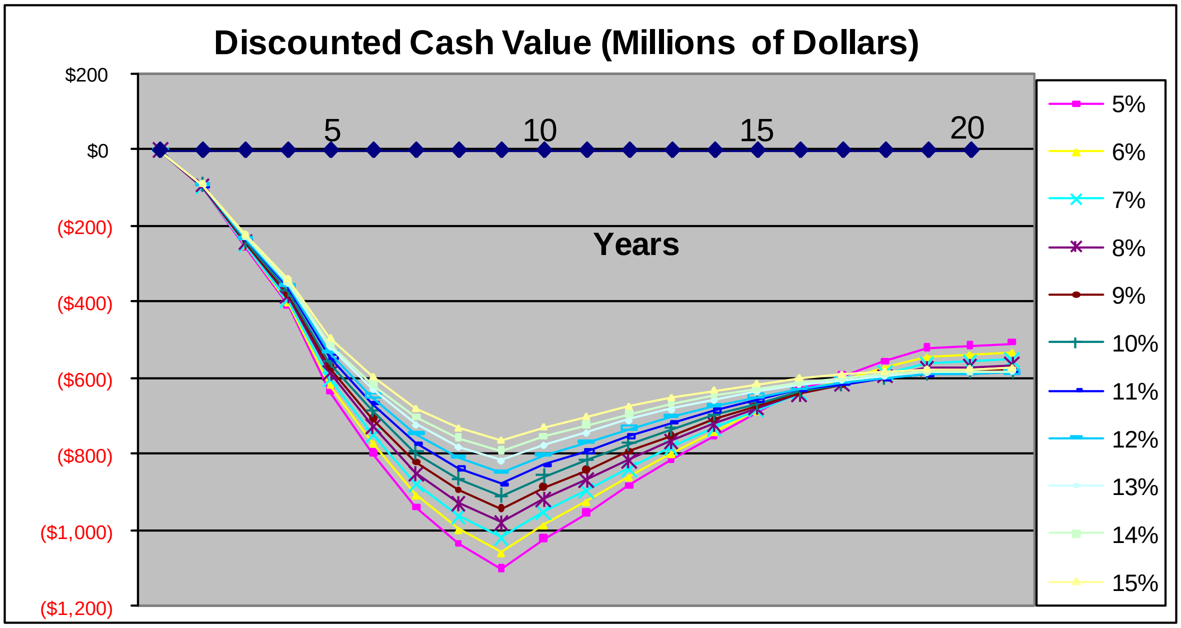


FIGURE 10-3: BUSINESS CASE DISCOUNTED CASH VALUE USING OPERATIONAL BENEFITS

Figure 10-3 shows that a positive cash flow may not occur. This graph uses only the operational benefits that the utility can expect to receive as a result of installing Smart Grid technologies in West Virginia. This type of discounted cash flow graph shows that an operational benefits-only approach is indicative of a poor business case and is not worthy of investment.

The importance of this graph is that it shows that the utility has no incentive to invest in Smart Grid technologies. The major benefactors of Figure 10-2, WV Society and WV Consumers, will not reap the rewards unless they participate in the investment or convince others to invest on their behalf.

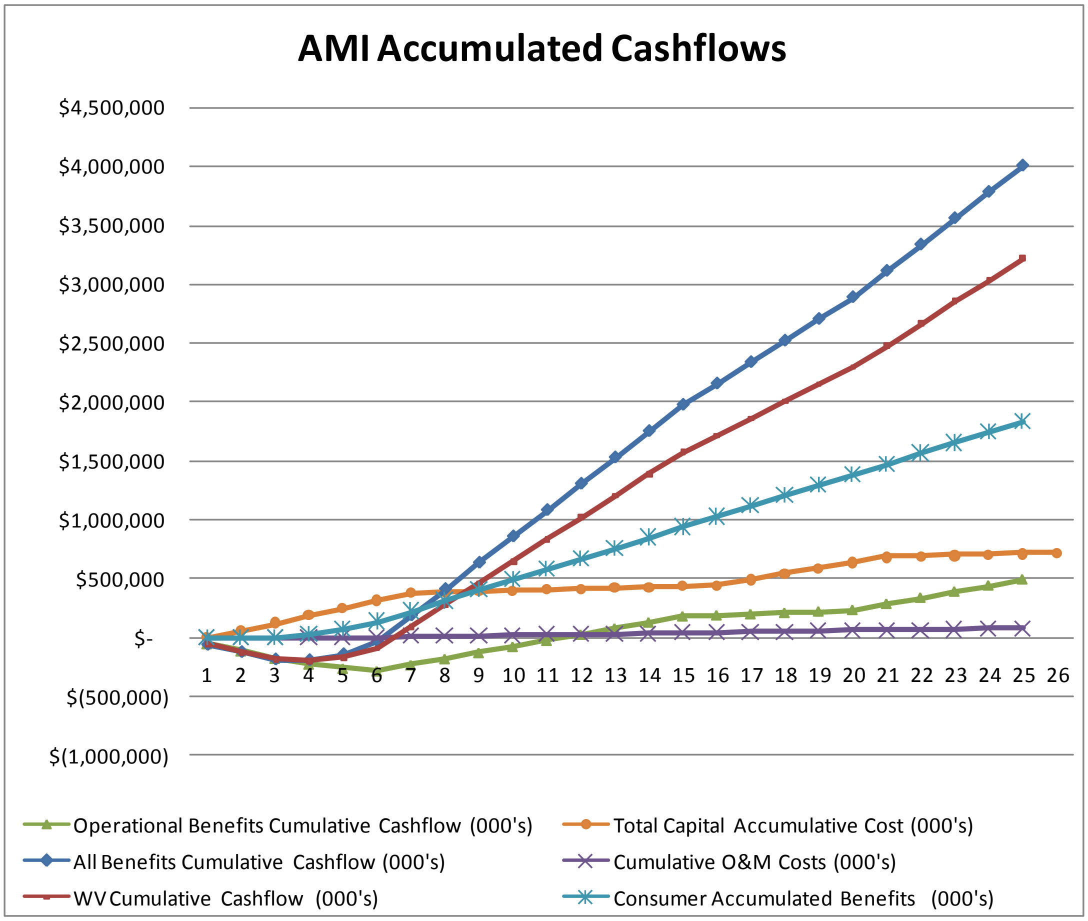


FIGURE 10-4: BUSINESS CASE AMI ACCUMULATED CASH FLOWS

The AMI Technology solution cumulative cash flows is depicted in Figure 10-4. The following can be said of the six parameters:

- Capital Costs rise linearly and level off at the end of the project
- Operating and Maintenance Costs begin at zero and rise nearly linearly with years
- Operational Benefits cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case time period
- Consumer cumulative benefits begin at zero and rise nearly linearly through the business case examination period
- All Benefits Cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case examination period
- WV Cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case examination period.

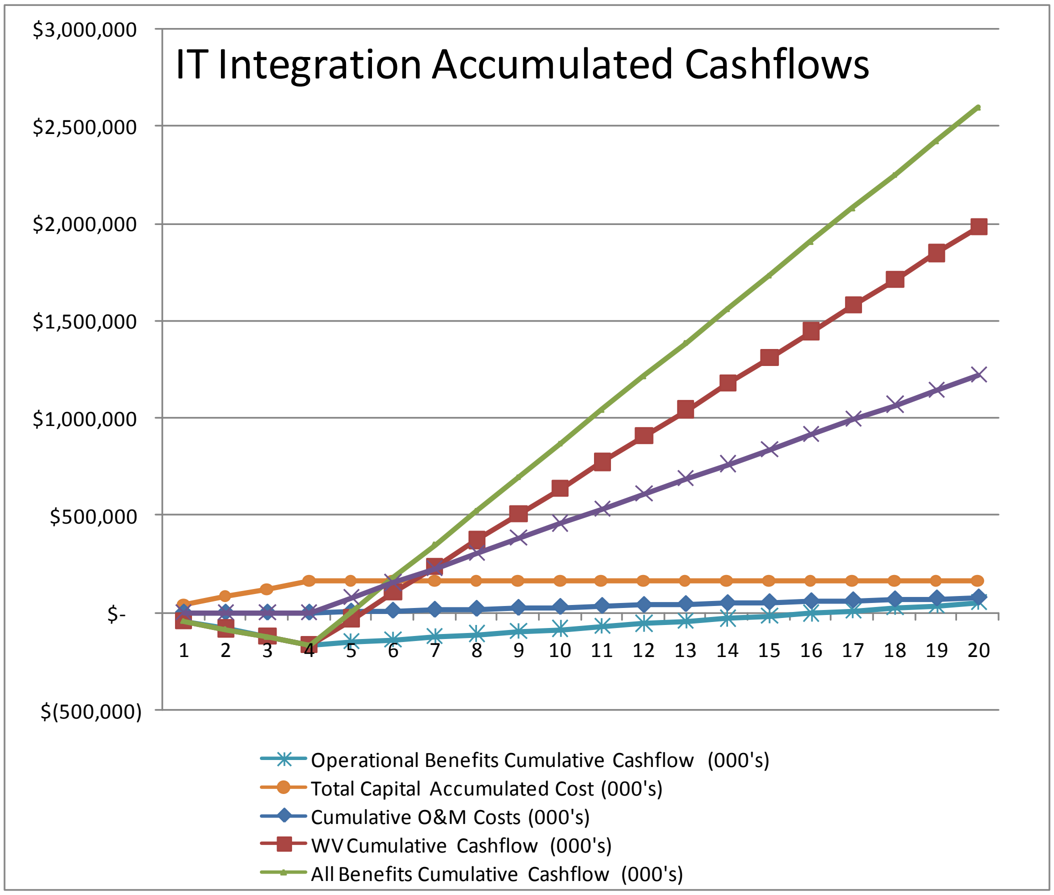


FIGURE 10-5: BUSINESS CASE IT INTEGRATION ACCUMULATED CASH FLOWS

The IT Integration technology solution cumulative cash flows is depicted on Figure 10-5. The following can be said of the six parameters:

- Capital Costs rise linearly and level off at the end of the project
- Operating and Maintenance Costs begin at zero and rise nearly linearly with years
- Operational Benefits cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case time period
- Consumer cumulative benefits begin at zero and rise nearly linearly through the business case examination period
- All Benefits Cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case examination period
- WV Cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case examination period.

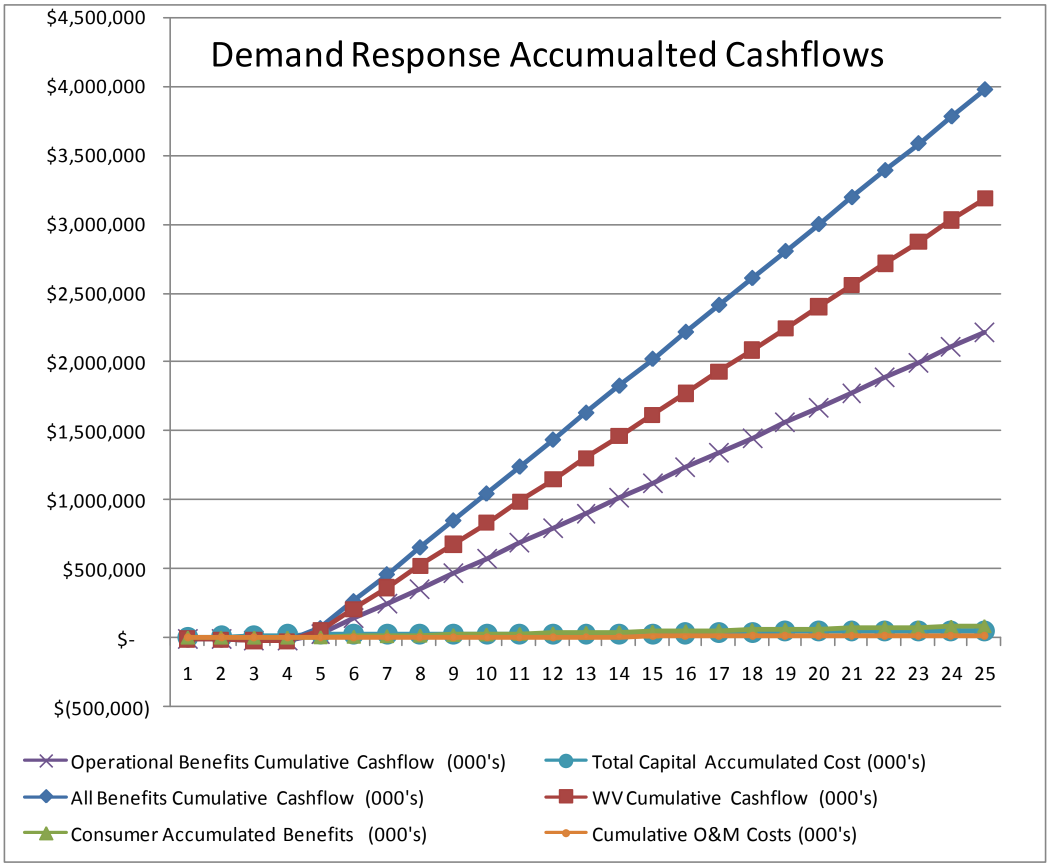


FIGURE 10-6: BUSINESS CASE DEMAND RESPONSE ACCUMULATED CASH FLOWS

The Demand Response technology solution cumulative cash flows is depicted on Figure 10-6. The following can be said of the six parameters:

- Capital Costs rise linearly and level off at the end of the project. The value is low and obscured by other near zero parameter values
- Operating and Maintenance Costs begin at zero and rise nearly linearly with years
- Operational Benefits cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case time period
- Consumer cumulative benefits begin at zero and rise nearly linearly through the business case examination period
- All Benefits Cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case examination period
- WV Cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case examination period

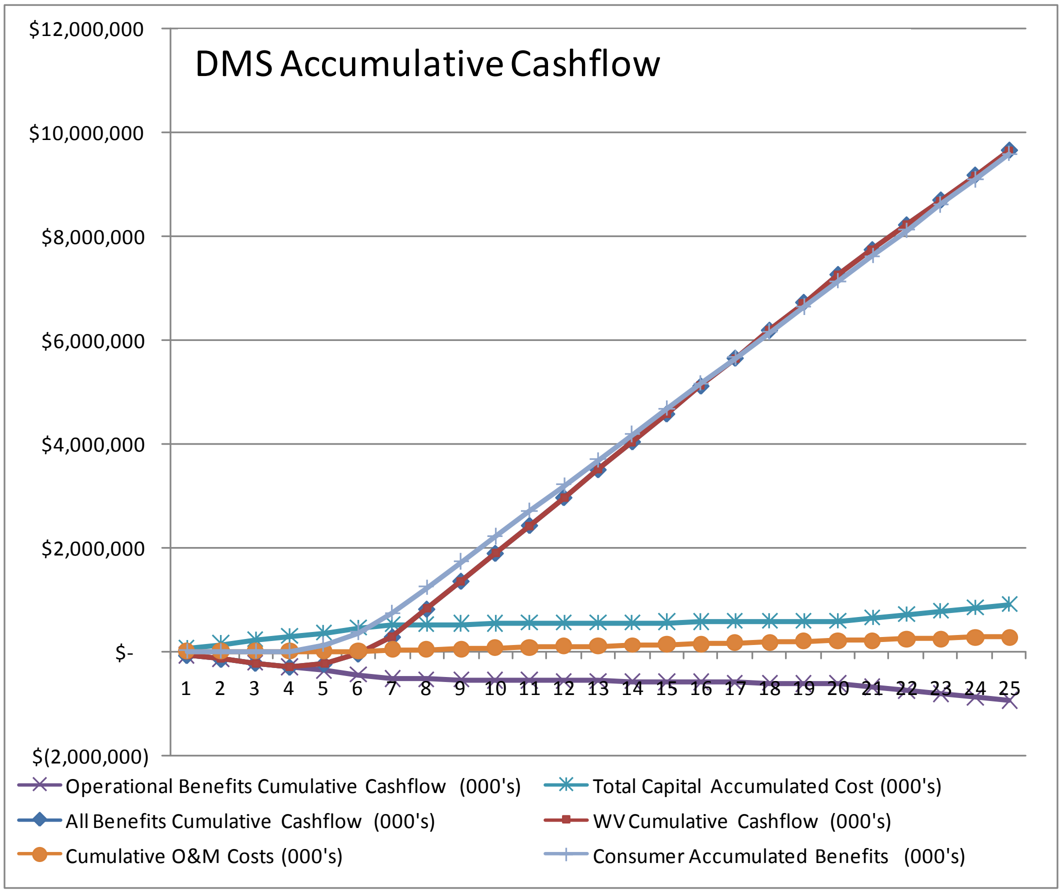


FIGURE 10-7: BUSINESS CASE DMS ACCUMULATED CASH FLOWS

The DMS technology solution cumulative cash flows is depicted on Figure 10-7. The following can be said of the six parameters:

- Capital Costs rise linearly and level off at the end of the project. The value is low and obscured by other near zero parameter values
- Operating and Maintenance Costs begin at zero and rise nearly linearly with years
- Operational Benefits cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case time period
- Consumer cumulative benefits begin at zero and rise nearly linearly through the business case examination period
- All Benefits Cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case examination period
- WV Cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case examination period.

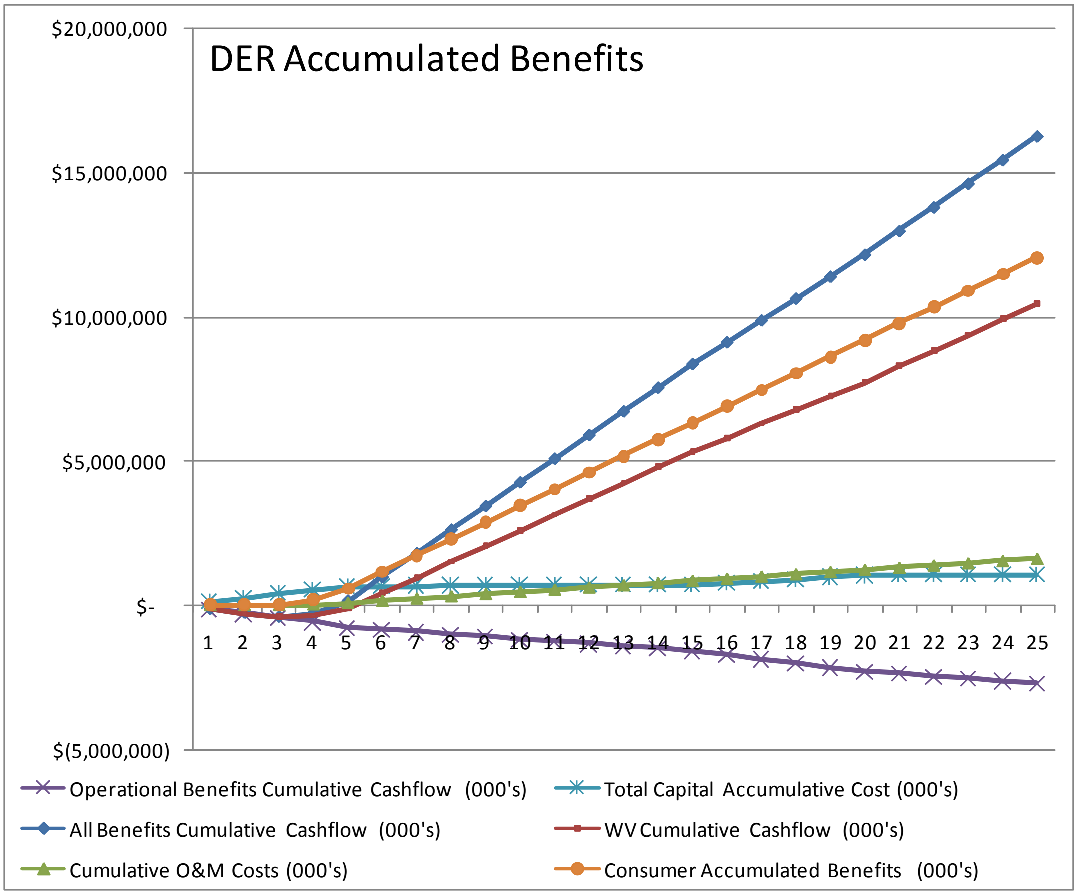


FIGURE 10-8: BUSINESS CASE DER ACCUMULATED CASH FLOWS

The DER technology solution cumulative cash flows is depicted on Figure 10-8. The following can be said of the six parameters:

- Capital Costs rise linearly with the start of the project and level off at the end of the project.
- Operating and Maintenance Costs begin at zero and rise nearly linearly with years
- Operational Benefits cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case time period
- Consumer cumulative benefits begin at zero and rise nearly linearly through the business case examination period
- All Benefits Cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case examination period
- WV Cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case examination period

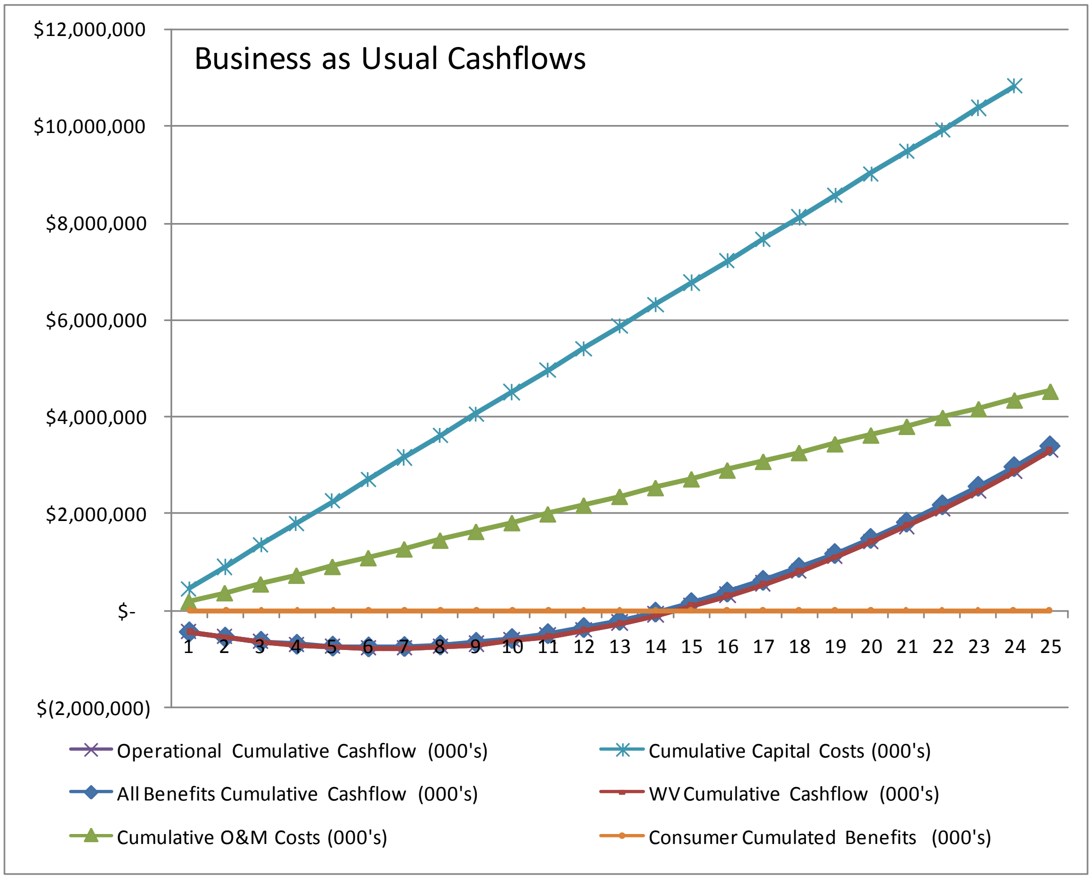


FIGURE 10-9: BUSINESS CASE BUSINESS AS USUAL ACCUMULATED CASH FLOWS

The Business-As-Usual technology solution cumulative cash flows are depicted on Figure 10-9. The following can be said of the six parameters:

- Capital Costs rise linearly as every year a new budget is approved for additional spending
- Operating and Maintenance Costs begin at zero and rise nearly linearly with years
- Operational Benefits cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case time period
- Consumer cumulative benefits begin at zero and remain there through the business case examination period as no consumer benefits accrue
- All Benefits Cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case examination period
- WV Cumulative cash flow includes capital and O&M costs so it drops below zero during the construction period before rising linearly through the business case examination period