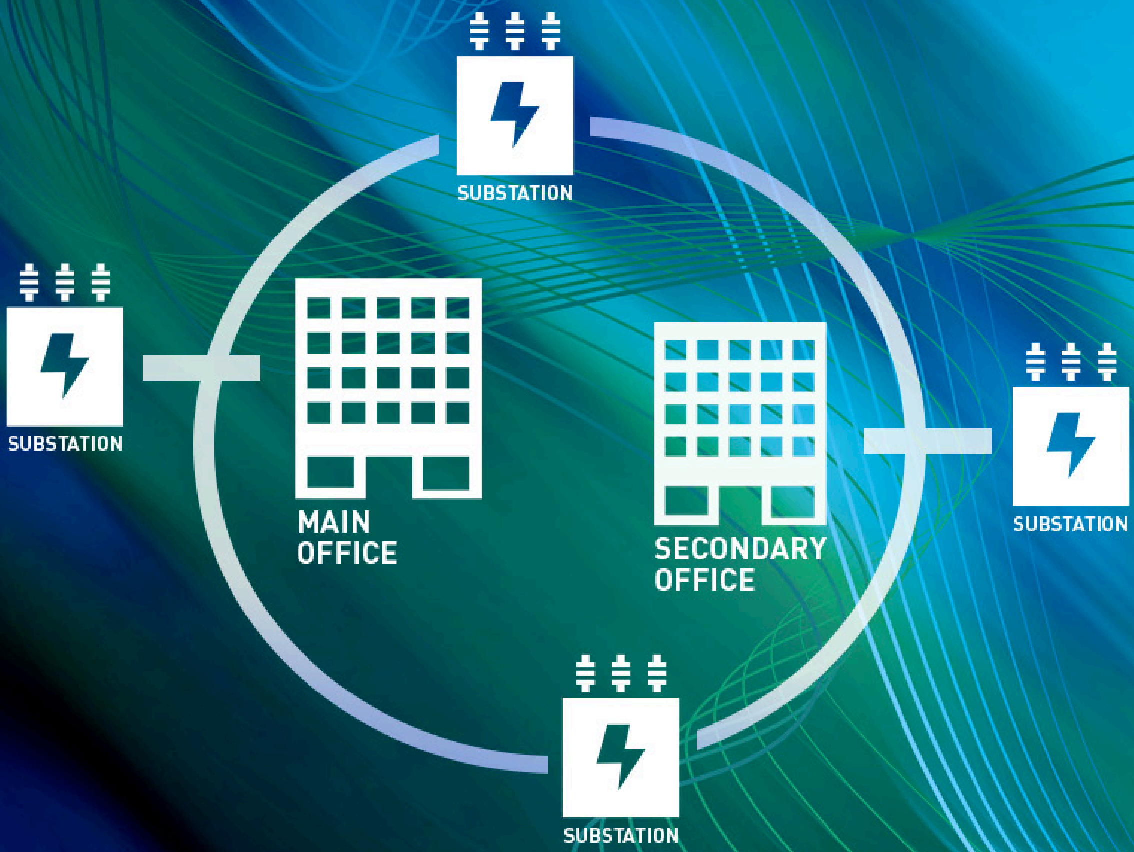
The Value of a Broadband Backbone

for America's Electric Cooperatives

A Benefit Assessment Study



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List of Abbreviations

AM	Asset management
AMI	Advanced metering infrastructure
AMR	Automated meter reading
AR	Augmented reality
ARRA	American Reinvestment and Recovery Act
CAGR	Compound annual growth rate
C&I	Commercial and industrial
CAIDI	Customer average interruption index
CBM	Condition-based maintenance
CVR	Conservation voltage reduction
DA	Distribution automation
DCEC	Delaware County Electric Cooperative
DEA	Dakota Electric Association
DER	Distributed energy resources
DG	Distributed generation
DM	Demand management
DOE	U.S. Department of Energy
DR	Demand response
DSM	Demand-side management
EIA	Energy Information Administration
EPB	Electric Power Board
ERCOT	Electric Reliability Council of Texas
EV	Electric vehicle
FLIR	Forward-looking infrared
FLISR	Fault Location, Isolation, and Service Restoration
Gbps	Gigabits per second
IP	Internet Protocol
IP/MPLS	Internet Protocol/Multiprotocol Label Switching
LiDAR	Light detection and ranging
LPWA	Low-power wide-area network
LTE	Long-term evolution
Mbps	Megabytes per second
MDM	Meter data management
MEC	Mobile edge computing
mMTC	Massive machine-type communications
NB-IoT	Narrowband Internet of Things
NRECA	National Rural Electric Cooperative Association
NRTC	National Rural Telecommunications Cooperative
PV	Photovoltaic (solar panels)
SA	Substation automation
SAIDI	System average interruption duration index
SAIFI	System average interruption frequency index
SCADA	Supervisory control and data acquisition
SGIG	Smart Grid Investment and Grant
TBM	Time-based maintenance
TDM	Time-division multiplexing
TOU	Time-of-use
UAV	Unmanned aerial vehicle
VAR	Volt-ampere reactive

1 EXECUTIVE SUMMARY

1.1 Purpose

This paper outlines and quantifies the benefits of a broadband backbone for electric cooperative operations.[1] For the purposes of this paper, a broadband backbone is defined as a high-bandwidth, low-latency data connection, enabled by wired or wireless technology, that connects systemically important infrastructure. Importantly, it provides transport—delivery of data collected by other utility networks—which is critical to managing electric operations. Broadband backbones are necessary to accommodate new data-intensive use cases that optimize operations and adapt to changing consumer behavior.

1.2 Overview

The move to a smarter grid entails more data from more end points on a more frequent basis. Applications such as advanced metering infrastructure (AMI) and distribution automation (DA) enable cooperatives to optimize operations and reduce costs. Meanwhile, as the grid evolves to accommodate more distributed energy resources (DER), system infrastructure must be adapted. At the same time, utilities are moving to take advantage of new technologies, such as drones and video monitoring, to increase grid reliability and security. Many of these use cases can be supported by lower-bandwidth solutions but will continue to advance and require additional bandwidth in the future. Given the fast pace of technological change and the rapid expansion of data, cooperatives should develop and regularly update 10-year plans to address their communication needs, and account for their expected technology and operational use cases over that time.

1.3 Technology Options

A broadband backbone can be comprised of both wired and wireless technologies. To guarantee the performance of all aspects of a network, a fiber backhaul system is typically the best option. Fiber offers the most secure, most reliable, highest-throughput, and lowest-latency wired communications option for cooperative network connections. In addition, fiber provides the opportunity to connect the grid reliably with enough capacity for both current and future use cases. Today, fiber solutions can provide up to 10 Gigabits per second (Gbps) as the wired option. However, fiber has both geographic and cost impediments that limit its use in all situations. In such cases, point-to-point wireless solutions can support the transfer of data with the reliability, bandwidth, latency, and security necessary for cooperative applications. Wireless point-to-point solutions can support all use cases profiled in this white paper. Today, they can provide up to 1 Gbps, with the potential to provide higher speeds in the future. A mix of both wired and wireless solutions will be necessary for most electric cooperatives.

Although it is outside the scope of this paper to analyze the opportunity in depth, cooperatives may be able to leverage this new backbone to provide broadband services to their member-consumers and communitites. The backbone is a major step toward providing those services, either directly or through a third party.

1.4 Use Cases and Quantification

Use cases are technologies that improve the operations or service of a cooperative. The move to a smarter grid is underway, and that smarter grid already has many use cases deployed that collectively require broadband communication. The number of use cases will expand as cooperatives continue to innovate and invest in a smarter grid and the analytics to support it. As described in this study, the value of a broadband backbone depends on the cost avoidance or revenue enhancement associated with use cases on a per-meter basis, collected from publicly accessible data. We evaluated the following use cases: DA, substation automation (SA), AMI, volt/VAR optimization, demand management (DM), outage reduction, asset management (AM), DER, replacement of existing telecommunications carrier costs, and new revenue from leasing dark fiber. This analysis estimates $1.7 million to $2.9 million and $10 million to $16.6 million in economic gain from these cases for a fully implemented 10,000 member and 50,000 member electric cooperative respectively. The value of a broadband backbone is

1 Note that an evaluation of the business case or economic benefits of broadband deployment to member-consumers in electric cooperative territories is beyond the scope of this paper; however, such impacts are "are likely to be substantial." See *The Competitiveness and Innovative Capacity of the United States*, U.S. Department of Commerce (January 2012), pp. 5–8 to 5–10. As each electric cooperative has unique characteristics, the benefits described in this paper are estimates and will vary from system to system.

demonstrated by its essential contribution to achieving these gains. It is a necessary component to enable these benefits, though it is not sufficient to implement these use cases on its own.

1.5 Proposed Actions

Developing a broadband backbone communications solution will provide the reliability, security, speed, and bandwidth necessary to allow electric cooperatives to adopt emerging use cases and new technologies to optimize grid operations. For most co-ops, that solution will likely include a combination of fiber and point-to-point wireless technologies, which will support the transition to a smarter grid that is connected and provides real-time situational awareness and control of grid assets.

2 INTRODUCTION

Rapid changes in technology can allow electric cooperatives to implement innovative solutions that benefit members and their changing consumer preferences. These changes reinforce the cooperative's member focus and align its goals with the interests of its members. Moreover, DER and other edge technologies are changing the grid from a linear, generation-centric system to a flexible two-way grid increasingly dependent on bi-directional communications.

3 TRANSFORMATION OF COMMUNICATION NETWORKS

Communications networks are long-term assets.[2] Thus, utilities need to account for data and communications needs for at least 10 years in the future, and preferably even further. As we move toward a smart grid—one that is two-way, networked, distributed, and intelligent—communications will provide the enabling technology upon which those applications will be built.[3] The U.S. Department of Energy (DOE) outlines four enabling technologies for the smart grid: (1) the communications network; (2) AMI; (3) meter data management (MDM); and (4) supervisory control and data acquisition (SCADA). Although important on their own, communications networks are also necessary to enable the other three technologies.[4] Upgrading telecommunications infrastructure is imperative to facilitate the improvement and advancement of operations and customer service.

3.1 What Is Driving Backbone Demand?

The proliferation of AMI technology has given utilities unprecedented insights into the performance of their systems. Several factors have impacted the current drive toward broadband networks (Table 1).

Factor	Description
Proliferation of Smart Grid	Backhaul communications necessary to support the data
Cyber Security Needs	Older technologies do not have the encryptions and firewalls necessary to protect data in transit over lines
Additional Data Usage	New applications, particularly video-enabled monitoring, require high bandwidths to leverage them to their full potential
Latency Requirements	Technologies with automated response systems require low-latency systems to respond to signals quickly enough to make actionable decisions
Improved Distribution Reliability	Real-time monitoring of critical equipment can identify failures before they occur, allowing for replacement and circumventing a potential outage
Availability of Current Telecommunications Services	Third-party carriers and providers are discontinuing older technologies as they transition to digital networks

Table 1: Reasons for the Move to a Broadband Backbone

2 NRTC, NRUCFC, NRECA, and CoBank, *Due Diligence of High-Speed Broadband Investment and Business Creation by an Electric Cooperative*, 2017, 5, https://www.cooperative.com/programs-services/bts/documents/reports/broadband-due-diligence.pdf.
3 Navigant Research, *Defining the Digital Future of Utilities*, 2017, 1.
4 National Rural Electric Cooperative Association and the U.S. Department of Energy, *Smart Grid Demonstration Project*, "Communications: The Smart Grid's Enabling Technology," 2014, 1, https://www.smartgrid.gov/files/NRECA_DOE_Communications_1.pdf.

These factors create the need for utilities to upgrade systems as they operationalize emerging technologies. The lifecycle of a long-term asset forces them to look beyond current use cases to the expected needs of the future.

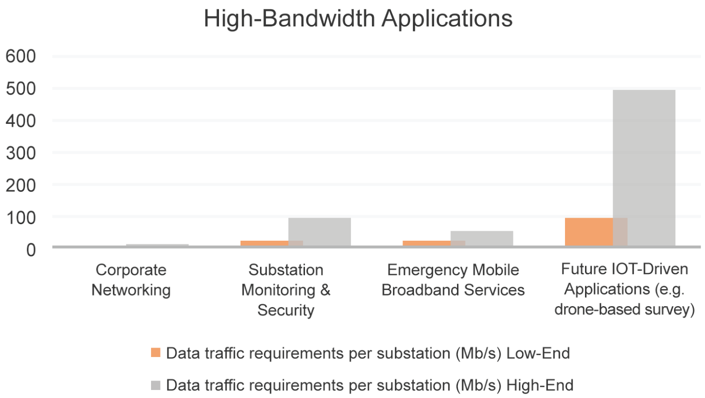


Figure 1: High-Bandwidth Applications *Source: inCode Consulting*

3.1.1 Overview of Changing Customer Behavior

As consumers adjust to new technologies and incentives, their behaviors are changing. More consumers are investing in energy efficiency, distributed generation (DG), electric vehicles (EVs), and storage in the home. Together, these factors are expected to create new "prosumers"—consumers who also produce and/or store energy—for utilities to engage. Consumers also have greater expectations from their utility regarding communication and response. In a 2017 consumer survey, 40% of consumers expressed a desire to have smart grid-enabled solutions for demand response (DR), energy efficiency, or other DER, but only 21% participated. This gap shows that latent demand will likely increase the need to support these solutions more broadly.[5]

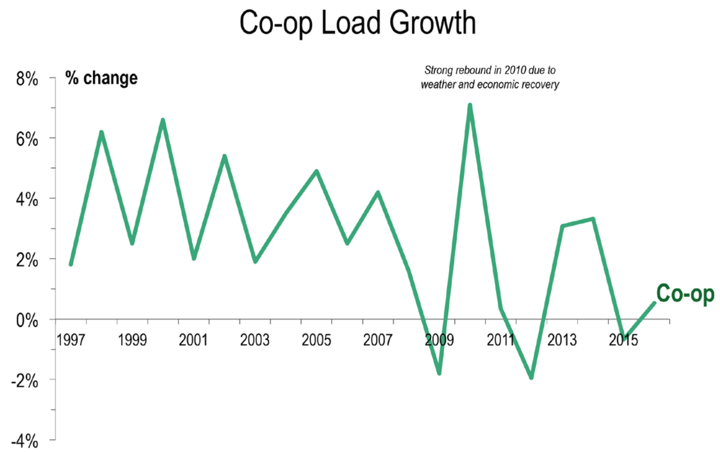


Figure 2: Co-op MWh Sales Growth *Source: U.S. Energy Information Administration*

5 Smart Energy Consumer Collaborative, *Consumer Experience and Expectations Survey*, 2017, https://www.publicpower.org/periodical/article/consumers-becoming-more-aware-smart-grid-issues-offerings-survey.

Spotlight: Mid-South Synergy

In addition to sensors, utilities are leveraging new technologies to inspect assets across territories. Some cooperatives are piloting unmanned aerial vehicles (UAV) for jobs that previously required a truck roll or helicopter ride. Mid-South Synergy serves 30,000 members across a six-county territory based in Navasota, Texas. After experiencing many vegetation-related outages from trees outside of its right of way, it started an aggressive vegetation management program. During this program, Mid-South saw the importance of light detection and ranging (LiDAR) and forward looking infrared (FLIR) images from UAVs, and in 2016 implemented UAVs for its program. The new images allowed the cooperative to prioritize vegetation management and save 5% on its work plan for the program by decreasing truck rolls. It also improved customer satisfaction by removing only those trees that posed a threat to their power lines. UAVs offer both cost savings and additional data on remote assets for utilities, giving them potential to grow as part of the asset management profile.

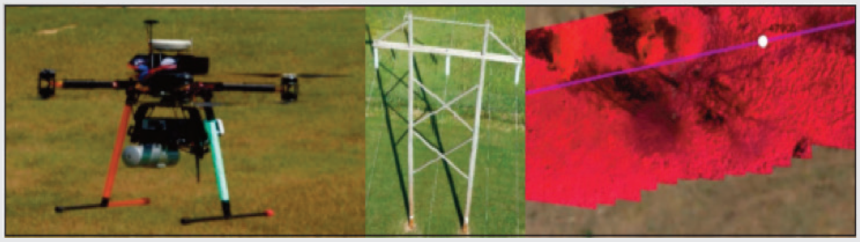


Figure 3: UAV Images *Source: NRECA, TechSurveillance, BTS, Case Studies: Success with Unmanned Aerial Systems, August 2017.*

3.1.2 A Brief Overview of Operational Needs

Utilities nationwide are investing in a wide range of digital technologies as they strive to transform their operations. These digitalization efforts involve smart grid uses, electricity systems software, energy management, and building energy efficiency controls. Utility spending on digitization of the energy infrastructure has grown by a compound annual growth rate (CAGR) of 20% since 2014, reaching $47 billion in 2016.[6] In 2017, 60% of utilities said they expected to increase their digital investments.[7] This spending on communications technologies will facilitate an increase in smart grid spending from $7 billion in 2017 to $12 billion by 2020.[8]

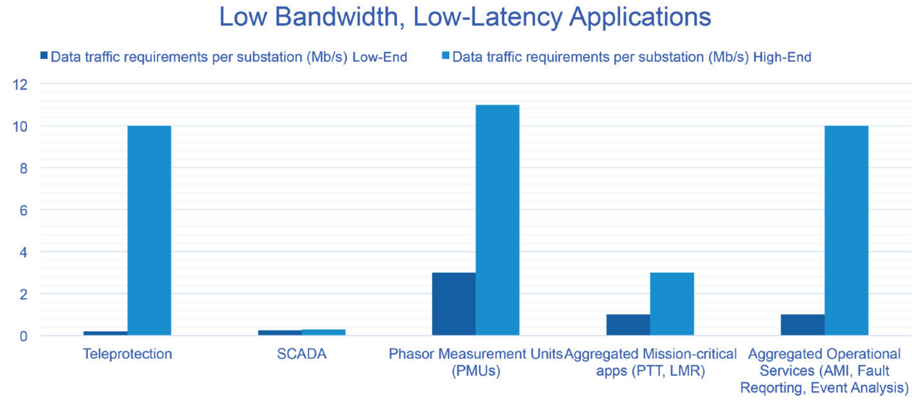


Figure 4: Low-Bandwidth, Low-Latency Applications

The growth of monitoring devices will be particularly apparent in the narrowband-internet of things (NB-IoT) space.[9] Utilities have a large number of assets in the field, often spread over large territories, which drives a need for the growth in connected devices. These solutions often operate on low-power wide-area (LPWA) networks that enable smart devices to be deployed at low cost and can transfer small amounts of data quickly and cheaply. Overall, the market for LPWA is expected to grow at a CAGR of 38%, from a low base of $2.7 million in 2017 to $54.7 million in 2026, as a low-priced network solution.[10] These devices will monitor every part of generation, transmission, distribution, and the consumption of energy, making the grid more responsive and flexible to changing conditions.

Actionable business intelligence, derived from real-time data, is the principal enabler of the smarter grid. The availability of massive amounts of operating data provides the predictive analytics required to transform asset management policies from traditional time-based maintenance (TBM) to measurement-driven condition-based maintenance (CBM) practices that can lower operational costs and defer capital expenditure.

The key to such capabilities is the availability of a future-proof communications network backbone. Having a broadband backbone meets the volume-of-data and low-latency demands of future grid applications that are at the cusp of commercialization, such as real-time video and infrared imagery sent by drones for asset inspections.

3.1.3 A Brief Overview of New Applications[11]

New applications are coming onto the grid, driven by customers and utilities. The growth of roof-top and community solar has newly emphasized the integration of DER and the importance of a two-way grid. For cooperatives in particular, the community solar market has taken off, growing from a handful of projects in 2010 to more than 80 MW by the end of 2017 (Table 2).[12] Solar development creates both opportunities and challenges for cooperatives.

The rise of EVs also presents a mix of opportunities and challenges for cooperatives. EVs offer co-ops a solution to flat loads, with the potential for almost $1 billion annually in additional cooperative revenue by 2026.[13] However, EVs will require a new charging infrastructure to support that growth, including equipment for home charging and charging stations, which must be built, integrated, and managed.

6 International Energy Agency, *Digitalization: A New Era in Energy?* 2017, 25, https://www.iea.org/publications/freepublications/publication/DigitalizationandEnergy3.pdf.
7 Global Data, "Technology Trends in Utilities," 2017, 9.
8 Markets and Markets, *Internet of Things in the Utility Market*, 2016.
9 NB-IoT: Narrowband internet of things, standard for connecting IoT devices to cellular networks.
10 SIGFOX: French LPWA company; LoRa: Semtech standard; RPMA: Random Phase Multiple Access (proprietary to Trilliant); LTE-Cat-M1: cellular-based standards; NB-IoT: narrowband internet of things. All are LPWA solutions.
11 Forecast reproduced with permission.
12 NRECA, *Community Solar*, https://www.electric.coop/wp-content/Renewables/community-solar.html.
13 $930 million—calculated as a portion of total national EV revenue based on installed cost and average annual cost to charge a vehicle. Data come from DOE. https://www.energy.gov/eere/electricvehicles/saving-fuel-and-vehicle-costs.

U.S. Total (installations)	2018	2019	2020	2021	2022	2023	2024	CAGR (2017–2024)
Distributed Solar PV	4,548	5,777	6,478	7,588	8,888	10,411	12,194	20%
Small & Medium Wind	14	18	22	28	35	43	54	20%
Microturbines	131	157	185	221	245	287	340	19%
Fuel Cells	146	206	279	356	451	558	696	31%
DG	20,801	22,916	24,577	26,714	29,096	31,801	34,872	9%
Distributed Energy Storage	1,694	1,824	1,976	2,197	2,301	2,410	2,527	16%
Microgrids	550	627	746	790	906	1,038	1,190	16%
EV Charging Load	4,557	5,964	7,551	9,179	10,884	12,640	13,950	23%
DR	35,456	40,200	45,291	50,582	57,214	62,877	69,125	12%
Total	**63,058**	**71,532**	**80,141**	**89,462**	**100,401**	**110,766**	**121,664**	**12%**

Table 2: Projection of DER Generation, by Type. *Source: Navigant DER Generation Forecast*

3.2 What Is The Impact Of Communications Network Transformation?

3.2.1 Utilities

Communications are foundational investments for utilities and, as noted above, have been identified by DOE as one of the four enabling technologies for the smart grid. Cooperatives can see benefits to their operations and increased revenue coming from their communications investments. Operationally, communications investments allow for increased reliability, decreased labor costs, better equipment usage, more efficient voltage control, and other benefits that translate to cost avoidance and higher net revenue. However, broadband backbone communications systems are necessary but not sufficient aspects of many use cases.

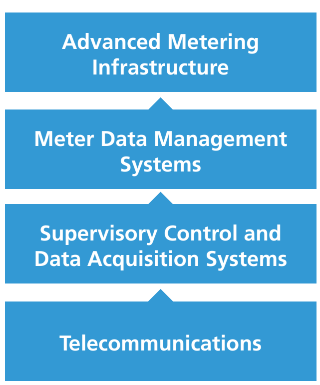


Figure 5: Smart Grid-Enabling Technologies *Source: Department of Energy, NRECA*

Figure 6: Reasons for Circuit Transition *Source: InCode Consulting*

Utilities have thousands of leased lines and circuits to critical grid infrastructure sites that are at risk of being decommissioned as telecommunications carriers transition from time-division multiplexing (TDM) circuits to Internet protocol/multiprotocol label switching (IP/MPLS) circuits. Carriers are willing to continue supporting utilities' use of these circuits, but at a substantial cost increase—expected to be between 30% and 90% CAGR for 5 years to reach a leveling point.[14] This cost increase has forced utilities to consider their capital expenditures in a way that will create a smooth transition away from TDM circuits over the next couple of years. The transition process and fear of being caught in a similar situation in the future regarding leased infrastructure has created an additional push for utilities considering broadband backbone options.

3.2.2 Enterprises

When utilities invest in communications infrastructure, the other large enterprises in the community will also benefit from improved operations. Agriculture, manufacturing, oil

14 Proprietary sourcing.

Communities See a Connected Future

Figure 7: Smart Community Use Cases *Source: NRTC*

and gas, technology, and automotive companies will be positioned to benefit by leveraging excess capacity from networks. These industries can lease fiber bandwidth from utilities to meet their needs for voice/video connections, surveillance, telemetry, asset management, and other applications to improve their efficiency.[15]

3.2.3 Communities

Investments in communications technology by electric utilities can provide benefits to all parts of their communities. Utilities can provide a bridge to smart towns and cities, and new services, such as smart traffic lights, digital infrastructure, and waste management.[16]

Communities may also leverage fiber and other communications to connect citizens in rural areas to broadband Internet.[17] Access to broadband enables advances in health care, education, business and economic growth, and other areas of community interest. Broadband is therefore a vital component in keeping rural communities competitive in the long term.

4 ANALYSIS OF BROADBAND BACKBONE

In the past, cooperatives typically adopted the communications technology that worked best with each grid application. However, once multiple use cases are implemented, this uncoordinated process can lead to a fragmented communications architecture that is difficult to manage. Cooperatives should develop a comprehensive 10-year plan that accounts for communications needs for all anticipated use cases over that period. Without a timeline and use case goals, cooperatives may sub-optimize their networks or be forced to retire assets early.[18]

4.1 Network Backbone: Technology Options

Cooperatives have and likely will continue to have multiple networks to serve all their communications needs. A co-op broadband network could include a hybrid backbone with both fixed wireless and wired solutions, as appropriate. Each network creates additional operational complexity for the cooperative due to the need to support the different systems. Dedicated communications planning allows

15 SNS Telecom and IT, *The Private LTE and 5G Network Ecosystem: Opportunities, Challenges, Strategies, Industry Verticals, and Forecasts*, 2018.
16 NRTC internal.
17 NRECA, *Broadband Case Study: Orcas Power and Electric Cooperative & Rock Island Communications*, 2018, 2.
18 NRECA, *Communications: Smart Grid's Enabling Technology*, "Defining Communications Requirements for Present and Future Applications," 2014, 10.

cooperatives to streamline their communications systems and reduce fragmentation. Although it is impossible to suit all geographic areas and use cases with one solution, having fewer networks and technologies creates additional operational efficiency.

4.1.1 Point-to-Point Wireless

Point-to-point provides wireless backhaul service to the grid. Although 80% of current sites have much lower speeds of 25 megabytes per second (Mbps), and even more advanced sites typically have speeds of only up to 150 Mbps, the latest point-to-point technologies offer speeds of up to 1 Gbps and are expected to provide up to 3–5 Gbps by 2025.[19] The development of long-term evolution (LTE) and the rollout of 5G have encouraged microwave point-to-point solutions. Microwave connects dispersed aspects of the grid. It is frequently the most cost-effective option for backhaul, especially if there are existing towers for the cooperative to leverage. Microwave backhaul should be considered in conjunction with the metering infrastructure, right-of-way, and existing infrastructure.[20]

4.1.2 Fiber

Fiber offers the most secure, most reliable, highest-throughput, and lowest-latency communications option for network connections. In addition, fiber provides the opportunity to connect the grid reliably with enough capacity for both current and future use cases. To guarantee the performance of all aspects of a network, a fiber backhaul system is typically the best option. As data needs continue to increase, bringing fiber closer to users and devices improves the performance of the system.[21] Building a fiber solution is time and capital intensive, and requires extensive planning and expectations of future use cases, as it is the longest-lived asset available. Fiber is the backbone of modern community communications, facilitating advances beyond just the cooperative use cases and opening the opportunity for new revenue and business models.

4.1.3 Costs of the Backbone

The cost of a broadband backbone can vary depending on many factors. For fiber backbones, the primary cost driver will be the percentage of aerial deployment using electric poles rather than underground installation. Aerial costs range from $13,000–$17,000 per mile, depending on the amount of "make ready" necessary for the poles and the distances of the runs. Underground costs are significantly higher due to the effort of trenching, ranging from $45,000–$55,000 per mile.[22] These estimates include both equipment and labor (construction, engineering design, and project management). By understanding these cost dynamics, it becomes clear that cooperatives have a potentially substantial cost advantage over other providers due to their ability to leverage electric poles and other assets. Many cooperatives achieve more than 90% of their fiber builds on aerial facilities.

Point-to-point backbones can be significantly more cost-effective than fiber. A direct cost comparison with fiber is difficult, as situations can vary on distance, equipment needs, and other factors. However, point-to-point solutions typically cost substantially less than fiber.

19 Ericsson, *Ericsson Microwave Outlook: Trends and Needs in the Microwave Industry*, 2017, 3 and 4, https://www.ericsson.com/en/microwave-outlook/reports/2017.
20 NRTC, NRUCFC, NRECA, and CoBank, *Due Diligence of High-Speed Broadband Investment and Business Creation by an Electric Cooperative*, 2017, 5.
21 Ericsson, *Fiber Network Deployment*, 2017, https://www.ericsson.com/ourportfolio/networks-services/fiber-network-deployment?nav=fgb_101_116%7Cfgb_101_0823%7Cfgb_101_0573.
22 Pulse Broadband internal estimate.

Spotlight: Delaware County Electric Cooperative

Delaware County Electric Cooperative (DCEC) in New York State deployed a fiber backbone to serve its new AMI system by providing IP communication to all substations and remote offices. It chose the technology based on cost and the data rate requirements for both its AMI and SCADA systems, while accounting for its particularly mountainous and large service area. DCEC saw great success with its solution but also saw the system as an opportunity to prepare for the future.

4.2 Consumer Broadband

Participation in the modern economy requires access to broadband. Bringing broadband to underserved communities is an important consideration for many electric cooperatives. Co-ops are well positioned to offer these services because they already have much of the needed infrastructure and have existing relationships with their member-consumers. Moreover, offering Internet or triple-play services for customers potentially opens a large, new revenue stream for cooperatives.[23]

A fiber backbone also offers the potential to extend the network to the middle mile or last mile and eventually provide broadband to the wider member-consumer community. An expanding number of cooperatives are deploying broadband to serve their communities. Deploying all-fiber or stand-alone fixed wireless and hybrid fiber-fixed wireless networks allows the broadband backbone to be leveraged to support both fiber and wireless last-mile options.[24] If the cooperative chooses not to take on the risk of establishing a new retail broadband business, it can still participate by putting in the backbone for its system and allowing a third party to leverage their excess capacity and complete the network.

4.3 Overview Of Benefits Of A Broadband Backbone

4.3.1 Operational Benefits

Advanced communications networks offer the ability to control and operate the grid in new ways, and allow cooperatives to track their assets in the field and operate a two-way grid, integrating new assets.

With more than 1,000 annual fatalities throughout the U.S. electric industry, safety is a primary concern for all utilities. Orcas Power and Light Cooperative in Washington State saw the safety impacts of poor communication after a serious accident to a lineman, when it barely had the communications coverage needed to call for medical assistance.[25] Because of the backhaul provided by a broadband backbone, critical mobility services will also stay functional during outage events.

In addition to safety, communications networks facilitate many other operations that increase both grid resiliency and reliability. Improved communications combined with sensor technology can improve System Average Interruption Duration Index (SAIDI) and Customer Average Interruption Index (CAIDI) scores. The dispersed offices of utilities need improved communications to meet daily business tasks; this need is further impacted by the rise of cloud computing and the growing amount of critical data stored off site.[26]

Figure 8: Cybersecurity Frameworks *Source: NIST, Cybersecurity Framework version 1.1*

The increasing number of sophisticated cyberattacks also necessitates improved in-house communications systems and the need for a private network, rather than third-party carriers, to house and transmit sensitive data. Data security and the ability to control the upgrades necessary to protect the grid will continue to grow in importance.[27] Additionally, private networks are more reliable because cooperatives then are no longer subject to third-party carriers and their network needs and outages.[28]

4.3.2 Economic Benefits

Communications are best considered as an enabling technology for all other use cases that are part of the smart grid. To quantify the benefits of a broadband backbone, one must quantify the individual ways the use cases improve operations and service through reliability, voltage optimization, equipment usage, and labor savings. By optimizing the voltage on the line and delivered to a customer, utilities can minimize line loss and decrease their generation requirements. More sophisticated equipment

23 Triple-play services are home telecommunications packages that bundle Internet, cable, and telephone into one service.
24 NRECA, *Communications: Smart Grid's Enabling Technology*, 2014, 7.
25 NRECA, *Broadband Case Study: Orcas Light and Power Cooperative & Rock Island Communications*, 2018, 2.
26 NRECA, *Communications: Smart Grid's Enabling Technology*, 2014, 11.
27 https://www.nist.gov/cyberframework.
28 For more information on cooperative cyber security options, please see the *NRECA Guide to Developing a Cyber Security and Risk Mitigation Plan*, https://www.cooperative.com/programs-services/bts/Documents/guide-cybersecurity-mitigation-plan.pdf.

monitoring can often lengthen the life of equipment and reduce equipment failure by optimizing operations and maintenance across the entire distribution system, thereby promoting improved reliability. Labor savings come from reduced overtime, less need to hire additional employees, and less time to complete specific tasks. Finally, new revenue can be generated by leasing unused communications capacity, such as dark fiber or other sources, to enterprises.

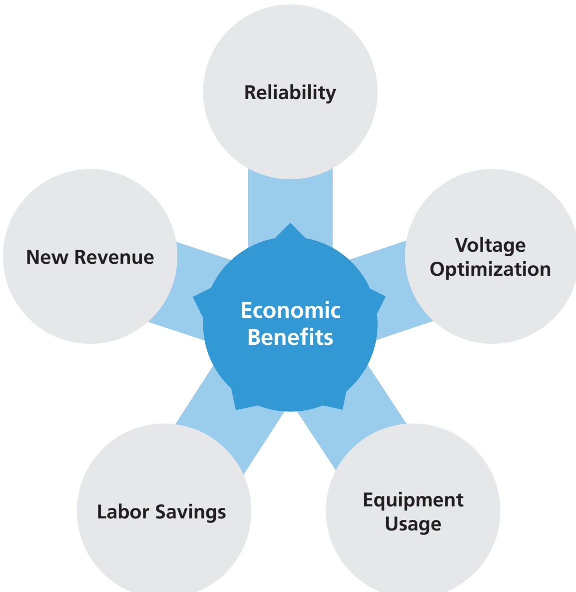


Figure 9: Operational Benefit Categories *Source: InCode Consulting*

4.4 Industry Case Studies

4.4.1 Cooperatives

Many cooperatives have deployed broadband backbones to support their current needs and prepare for future use cases. Dakota Electric Association (DEA) began looking at options in 2013 to replace its iNet Radio backbone. Dakota's primary goal was to support its planned AMI system with the required backhaul communications, specifically by connecting its substations. It examined multiple technologies and options, including microwave, LTE, and leasing dark fiber from public and private entities. Ultimately, the co-op partnered with Dakota County, Minnesota to deploy fiber to their substations. It built the business case on the cost and security comparison

> "The biggest initial driver was security … but the number of new ideas we hadn't thought about beforehand has been great."
>
> – Craig Turner, Dakota Electric Association

between fiber and microwave, and developed a strong partnership with the county to serve its future AMI needs. Craig Turner, Director of Engineering Services at DEA, said that "the biggest initial driver was security … but the number of new ideas we hadn't thought about beforehand has been great." The co-op has since enhanced its security by splitting applications onto different wavelengths and fiber strands to make a breach into any one part of the system irrelevant.[29]

4.4.2 Communities[30]

Spotlight: Electric Power Board – Chattanooga

When the Electric Power Board (EPB) determined to invest $300 million to implement AMI and build 6,000 miles of fiber in Chattanooga to deliver advanced city services, it anticipated value for the utility, businesses, households, and the wider community but did not anticipate as much benefit as the project eventually created, especially for the community. A grant from the American Reinvestment and Recovery Act (ARRA) supported upgrades in smart switches, sensors, and controls. The project was expected to bring the utility value through smart grid operations, and in new broadband revenues. By 2015, the project had already generated more than $200 million in value through the smart grid alone, and between $860 million and $1.3 billion in value across the utility, businesses, the community, and individual households. The smart grid provides more than 20% of the benefits, with new investment spurred by the fiber backbone providing the largest impact, comprising 30% of the total benefits.

29 Based on an interview with Craig Turner, Director of Engineering Services at DEA, conducted on April 20, 2018.

30 Bento Lobo, *The Realized Value of Fiber Infrastructure in Hamilton County, Tennessee*, 2015, 3. See also *"The Competitiveness and Innovative Capacity of the United States,"* U.S. Department of Commerce (January 2012), http://ftpcontent2.worldnow.com/wrcb/pdf/091515EPBFiberStudy.pdf.

5 BROADBAND BACKBONE USE CASES FOR ELECTRIC COOPERATIVES

Cooperative use cases for broadband backbones are evolving quickly, and each cooperative has unique business processes and service territories to utilize the backbone and its associated technologies. As DOE has stated, "because advanced communication and control is required to operate even one smart meter or automated device, these systems and networks represent a fixed cost for all projects, from small pilots to full-scale deployments. These systems provide a platform for a smarter grid over the next decade or more."[31]

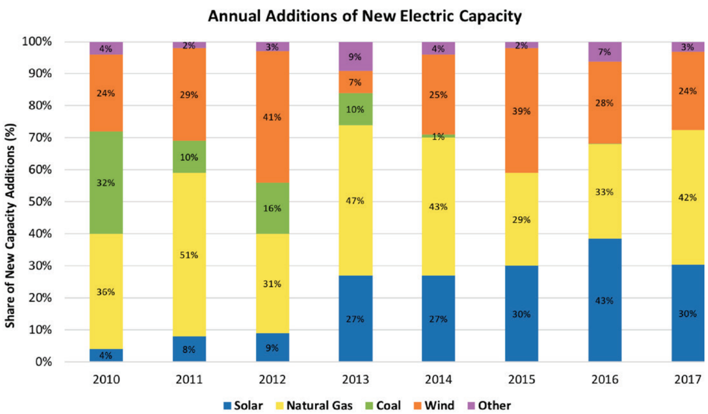


Figure 10: Annual Generation Capacity Additions *Source: SEIA*

5.1 Generation Applications

5.1.1 Integration of Renewables

Renewable resources have steadily increased their share of total U.S. load, with solar and wind energy combined accounting for more than 50% of new generation capacity every year since 2014, increasing to 7% of total generation today.[32] New technology can expand electric distribution systems' ability to host these generation assets, monitor power sources, and improve forecasting capabilities to integrate the intermittent nature of their production onto the grid. For example, a smart syncrophaser found a damaging oscillation in wind production in the Electric Reliability Council of Texas (ERCOT) system and was able to constrain the output of the unit while the precipitating malfunction was fixed. Traditional monitoring systems could not have caught this problem.[33] These types of monitoring systems and the communications that enable can be increasingly beneficial as more renewable energy sources are added to the grid.

5.2 Distribution Applications

Distribution applications cover all uses after the transmission and include distribution lines and substations. Due to the large number of cooperatives without transmission or generation facilities, this report focuses only on distribution use cases.

5.2.1 Substation Automation

Substations transform the voltage of power between different levels of the distribution grid. Studies have shown that more than 90% of cooperatives have some substation automation (SA) programs in place.[34] SA can generate savings in a variety of ways, from SCADA systems that monitor and report back on the state of substation equipment to automated switches that control voltage levels and reroute power. These applications are critical to the operation of a cooperative and require constant monitoring. Traditionally, they were controlled manually—either physically switched onsite or from the control house. Significant reliability is required in the communications system to allow these critical aspects of the grid to become automated.[35]

5.2.2 Volt/VAR Optimization

AMI, load tap transformers, automated capacitors, and voltage regulators can be used to improve voltage supply delivery and reactive power compensation. This process optimizes voltage levels and reduces electricity requirements during both peak and off-peak periods, and improves the performance of critical infrastructure. These devices, under coordinated control enabled by the broadband platform, can improve power quality and produce non-intrusive energy savings of 2–4% per year, and reduce reactive power by 10–13% over a year.[36]

31 U.S. Department of Energy, *Smart Grid Investment and Grant Final Report*, 2016, 31, https://www.smartgrid.gov/files/Final_SGIG_Report_20161220.pdf.
32 EIA, *Electricity in the United States Is Produced with Diverse Energy Sources and Technologies*, https://www.eia.gov/energyexplained/index.php?page=electricity_in_the_united_states.
33 Department of Energy, *Smart Grid Investment and Grant Final Report*, 2016, 32.
34 Newton-Evans Research Company, *By the Numbers: A Look at the Substation Automation and Integration Market*, 2007, https://www.elp.com/articles/powergrid_international/print/volume-12/issue-2/features/by-the-numbers-a-look-at-the-substation-automation-and-integration-market.html.
35 Navigant, *Networking and Communications for Smart Grids and Smart Cities*, 2016, 11.
36 Department of Energy, *Smart Grid Investment and Grant Final Report*, 2016, 10.

5.2.3 Distribution Automation and Fault Location, Isolation, and Supply Restoration

Fault Location, Isolation, and Supply Restoration (FLISR) allows utilities to pinpoint the location and extent of an outage to better direct repair crews and resources with precise, real-time information. The FLISR capabilities triangulate the impacted area and relay that information back to cloud-based data systems.[37] Further, FLISR can allow for automated fault detection and feeder switching, which can restore power to customers in seconds. FLISR technologies have been able to reduce the number of customers affected by an outage by up to 55% and reduce the total number of disrupted minutes by 53% using "self-healing" automation. The deployment of these technologies has helped utilities improve their System Average Interruption Frequency Index (SAIFI) scores by as much as 58%.[38]

5.2.4 Distributed Energy Resources Integration

Customers are purchasing DER in multiple forms, through solar photovoltaic panels, energy storage solutions, and other methods. DER can change the shape of their energy loads, and increasingly utilities need to integrate these resources. This is especially true for electric cooperatives in their role as consumer-centric utilities. To successfully add these resources to the system, the grid must manage two-way power flows through two-way communication.[39] In an example of this new trend, Southern California Edison is attempting to integrate 10,000 solar installations onto its system as part of DOE's SunShot program. To successfully complete the task, it is focusing on the software portal, a grid integration and software provisioning process that takes less than 10 days, and a real-time DER control system.[40]

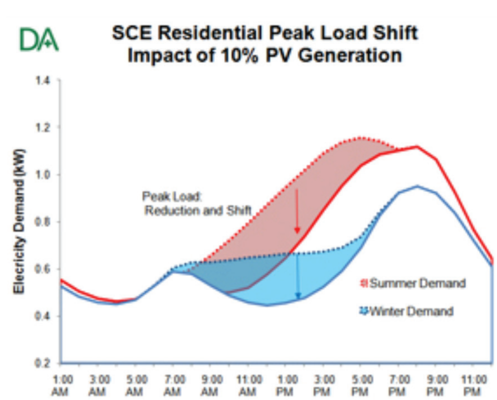


Figure 11: PV Generation Peak Load Shift *Source: SCE*

EVs offer utilities an additional revenue source as they become a larger part of the transportation mix. The growth of EVs offers cooperatives, which have experienced slow load and revenue growth for the last 10 years, the opportunity to achieve almost $1 billion in additional revenue by 2025 at current projections.[41]

Just as the integration of DER will continue to put pressure on utilities' capital expenditure and operating expenditure models, changes in customer behavior—such as rapid adoption of EVs—will impact electricity demand management and pricing models.

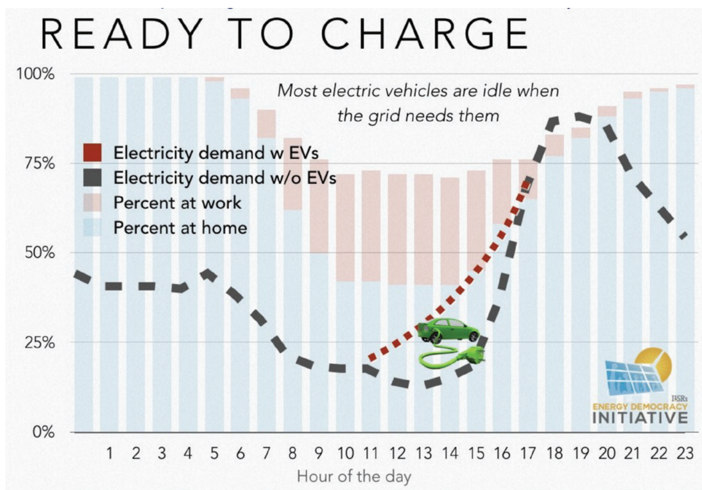


Figure 12: EVs as Potential Storage *Source: Scott Madden*

5.3 Retail Applications

5.3.1 Advanced Metering

AMI, along with communications, is another of the base technologies that supply the information flow to make the grid work effectively. Electric cooperatives are leading the industry in AMI "smart meter" deployment, with AMI deployed at 60% of all co-op meters. Because of the low population density in their service territories, cooperatives were some of the first companies to move

37 Jean-Philippe Moreau, Mario Tremblay, and Troy Martin, DistribuTECH 2018, *Voltage Sag Measurements for Advance Fault Location and Condition-Based Maintenance*, 2018.
38 Department of Energy, *Smart Grid Investment and Grant Final Report*, 2016, 9.
39 Department of Energy, *Smart Grid Investment and Grant Final Report*, 2016, 32.
40 Bob Yinger, Le Xu, Pete Maltbaek, Chad Abbey, *DistribuTECH, Southern California's EASE Project*, 2018.
41 Calculated from Energy Information Administration (EIA) projections of EV-installed base and average charge cost, spread across all cooperative customers.

to automated meter reading (AMR) meters and this trend has continued with AMI, with many AMR meters being replaced with AMI.[42] Smart meters are integrated with communications systems, allowing them to maintain two-way communications with the cooperative and offering the cooperative the opportunity to send time-of-use (TOU) pricing and other energy information back and forth.

AMI meters can enable decreased operating expenses in several ways, including remote connect/disconnect features, outage monitoring, voltage monitoring, and business loss measurements. AMI also supplies the information necessary to the functioning of DA, SA, DM, VVO, and DER, making it relevant to all other applications discussed in this paper.

5.3.2 Demand Management

DM broadly refers to all programs designed to affect consumer demand for electricity. Energy efficiency programs aim to reduce total energy usage and can potentially defer capital investments in new capacity. DR programs focus on shifting the energy load for customers from certain peak usage times, when energy is more expensive, to off-peak times, when energy is less expensive.[43] Utilities may also lower or increase retail energy prices at certain times to encourage or discourage use (called time-of-use [TOU] pricing), which reduces peak demand by 15% on average.[44] The effectiveness of DM programs varies widely by geographic region, load profile and extent of use, and wholesale power arrangements; cooperatives must assess for themselves which programs might deliver benefits for their systems.[45]

New technology in homes has helped increase the effectiveness of DR. Combined, hot water heaters and HV/AC systems account for two-thirds of residential consumer energy use. Smart thermostats and smart hot water heaters can shift the usage of those systems to lower use times without manual intervention from consumers and without a noticeable change in the effectiveness of their appliances.

6 BENEFIT ANALYSIS OF SELECT USE CASES

6.1 Overview Of Use Cases

The smart grid can transform the production and distribution of energy from a one-way single source grid into a two-way grid incorporating DER—one that is more resilient and more efficient than previous iterations. Many different specific use cases are a part of that transformation; this paper assesses those uses with the most impact at a qualitative level.

6.2 Use Case Selection Qualifiers

To value a broadband backbone, utilities must travel down the value chain to the operational benefits and new revenue that the backbone can enable. These use cases will require up to 100,000 times the amount of data required by today's grid.[46] A robust communications network is necessary to capture these benefits today and will only grow in importance over the life of the asset as new and improved technologies emerge. To quantify the value of the broadband backbone, this paper will not differentiate between the technologies necessary to enable the operational efficiencies and the efficiencies themselves. Communications is only one part of the value chain and should be considered that way. Furthermore, this paper estimates the value of a use case across the country. In reality, these values will vary both regionally and from cooperative to cooperative, based on the load profile and specific grid technologies involved. Also, each cooperative will vary based on its customer profiles, territory size, and geography. These quantifications should be used as a guide and a directional assessment of the value of a broadband backbone and its enabling use cases.

The model is built primarily on a per-meter valuation, which is applied across different-sized cooperatives. Different economies of scale will create different values when cooperatives implement them, but they are estimated to be the same in this case, due to a lack of differentiating data and effective measurement by those utilities that previously implemented the use cases.

42 NRECA, *Technology Advisory*, "Electric Cooperatives Lead Industry in AMI Deployment," 2018, 1. AMI meter penetration data comes from EIA Form 861 (2016).

43 These include annual peak times, generally the hottest and/or coldest days of the year, when demand for space cooling and heating is the highest, as well as daily peak times, such as when customers first wake up in the morning or return from work, and usage increases.

44 TOU programs are also aimed at reducing usage at times when power costs are more expensive and are generally tied to time-based wholesale power costs. *Department of Energy, Smart Grid Investment and Grant Final Report*, 2016, 45.

45 NRECA, *Distributed Energy Resources Compensation and Cost Recovery Guide*.

46 National Rural Electric Cooperative Association and U.S. Department of Energy, *Smart Grid Demonstration Project*, "Communications: The Smart Grid's Enabling Technology," 2014, 1.

Application	Benefit Case	Data Need	Broadband Impact
AR-Based Substation Monitoring	Condition-Based Asset Monitoring	Bandwidth, Latency	High
DA	Reliability, Equipment Usage, Labor Savings	Latency, bandwidth	High
AMI	Reliability, Volt Opt, Equipment Usage, Labor Savings	Bandwidth	High
SA	Reliability, Volt Opt, Equipment Usage, Labor Savings	Latency, Reliability, Security	High
Demand-Side Management (DSM), Volt/VAR, CVR	Volt Opt, Equipment Usage, Labor Savings	Reliability, Security	High
AM	Volt Opt, Equipment Usage, Labor Savings	Reliability, Security	High
Broadband to Home	New Revenue – Triple Play Services	Bandwidth, Reliability	High
Security – Video Surveillance	Threat Reduction	Bandwidth	High
Emergency Load Shedding	Volt Opt, Equipment Usage	Latency, Reliability, Security	High
Broadband Service to Commercial and Industrial (C&I)	New Revenue	Bandwidth, Reliability	High
DR	Volt Opt, Equipment Usage, Labor Savings	Reliability, Security	High
Outage Management	Reliability, Volt Opt, Equipment Usage, Labor Savings	Bandwidth	High
Self-Healing Feeder Automation	Reliability, Volt Opt, Equipment Usage, Labor Savings	Latency, Reliability, Security	Medium
Load Forecasting	Volt Opt, Equipment Usage	mMTC	Medium
EV Management	Volt Opt, Equipment Usage	mMTC	Medium
Relay Protection	Reliability, Volt Opt, Equipment Usage, Labor Savings	Latency, Reliability, Security	Medium
Phasor Measurement Unit	Reliability	Latency	Medium
DER, Renewables	Volt Opt, Equipment Usage	Security	Medium
Teleprotection	Equipment usage, labor savings	Latency, Reliability, Security	Medium
SCADA	Reliability, Volt Opt, Equipment Usage, Labor Savings	Latency, Reliability, Security	Medium
Workforce Mobility	Reliability, Labor Savings	Reliability	Medium
Mission-Critical Apps (PTT)	Reliability, Labor Savings, Equipment Usage	Reliability	Medium
Power Quality	Volt Opt	Latency, Reliability, Security	Medium
Smart Home	Volt Opt, Equipment Usage, Labor Savings	mMTC	Low
Electronic Mapping	Equipment Usage, Labor Savings	Latency, Reliability, Security	Low
Energy Conservation	Volt Opt, Equipment Usage	mMTC	Low
Energy Efficiency	Volt Opt, Equipment Usage	mMTC	Low
Facilities Energy Management	Volt Opt, Equipment Usage	Latency, Reliability, Security	Low
Building Automation	Volt Opt, Equipment Usage	mMTC	Low

Table 3: Application and Benefit Case

6.3 Benefit Quantification Methodology

All use cases were divided into major application areas and valued in those categories. In addition to direct use for the cooperative, an estimated value for the cooperative to lease dark fiber to other enterprises in the area generated additional income for the asset at a valuation of $200 per strand mile annually; note that most leasing agreements have a flat rate for a 20-year contract.[47] See Appendix Section 8.1 for additional details and methodology.

When factoring in slow load and customer growth, a 50,000-member cooperative has the potential for economic benefits of $10 million to $16.6 million today and $15.1 million to $25.2 million by 2027, depending on the utility-specific implementation and regional load profile.[48] This value is driven by the improved resiliency and reliability of the grid, as demonstrated by DA, SA, outage reduction, and AM aspects of the model.[49]

Application	Annual Valuation per Meter
DA	$20–$30
SA	$1–$3
AMI	$12–$18
VVO	$14–$29
DM	$88–$140
Outage Reduction	$1–$3
AM	$45–$85
DER	$3–$6
Carrier Cost Replacement	$1–$3

Table 4: Application and Valuation

6.4 Benefits For Different Sizes Of Electric Cooperatives

6.4.1 A 10,000 Member Cooperative

Small cooperatives may see economic value of $1.7 million to $2.9 million per year through their operations. Small cooperatives may realize many of the benefits outlined above but may be too small to create efficiencies in all of them. They may also be impacted by the scale necessary to create the variance in performance that allows for increases in efficiency to take place. For CVR, different value-based solutions, such as aggregation and defined services, may be needed to assist in achieving the long-term benefits required by smaller cooperatives. Similarly, voltage control solutions that behave like traditional DR programs can have large impacts because power supply costs are the largest part of the cooperative cost structure.

2018 Valuation for a 10,000 Member Cooperative

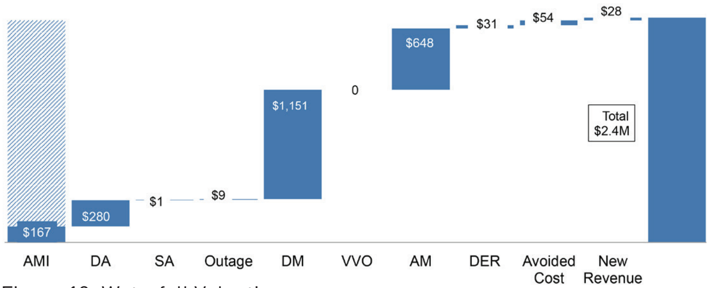


Figure 13: Waterfall Valuation

6.4.2 A 50,000 Member Cooperative

A cooperative of 50,000 members may see between $10 million and $16.6 million in economic benefit annually by implementing the use cases outlined above.[50] DR may play the largest role in determining the success of this operational efficiency through modernization of the grid. Additionally, the revenue could vary, depending largely on how successful the cooperative is in selling its excess fiber capacity to other enterprises.

2018 Valuation for a 50,000 Member Cooperative

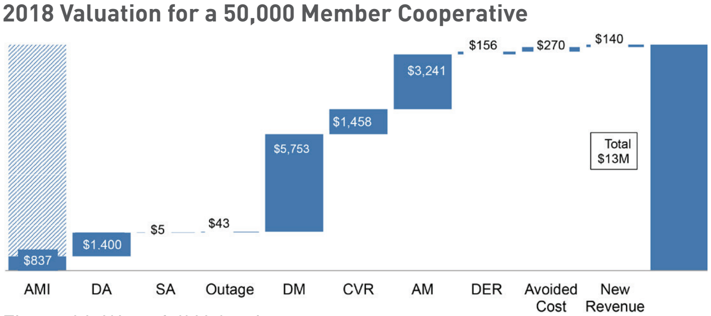


Figure 14: Waterfall Valuation

6.4.3 A 100,000 Member Cooperative

Large cooperatives may see a range of benefits of $20 million to $33.2 million per year. These benefits will follow much the same pattern as those from the smaller-

47 Craig Turner, *Tech Advantage*, "How to Navigate the Backbone," 2015, 17.

48 Assumed 1% load growth.

49 This value is the value generated by all use cases cumulatively but requires additional equipment to operate the use cases. Additionally, it represents the total value, not a net value that would take costs into account.

50 The range of values is driven by utility-specific implementations of the use cases, the benefits of multiple-use cases used in conjunction to create additional value, and regional differences in load profile leading to different opportunities for generating savings.

sized co-ops. Large cooperatives have the scale to allow for more investment in these use cases and may be able to implement more of them because of their larger investment budgets.

7 HOW TO USE THE GUIDE

This guide should be considered an input to decision making for cooperatives assessing the value of a broadband backbone for electric operations. A broadband backbone is a foundational technology for other smart grid use cases that will likely become necessary to execute business tasks going forward. Because of changing consumer behavior and the rise of DER, an intelligent grid and the communications network to support it will likely become imperative for safe maintenance of the grid. A communications network is a long-term investment, which requires its own strategy outside of an ad hoc implementation as part of other use cases. Furthermore, utilities with a broadband backbone can benefit from current use cases as well as positioning themselves to benefit from other use cases not yet commercially viable or even envisioned.

8 APPENDIX

8.1 Model Explanation

We built the model based around a per-meter valuation of different use cases. The use case valuations were sourced from published benefit quantifications, as outlined specifically below. Those benefits were estimated on a per-meter basis, then qualitatively assessed and adjusted to reflect cooperative use cases, data quality, and execution ability. The valuations were then vetted by subject matter experts—including vendors, cooperative employees, and the sponsors of this paper—to examine quantification method, value, feasibility, and scalability. Those initial valuations were then scaled over time to account for growth in customers, loads, and use cases. Although the valuations did not account for specific regional or load profile differences, regional variability informed the ranges of values ultimately selected. All dollar amounts are provided for illustrative purposes only. Each electric cooperative has unique circumstances and should make its own independent business decisions.

The following sections present the different inputs utilized in the benefits case. They provide references to the original data points and supporting sources, as well as the adjustments necessary to account for the per-meter structure of the model and the differences between cooperatives and other utilities.

Size of Cooperative: 50,000 Members

Utility Broadband	2018	2019	2027
Item			
Revenue			
Business	$140,000	$144,200	$182,668
Revenue - Total	**$140,000**	**$144,200**	**$182,668**
Cost Avoidance			
Distribution Automation	$1,400,000	$1,442,280	$1,829,877
Substation Automation	$5,000	$5,101	$5,985
AMI	$837,000	$862,277	$1,094,005
Outage Management	$42,500	$43,784	$55,550
Demand Management	$5,753,400	$5,927,153	$7,520,011
Volt/VAR Optimization	$1,458,000	$1,502,032	$1,905,686
Asset Management	$3,240,741	$3,338,611	$4,235,827
DER	$155,535	$220,300	$1,738,741
Previous Telecom Costs	$270,000	$329,400	$1,616,599
Cost Avoidance - Total	**$13,162,176**	**$13,670,937**	**$20,002,282**
Total Economic Value	**$13,302,176**	**$13,815,137**	**$20,184,950**
High Estimate	$16,627,720	$17,268,921	$25,231,188
Low Estimate	$9.976,632	$10,361,353	$15,138,713

Figure 15: Valuation Sheet

8.1.1 Advanced Metering Infrastructure

AMI

AMI also provides data to optimize other use cases, including outage management and voltage optimization

Method

Data Point
$16.74 per meter

×

Customer Count
50,000

=

Annual Expected Savings
$835,000

Rationale / Source

Sources:

1. AMI summary report

- Meter reading
- Tamper detection
- Outage monitoring
- Prevent truck rolls

Further Sources

1. Final SGIG report
2. Distributech
3. Navigant

8.1.2 Distribution Automation

Distribution Automation- FLISR

DA can also generate savings through load balancing

Method

Data Point
$7M saved

×

Customer Count
250,000

=

Savings per Meter
$28

Rationale / Source

Sources:

1. Distributech 2017 White label utility (2 examples)
2. DOE, NRECA Smart Feeder Switching Report

Savings per Meter
$28

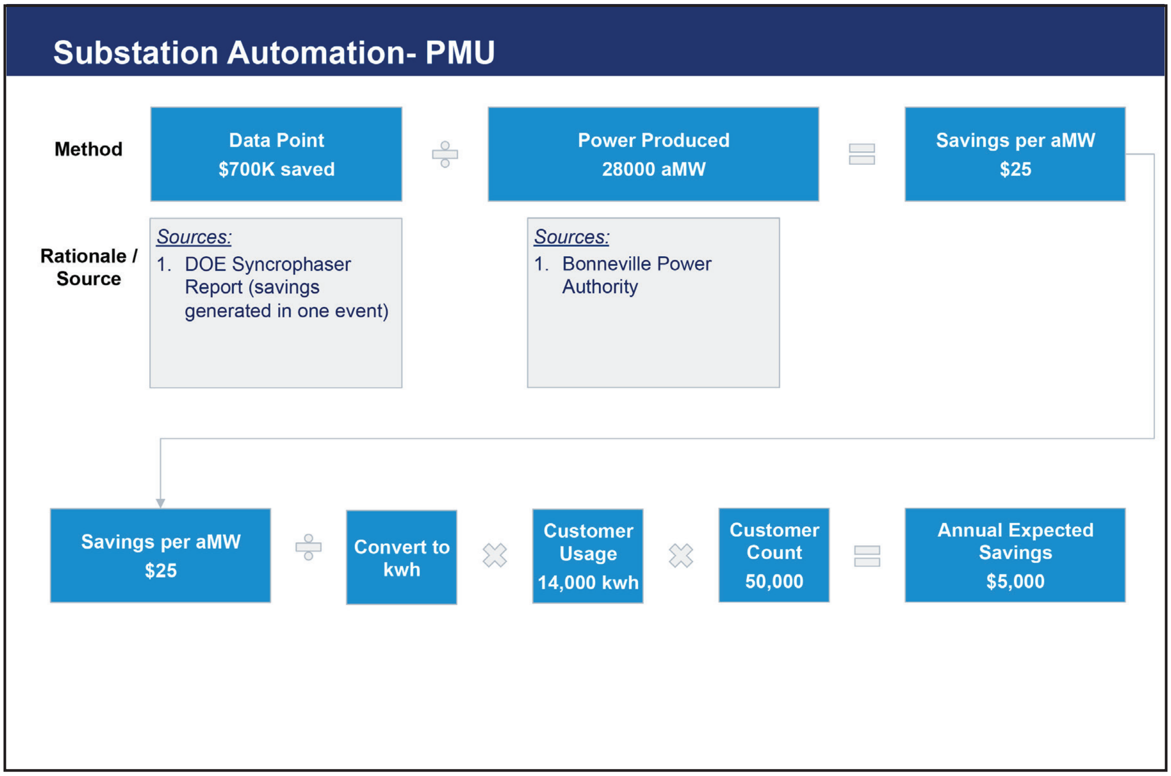
×

Customer Count
50,000

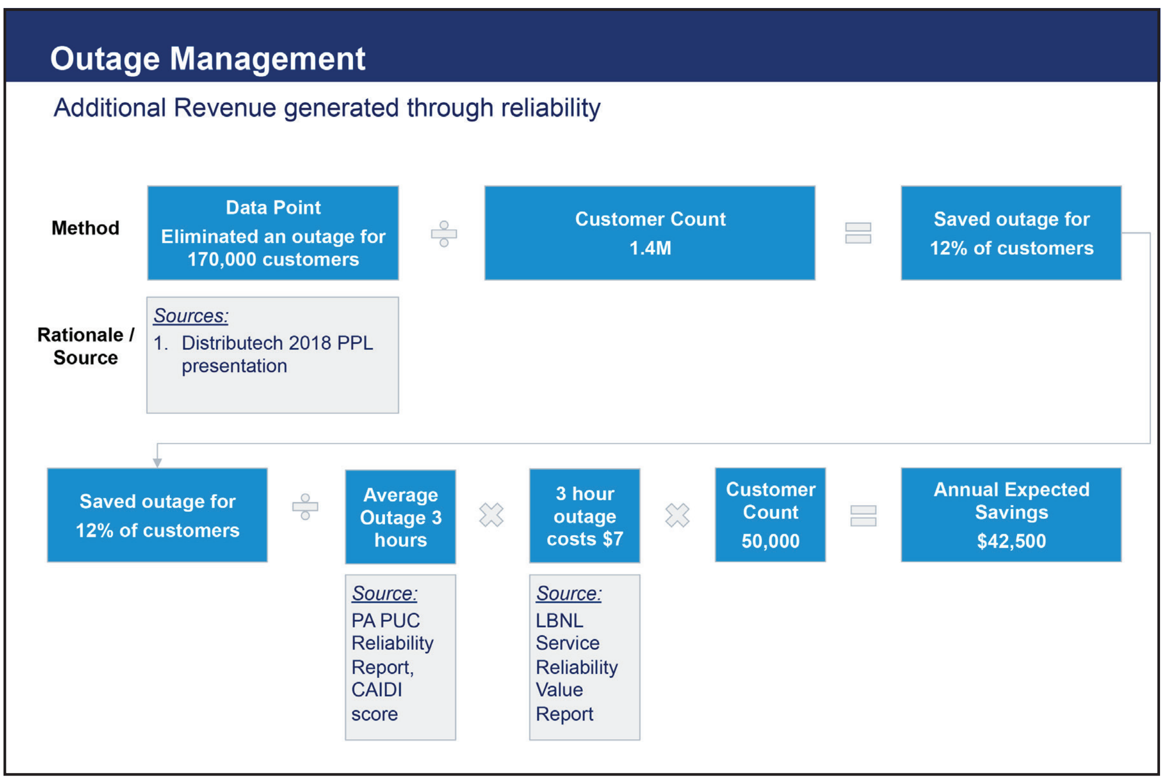
=

Annual Expected Savings
$1,400,000

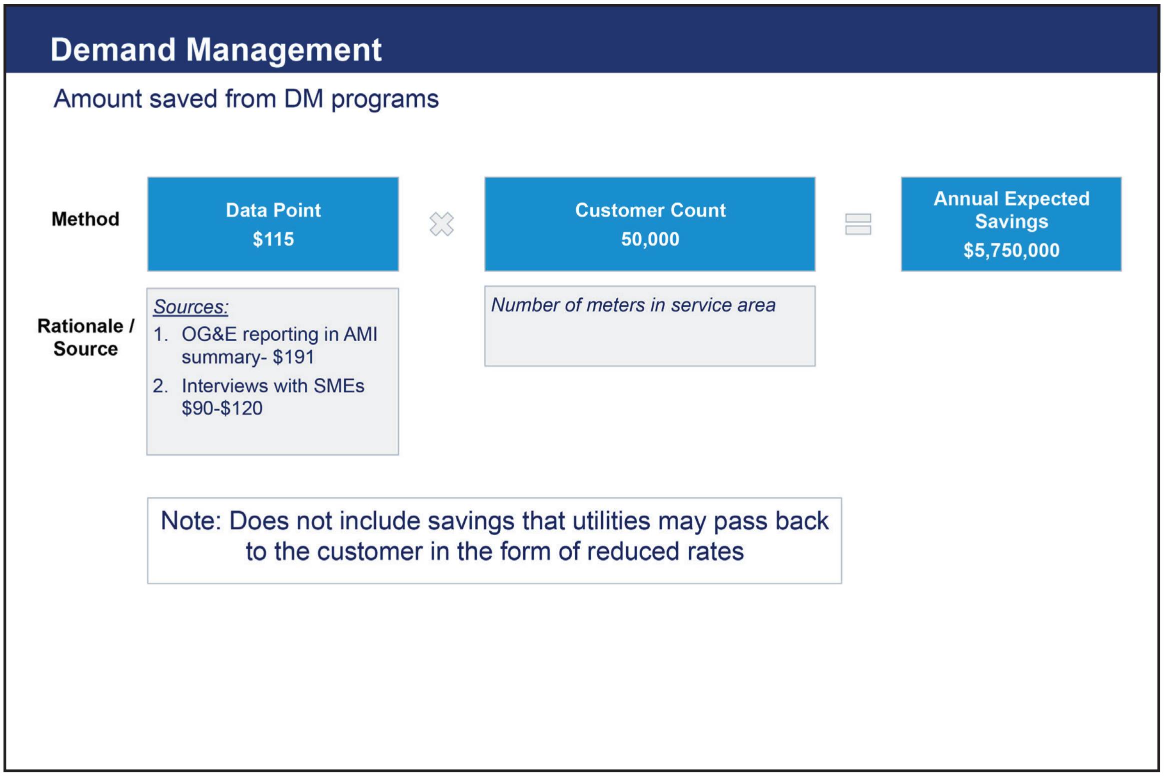
8.1.3 Substation Automation



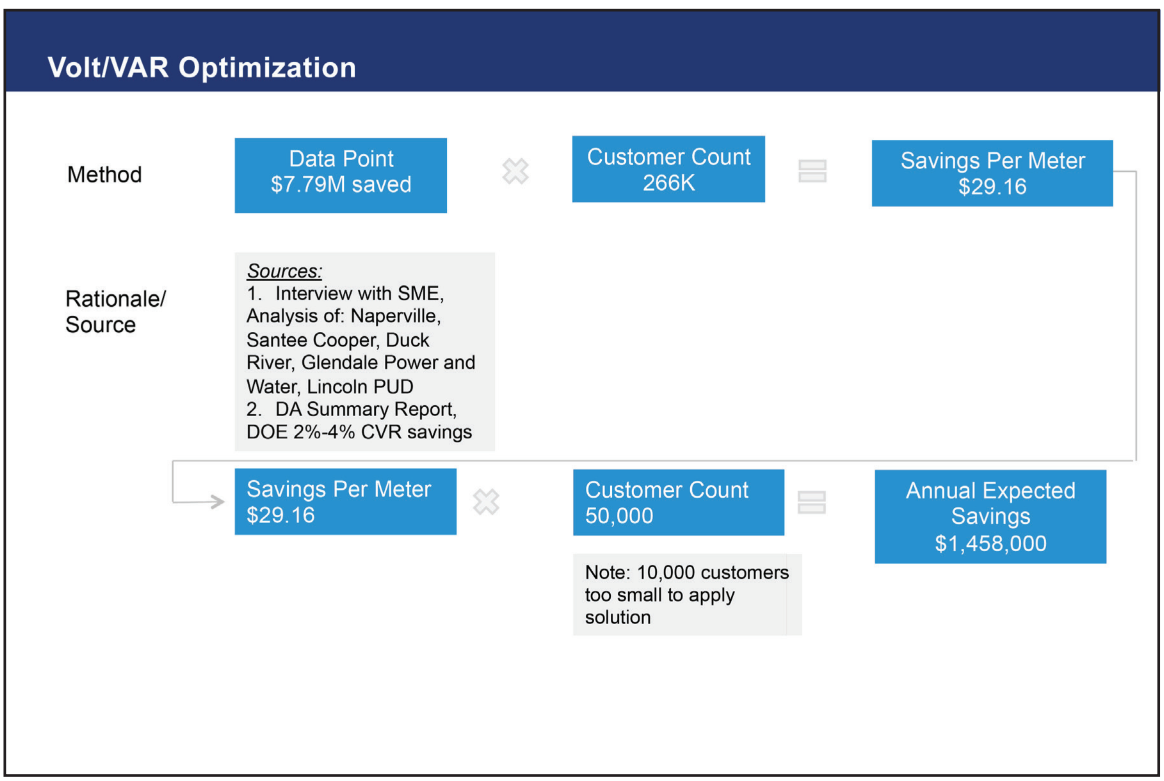
8.1.4 Outage Management



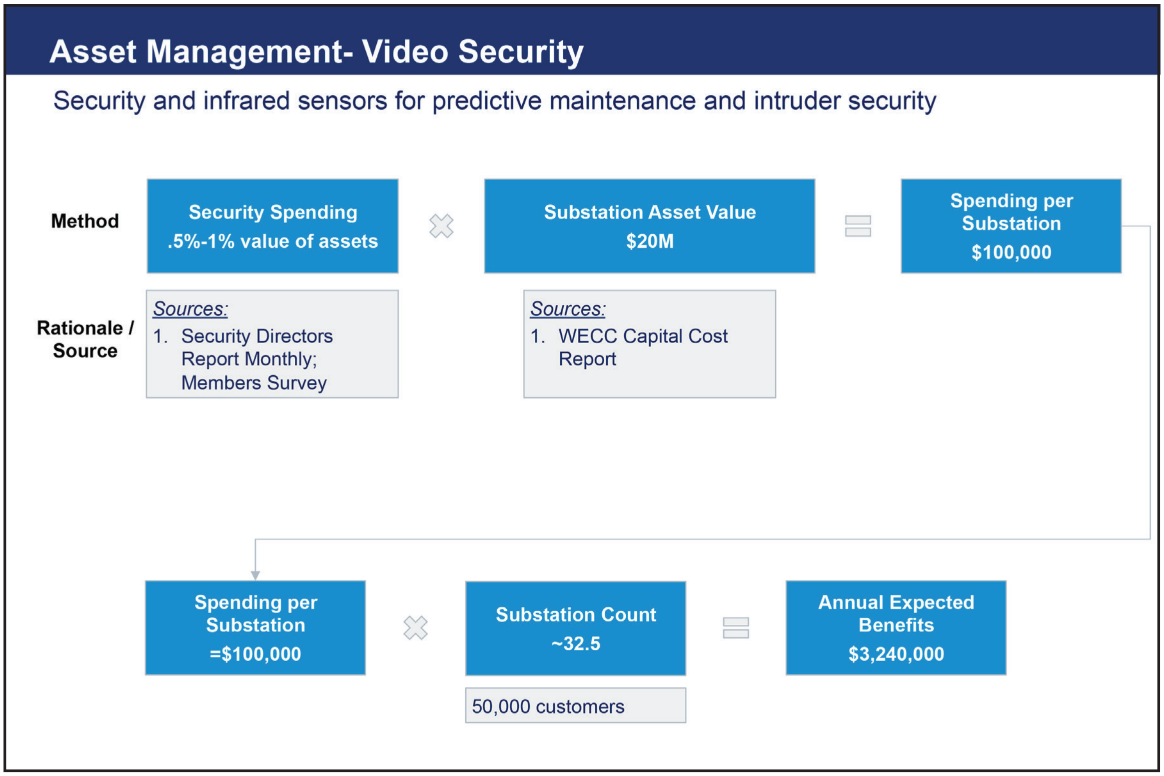
8.1.5 Demand Management



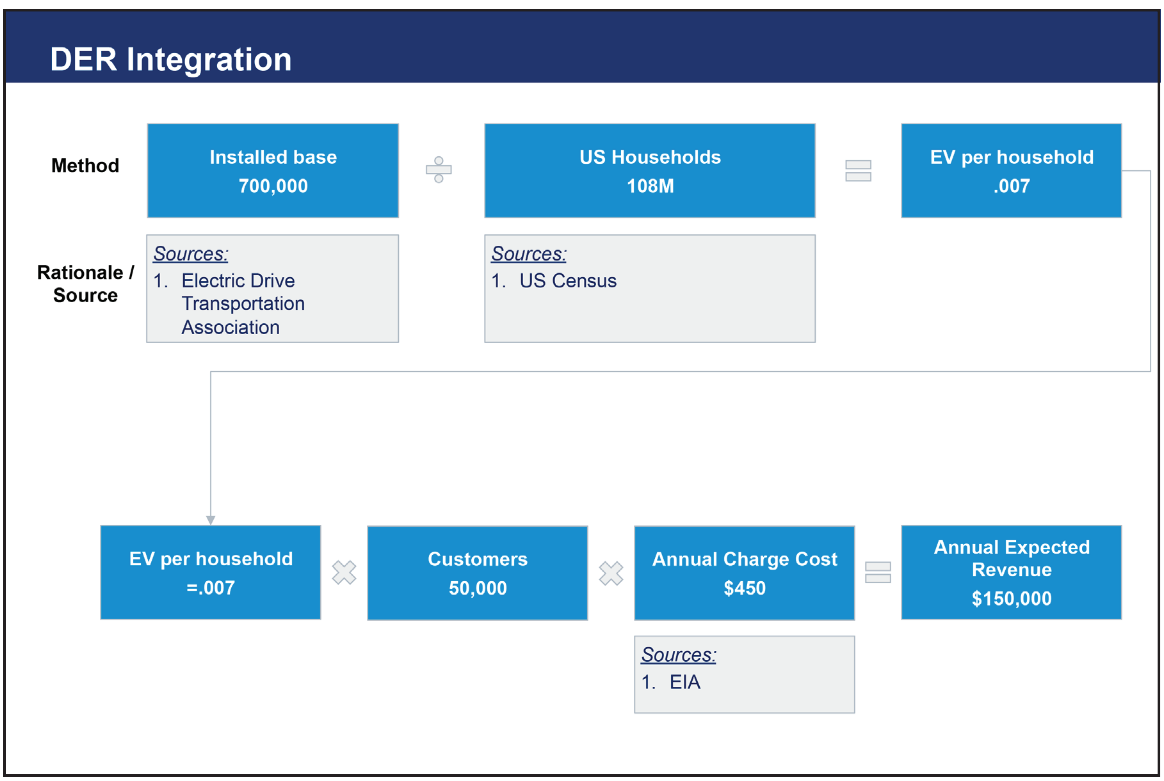
8.1.6 Volt/VAR Optimization



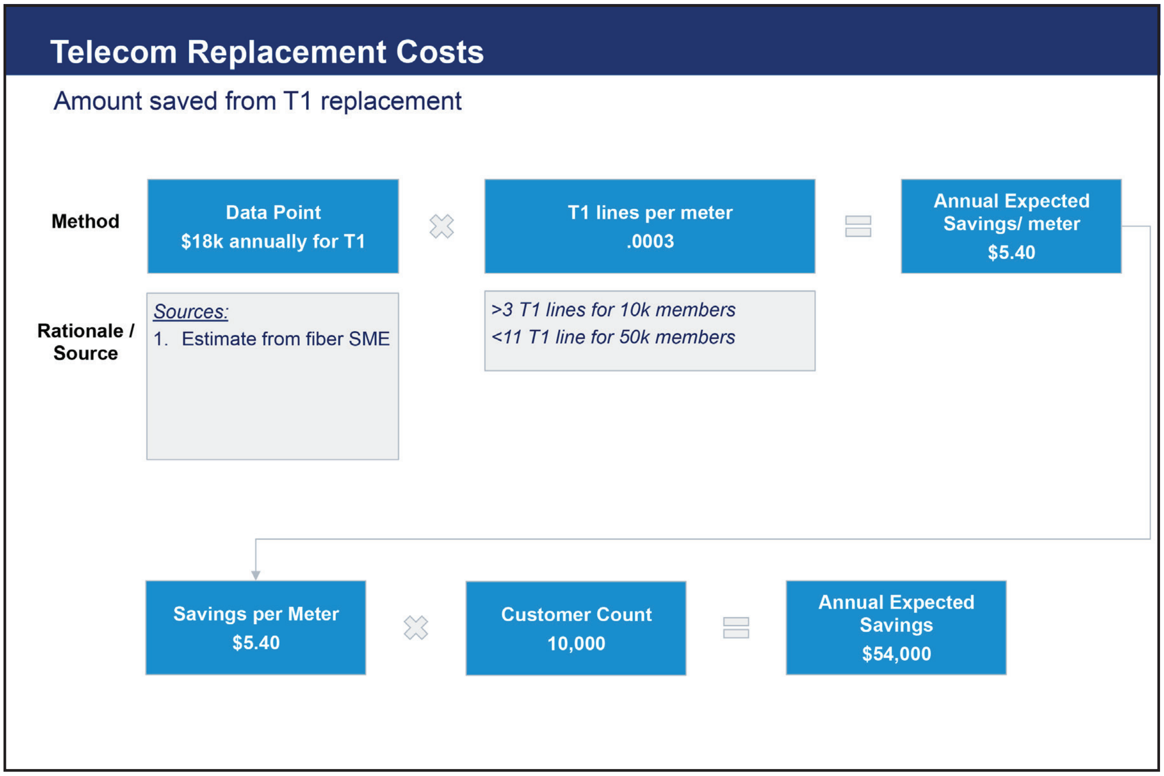
8.1.7 Asset Management



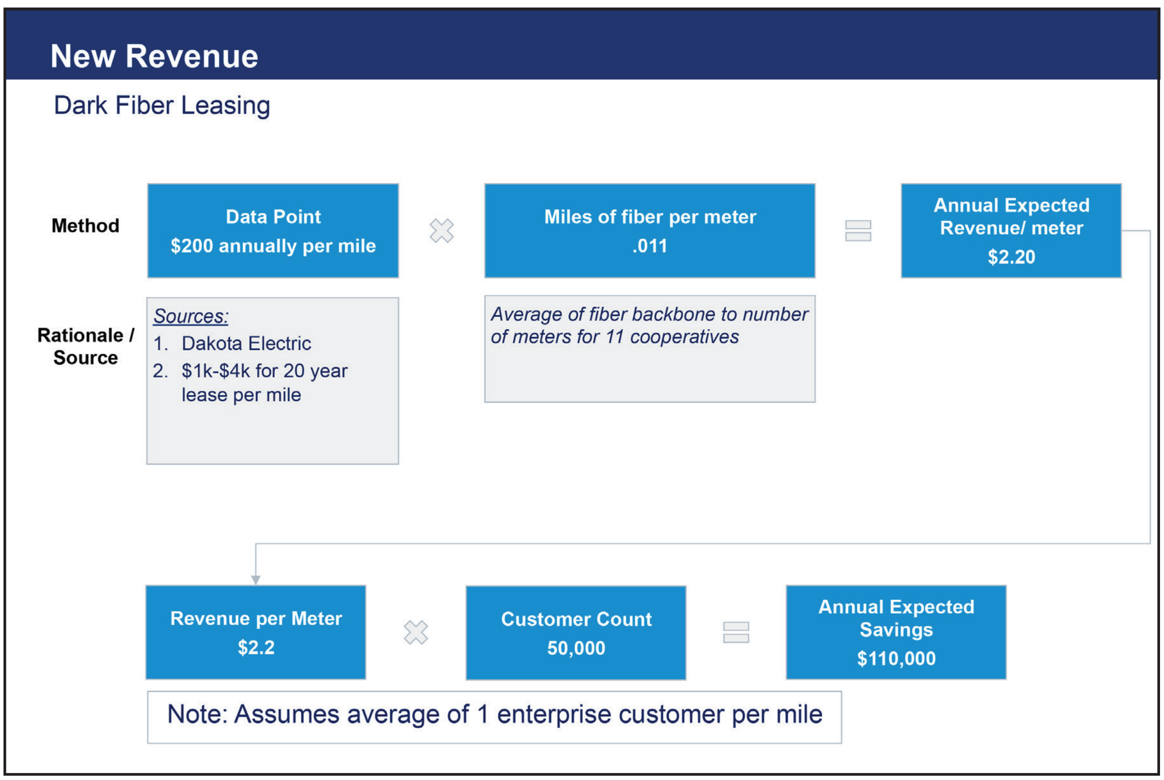
8.1.8 Distributed Energy Resources



8.1.9 Avoided Costs



8.1.10 New Revenue



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