AVISTA

Smart Grid Technology Report

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Executive Summary

Avista Utilities' ongoing commitment to deploy smart grid and grid modernization technologies throughout its service territory leverages the opportunity to improve the reliability and enhance the performance of the power grid to the benefit of our customers. The modernization serves to meet the current and foreseeable energy needs throughout the region. Electric system generators, suppliers, and consumers are all part of the complex power network and contribute to the value realized by investments such as automated distribution feeders, intelligent substation equipment, and communication capabilities that enhance power delivery and consumption information. Interactive appliances in homes, increased system automation, and system-wide sensors monitor activities in real time, exchange information about supply and demand, and can adjust critical power parameters based on real-time data.

Since the original electric grids began taking shape in the 1890s, incremental improvements have proved their worth in power quality, availability, and reliability. However, the recent technology advancements associated with the smart grid affecting the transmission, distribution, substations, transformers, and meters of the electric grid establishes an efficient and effective infrastructure to help control costs, reduce emissions, incorporate renewable energy sources, increase grid reliability, and provide greater flexibility for consumers.

Avista continues to evaluate new technologies and service approaches to improve operational efficiency, system reliability, energy efficiency, generation capacity, and customer education and participation. Management of the appropriate level of operation and maintenance (O&M) expenses, linked to evaluations of life cycle economics, includes the principal elements of the smart grid devices discussed in this report. Characterizing the smart grid effort as a functional strategy rather than simply a set of technology upgrades places the focus on the benefits to the system as a whole, where improved reliability, enhanced system information, improved outage recovery, integrated microgrids, and coordinated distributed energy resources become viable outcomes.

Through the activities described in this report, Avista has experienced many of the challenges of implementing the 'system of systems' that comprise any smart grid deployment, along with the realization of the initial benefits and opportunities the system provides. It is expected that continued integration of smart devices such as switches, breakers, capacitors, regulators, and transformers, along with the associated communication network links, and risk-based cyber security, will contribute to future benefits as well. The Distribution Management System (DMS) and Advanced Metering Infrastructure (AMI), implemented through the Smart Grid Investment Grant (SGIG) and the Smart Grid Demonstration Project (SGDP), continue to serve as validated baselines for infrastructure replacement and expansion in other areas of the Avista service territory to maximize the operational efficiencies and customer benefits in each instance.

As the utility landscape continues to evolve, Avista is confidently positioned to be a key energy system participant, leveraging not only the technical investment, but also the knowledge and experience provided through the smart grid technologies deployed in its service territory.

Background

Fundamentally, a smart grid is the integration of digital communication and control technologies supporting real-time monitoring, control, and data collection throughout a utility's electric transmission and distribution system, extending to the customer's meter. Avista's smart grid system incorporates intelligent controls, automation, technologies, and equipment to coordinate the active management of the electric grid. Some benefits of the smart grid deployment include expedited restoration of electric outages, peak demand management, integration of distributed energy resources (DERs), increased network security, and improved efficiency of electricity transmission.

A smart grid is recognized not only for its implementation of technologies and equipment within a utility's electric grid, but also for the information, tools, and choices it provides to the customers. The opportunities for customer engagement and participation in the energy sector is dramatically increased through modernized grid technologies, including real-time access to consumption and billing information, participation in demand response, selection of desired energy sources, and linking local generation to the greater energy grid.

Beginning in 2004, Avista increased its emphasis on asset management with a focused analysis of total lifecycle costs, equipment reliability, maintenance expenses, and capital versus O&M spending. Reviews and analysis of specific equipment classes were prioritized based on historical failure rates, risk, and potential consequences. The results of these efforts led to the creation of a systemic Feeder Rebuild program with three primary objectives, specifically the reduction of maintenance expenses, reduction of energy losses, and increasing system reliability. For the identified feeders, the program's implementation included the addition of automated capacitor banks, replacement of high loss distribution transformers, and replacement of high loss conductors. The feeders were systematically rebuilt and data collected to determine overall effectiveness of the program.

Subsequent to the Feeder Rebuild program, Avista engineers began to utilize a Distribution Reliability and Energy Efficiency (DREE) program that could be considered as first defining the specific drivers for the opportunities, needs, and benefit considerations of a smart grid system. Using newly available sensors and systems to gain additional understanding and control of the distribution networks was found to provide an array of savings for the customer in long term O&M costs, increased reliability, and improved system efficiency. The DREE program leveraged geographic information and outage management systems installed several years prior, and was incorporated under a distribution management system integrated with additional sensors, switches, and controllers located throughout the grid.

The American Recovery and Reinvestment Act of 2009 (ARRA) provided the Office of Electricity and Energy Reliability within the U.S. Department of Energy (DOE) with $4.5 billion to support modernization of the electric power grid and to fund Title XIII of the Energy Independence and Security Act of 2007. These funds were to be allocated by the DOE as grants to utilities to begin building and deploying the requisite smart grid infrastructure.

According to Section 3 of the ARRA, the purposes of the Act included:

- To preserve and create jobs and promote economic recovery.
- To assist those most impacted by the recession.
- To provide investments needed to increase economic efficiency by spurring technological advances in science and health.
- To invest in transportation, environmental protection, and other infrastructure that will provide long-term economic benefits.
- To stabilize State and local government budgets, in order to minimize and avoid reductions in essential services and counterproductive state and local tax increases.

The ARRA funding provisions targeted four smart grid programs, namely Smart Grid Investment Grants, Smart Grid Demonstration Projects, Standards Interoperability and Cybersecurity, and Workforce Training, with the majority of funding designated to the Smart Grid Investment Grants and Smart Grid Demonstration Project initiatives. The focus of the SGIG was to deploy existing smart grid technologies, tools, and techniques within utility electric grid systems. The emphasis of the SGDP was on demonstrating advanced concepts and innovative applications in regional smart grid and energy storage demonstrations. In October 2009, through an open application process, the DOE selected and announced grant-based awards for 99 SGIG projects and 32 SGDP projects.

As part of the DOE award process, Avista was selected to receive a $20 million matching grant for a Smart Grid Investment Grant project to upgrade portions of its electric distribution system with integrated smart grid equipment and associated technologies. The Company committed an additional $22 million toward the project costs. The project, internally identified as the Smart Circuits project, significantly enhanced 58 electric distribution feeders and 14 substations in the greater Spokane area. The updated feeders demonstrated reduced energy losses from electric line loss, improved reliability, and increased operational efficiency of this portion of the feeder system. The substation upgrades included intelligent transformers, line devices, and control system software to enable smart grid capabilities. Tangential benefits included reducing the requirement for additional energy resources and a decrease in greenhouse gas emissions. The upgraded distribution feeders were primarily located in high-density population areas of north and south Spokane, serving approximately 110,000 customers.

Smart transformer installation

Additionally, and in conjunction with the DOE award process, Avista participated in a Smart Grid Demonstration Project that created the first "smart community" in the Pacific Northwest, located in the City of Pullman Washington and the nearby area. The funds for the $38 million project were a portion of a larger $178 million DOE grant for the Pacific Northwest Smart Grid Demonstration project that was administered by the Battelle Memorial Institute[1]. Avista's designated portion of the matching funds was approximately $13.1 million. Avista, in conjunction with several other companies including Itron, Hewlett-Packard (now Agilent), Spirea, and Washington State University, used this project to illustrate how a system with the ability to share information between the utility and its customers can achieve the benefits of a functional smart grid. Avista's contribution to the project helped to transform Pullman into a "smart city" by providing the Advanced Metering Infrastructure, including 13,000 smart electric meters and 5,000 natural gas encoder receiver transmitters, placed at customers' homes and businesses. In the homes of a subset of residential customers, Avista also installed smart thermostats with the capability to display energy consumption information for the customer and to also communicate that data to Avista through the AMI communication network. Battelle Memorial Institute's Technology Performance Report noted this project "was one of the largest and most comprehensive demonstrations of electricity grid modernization ever completed." (Hammerstrom, 2015, p. iii)

The Smart City of Pullman, Washington

Utilizing AMI technology allowed Avista to manage services remotely, which translated into improved customer service, a reduced number of service calls, and increased operating efficiency, which results in savings of approximately $235,000 annually for this region. In addition, fault detection, isolation, and restoration systems and other reliability enhancements led to an annual average of 17% fewer outages and shortened outage durations by 12%. These results provide key reference points as the SGDP efforts are leveraged into the current planning processes for a broader scale deployment of AMI technology for Avista's remaining Washington electric customers.

In addition to the expected system benefits already noted, this project helps to move the region and the nation closer to establishing a more efficient and effective electricity infrastructure. With the functional communication and control capabilities of a smart grid, the integration of renewable energy resources such as wind and solar are more easily managed, providing significant benefits for the grid operators and energy consumers.

[1] The Battelle Memorial Institute is an international science and technology enterprise that explores emerging areas of science, develops and commercializes technology, and manages laboratories for customers. Battelle supports community and education programs to promote an enhanced quality of life for its community neighbors. The Battelle Memorial Institute's Pacific Northwest Division operates the Pacific Northwest National Laboratory.

The Smart Grid Demonstration Project concluded in December 2014, at which time Battelle began analysis and reporting on data gathered from all participating utilities to determine the value derived from the coordinated smart grid projects. The resulting document, the *Pacific Northwest Smart Grid Demonstration Project Technology Performance Report*, was published in June 2015. It includes a review of achievements and conclusions regarding the transactive system and the implementation of smart grid technologies deployed through the project, and also put forth recommendations to the DOE on future and expanded smart grid deployments. One significant finding involves the project's experience with the vast amounts of data, including the quality of data and its management, within a smart grid environment. One key recommendation centered on the improvement of meter data quality, the related databases, and the data processes at all levels of the smart grid. This included improved intelligent toolsets to be developed for utilities in order to manage the devices and information that comprise the smart grid.

Referencing back to Avista's original Feeder Rebuild program, 100% of the Smart Grid Investment Grant project costs in Spokane and approximately 60% of the Smart Grid Demonstration Project costs in Pullman would likely have been expended under the original rebuild program. The timeliness and availability of the ARRA grants allowed these investments in Avista's infrastructure and the related system-wide benefits to be made at a 50% discount to Avista customers.

The success of both the SGIG and SGDP projects has led Avista to develop a systematic approach to feeder expansion and extensions. The premise of this Grid Modernization program is to consider all necessary upgrades to the feeder infrastructure at one time, essentially optimizing the investments by merging the objectives of the Wood Pole Management, Smart Grid, and the Feeder Rebuild programs. With over 340 feeders in its Washington and Idaho service territories, this program intends to upgrade six feeders each year. Each feeder will be individually assessed to determine the suitable level of automation and smart technologies, like those deployed through SGIG and SGDP projects, will be installed as appropriate.

In addition to the SGIG and SGDP awards, Avista also received $1.3 million of a $5 million grant to contribute to the development a Smart Grid Workforce Training (SGWT) program in partnership with several utilities, colleges, and universities in the region. The goals of the smart grid workforce training program included:

- Create and deliver curriculum, programs, and training for smart grid technologies and applications to utility workers in Washington, Idaho, Oregon and Montana,
- Create an online smart grid training and information portal to be shared by utilities, businesses, and consumers throughout these four states, and,
- Share best practices on smart grid workforce training from a regional perspective.

The project specifically targeted 10 supply- and demand-side occupations that required unique training programs to help prepare the labor force for positions in the emerging smart grid employment fields. Identified supply-side occupations included instrument control and relay specialists, generation and load dispatchers, generation, load, and substation operators, line workers, substation wireman and mechanics, and ground crews. The demand-side positions included customer service representatives, meter technicians, energy advisors, energy conservation program administrators, and resource conservation managers.

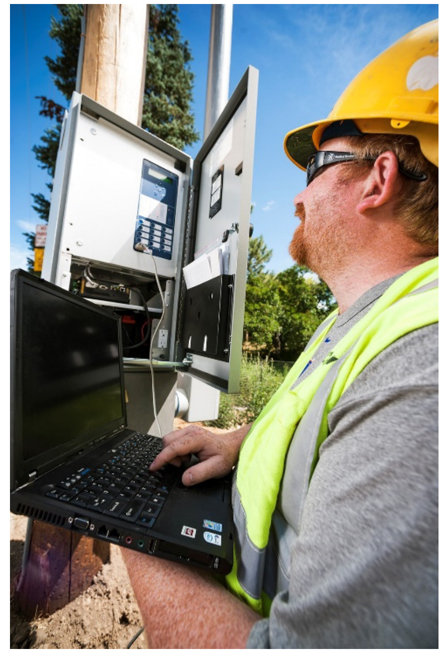
Avista continues to use the curriculum materials and concepts developed by the Smart Grid Workforce Training grant to train existing and new employees. Pre-line apprentice-, apprentice- and journey-level training programs incorporate smart grid technology applications and materials in their particular course of study. The SGWT course content and references have also been updated and enhanced since the grant period concluded in 2013. Avista also continues to leverage the training substation and training distribution feeder physical assets built during the SGWT grant period for training employees and others related to the field. Subsequent to the grant, Avista has also made additional enhancements to the physical training assets and training scenarios used at its craft and technical training campus, the Jack Stewart Training Center, located in northeast Spokane. These improvements include additional build out of the Safety Town mock neighborhood with simulated residential and commercial buildings that interconnect to the site's smart grid substation and distribution feeders to enhance training opportunities made available to the participants.


Smart Grid Technology Training

Smart Grid Technologies

The smart grid technologies that are considered, evaluated, and deployed within Avista's service territory are intended to meet several objectives, providing benefits and advantages for all parties connected to the electric grid. The inherent value of specific benefits may vary between participants on the electric grid, but some representative themes of merit are noted below.

- Increase of energy delivery information
- Reduction of energy losses
- Increased system reliability
- System safety
- Integrating distributed energy resources
- System voltage control
- Extending the viability of existing infrastructure
- Measurement and validation of system data
- Operational efficiencies
- Minimized need for new energy sources
- Reduction of greenhouse gas emissions
- Remote control of smart system elements
- Automated fault detection and restoration
- Integrated voltage and reactive power compensation
- Conservation voltage reduction



Automated smart grid control systems

The Smart Grid Demonstration Project

In coordination with Battelle and the other project partners, the Smart Grid Demonstration Project formally concluded in June 2015. This broad project implemented one of the world's first energy transactive systems, able to negotiate and coordinate the real-time supply and consumption of energy. For Avista, the SGDP involved the automation of many parts of its electric distribution system using advanced end-use metering, enhanced communication networks, appliances within customer premises, substation automation, and transmission line sensors. These specific technology enhancements will be addressed in subsequent sections of this report. This project also leveraged some of the same technologies as the Smart Grid Investment Project in Spokane. For example, the Distribution Management System that controls smart devices such as switches, capacitor banks, fault indicators, and voltage regulators, was able to be utilized for both projects. The DMS portion of both SGIG and SGDP projects was fully implemented by the end of 2013.

In conjunction with the SGDP, the communication services were supported by the build out of an 802.11 wireless mesh network supporting the AMI functions in the Pullman surrounding areas. This network served to gather meter data from the electric smart meters and natural gas encoder receiver transmitter modules.

The initial objectives of the overarching Pacific Northwest Smart Grid Demonstration project, going back to the project's inception in December 2009, intended to provide a significant increase in the knowledge and understanding of several facets of a smart grid and its impact on the future operations of a utility and the customers its serves. These objectives included:

- Create a regional smart grid foundation to support continued future growth,
- Develop and validate interoperable communication and control infrastructure to coordinate a broad range of customer and utility assets,
- Integrate demand response, distributed generation, energy storage, and distribution automation,
- Measure and validate smart grid costs and benefits for customers, utilities, regulators, providing business case support for future smart grid investments,
- Contribute to the development of standards and control methodologies for interoperable smart grid environments, and,
- Apply smart grid capabilities to support the integration of the region's renewable energy resources.

The general success of the regional effort, including Avista's specific contributions, was described in Battelle's post-project report. Some noteworthy results included the creation of a transactive system bridging the link between transmission system assets and individual premises, assessing the interoperability of vendors' equipment and software toolsets, validating the rapidly-changing communication standards, and understanding the functional challenges of implementing an AMI system in the field.

As has previously been noted, Avista and its customers have garnered significant benefits and lessons learned through the experiences associated with the SGDP. For instance, proficiencies have been gained through the process of deploying and operating smart grid equipment in all levels of its electric grid along with a recognition of the current and future opportunities for grid management the smart grid technologies provide. These experiences continues to guide current and future smart grid plans and investments for the utility.

Electric smart meter

These experiences have also exposed areas where limitations and challenges remain. One forward-looking requirement is to extend supervisory control and data acquisition systems throughout the distribution system, including distribution metering. These improvements are necessary to help support the validation of any smart grid expansion. Another challenge includes interoperability standards and conformance testing of third-party products and toolsets to reduce the expense associated with integration of smart grid equipment, along with providing a practical, affordable upgrade paths for smart grid systems to avoid the risk of technologically stranded assets. Ongoing research to support the seamless integration of distributed energy resources is expected to provide functional and architectural requirements that are able to be used to further progress grid transformation.

Included in the Battelle report (Hammerstrom, 2015, pp. 7.120-7.122 Sec. 7.13) are the Conclusions and Lessons Learned associated with Avista's SGDP activities, both internally and in relation to the other partners in the Pacific Northwest Smart Grid Demonstration project (PNWSGD). For reference and consistency, these SGDP results are included herein.

Avista greatly modernized the Pullman site distribution system and considers its participation in the PNWSGD to have been very successful. During the project, the utility implemented IVVC on many of the 13 feeders. The project was able to confirm that these efforts would indeed conserve about 2% of the electrical load in Pullman. Power factors were significantly improved on at least 9 of the 13 feeders. Avista values this conservation at over $0.5 million per year, based solely on the value of avoided energy purchases. The utility initially encountered delays as it calibrated the system's sources of end-of-line voltages, but they were eventually able to measure customer voltage within the 0.5% accuracy that was needed by the voltage optimization system.

A couple of miles of reconductoring was necessary to reduce system losses and maintain the flexibility needed for optimal circuit topology. The utility estimated that 29.6 MWh will be conserved each year due to the improved conductors. The utility replaced its oldest, least efficient distribution transformers with about 400 smart transformers. Regrettably, the transformers were not monitored in a way that would have permitted the project to confirm such energy savings from improved energy efficiency. The smart transformers provided new voltage and status metering points. The newly available information now facilitates transformer health assessment, finding of energy loss and theft, and operation of the distribution system closer to acceptable voltage limits.

About 70 smart, communicating ecobee thermostats were supplied to a group of Pullman residential customers. Recruitment of these participants was challenging. The project was able to tentatively confirm a very, very small conservation during the project's transactive events. Questions remain about when and whether these events were, in fact, communicated to the thermostats and Avista conducted additional demand response DR events that were unknown to the project. Regardless, the utility learned much about recruitment and customer acceptance of this type of program. Those customers who had received thermostats were generally satisfied with their program experiences.

Avista investigated how its customers would use energy web portals and whether they would conserve energy given transparent information about their own energy consumption habits. Small, but statistically insignificant, energy conservation was found for customers who were provided access to a customized energy web portal. This finding was consistent with that in the contracted Freeman, Sullivan, and Co. report. Regardless, by Avista Utilities' assessment, the modern features of AMI were attributed by them with saving $235 thousand per year in Pullman through a combination of remote meter reading, improved customer services, and reduced service site visits. By the utility's estimation, 2,714 truck rolls per year are being avoided with the AMI's ability to confirm power status and remotely open and close accounts.

The utility installed an FDIR system to more quickly respond to outages and reduce the duration of outages that its customers experience. The project observed that these *improvements were not evident in the reliability metrics SAIFI, SAIDI, or CAIDI. The utility's conclusion may be more optimistic based on automated reports of avoided customer outages from its upgraded DMS. By the utility's estimation, the FDIR system reduces 12,000 to 16,000 customer outage hours per year, valued at $10 per customer outage hour. The more efficient identification of and response to outages also reduces vehicle miles and emissions.*

The utility worked closely with Washington State University to make a set of campus loads responsive to DR requests from the utility. The assets included reduction of building air circulation fan load, reduction of cooling-loop pump load, and control of three onsite diesel and gas generators. The project confirmed that about 240 kW was conserved by the curtailments of air circulation fans, and about 380 kW was conserved through control of the chiller loops. The project was able to find no evidence that the times that the generators were operated had been influenced by project signals, but if Avista can procure control of these assets, it might procure up to 3.7 MW of distributed generation.

Overall, the utility estimated that its activities under the PNWSGD project reduced greenhouse gas emissions by 2,367 tons of CO_2.

While Avista Utilities encountered immaturity among the smart grid assets that it deployed during the PNWSGD, these challenges were mostly overcome, and the Pullman, Washington, distribution system has been significantly modernized by its participation in the PNWSGD project.

With the conclusion of the Pacific Northwest Smart Grid Demonstration Project at the end of 2014, the transactive system was placed in a suspended state but remains available for activation for future applications. The main server, communications, and software components continue to be maintained. Avista anticipated this end of project conclusion, and as a result, invested the effort to insure the system would be useful beyond the regional transactive experiment.

Smart Grid Investment Grant Project

At this time, the construction, installation, and implementation aspects of the distribution feeder system associated with the SGIG project has been completed. This included the installation of 380 line devices, 29 miles of primary conductors, and equipment upgrades within 14 substations. Additionally, the Distribution Management System that serves as the command and control hub of the deployed smart grid technologies, has been managing the Fault Detection, Isolation, and Restoration module and the Integrated Volt/VAr Control functions for the 59 active smart grid feeders[2].

Between 2010 and 2013, the SGIG project also included the extension of Avista's fiber infrastructure and the deployment of a private Multi-Protocol Label Switching network and an 802.11 wireless mesh network in the Spokane service area.

The DMS deployment continues to provide a considerable amount of real-time data capturing the distribution system's operational behavior under various load, configuration, and environmental conditions. This level of accumulated information increases the visibility into the operation of the distribution network, providing intelligent insight for configuration management, performance monitoring and network fault monitoring activities.

One of the principal advantages in the management of this smart grid is the ability to automatically reconfigure the smart devices to achieve dramatic reliability improvements. This benefit is realized during an outage event as the system autonomously determines the feeder section needing to be isolated and then determines and implements the restoration process to both upstream and downstream customers. The direct result is to minimize the outage duration for all affected customers, and reduces the number of customers affected by any long-term outage.

Capacitors banks for distribution lines

[2] While the original architecture designated 58 feeders for the smart grid enhancements, one additional feeder was added to the project to address heavy loading and distribution planning requirements.

Network Communications

Integral to the functionality and operation of both the Smart Grid Investment Grant and the Smart Grid Demonstration projects was the construction of state-of-the-art communication systems and diligent cyber security oversight. Smart grid communications infrastructure interconnect the grid's smart devices with Avista's transmission and distribution systems to enable energy management, distribution management, data collection, and control systems.

The need for secure, reliable, and flexible network communications capabilities have a clear trend of increasing importance cross-cutting to Avista's current and future role in the communities that we serve. Today, tens of thousands of digital transactions take place each second across our customer, operations, generation, electric and gas transmission and distribution systems to ensure safe, reliable, and affordable energy and related services to our customers. The network communication infrastructure provides a critical foundation for any smart grid implementation.

Network Communications Strategy

Avista's network communications strategy is directly aligned to the utility's strategies and technology objectives in terms of its evolving digital landscape. Digital technologies and information can help to enable customer choices and provide the foundation to support the transition towards an increased renewable and distributed energy future.

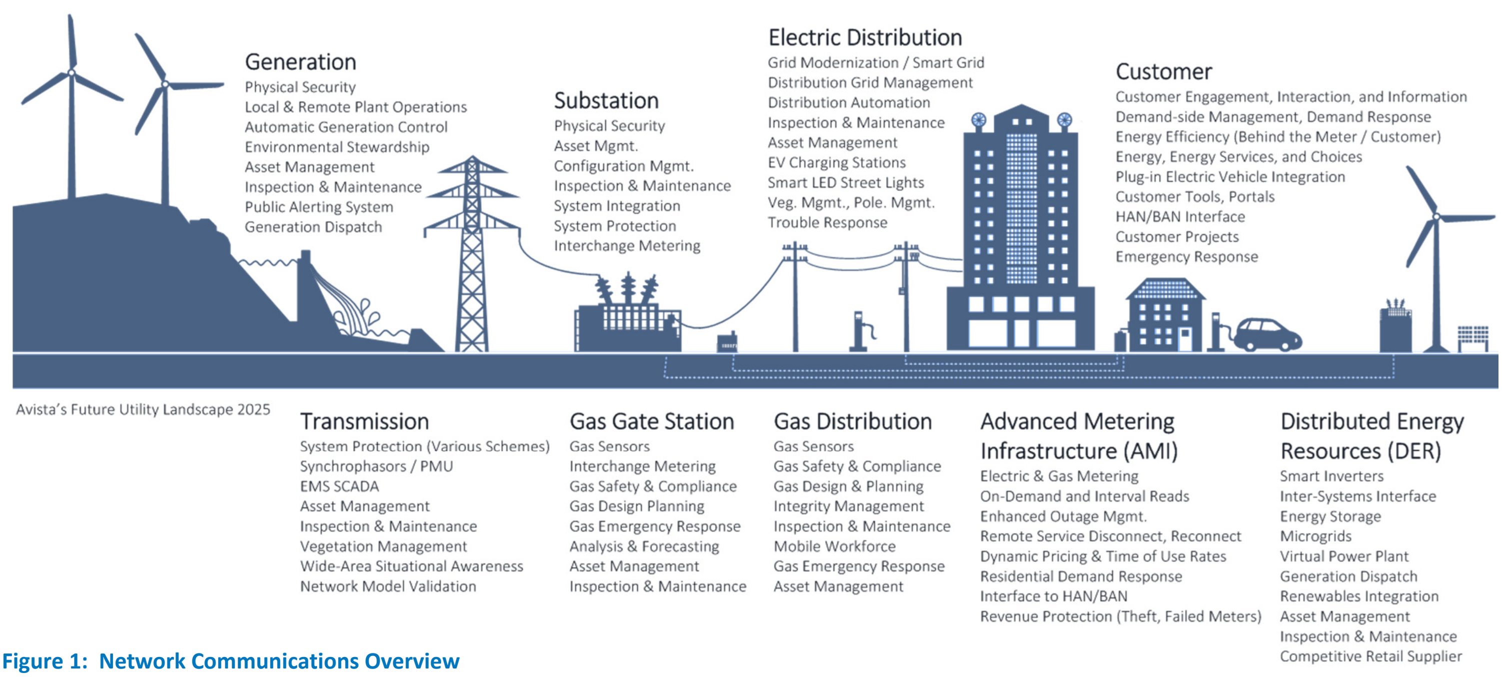


Figure 1: Network Communications Overview

Key areas of digital transformation that Avista will undertake in the next five years include:

- Customer Initiatives (Vision 2020)
- Advanced Metering Infrastructure
- Grid Modernization
- Physical and Cyber Security
- Workforce Mobility
- Next Generation Radio
- Increased renewable and distributed energy resources
- Smart City
- Cloud Services
- Data Science

Avista's network communication strategy is both a business and technology strategy as it considers internal and external disruptive forces, risks and opportunities across the strategic areas of our company, its operations, services, and role in the communities that we serve. This includes strategies for customer engagement and value, community vitality, safe and reliable infrastructure, effective regulatory outcomes, financial performance, people and performance, and responsible resources, including an environmentally responsible and sustainable energy mix. Internal and external forces, such as policy, legislation, regulation, social, technology, resources, workforce, financial, economic, markets, amongst others, influence our company strategies and therefore directly and indirectly influence our network communications strategy. As Avista becomes more digitally dependent, network communications infrastructure becomes as crucial as the pipes and wires in the delivery of safe, reliable, and affordable energy services and choices to our customers.

Key factors influencing our network communications technology and infrastructure roadmap is the operations, maintenance, and lifecycle management of existing and planned network the infrastructure assets and interfacing technologies. In order to manage increasing complexity as our utility's digital capabilities evolve and demonstrate value across customer, operations, grid, resources, market, and enterprise domains; it is necessary to move towards a converged network communication architecture and the concept of a unified platform that can be optimized for performance, resiliency, reliability, security, manageability, flexibility, and cost-effectiveness. Moving towards a unified network communications platform architecture can enable a more reliable, secure, and cost-effective service for Avista's customers.

Consideration of the network communications assets, services, and connected technologies may be at different stages of their respective lifecycles. Avista's current critical services and expanding business plans with priority for new digital technologies and capabilities such as physical security, AMI, grid modernization, workforce mobility; state of financial liquidity versus operating expenses and available capital, and enterprise risk management are all contributing factors of strategic investments, priority, and planning as to how the network communications capabilities evolve into the future.

Of these considerations, specific examples include:

1. Carrier Service Providers announce planning to retire legacy services (i.e., dedicated 2-wire, 4-Wire). Legacy 2-wire and 4-wire leased circuits currently support Supervisory Control and Data Acquisition (SCADA) to many of Avista substation EMS and DMS remote terminal units. The announcement from carrier service providers to retire these legacy telecommunication services drives the case and priority for Avista to migrate SCADA telecommunications towards alternate viable solutions other than leased wireline, such as private microwave, fiber, or other.
2. Avista is implementing Advanced Metering Infrastructure across its Washington electric and gas service territory. This is driving new architectures and internal design standards for utility field area networks and associated backhauls. The Washington AMI project will introduce over 500,000 digital endpoints on our electric distribution system.
3. Avista's grid modernization initiatives continue to drive the case for Avista to develop its field area and network communication backhaul capabilities. The security aspects for command and control transactions between devices, the substation controller and our centralized distribution management systems and dispatch operations, drives the case for private and secure network communications of which utilities own, operate, and manage the network communications infrastructure. The operational capabilities of the field devices, control and visibility to dispatch operators, and for the distribution protection system to be able to in real-time detect and respond to grid events, isolate, and stabilize the state of its electrical subsystems including energy resources and load, further drives the case for utilities to own and operate the associated underlying network communications that enable these functions. During normal operations, information exchange and operations of field devices enable energy conservation and efficiency applications and support field work, such as hotline holds, in addition to providing operational awareness and insight that is used by grid operators and planners.
4. A large portion of the fiber backbone infrastructure that Avista currently leverages to support high concentration data backhaul from remote offices, facilities, and field area networks, will reach end of term for right of use within the next 10-15 years. A strategic long-term investment to build-out a high-capacity fiber infrastructure is needed to address this issue and mitigate the financial and operational risk. Avista's network communication strategy calls for the development of a 10-year business case to address this in addition to Avista's current and future network communication requirements. Building a fiber backbone infrastructure is costly and time consuming. Fiber assets, however, have a long life expectancy up to 50 years for higher quality materials, and provide virtually unlimited bandwidth capability, generally limited by the maximum speed that the light transceivers can switch. Because of the low latency, longevity, and high bandwidth capabilities of fiber, the transport medium is high demand for both government and private sectors, and

increasingly more so as the world continues to move toward a digital and connected economy.

5. Smart City concepts and innovations continue to challenge our thinking in how we work together maximizing the shared resource potential across governments, private sectors, and our communities; to be more effective, efficient, sustainable, and collaborative; and to enhance our local and regional economies; empower our communities and attracting meaningful investments and growth to our cities. Smart City is challenging the way that we plan, design, implement, operate, and maintain our network communication infrastructures in the communities that we serve. Opportunities to work with government and private entities as we plan our refresh and expansion of our network communication infrastructures and capabilities may be considered. Other opportunities for partnerships that can achieve adjacent value streams within our communities with potential to enhance the economic vitality and broaden prosperity to the citizens of the communities that we serve are also of interest. Avista is exploring these possibilities as part of our involvement and support for a smart city experimental zone in the Spokane's University District. The 770 acre area will serve as a living laboratory to test the interrelationship of energy, water, health and the environment in ways never before possible. Spokane was designated as one of just ten Envision America Smart Cities in the country. Envision America is a nationwide nonprofit that has issued a challenge to America's cities to become smarter by accelerating deployment of innovative technologies that tackle energy, water, waste, and air challenges.
6. Risk-based security investments across our utility enterprise, such as increased video surveillance, identity and access management, and emergency response systems, are driving new network communication requirements for security and influencing a more strategic network architecture. Avista and the utility industry are experiencing an increasing frequency and severity of cyber and physical attacks. The PG&E Metcalf substation incident, April 16, 2013, was a significant physical-attack on energy industry assets. More recently, the Ukraine incident on December 23, 2015, was the first cyber-attack on energy industry assets that resulted in widespread power outages. At Avista, we are committed to continuously monitor, assess, and implement effective risk-based measures to protect people, information, and assets. As part of a larger coordinated effort towards cyber resiliency, we are implementing the voluntary Cybersecurity Framework released by NIST. The risk-based cyber security framework consists of standards, guidelines, and practices to promote the protection of critical infrastructure through collaboration between private sector and government. Avista continues to classify our assets and apply risk-based security measures to protect people, information, and assets.

Avista is actively engaged with the elements of change all around us. Our utility strategies and customer, community, grid, resource, business and technology initiatives continue to drive innovations and shared values in the communities that we serve. We continue to innovate and build towards the future.

Architecture

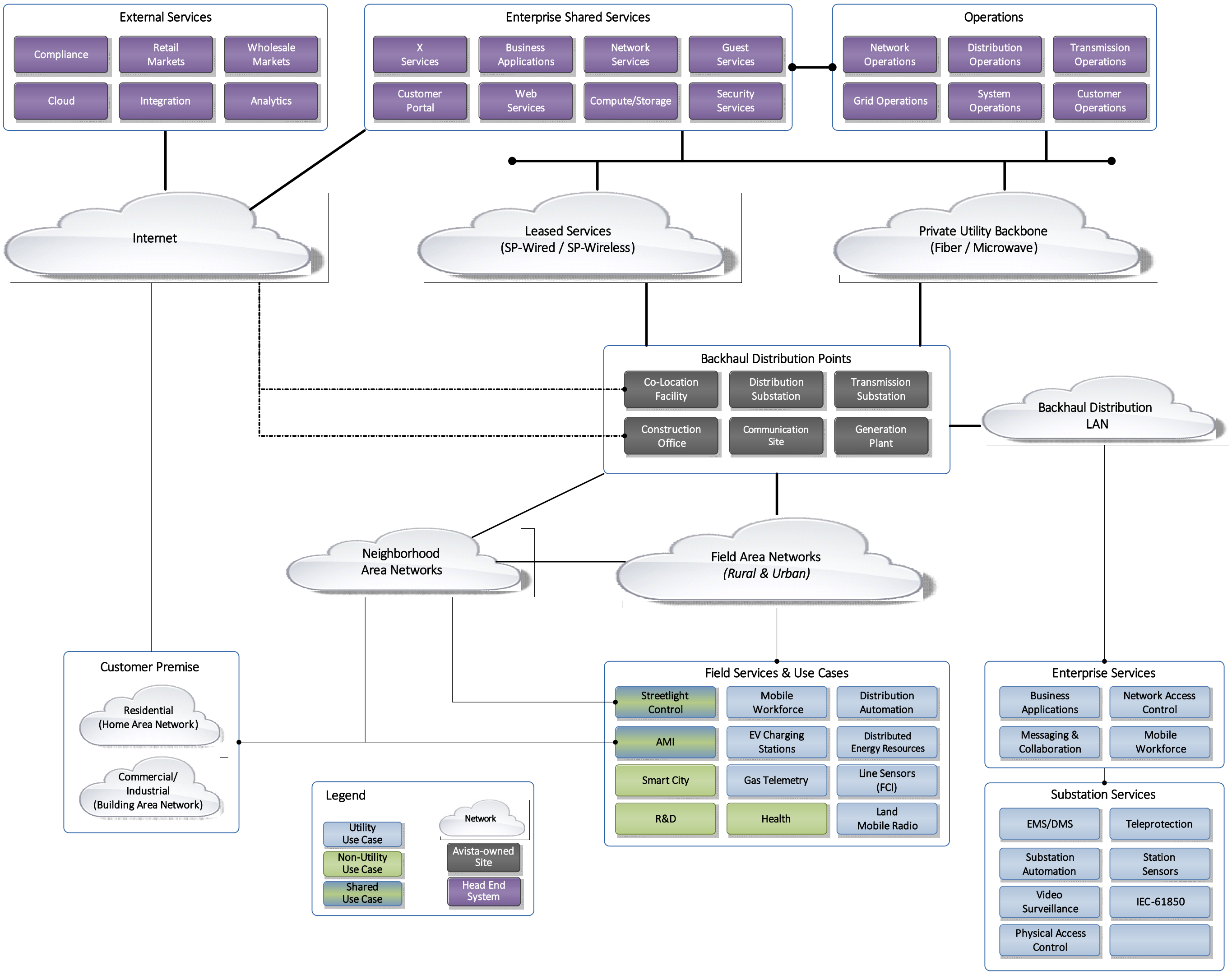


Figure 2: Avista's Future State Network Communications Conceptual Reference Architecture

Customer Premise Networks

The Customer Premise Network (CPN) is the private wired or wireless network within a building or customer facility. It provides network access to smart home devices, in-home displays, or personal computing devices. The meter provides the gateway from the CPN to the Neighborhood Area Network for information exchange between customer devices and the utility. The CPN may also include a personal gateway device and services connecting directly, or via the customer's private network, to the Internet independent of the utility Neighborhood Area Network.

Neighborhood Area Network

The Neighborhood Area Network (NAN) provides network connectivity to endpoints such as meters, streetlights, or Distribution Automation devices. The endpoints form a mesh network based on radio frequency (RF) or power line carrier technologies. The RF technology is low frequency and low bandwidth – e.g. 900MHz RF. Standards-based solutions allow disparate applications to utilize a common mesh network for communications to the Control and Data Centers. A routing device provides media transition between the NAN and Field Area Network media types and may provide an aggregation point for multiple NANs, devices or media types utilized for the data transport.

Desired Characteristics of Neighborhood Area Network:

- Reliable – dynamic routing protocols allow for diverse communication paths.
- Scalable – thousands of devices could potentially participate in the wireless mesh network.
- Secure – network access controls and data encryption.
- Low Power – low energy consumption endpoints allow for efficient use of power.
- Open Standards – interoperability between devices increases lifecycle capabilities.

Field Area Network

The Field Area Network (FAN) provides network connectivity to resources and assets within the energy distribution network. The FAN is most often implemented using Radio Frequency technology due to large coverage areas. As such, multiple technologies can be used within the FAN to support the geography, topography, and rural service territories. The FAN is also a means to connect mobile field-workers to systems at the Control and Data Centers. The RF technologies leveraged by the FAN would include cellular, Point-to-Multipoint, and 802.11 wireless mesh networks.

Desired Characteristics of the Field Area Network:

- Reliable – the communications network is most critical during outages.
- Scalable – must be able to cover large geographic areas within the service territory.
- Self-Healing – ability to dynamically adjust to interference, failures and network congestion through network re-route capabilities.
- High Performance – the network will need to support many existing and new devices and applications. Some devices/applications are latency sensitive, therefore supporting low latency and prioritizing network traffic is required.
- Secure – the network must include robust security mechanisms to protect the integrity and reliability of the systems.
- Open Standards – supporting interoperability between various devices – new and legacy.

Wide Area Network

The Wide Area Network (WAN) is a combination of high speed, high capacity transport links between geographically distant locations – e.g. Control and Data Centers to the Backhaul Distribution Points. Where feasible, Avista prefers its Private Utility Backbone (PUB) infrastructure in favor of leased services, but is not restricted to one or the other. The PUB is designed to enhance reliability, capacity, and latency capabilities over other public transports while providing traffic prioritization, deterministic failover, and security safeguards supporting Avista's critical utility business systems.

Desired Characteristics of the Wide Area Network:

- Reliable – diverse paths and/or technologies support unplanned outage management and availability.
- Scalable – backhaul must support future expansion without undergoing a full technology change.
- High Performance – the backhaul is an aggregation of multiple services, therefore high capacity links must be considered.
- Secure – connecting critical infrastructure components and sites must comply with robust security measures.
- Technologies that provide the PUB transport include private Avista-owned fiber, leased dark fiber, and private Avista-owned microwave.

Control/Data Center Networks

The Control/Data Center Networks represent the head end system locations where command and control, data, storage, analytics, monitoring and service provisioning activities reside. The locations represent primary, secondary or backup locations maintaining business continuity and recovery objectives, and serve as integration points with third-party vendors, X as a Service, and business analytics.

Backhaul Distribution Points

The Backhaul Distribution Point (BDP) represents the transition point between Field Area Networks and the high speed backhaul network. Typically based on a "brick and mortar" facility, the locations may include substations, construction offices, service centers, co-location facilities, or mountaintops supporting high speed, private, and microwave infrastructure. The BDPs leverage Wide Area Network services to segregate and prioritize data and services from the NAN, FAN, and Local Area Network specific to the site.

Backhaul Distribution Point Desired Characteristics:

- Reliable – environmental controls improve equipment resiliency to faults
- Redundant – sustained access to backhaul transport services

- Scalable – ability to grow as needed and simply, without an architectural redesign
- Secure – cyber and physical security maintains the integrity of the system and services

Network Service Classifications

There are four distinct service models that Avista's network communication services are generally classified as:

- Customer,
- Back Office,
- Emergency, and,
- Control.

These services and their delivery, operations, management and support are the core of Avista's network communications.

Customer

Customer classification involves interface to consumer related application, such as the network communication services that support customer access to Avista web, mobile, social, contact center channels.

Back Office

Back-office service classification refers to network communication services that support Internet and intranet communications such as mobile workforce access to our centralized geographic information system.

Emergency

Emergency classification refers to network communication channels that support emergency response services, or emergency functions. The network communications services that support Avista's next generation mobile radio that crews interact with each other and with dispatch is one example of Emergency classified network service.

Control

The Control classification refers to any network communication services that directly enable control traffic, such as Automatic Generation Control (AGC), Supervisory Control and Data Acquisition, amongst others.

Preferred Networks

Avista generally prefers that Customer and Back Office classified services leverage leased carrier networks, while our Emergency and Control network services are Avista owned and operated networks. In this model, Avista maintains a responsible mix of leased and owned network communications capabilities providing our company with the flexibility and scalability that it needs for Customer and Back-office use cases, and ensures that we continue to manage the reliability and restoration priority of our Emergency and Critical network services.

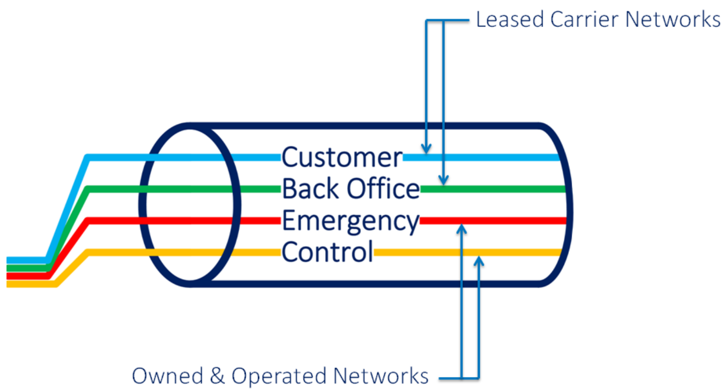


Figure 3: Preferred Network Options

In classifying the digital services across our current and future utility landscape, we find that our future communications infrastructure needs to support a mix of use cases (customer, back office, emergency, and control). This emphasizes the motivational aspects of a shared services platform, and provides insight where the greatest value exists for such a platform, rather than building individual transport infrastructure for each service.

Trends

With the increased reliance on the digital communication infrastructure, the number of discrete messages in the operational smart grid and communication network will continue to increase at a significant pace. Based on the message quantities associated with current technologies in the field, the projection of the number of discrete messages based on a complete installation of AMI in Washington estimates the number of communication packets approaching 600 billion on an annual basis, as shown in Figure 4. Considering the range of priorities, criticality, and content of these messages, this places a significant burden on the entire communications network that must be proactively managed.

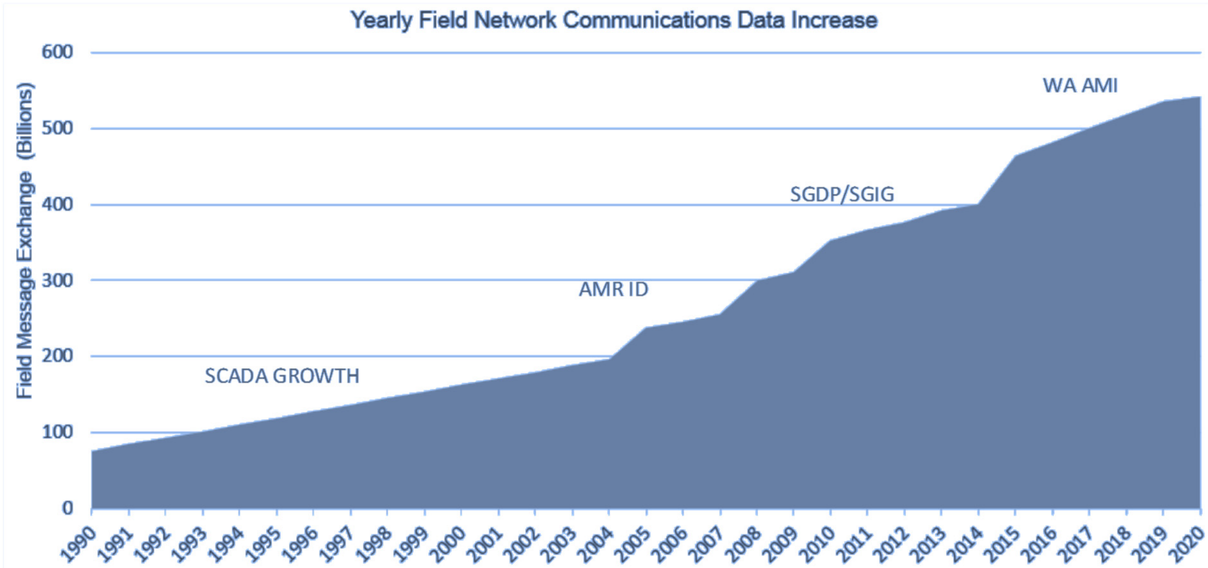


Figure 4: Communication Density Trends

Advanced Metering Infrastructure-Washington Project

The advanced metering system can transmit energy consumption information to both the utility and the customer, and can also receive and respond to operational signals sent from the utility to the meter. Utilities are deploying advanced metering systems to optimize the value of other smart technologies and to provide customer benefits ranging from lower operating cost and improved reliability, to providing customers information and tools to better understand and derive greater value from their energy service. Avista views advanced metering as an enabling technology key to achieving its long-term customer service objectives as it provides a foundation for innovation in the opportunities Avista has to interact with its customers and operate its distribution system.

Building on the experiences and lessons learned from the SGDP AMI deployment in Pullman, Avista is pursuing a larger AMI project that would encompass the remainder of its Washington service territory. The Washington AMI project will include approximately 253,000 electric and 155,000 natural gas meters. Electric meters will collect consumption data in the range of five to 15-minute intervals, and natural gas will collect data in one hour intervals.

Avista's current estimate of the total capital cost of the Washington AMI project is $166.7 million, as approved by Avista's executive leadership and board of directors. The cash value of the total operating expense over the Project lifecycle is $123.4 million, as shown in Table 1 below.

Major Cost Components	Total Capital Investment (Cash value, millions)	Total Operating Expense (Cash value, millions)
Meter Data Management	$12.0	$18.0
Head End Systems	$12.8	$20.3
Collector Infrastructure	$31.7	$29.0
Data Analytics	$5.1	$19.1
Meter Deployment	$100.4	$12.0
Energy Efficiency	$4.7	$6.4
Regulatory Process	$0.0	$18.6
Total	**$166.7**	**$123.4**

Table 1: Washington AMI Project Costs

The Project will provide a range of benefits with quantified financial value for customers, such as the avoided costs for manually reading meters and reduced field service calls. These benefits are grouped by major area as listed in Table 2, below. The total cash value of the estimated benefits over the Project lifecycle is $510.7 million. The present value of the lifecycle benefits is $241.7 million. Additional detail on the descriptions, estimates of the value, and the timing of realizing these benefits, is provided in Section VII, and Appendix B of the Avista Utilities Advanced Metering Project (Washington) Business Case (Malensky, 2016).

Area of Benefit	Total Benefit Value (Cash value, millions)	Total Benefit Value (Present value, millions)
Meter Reading and Meter Salvage	$162.0	$75.9
Remote Service Connectivity	$45.7	$24.3
Outage Management	$86.4	$40.3
Energy Efficiency	$127.2	$59.4
Energy Theft and Unbilled Use	$62.8	$28.9
Billing Accuracy	$22.2	$10.7
Utility Studies	$4.4	$2.2
Total	**$510.7**	**$241.7**

Table 2: Washington AMI Customer Benefits

Extensive analysis regarding the capital costs, operating expenses, and identified benefits can be found in the Avista Utilities Advanced Metering Project (Washington) Business Case.

Beyond these quantified benefits, there is a range of unquantified or intangible customer benefits that will be provided by the Project. Though these nonquantifiable benefits certainly provide customer value, they are not included in the analysis of costs and benefits at this time. These customer benefits include:

- Customer access to interval energy use data
- Customer Home Area Network interface
- Energy Alerts
- Customer privacy
- Engineering studies and asset planning
- Utility employee safety
- Future benefit opportunities including:
    - Rate options
    - Microgrids and Smart City initiatives
    - Additional data analytics
    - Distributed energy resources
    - Demand response
    - Electric vehicle interfaces
    - Pre-paid utility services
    - Flexible billing schedules

AMI provides the information necessary to understand customer behavior when coupled with energy consumption education, ultimately providing consumers with the ability to manage their energy costs. Without AMI, consumers may lack timely information to understand their energy consumption. Real-time information will allow Avista to study the impact of active customer participation, including customer engagement tools such as text alerts provided when a customer exceeds an energy consumption or budget set point. Text alert technology was demonstrated during the SGDP in Pullman and will be included in future AMI deployments.

Smart meters also provide outage information at an individual service. The customer no longer needs to contact Avista in order for the customer's power status to be known. This outage information, when coupled with Avista's existing outage management system, allows for a level of restoration service and crew efficiency that had not been previously been possible. Additionally, individual service outages will not be missed after restoration of large portions of circuits.

Voltage alarming from AMI systems can be integrated with Conservation Voltage Reduction in order to allow greater energy savings as the voltage information can be monitored at multiple points on the feeder. Customers may also choose to use their real-time and interval energy consumption information to explore ways to save energy and expense.

Operational efficiency also comes in the form of reduced labor, vehicle miles and timely response to system issues. The Pullman project has reduced the need for meter reader staff due to remote read capability. Account open and close reads are also made remotely, along with power status validation at the meter without crew trips to a customer premise. System outage status is better understood for efficient routing of crews and resources.

Smart meters also provide the information necessary to understand the automated response of the electrical distribution system with respect to a regional signal which allows for automated response to intermittent energy sources and loads. Additionally, AMI meters can be configured for net metering when necessary.


Electric smart meters

Data collected through an AMI system can be used to build accurate load models across all tiers of customers. These load models will provide the necessary data set from which can be developed an accurate load profile of the utility system. This analytic capability will support accurate system planning to ensure the system load requirements are identified. Over time, customer energy consumption patterns will certainly adjust as equipment and technology change. The load profile data provided by the AMI system will provide support for rate studies, energy efficiency, system planning, distribution engineering, and asset management.

Avista is committed to keeping customer information confidential. AMI systems incorporate modern cyber security methods to protect data as it transfers between meters and the secure data center. Data is encrypted at the meter, and any personal access to metering systems requires pre-authorization and authentication. As described in the Cyber Security Plan section of this report, Avista's Smart Grid AMI System Security Plan is evaluated annually by its Enterprise Security Working Group.

When designing an AMI system, Avista makes security and interoperability top priorities. Avista recognizes that the grid of the future will be heavily reliant on the ability for multiple systems to provide information to multiple applications. A complete synopsis of the AMI privacy, security, and interoperability requirements are addressed in Chapter Five of the Avista Utilities Advanced Metering Project (Washington) Business Case (Malensky, 2016).

The Washington AMI project is tentatively slated to begin deployment in 2017, be operational by 2020, and completed by 2022. The scoping analysis in included in Avista Utilities Advanced Metering Project (Washington) Business Case (Malensky, 2016).

Energy Storage

Service to key customers and energy efficiency are top business objectives for both Avista and Schweitzer Engineering Laboratories. The energy storage systems installed and commissioned in the spring of 2015 in Pullman, Washington provide combinational power factor correction and voltage regulation while lowering the distribution voltage to reduce both losses and loads. Additionally, a four-quadrant inverter can maintain unity power factor that allows for maximum voltage reduction while in discharge mode. For this project, named the Turner Energy Storage System (TES), Avista selected a Vanadium Flow Battery and associated inverter with 1MW of power and energy capability of 3.2MWh.

Vanadium Flow Battery as installed at the Turner facility

This battery can be leveraged for not only localized load problems on the feeder, but can be dispatched for power supply use. There are numerous use cases considered in the business case for this project. Each use case is being evaluated for effectiveness, coincident opportunity, constraints, and performance. The battery is commanded through Avista's DMS and Energy Management System (EMS) as dispatched events. Day-ahead schedules, renewable energy availability, anticipated power costs, local constraints, local loads, battery management and system needs will be evaluated in a multi-variant set of equations to determine battery operation. This approach is unique in that transmission and distribution operations can both command the distributed resource installed on the distribution system with prioritization based on optimal value achieved.

The DMS and EMS will be configured, and a bridge application between the battery's control system and the Avista systems is being developed to provide modeling, simulation and operating tools for use with energy storage systems. This portion of the project has proven to be more complex than expected as very few automated battery control systems have been implemented and the available solutions are less than optimum for this application.

A key business case being explored with the new energy storage system is the ability to service a microgrid or individual loads with the battery during a system outage. The Pullman installation has been configured so that critical loads served from the feeder on which the battery has been connected can be supplied for a period of time with the energy stored within the battery. The validity of this possibility will be fully tested as part of the use case testing and stands to provide a significant value to the customer if successful.

In addition to Avista, a Washington-based project consortium is engaged in this project, including the Pacific Northwest National Laboratory (PNNL), Washington State University (WSU), and

UniEnergy Technologies. The consortium intends for this battery to integrate with renewable energy projects, both solar and wind, so that unanticipated changes in supply or prediction of such changes can be mitigated with this battery. The intention is to demonstrate the dispatch of the energy storage resource from Avista's distribution and bulk power operation centers with sophisticated valuation and control methodologies. Finally, this battery installation will improve reliability on the intended substation and feeder while reducing the cost of intermittent or distributed energy resources.

The project, as designed, will help to establish engineering practices or standards that allow for deployment at other substation or line locations throughout the Avista service territory. Additionally, the project will create assessment tools that can be used to evaluate one or more use cases either singularly or coincidently. Coupled with previous infrastructure upgrades, the project provides for development, integration, and testing of a wide variety of use cases applicable to this technology.

The project was funded through a Clean Energy Fund grant from the Washington State Department of Commerce in the amount of $3.2 million. Avista provided an additional $3.7 million for the project.

This energy storage project was placed into service in April 2015. Use case testing and analysis continues to be performed by PNNL is expected to be completed in the spring of 2017. The use cases being considered and evaluated are:

- Avoided Cost,
- Ancillary Services,
- Conservation Voltage Reduction (CVR),
- Flex Market Ramping,
- Negative Pricing,
- Operations and Maintenance, and,
- Energy Sales.

In the process of this energy storage system interacting with the distribution system several operation benefits are expected. Operationally, use of the battery in a regulation function can help to maintain bus voltages closer to optimal levels due to the bidirectional flexibility of the resource. This would allow larger generation units to function in their base load range and limit the need for them to respond to minor system fluctuations. Enhanced CVR, both on- and off-peak, is possible as the battery provides a peak flattening service while also performing a power factor correction that keeps voltage sags from limiting CVR operation during peak periods. Off-peak is also affected as voltage rises during low load periods. In a microgrid application, the battery will become useful for supporting local critical load in a major outage event. Through peak shifting[3] and energy efficiency savings achieved through CVR, CO_2 emissions are also expected to be quantifiable.

The effects of new loads added to the same distribution feeder as this energy storage project will be more clearly quantified as the project continues. The nature of the project's hour-by-hour analysis and justification through the identified use cases details the load profile in much greater detail than previously available. This load detail can be used to better anticipate the impacts of new loads both at a local level and a system level.

[3] In this context, storage in off-peak and discharge in on-peak. The difference between the emissions of an on-peak resource mix and an off-peak is variable, but generally on-peak resources are more likely to be comprised of higher emissions resources.

Electric Vehicle Supply Equipment

In January 2016, Avista proposed an electric vehicle supply equipment (EVSE) pilot program for Washington customers that was approved by the Washington Utilities and Transportation Commission in April 2016. Under this program, the utility will own and maintain EV infrastructure on customer premises, gather important data and customer survey information, and conduct controlled charging experiments for the life of the equipment. Installations began in July 2016, and will be completed by June 2018. Avista has targeted installations of EVSE in 120 homes and approximately 80 business and public locations throughout Eastern Washington, for a total of 272 vehicle port connections, including seven DC fast chargers. The installation phase will be followed by several years of data collection and analysis. This experiment will help to determine the costs and benefits of shifting to electric transportation, support early EV adoption, and demonstrate how utility involvement may accelerate it. It is expected that Avista will be in a stronger strategic position to implement smart, effective management of EV charging and grid infrastructure in the years ahead based on the lessons learned from this pilot program.

One of the least publicized aspects about EV expansion is that they have the potential to benefit customers who themselves don't drive electric vehicles. Over time, the adoption of EVs can result in less reliance on foreign energy sources, lower regional air pollution, and keep more money in local economies from fuel and maintenance savings. In addition, EVs can contribute to the efficient operation of electric utility systems in a manner that reduces costs to all customers. This is especially true if more EV charging can be done at night and other times of low system demand, so that grid assets are not as strained and are better utilized. This can create an economy of scale that reduces system costs borne by all electric customers, while providing additional revenue from EV charging that helps pay for overall system costs.

The number and type of EVSE installations were very carefully targeted to achieve the pilot's objectives, using an integrated network to collect data and communicate with the EVSE. This provides a unique opportunity to achieve a holistic view of charging behavior at home, at work, and in public locations. As depicted in Figure 5 below, the integrated design allows for insights such as how the availability of workplace charging affects EV charging behavior at home, utilization and effectiveness of public charging, different needs and behaviors of EV drivers, and other factors. Initially, data will be collected to establish baseline charging profiles for different statistical categories of EV drivers. Following this, Avista will begin demand response experiments, dynamically curbing the charging rate with customer notifications and the customer's ability to opt out during certain variable times each day, coincident with local and system demand peaks and valleys. The goal of this phase of the pilot is to demonstrate to what degree EV charging loads can be shifted from on-peak to off-peak times without a time-of-use rate, while maintaining high customer satisfaction.

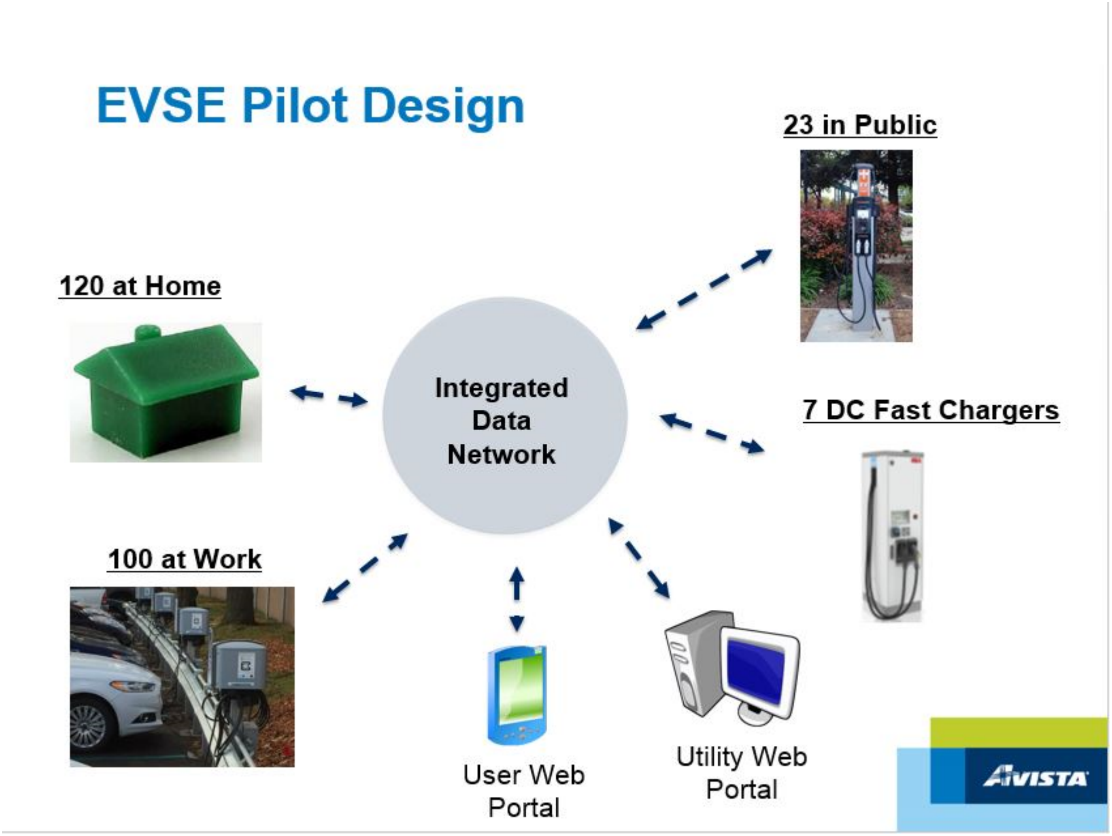


Figure 5: EVSE Pilot Design

The Integrated Data Network will leverage Avista's AMI network and other smart grid elements to communicate with, collect data from, and possibly control the vehicle chargers. Avista is monitoring external research that is investigating the possibility of the utility controlling the EV charging directly through the vehicle, rather than through the charger. The EVSE pilot is Avista's first step toward gaining an understanding of the criteria, experiences, and expectations that may support EV adoption. This information should also guide future decisions as to providing customers services in this business space.

Figure 6: EV charging equipment based on Open Standards

For this pilot, Avista is utilizing Greenlots' third-party software hosted in the cloud, accessible through a secure utility web portal. One of the principal reasons for choosing Greenlots was the use of open standards for communication protocols between the EVSE and the network. This allows the utility to maintain flexibility using various EVSE hardware, capitalize on innovations in the market as they develop, and minimize operational risks.

Existing utility distribution infrastructure and capacity are expected to be sufficient to handle EV charging over the next five to 10 years. However, over longer time horizons the additional loads from EV charging could become significant, on the order of 25% or more of current residential, and in some cases, commercial demand. This shift would require intelligent management and infrastructure planning. EVs offer the attractive possibility of flexibly shifting this new load to help smooth out peaks and valleys in the system, thereby maximizing net benefits to all electric customers. In addition to other loads and energy sources, such as solar, wind, and energy storage, EV charging could become integrated with utility systems to optimize overall system performance, grid resiliency, and infrastructure lifecycle costs. The EVSE pilot will help Avista begin to understand customer requirements, project future impacts, and take deliberate, intelligent steps toward the smart grid of tomorrow.

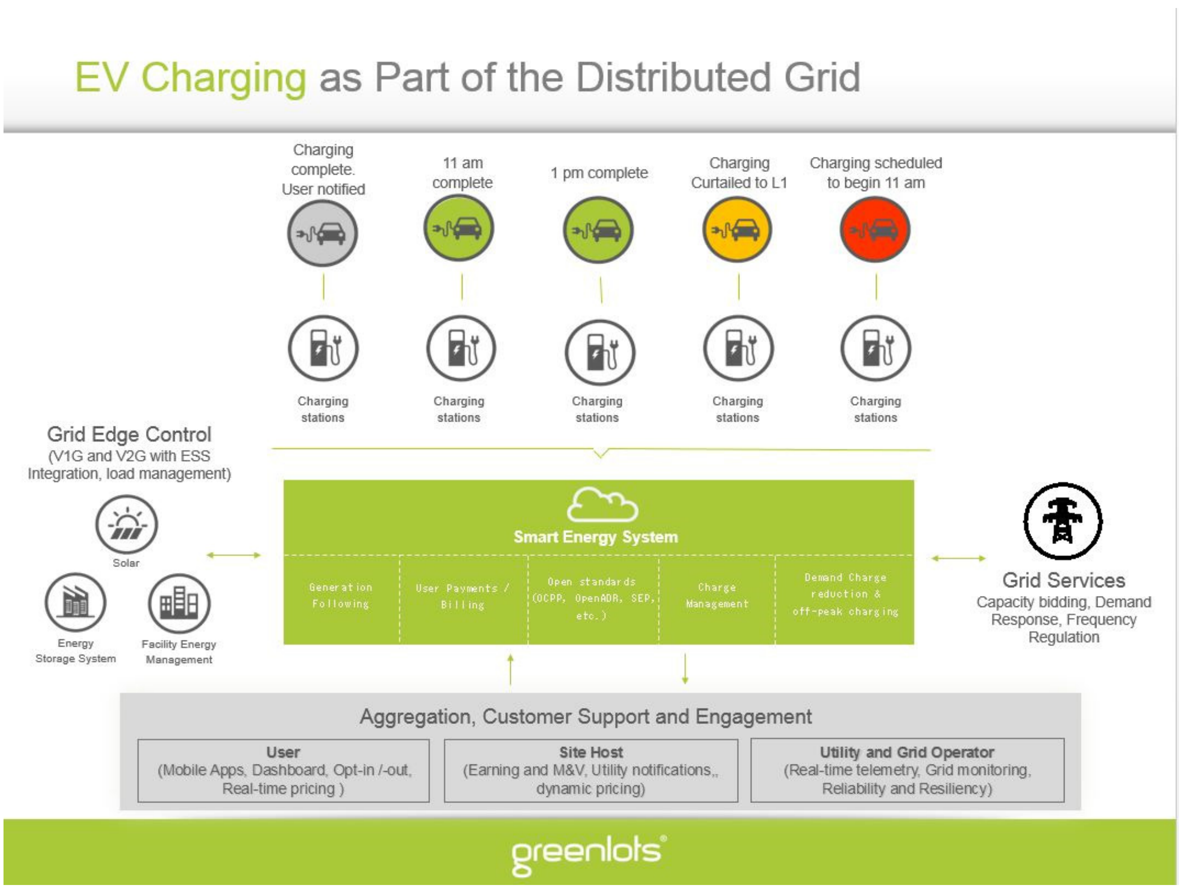


Figure 7: EV participation in the Distributed Grid

Substation Integration and Smart Grid Communications Backhaul

Avista's smart grid data and communications backhaul in the Spokane metropolitan area is primarily supported by a private high speed and high bandwidth fiber infrastructure Multi-Protocol Label Switching (MPLS) backbone that also supports substation integration and corporate network data and voice communications to Avista offices and generation facilities. Gateway radios for the Spokane area wireless mesh network reside at substation locations where IEDs were installed or planned for installation on the electrical distribution network served by that substation.

Avista's smart grid data and communications backhaul in the Pullman region is primarily supported by a private high speed and high bandwidth MPLS over fiber infrastructure backbone that also supports substation integration and IP telephony to three substations, in addition to corporate network and IP telephony to the Pullman local construction office. Spokane and Pullman private MPLS networks are linked via fiber, as well as bonded leased services utilized as a secondary connection in the event of fiber interconnect failures.

Primary goals and decision point for an MPLS architecture included the following:

- Avista wanted to best leverage the fiber network for other use cases in addition to smart grid
- Avista wanted to provide network virtualization and segregation of services across use cases
- Avista wanted to utilize a standards-based protocol overlay to the fiber network

Avista's private MPLS network provides a secure, reliable, scalable network backbone for smart grid communications that supports IP addressable wide area wireless network for smart grid and metering telemetry.

The bulk of the smart grid communications backhaul infrastructure installation in Spokane and Pullman regions were completed between 2010 and 2012. Projects that are currently or planned to leverage or extend backhaul capability or MPLS network reach include a business continuity project that is currently active with planned completion date of 2015 that will increase the availability and resiliency of the MPLS fiber interconnect between Spokane and Pullman by providing alternate path redundancy. Avista smart grid communications roadmap includes further integration and leveraging of the MPLS backbone to provide network services over a common platform that provides resilient, multi-

Substation voltage regulators

tenant, multi-use, secure, reliable, scalable, and low latency communications.

In parallel with Avista smart grid initiatives, a telecommunications High Voltage Protection (HVP) initiative mandated the refresh of end of life telecommunications protection equipment protecting leased wire-line services to substations serving substation SCADA and phone in 2010. This provided an opportunity to leverage and extend Avista's private MPLS network by migrating leased wire-line services to services provided over Avista's private MPLS backbone. Because fiber is a dielectric medium and non-conductive, this was a more suitable option for the delivery of communication services into substation high voltage environments versus leased wire-line. During 2012 and 2014, HVP project have extended the MPLS network to an additional 10 substations in the Spokane and Coeur d'Alene region. Avista's current MPLS network interconnects 52 Avista facilities to include substations, local offices, call centers, and corporate; and covers regions in Spokane, Lewiston, Pullman, Moscow, Post Falls, and Coeur d'Alene.

Lessons learned from the current-state backhaul engineering and deployment include the following:

- Relatively limited product offerings and environment-related equipment standards can drive sub-optimal network design. Grid network designers should keep up on vendor offerings and consider planning relatively short infrastructure equipment refresh cycles for the time being.
- Combining layer two virtual private network (VPN) architecture and MPLS L3 VPN architecture can prove challenging. Backbone designers should consider using solely L3 VPN architecture.
- Flexible, open Network design has proven to be the right approach for Avista. It has made broader use of the MPLS network relatively easy, allowing expansion of services and integration with other enterprise network backbone segments less complicated than it would have been had a closed system design base been used.
- Network provision tools specific to MPLS should be considered from onset as early adopted design requirement.
- Comprehensive network monitoring and management tools that support end-to-end (wired and wireless) are critical for effective network operations.

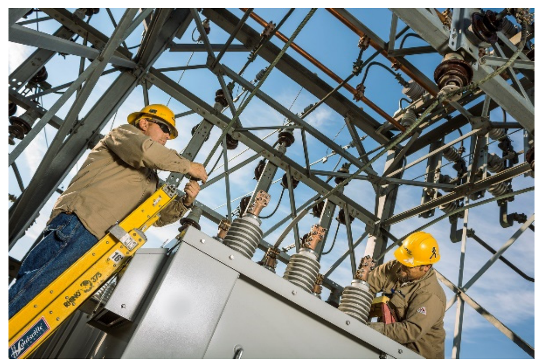
Avista continues to architect network capabilities that leverage or extend the MPLS network. Avista's future-state smart grid communications roadmap includes:

- Addressing future security needs
- Supporting increased availability and fault tolerance
- Supporting low-latency applications
- Enhancing network management capabilities
- Network convergence to a single coherent architecture

Communication benefits of the backhaul architecture extend beyond simply enabling smart grid technologies. The cost effectiveness of the communications infrastructure enabling smart grid functions is a contributor to the overall cost effectiveness of Avista's smart grid system. Avista has leveraged and extended parts of its existing privately owned fiber infrastructure for a large percentage of its smart grid communications backhaul. In addition to smart grid communications, Avista leverages its backhaul infrastructure for multiple use-cases; including but not limited to, corporate network communications, and IP telephony. This makes it difficult to quantify the cost effectiveness supporting smart grid communications; however, it is believed to be lower a lower cost model than other available options for providing communications backhaul services including wireless and wired leased services. Wire-line based leased services into substation high voltage environments require high voltage protection and isolation equipment, whereas private fiber-optic services to substations are non-conductive and immune to the effects of high voltage. Wireless services are typically lower bandwidth point to point communications between the customer and the carrier and Avista's head end; are not available in all services regions; and do not provide the reliability and scalability that leased wire-line or private fiber infrastructure can provide.

The availability of smart grid communications infrastructure services also supports smart grid device functions that enhance the reliability of the electric grid and the capability to integrate new loads distribution system.

The communications infrastructure enabling smart grid functions is a contributor to the overall operational savings observed with Avista's smart grid system by extending the communication services beyond the smart grid itself. Avista's private MPLS backbone that supports smart grid communications provides a more secure method for transport of utility operational and customer information by providing network segregation and packet encapsulation. In addition, secure socket layer (SSL) encryption techniques are used for transport of SCADA communications and data that is classified sensitive. The smart grid MPLS network was able to be leveraged to provide communications for IP-based access card readers, allowing enhanced physical security at certain substations and switchyards.



Substation infrastructure

Examples of other related benefits include:

- EBC–Utilization of MPLS for Redundant Network Paths: Enterprise Business Continuity plans will be able to utilize the future expansion of the original Smart Grid MPLS network to support Avista remote sites connectivity to the disaster recovery data center as well as a secondary path to Internet services, supporting existing business functions and future initiatives.
- Leverage Interoperability and Services for HVP: The MPLS network was leveraged for replacement of two- and four-wire circuits for telephone and DMS at certain substations with IP network transport.
- Trunked Radio System Backhaul: The MPLS network transport supports reliable IP communications linking radio base station sites to the control nodes

enhancing Avista's next generation two-way radio system. The network provides communication resiliency that could not be achieved in the original point-to-point communication design.

- Lewiston Call Center: The Lewiston Call Center Data traffic for customer support and corporate communications was moved from conventional WAN circuits to the MPLS backbone, resulting in far higher bandwidth and better customer support.
- Automated DNX Control: The MPLS network was leveraged to provide a network for automated reconfiguration of DNXs resulting in much faster restoration of SCADA circuit failures between three key substations.
- Pullman Service Center Network: The Lewiston Call Center Data traffic for customer support and corporate communications was moved from conventional WAN circuits to the MPLS backbone, resulting in far higher bandwidth and better customer support.
- Generation Control Locations: The MPLS network was leveraged to provide high-speed backhauls for segregated corporate networks to Avista's generation facilities at Boulder Park and Northeast, both in Spokane. The result was improved performance for general network connectivity. Control Network traffic for generation control and monitoring for a combustion turbine generating facility was also moved to the MPLS backbone in a migration from SONET.
- IP Telephony to Substations: The MPLS network was leveraged to for replacement of telephone circuits, replacing them with Voice over IP.

Cyber Security Plan

With the introduction of thousands of smart grid devices able to communicate digitally, the need existed to understand each component and ensure that equipment design included cyber security standards acceptable to Avista. At the outset of the smart grid projects, Avista created a Cyber Security Plan to outline management's intentions for the secure implementation of smart grid technologies. This strategy has been dubbed the "Security Life Cycle Approach" and is intended to be repeated over time as technologies and their respective risk profiles change and evolve. This lifecycle will help Avista ensure that technologies are deployed in a secure fashion and remain secure during their use. The goal of this plan was to follow a cyclical strategy with the following components:

- Risk Assessment
- Selection of Controls
- Implementation of Controls
- Assessment of Controls
- Authorize the System of Controls
- Monitor the Controls

An Enterprise Security Committee is responsible for oversight of the plan and related activities. Avista formed a Smart Grid Security Working Group to perform the steps outlined in the plan and report to the Enterprise Security Committee, and senior management when appropriate. The Smart Grid Security Working Group was made up of a representative cross-section of people from all areas related to the smart grid projects including representatives from the Meter Shop, System Protection, Transmission and Distribution, Network Operations, IT Security Operations, Web Application Development, and others as necessary.

The Cyber Security Plan was originally created in March 2010, in preparation for the project to begin and has received numerous updates since that time. The plan, as well as system-specific security plans, are reviewed once per year and updated as necessary. Within the design phase, each smart grid device was evaluated to ensure data integrity and the protection of customer information. Periodic testing of controls identifies new vulnerabilities or potential compromises and allows for evaluation of controls for potential improvements.

The Smart Grid Security Working Group was formed in 2010 as well and has met weekly to address any new or upcoming issues and perform the evaluations of the effectiveness of controls and make recommendations to the Enterprise Security Committee. Items such as data integrity and the protection of customer information were considered each time a particular technology was assessed for smart grid implementation. Initially, industry best practices, based on a variety of guidelines and standards, were used in this evaluation. It quickly became apparent that the guideline known as NISTIR 7628 would be the most appropriate for our scenario as it deals directly with "Guidelines for Smart Grid Cyber Security." This became the standard by which smart grid security is measured at Avista.

As the solutions and control structures became solidified and the installations of new equipment began to wane, the group met only once per month, beginning in May 2012. In January 2014 the Smart Grid Security Working Group was combined with a newly-forming Enterprise Security Working Group to carry out similar functions to those related to the smart grid, but in the greater context of security for the entire company. This group continues to meet monthly.

For all intents and purposes the smart grid projects are complete, yet the cyber security aspects continue on an on-going basis. Smart grid security has been folded into the overall security control structure for the enterprise.

As stated above, the Enterprise Security Working Group meets once per month and is responsible for handling any security-related issues or reoccurring Smart Grid security tasks. The following list is not all-inclusive, but provides a few examples of the kinds of things the group does:

- Review the Smart Grid AMI System Security Plan (annual)
- Review the Smart Grid DMS System Security Plan (annual)
- Review the Annual Smart Grid Vulnerability Assessment (annual)
- Review Exceptions to the Smart Grid Security Policy (annual)
- Perform Incident Response drills (annual)
- Assess and monitor the security of customer information (on-going)

As noted earlier, the primary compliance standard used for this project was the NISTIR 7628, Guidelines for Smart Grid Cyber Security. The guidelines are currently in their 1st revision, made up of 3 volumes. The first volume contains a section describing high-level security requirements. These requirements are those that were built into our Smart Grid Security Framework from the start. Volume 2 focuses on privacy. Customer privacy continues to be a key focus as the smart grid projects progressed. (Note: Volume 3 is a report on Supportive Analyses and References. Good information, more useful in a "what-not-to-do" exercise).

Certainly the primary goal of cyber security is to prevent any security breach. When such breaches do occur, the time and money lost can be counted in hours and minutes, dollars and cents. The immeasurable benefits of deploying smart grid technologies in a safe and secure fashion include efficient and consistent operation of the electrical system, the protection of customer privacy and personal information, and public confidence in Avista's competency, integrity, and ability to consistently and reliably provide its energy services.

Demand Response–Residential/In-Home Display

Demand response options are looked at regularly to determine if Avista can include them as a part of its supply side resource mix. A demand response potential assessment was conducted the end of 2014 as a part of Avista's Integrated Resource Plan (IRP) that was published August 2015. Demand response was not a selected resource because of lower projected load growth in Avista's service area, more thermal plant upgrades and the cost of demand response. As a result, Avista currently has no demand response programs or in-home-display programs. Avista's updated position on demand response will be formally available in the next electric IRP that will be published August 2017 but no changes from the 2015 IRP are expected.

In the prior Smart Grid Technology report, the residential Demand Response program pilot that was a part of the Smart Grid Demonstration Project was discussed. The program had begun June 2012 and continued through December 31, 2014. For the program, Avista used Smart Thermostats and advanced predictive analytics to initiate automated direct load control events for electric space heating or cooling loads in the Washington communities of Pullman and Albion. The purpose was three-fold. First, Avista was required at a project level to automatically respond to the regional value signal to curtail loads. Second, Avista tested residential demand response cost effectiveness. The third purpose was to learn the value predictive analytics provides to demand response event planning in comparison to the traditional command/control of demand response programs.

In addition, the enabling technology for demand response, the smart thermostat, served as an In-Home-Display for participating Demand Response customers to view near real time electric consumption. This too was a project-level requirement.

ecobee smart thermostat

In the second quarter of 2012, Avista provided a web portal that allowed 6,500 targeted customers in Pullman access to their energy data. The remaining 6,500 customers were offered the web portal as part of a control group in an effort to achieve valid customer statistics around web portal effectiveness. These control and target groups were selected randomly. Additionally, by the end of 2013, a subgroup of 75 volunteer customers had received advanced thermostats that provided near real-time five minute interval readings as energy consumption feedback.

The project entered a demonstration phase in the fall of 2013 and ended in January 2015. During that time, transactive functionality and customer feedback was monitored. Reporting in the final six-months of 2014 supported program assessment in the areas of system efficiencies, transactive control signal, reliability, and customer behavior.

Since the advanced meters were installed in Pullman and Albion, manual connects and reconnects has been significantly reduced. Remote connects and disconnect are now accomplished through the smart meter's OpenWay AMI communication system. Also, billing disputes and other informational queries are more easily addressed by Avista's customer service representatives by using real-time and historical AMI meter data. In addition, the system provided customer feedback for enhanced energy management benefits and also provided diagnostics of customer systems via utility analysis.

Since completion of the demand response pilot program in 2014, Avista has not implemented any demand response programs but has used the lessons learned from the SGDP thermostat program to implement an energy efficiency rebate program for customers that install a smart thermostat in their homes. Program and participation details regarding the smart thermostat rebate program can be found on Avista's website.[4]

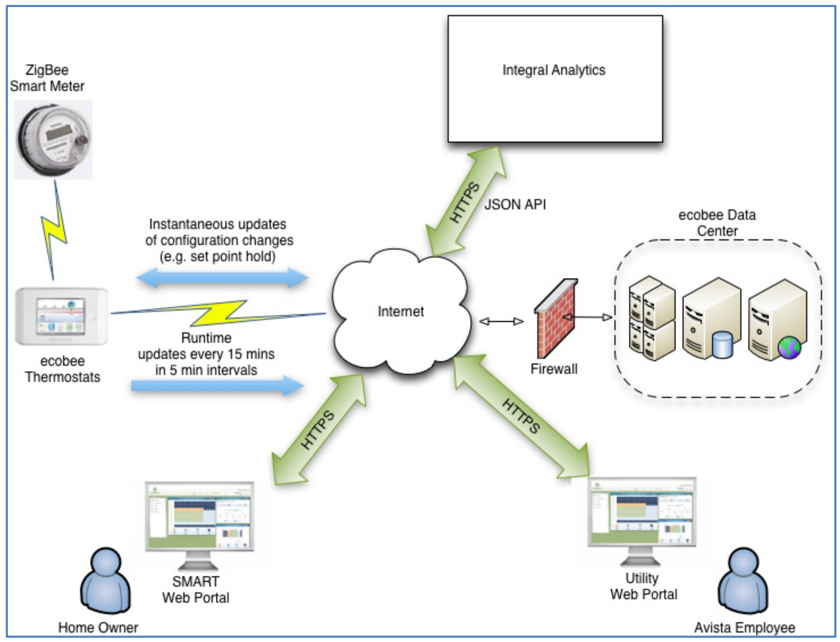


Figure 8: Avista Customer Equipment, Web Portals, and Automation Systems

The DR pilot was foundational to understanding the potential of controlling customer loads with minimal customer involvement and no loss of convenience or comfort. The pilot clearly showed that both outcomes were not only possible but were realized with high customer satisfaction. Although a DR program is not forthcoming the value of this pilot was invaluable to informing future opportunity.

Avista has two follow-on projects that will leverage these lessons learned to provide enhanced power quality, optimal distribution efficiency, increased reliability, load management, resiliency during outages, and opportunity for distributed energy resources such as solar and energy storage. These projects, funded by the Washington State Department of Commerce Clean Energy Fund, are the Turner Energy Storage System (TES) and the Micro Transactive Grid (MTG). The TES project focuses on delivering optimal dispatch of an energy storage system for enhanced power quality, optimal distribution efficiency, increased reliability and load management. The MTG

[4] Smart thermostat rebate program details can be found at: https://www.avistautilities.com/savings/rebates/Pages/WashingtonCustomerRebates.aspx

delivers TES capabilities as well as providing for resiliency and distributed energy resources such as solar and energy storage.

Benefits from the SGDP demand response program were evaluated to determine cost effectiveness and if a similar programs should be implemented when AMI is deployed to customers throughout the Avista service territory. While demand response isn't a near-term cost effective option for Avista, the smart thermostats in this program were determined to provide energy efficiency savings. The small sample size of 75 participants was less than desirable to provide statistically significant results for reporting purposes, but Avista observed the energy efficiency savings from its pilot were consistent with other smart thermostat pilots conducted throughout the United States and subsequently, Avista launched its smart thermostat energy efficiency rebate program noted earlier.

Providing cost effective demand response programs for Avista's customers is not currently feasible. As described in Avista's 2015 Integrated Resource Plan (Kalich, Gall, Lyons, Forsyth, & Maguire, 2015), no demand response program options for commercial, industrial, and residential customers were found to be cost effective.

The pilot produced savings by allowing operation of assets with minimal human intervention compared to conventional demand response notification methods though no other operational savings were identified. During the pilot, the scale of assets influenced by the transactive system was small, but the system as designed was expandable to provide demand response at a larger scale to help meet or modify the energy of peak loads. In addition, the system proved it could respond to the transactive signal as well as an internal signal for immediate response to grid needs, potentially increasing reliability.

The pilot program's system was designed for prediction and operation of distributed assets regardless of type. Accordingly, new types of loads such as electric vehicle chargers could be managed for demand response, load balancing, and time-of-use scheduling. These considerations are expected to be incorporated into future Avista projects.

Relative to cyber security considerations for this pilot, the protection of customer privacy and customer data is prioritized at all phases of the project. Avista followed strict security practices for data transfers and no security or privacy breeches were encountered during the term of the project. During the pilot, the system utilized available interoperability and communication standards. If and when Avista launches a demand response program, available interoperability and communication standards will be used.

Demand Response–Commercial and Industrial

As noted in the Demand Response-Residential section of this report, Avista has no current commercial or industrial demand response programs. As such, activities related to this topic are primarily focused on monitoring technology and program options within other utilities and regions of the country.

During the Smart Grid Demonstration Project Avista, in partnership with WSU, implemented a commercial demand response program. Demand response events were isolated to facilities within the WSU campus in Pullman, Washington. There were five demand response tiers including chiller loads, air-handler loads, two tiers of gas distributed generation, and a diesel-fired generator, that could be deployed one at a time or in conjunction with one another resource depending on the need. WSU has an operator in the control loop to accept or reject the event, but otherwise the command and control for the demand response events was established to be an automated operation. The purpose was three-fold. First, Avista was required by the SGDP protocols to automatically respond to the regional value signal to curtail loads or dispatch backup generation. Second, Avista was testing commercial demand response cost effectiveness. The third purpose was to learn the value predictive analytics provides to demand response event planning in comparison to the traditional command and control of demand response programs.

At the end of the pilot, the project confirmed that approximately 240 kW was conservable by the curtailments of air circulation fans and about 380 kW of demand reduction was available through control of the chiller loops. The project was not able to find evidence that the times when the generators were operated had been influenced by project signals, but if Avista can procure control of these assets, it could obtain up to 3.7 MW of distributed generation. This is significant to meet or modify peak loads. The pilot demonstrated that dispatch of assets is reliable and could be used to increase system reliability and that the system can provide for reserve capacity, regulation, peak loading, and most importantly provide impetus for the customer to more accurately control their load with more robust internal systems.

During the pilot, the system was designed for prediction and operation of distributed assets regardless of type. Accordingly, new types of loads such as electric vehicle chargers could be managed for demand response, load balancing, and time of use scheduling.

Applicable interoperability standards were implemented during the pilot, however, these standards were found to be insufficient and not yet comprehensive enough for all system capabilities and interconnections. This finding was supported in the Battelle SGDP report (Hammerstrom, 2015).

Distribution Management System

In coordination with and funded by both the SGIG and SGDP projects, Avista elected to purchase a centralized Distribution Management System (DMS). This system provides control interfaces for all smart devices deployed in the field and performs automated restoration, conservation voltage reduction, and power factor correction processes. Avista selected and implemented DMS software from Efacec ACS as this software was determined to support a distribution SCADA system with add-on modules to perform predictive and operational applications such as Fault Detection, Isolation and Restoration (FDIR) as well as Integrated Volt/VAr Control (IVVC).

Deployment of this system involved extracting a distribution model from Avista's geographic information system (GIS) that would provide a graphical representation of the feeders and all the connected components in the DMS. Given that the predictive applications are model based, the model integrated into the DMS software needed to clearly represent all electrical components whether the devices were intelligent, automated, or manual. Significant attention was given to ensure the model export process was repeatable considering the frequent equipment installation and replacement activities that occur in the field were tracked consistently in the GIS model. The DMS deployment was completed 2013, with server updates in the third quarter of 2014.

Distribution engineering and the DMS software

An important facet of the DMS deployment was to ensure a real-time device status syncing of all devices, whether smart of manual, between the DMS and the GIS-based Outage Management System (OMS). In order to ensure the safety of crews and the safe operation of our system, it is important that any topology changes that occur in OMS or DMS get mapped into the other system in a near real-time manner. Tools were developed internally and with the DMS vendor to negotiate the requisite device status information between the DMS and OMS.

While the initial plan was to perform a GIS to DMS model extraction nightly, this frequency proved to be too cumbersome. GIS to DMS model extraction is presently performed weekly to capture any equipment inventory changes. This frequency is modified if switching operations require devices that were recently added during the design process. For the identified field inventory, syncing of device states between DMS and OMT occurs real-time and operates continuously to identify and share device state changes between the two systems.

Currently, 81 feeders are completely modeled in the DMS software for use with the predictive FDIR and IVVC applications. Additional feeders are being incorporated in conjunction with Avista's Grid Modernization Program.

The initial hardware for the DMS deployment included 6 physical servers, with a redundant set of 3 systems, along with a single virtual machine for non-operator views. In order to provide greater reliability, the DMS was transitioned to running entirely on virtual servers in 2014. Seven virtual servers were deployed as a redundant pair of systems that run the applications and user interfaces, another redundant pair that provide communication services, a single relational database server, and a single view-only user interface server. That production environment is duplicated in a development environment for testing and validation.

The DMS system's predictive applications improve reliability and energy efficiencies through the Fault Detection Restoration Isolation and Restoration and the Integrated Volt/VAr Control applications, respectively. In addition to these predictive applications, the DMS software provides operational benefits by performing automated switching and tagging operations as well as the opportunity to remotely operate station and line voltage regulators. These benefits are discussed in greater detail within their corresponding sections of this report.

Energy Alerts and Notifications

During the Pacific Northwest Smart Grid Demonstration Project (SGDP), Avista implemented an alerts and notifications program to notify customers when an established bill target was reached or to provide messages regarding daily or weekly consumption since the most recent billing statement. The messages included a predicted estimate of the cost range of their next bill based on the consumption history and current and forecasted weather. Residential SGDP customers were eligible to participate and had the option to receive alerts and notification messages as text messages on their mobile device, email messages, or both. This tool provided a direct relational value to the smart meter for customers who chose to take advantage of the available information. It provided customers a way to have near real-time energy consumption information and recognize its potential financial impact at a point still early enough in the billing cycle to make choices to manage their overall bill. Customers interested in viewing this data tended to be highly engaged in managing their energy consumption and controlling costs.

Residential natural gas meter

The alerts and notifications program operated approximately six months and was discontinued when Avista upgraded its Customer Care and Billing system. Based on the lessons learned from this pilot program, Avista plans to implement a similar Alerts and Notifications program to customers with a smart meter during the AMI Washington project.

Funding for the pilot program was provided under the SGDP while any future program costs will be funded by Avista. While the pilot program functionality concluded in January 2015, Avista is currently in the design phase of the AMI Washington project and the web upgrade project, both due to be rolled out at different times during 2017 and 2018. These two projects will help enable the future iterations of the alerts and notifications program.

The pilot program was considered a success because of the level of engagement exhibited by our SGDP customers in Pullman to try the program and due to the valuable feedback they provided as a result. Participants especially found value in the weekly messages and suggested ways to improve the other notifications/alerts to provide more meaningful messages. For example, rather than have a static monthly budget value, customers suggested Avista compare the current year's consumption to the prior year's and provide a notification if there appears to be anomalies in the consumption or simply to provide a high-use alert. This information, along with future focus groups and studies, will be used to design the new alerts and notifications program expected to be available to AMI Washington customers in 2018.

While energy efficiency savings and cost effectiveness were not evaluated due to the short-term nature of this pilot program, other studies have demonstrated the potential for such savings in other installations. Vendors with enterprise-wide services will be used for any future programs that will provide cost effectiveness analytics and additional insight to customer preferences and message delivery.

For security purposes, customers authenticated their relationship with Avista through a website-based enrollment process. Enrollment was completed following a customer's affirmative response to an enrollment text message on their phone, serving as a Double Opt-In process. All data transfers were completed through an encrypted Secure File Transfer Protocol process.

Fault Circuit Indicators

In conjunction with the SGDP project, Avista deployed smart Fault Circuit Indicator (FCI) units to enhance the capabilities of the DMS and the Outage Management System (OMS) in the City of Pullman and at some test sites in the Spokane. The 130 FCI devices have been installed at primary fuse locations and main feeder junctions on eight of the 13 smart grid feeders within the SGDP project.

The FCI units are capable of automatically detecting fault currents and help to identify and isolate the location of the fault. Currently, faults that trip protective devices downstream of the DMS smart devices must be identified by a customer outage call. The information gathered from the FCI devices will be transmitted to the DMS using On-Ramp communication technology. The On-Ramp technology has a significantly greater range than the current TropOS communications technology but is constrained with a reduced data bandwidth. This communication platform is expected to work well with smart equipment that does not require continual data transfers, such as Fault Circuit Indicators.

On-Ramp also provides a web-based application called Total View that manages and monitors the Fault Circuit Indicators. The Total View application enables real-time monitoring and management along with remote configuration options. Additionally, a breadth of alarms to ensure complete operational visibility are included in the interface. As part of this project, Avista contracted with On-Ramp to be the system administrator for the first year of operation, allowing Avista to become familiar with this technology under the guidance of the manufacturer.

At this juncture, the planned portfolio of Fault Circuit Indicators have been installed and integration with the DMS and OMS tools has been completed. As for direct benefits of the FCI units, these devices enable quicker identification of the location of faulted equipment by reducing the area where the fault investigation must occur. Minimizing the area of the potential fault will reduce the time spent by first responder patrols to locate the fault, and in locations where underground facilities are involved, the time saved can be substantial. The rapid response to outages will likely improve the overall system reliability indices as well as limit costs associated with the patrol process. Data from the FCI units will also be used to analyze the loading on feeders and support load balancing to achieve system optimization objectives to maximize loss reduction.

Fault Detection, Isolation, and Restoration

One of the predictive applications of the DMS system Avista integrated is Fault Detection, Isolation, and Restoration (FDIR). Avista chose to deploy FDIR for all 72 feeders included in the SGIG and SGDP projects. FDIR allows for increased reliability for customers with rapid restoration, typically under three minutes, when a feeder breaker has opened due to a fault.

FDIR analyzes all the fault targets that it received from the switches and breakers along that feeder to determine in which section the fault is located. Once the application determines where the fault is located, FDIR sends commands to the smart switches and breakers both upstream and downstream of the fault. This isolates the fault from being reenergized during the restoration of customers outside of the faulted area. With the fault isolated, FDIR then restores customers upstream of the fault by closing the breaker that originally opened and triggered the FDIR process. Upstream restoration reenergizes the customers with the same source they were on prior to the fault. There is no risk for overloading equipment along the feeder given that this load was on the feeder just prior to the fault.

However, downstream restoration requires FDIR to consider which adjacent feeders could handle the transfer of load without overloading equipment. FDIR determines adjacent feeder capacity by running a power flow analysis of the feeder. The power flow analysis leverages real-time telemetry information to determine feeder loading prior to the fault. If an adjacent feeder has the capacity to support the customers downstream of the isolated fault, FDIR sends a close command to a normally open tie switch. The full FDIR process takes place in under three minutes. Prior to implementing FDIR on a feeder, this process would take between one and three hours.

By way of example, on August 13, 2013, while the Company was in the training and implementation phase of FDIR, Avista experienced an outage in north Spokane at approximately 10:18 am, where a garbage truck hit a pole. This caused a fault on the company's Lyons and Standard feeder. The incident immediately affected 897 customers, including the NorthTown Mall. The DMS software correctly performed upstream restoration of 811 customers at 10:19 am and Avista's Distribution Dispatchers correctly performed downstream restoration of an additional 72 customers by 10:33 am. An Avista crew arrived on scene to replace the power pole that was required to restore power to the remaining 14 customers. The Company estimates the total customer outage time saved during this one outage to be 36,374 minutes, or over 600 outage hours. Ultimately, the benefits of this system include a more reliable and efficient grid, along with improved customer service.

FDIR-triggering pole impact event

Table 3, Table 4, and **Error! Reference source not found.** show the reliability improvements attributable to the smart grid deployments, with results shown for 2013, 2014, and 2015. Results are shown for the Pullman-area Smart Grid Demonstration Project, the Spokane-area Smart Grid Investment Grant, and the Avista system.

Smart Grid Reliability Improvements: SGDP (Pullman)	2013	2014	2015	Since Inception
Customer Outage Minutes Saved	271,320	82,016	832	354,168
Customer Sustained Outages Avoided	1,785	2,985	832	5,602
Total Area Customer Outage Minutes	721,027	1,623,079	474,794	2,818,901
Total Area Customer Outages	4,033	18,614	2,875	25,522
SAIFI Improvement	30.68%	13.82%	22.44%	18.00%
SAIDI Improvement	27.34%	4.81%	0.17%	11.16%
CAIDI Improvement	-4.82%	-10.45%	-28.71%	-8.34%

Table 3: Smart grid reliability metrics, Pullman SGDP

Smart Grid Reliability Improvements: SGIG (Spokane)	2013	2014	2015	Since Inception
Customer Outage Minutes Saved	422,823	738,334	376,584	1,537,741
Customer Sustained Outages Avoided	11,284	15,459	8,731	35,474
Total Area Customer Outage Minutes	4,995,964	6,546,272	5,500,967	17,043,203
Total Area Customer Outages	45,475	47,402	51,705	144,582
SAIFI Improvement	19.88%	24.59%	14.45%	19.70%
SAIDI Improvement	7.80%	10.14%	6.41%	8.28%
CAIDI Improvement	-15.07%	-19.17%	-9.40%	-14.23%

Table 4: Smart grid reliability metrics, Spokane SGIG

Smart Grid Reliability Improvements: Avista System	2013	2014	2015	Since Inception
Customer Outage Minutes Saved	694,143	820,350	399,880	1,914,373
Customer Sustained Outages Avoided	13,069	18,444	9,563	41,076
Total Area Customer Outage Minutes	73,714,109	162,585,447	48,003,503	284,303,059
Total Area Customer Outages	444,752	578,073	312,140	1,334,965
SAIFI Improvement	2.85%	3.09%	2.97%	2.99%
SAIDI Improvement	0.93%	0.50%	0.83%	0.67%
CAIDI Improvement	-1.98%	-2.67%	-2.21%	-2.39%

Table 5: Smart grid reliability metrics, Avista system

This data represents the occurrence of 10 automatically-triggered and two manually-triggered FDIR events. Manual FDIR events were isolated by Distribution Dispatch staff within a five minute window by executing remote switching procedures. The automatic FDIR events affected 8,530 customers and the manual FDIR events affected 1,033 customers. The FDIR implementation saved these customers 369,549 and 30,331 outage minutes, respectively.

Employee and public safety were key considerations during FDIR commissioning. Avista resolved to safeguard against any nondeterministic operation of FDIR switching activities. To demonstrate the security mechanisms embedded in the FDIR application, Avista utilized a simulation environment to evaluate a variety of use case scenarios. Use case scenarios were able to address many questions that field personnel posed regarding the conditions by which FDIR would and would not perform restoration activities. The use case scenarios were also beneficial training tools for Distribution Dispatchers that would be interfacing with the DMS controls.

As a part of the commissioning process, field tests were performed to demonstrate the capability of FDIR in a real world environment. Field devices were bypassed to prevent customer outages as switches were requested to open from an FDIR event. A fault was simulated by a relay technician injecting current into a current transformer at a substation breaker to mimic a downstream fault. In addition, the relay technician initiated fault targets to simulate a fault at a predetermined feeder section. FDIR was allowed to perform upstream restoration and downstream restoration on these feeders. These tests were repeated on several feeders and provided functional validation to FDIR operation staff as well as coordination of protection settings across the distribution network.

Once FDIR simulations and demonstrations were complete, the FDIR was deployed on the 72 SGIG and SGDP feeders in a supervised mode. In this mode, FDIR performed the fault detection and created a switching notice for isolation of the fault and upstream restoration without actually implementing the notice. These switching notices were stored in the DMS SWORDER tool for the Distribution Dispatchers to review prior to being executed. After several months in this mode, FDIR was set to Auto Upstream mode. In this mode, FDIR would perform the fault detection, isolation and upstream restoration and generate a downstream switching notice in SWORDER for the Distribution Dispatcher to review prior to implementation. After several additional months in this mode, FDIR was set to full upstream and downstream restoration mode.

Given the success of the FDIR deployment for the SGIG and SGDP project, FDIR will be considered for deployment on each of the six Grid Modernization feeders planned to be upgraded on an annual basis, and as such, FDIR is has been extended to operating on 80 feeders.

Both the SGIG and SGDP grants require Avista to report the reduction in customer outage minutes following implementation. The reduction is primarily attributable to remote switching capability as well as the automated DMS application that is responsible for FDIR activities. Table 6 provides the to-date savings in customer outage minutes at an assumed value to the customer of $100/customer outage hour. Avista did not assume a revenue benefit for higher reliability.

Task	Number of Events	Minutes	Savings at $100/Customer Outage Hour
FDIR	20	917,280	$1,528,800
Remote Switching to Restore Outages	16	511,220	$852,033

Table 6: Customer outage savings

Prior to smart grid when a feeder breaker locked open, a serviceman would have to patrol the entire main feeder trunk to determine the location of the fault. This was not only time consuming but also left our customers without power until the problem could be located and isolated for restoration. The ability demonstrated by FDIR to rapidly determine the location of the fault, perform the isolation optimization, and restore customers both up and downstream of the faulted area has had positive effects on our reliability indices.

Reliability was also positively impacted by the protection devices that were added along the feeder as part of SGIG and SGIP. Independent of FDIR, these devices will operate instead of the feeder breaker. This effectively decreased the number of customers that were affected by a fault on feeder trunk.

Smart Grid Reliability Improvements	2014	2015	Inception to Date
Customer Minutes Saved	820,350	399,880	1,914,373
SAIFI Improvement	3.09%	1.06%	3.10%
SAIDI Improvement	1.55%	0.65%	1.55%
CAIDI Improvement[5]	-1.59%	-0.41%	-1.61%

Table 7: Smart grid reliability Improvements

[5] CAIDI is a negative number because FDIR reduces the number of short customer outages, effectively reducing the base of short outages. It doesn't actively make CAIDI worse, but rather the average time a customer is out must increase as the shorter outages, those less than five minutes, are eliminated.

Green Button Initiative

Currently Avista provides residential customers through rate schedule 22 and business customers through rate schedule 21 the ability to download 24 months of energy consumption and billing data through the on-line Bill Analyzer tool. Large Commercial and Industrial customers, rate schedule 25, have access to their data on a daily or greater frequency of their choice by means of a manual report generation process performed in the Avista meter shop. In addition, Smart Grid Demonstration Project customers in the Pullman and Albion communities, both residential and small and medium businesses, can download five-minute electric interval consumption data and daily gas consumption data.

The Green Button initiative is becoming more widely recognized by consumers. While Avista is already securely providing its customers with energy consumption and billing information online, a standardized format for customer data download is an important pursuit. As part of its current web upgrade activities, namely Project Phoenix, Avista will implement Green Button Download to give its customers the ability to download their consumption data in the standardized Green Button format. Customers can then take this data and upload it to third party analytics engines of their choice, such as the Department of Energy's Yardstick application. In respect of customer choice on the way that they engage and manage their consumption in the most meaningful way for themselves, this tool provides another option some customers may prefer. Green Button Connect is not on Avista's roadmap at this time.

While Avista cannot currently quantify the amount of operational savings, adoption of the Green Button standard could potentially mitigate some customer inquiries regarding explanation of their billing statement and consumption. Protection of customer privacy and customer data is paramount in the design of this program. Customers would have to authenticate on the Avista Utilities website to access their *MyAccount* Summary where the Green Button Download button will be available.

The value of the Green Button tool is to help customers better understand their energy use and support an elevated level of customer engagement. With a better understanding of their energy use, customers manage their energy use more effectively and save on their energy bills.

Integrated Volt/VAr Control

Integrated Volt/VAr Control (IVVC) is one of the applications embedded in the DMS system that Avista elected to deploy. This IVVC system has two main components including Capacitor Bank Control and Voltage Control.

Capacitor Bank Control (CBC) is the application in the DMS for power factor correction. CBC allows remotely controlled capacitor banks to be operated based on predetermined and defined kVAr parameters. One hundred fifty-three remotely controlled capacitors were installed across the 72 SGIG and SGDP feeders. Capacitors range from 300kVAr to 1200kVAr in size. Telemetered kVAr values along the feeder are used to determine where kVArs are or aren't needed. Avista selected 30 seconds for the CBC to check the telemetry along the feeder to determine if the kVAr is within the desired band of approximately -360 to 360kVAr. If the telemetry indicates that the three phase kVArs are not within the desired band, the DMS issues a control command to the capacitor to correct the feeder kVAr. CBC can operate multiple capacitors in one 30 second iteration.

Voltage Control (VC) is the second application embedded in the IVVC application. The VC regulator's remote control initiates tap operations based on results of a power flow calculation. Real time telemetered values are polled every 30 seconds and used in a power flow to determine what the lowest and highest voltages are at distribution transformers along the feeder. If the low voltage is outside of the desired predetermined band, then a tap control is issued from VC to the regulator. Given then the accuracy of the telemetry and power flow, Avista was able to implement a conservation voltage reduction (CVR) scheme and lower the voltage along the feeder approximately two percent.

As part of the IVVC deployment, Avista partnered with Washington State University to develop a methodology to quantify the real-time savings of both CBC and VC. The initial focus of WSU's project was to determine the load response to a day when IVVC was running versus a day where IVVC was not running. As the study progressed, WSU discovered that the nexus of the load response were the ZIP parameters of the load. The ZIP parameters are the percentage of load that is constant impedance (Z), constant current (I) and constant power (P). As the voltage is lowered for CVR, each load responds differently according to whether it is a Z, I, or P type load. WSU discovered that not only do the loads differ in their response, but also that the ZIP parameters of a feeder are dynamic throughout the day. Presently, Avista is developing a tool to determine the ZIP parameters throughout the day for each feeder. With these values, the actual IVVC savings can be calculated.

Given the successful implementation of IVVC for both the SGIG and SGDP project, Avista has expanding the smart grid foot print through its Grid Modernization Program. The Grid Modernization program is a programmatic 60-year program intended to address our distribution infrastructure while finding the right size of feeder automation for each feeder.

IVVC is currently running on the 80 SGIG, SGDP, and Grid Modernization feeders. The smart grid footprint will continue to be expanded through our Grid Modernization program, with six feeders being considered for IVVC automation each year. Since 2014, eight feeders have been updated with smart grid through the Grid Modernization program

As part of the SGIG and SGDP project, the Washington Utilities and Transportation Commission required Avista to provide a third-party verification of the IVVC savings attained across the 72 feeders. Navigant Consulting, Inc. performed the required third-party verification by developing a methodology that relied on direct regression modeling to estimate energy savings.

The Navigant analysis projected Avista's annual CVR to be approximately 43,000MWh annually. To understand how this relates to customer billing, a more detailed explanation is needed. Per the Navigant report (Cooney, Greenberg, Stern, Higgins, & Shlatz, 2014, p. 18) the weighted average voltage reduction factor (CVRf) created using IVVC was 0.883. This factor translates how much the power reduction would be for the 2.02% weighted average voltage reduction IVVC delivered. Multiplying them shows that the average customer should see a reduction in their power use of 1.78% with commensurably lower bills. However, the averages smooth out a wide spread; voltage reduction from 2.6% to 0.84%, CVRf factors from 1.9 to 0.106. This implies that some customers are likely to see power use reduction above 1.78% and some could see reductions well below that. Comparison to prior year bills may or may not demonstrate the savings as one year can be hotter or colder than another or have other local variations outside Avista's control.

In accordance with the RTF Automated CVR protocol No. 1, Avista was asked to run IVVC only every other day. Navigant utilized the telemetry data from Avista's line devices during this on/off cycling to quantify the energy savings of SGIG and SGDP. Navigant estimated that across the 72 feeders that Avista was attaining 42,374 MWh annually (Cooney, Greenberg, Stern, Higgins, & Shlatz, 2014, p. 18).

The peak load relief due to IVVC has to be evaluated on a feeder by feeder basis. During peak load, the quantity of CVR benefits are bounded by two conditions. One is the absolute loading on the line. Heavily loaded lines have more line losses hence a bigger difference between the source voltage and the voltage at the low point. Consequently, heavily loaded lines reduce the amount voltage bandwidth available for voltage reduction. The second bound is by the load composition or ZIP parameters. Initial models from Washington State University suggest the constant impedance loads contribution to total load for some feeders may reduce during peak periods. The constant impedance load is the component of load composition which is significantly influenced by voltage variation.

The dynamic ability of CBC also allows for immediate response to new inductive loads added to the distribution system.

Deployment of Smart Devices

As part of the SGIG and SGDP projects, Avista installed remotely operable devices on 72 of its distribution feeders. Between the fourth quarter of 2009 and July 2013, Avista installed four types of devices in Spokane and Pullman that would be integrated into an overall Smart Grid system. These devices included 297 reclosers and switches, 153 capacitors, and 216 voltage regulators. All of these smart devices can be operated remotely by either an operator or the predictive applications of the DMS, namely FDIR and IVVC.

Approximately three hundred smart switches (S&C SCADA-Mate®) and breakers (G&W VIPER-ST Reclosers®) were strategically placed along feeder trunks with the intent of sectionalizing the load into four nearly equal sections. In addition, smart switches were also placed between feeders as "normally open" points to allow remote load transfers between feeders.

This sectionalizing scheme supports FDIR by allowing for fault isolation and a rapid remote restoration for customers. In addition to supporting FDIR schemes, the smart switches and breakers are used for daily planned switching and tagging procedures. The remote switching and tagging capability has reduced the once manual process from hours to minutes.

As a part of the sectionalizing scheme, a midline recloser was installed with each smart feeder. The midline recloser is a coordinated protection device which will run through a trip and reclose event in response to a downstream fault. The midline recloser device effectively reduces line exposure to events, particularly customer outages, by approximately 50%.

The 153 smart capacitor banks and 213 smart voltage regulators were installed as a part of the integrated Volt/VAr control component of the DMS. In addition to being controlled by IVVC, these devices are remotely controlled by Dispatch personnel should additional voltage or VAr support be required on either the transmission or distribution systems. In addition, smart voltage regulators can now be controlled remotely by locking the regulator on step, a procedure once done manually by a serviceman that is required to parallel feeders.

Field installation of recloser devices

Considering the successful implementation of these smart devices for both the SGIG and SGDP project, Avista has expanding the smart grid footprint through its Grid Modernization Program. The Grid Modernization program is a programmatic 60-year program intended to address our distribution infrastructure while finding the right size of feeder automation for each feeder.

Deployment and remote capability of these devices has proven to be a success. Remote operations are becoming the norm for Avista and expanding the smart grid footprint is now an ongoing piece of the Grid Modernization program.

Remotely controlled smart devices have reduced the number of crew hours required to perform switching operations and to place Hot Line Hold status on devices. The DMS provides the ability to perform remote switching and tagging which results in a reduction in the number of crew trips for both Spokane (SGIG) and Pullman (SGDP). These trip reductions provide a quantifiable reduction in CO_2.

The additional smart devices along the feeder, such as switches and reclosers, allow for more telemetered data to determine loading and voltage all along the feeder. This information can be utilized for optimizing feeder configuration and system planning. During peak loading, load can remotely be transferred from heavily loaded feeders in order to prevent damage to utility infrastructure.

In addition to the benefit of reduced customer outage minutes mentioned above, the smart devices also allow Avista's operators to remotely transfer large customers and sensitive loads to adjacent feeders during construction on their primary feed. Given that more sensitive trip settings are applied to the feeder breakers upstream of crew construction, these transfers minimize the susceptibility to outages for these customers.

With the increased telemetry data along the feeder, capacity constraints for future loads along that telemetered section can more accurately be deduced. As new loads come on to the system, planning predictions can be compared to actual load for refinement of future projections.

Smart Transformers

As a part of the Smart Grid Demonstration Project 380 transformers with enhanced wireless data collection electronics were installed in Pullman and the surrounding area. The three major goals of the installation of smart transformers include obtain additional customer loading information to better size future transformer installations, utilize the smart transformer voltage reads to enhance IVVC model calibration, and determine transformer useful life by scanning oil and winding temperature.

Smart transformers with internal and ambient temperature sensing, as well as low side bushing measurement devices, were installed as part of SGDP. These transformers were intended to be utilized to attain customer loading information to better size future transformer installations and determine transformer useful life by scanning oil and winding temperature, and were extremely useful in the DMS commissioning of the voltage control portion of the integrated Volt/VAr control. The DMS power flow output results were compared to the telemetered values from the smart transformers in order to verify the power flow accuracy. The smart transformers were also used to determine correct phasing as documented on Avista's GIS system.

Installation of smart transformer

Due to the complexity of the transformer radio to backbone interface, a small subset of the devices are not communicable at this time. Some Smart Transformers had radio upgrades, but others may intentionally be left as non-communicating units to avoid the customer outages required by a replacement process.

Smart Transformer data is now available as historical information and can be used for engineering analysis. This information has been used to determine actual customer loading for pending customer load additions and allows accurate loading to be used to size replacement transformers. Smart Transformer voltage information has also been utilized to verify IVVC accuracy. By using models and integrating the transformer voltage information, Avista engineers have been able to verify and predict the loss savings and effective implementation of IVVC on various feeders. Using a feeder model with node data provided by these devices helps to authenticate that the IVVC computer program operates as designed. The transformer data was integral to our acceptance testing with the IVVC model provider.

Smart Transformers include custom electronics and design of a mini communications radio that attaches to each transformer. This causes problems with radio replacement or repair if the radio does not communicate properly. Reliable radio communications has been an issue for these units. Future purchases of Smart Transformers will involve significant manufacturer verification and warranty that the communications systems have been fully tested, and can be replaced in the field without causing a customer outage.

Additional benefits from Smart Transformer installations has been incorporating newly designed low loss transformers, removal of possible PCB transformers, and replacement of old adjacent facilities. These benefits will be seen by customers as lower lifetime costs for each transformer, appropriate disposition of PCB contaminants, and improved reliability due to replacement of old plant.

The data provided by each Smart Transformer will be accumulated and create a historical trend for various customer types. For instance, information about load factor and consumption is expected to be different for commercial customers versus residential customers. The data must accumulate for several seasons and then will be analyzed by our distribution engineering department. Avista expects the results will support new methodologies for accurate transformer sizing, creating direct customer savings due to less cost by utilizing properly sized transformers for service to new customers. In addition, smart transformers, when paired with smart meter information, can be used for theft detection.

Historical and thermocouple data is expected to provide increased predictability on transformer service life expectations. This should assist the engineering department to identify when a transformer is at the end of its useful life and when replacement is required. This preventive maintenance should reduce unplanned outages and overtime labor.

AMI and Customer Engagement Web Portal Description

Avista successfully launched a web portal tool with customer engagement features as part of the Smart Grid Demonstration Project. The web portal tool delivers near real-time energy consumption information to customers via the internet using AMI system. Current access to the tools is limited to approximately 13,000 customers in the Pullman and Albion, Washington, communities due to the required interface of a smart meter. This tool also provides relevant tips, tools and insights using the AMI data to help engage customers to better manage their energy consumption in a meaningful way for themselves.

A modified and improved version of this tool will be made available to any AMI customer as the AMI Washington project rolls out the new metering system to Washington customers. Avista will be funding the new AMI web-portal and customer engagement features with the AMI Washington project and the new Avista web project identified as Project Phoenix.

Work will begin on the modifications and improvements to the web-site beginning July 2016, and will continue through the AMI Washington project meter deployment beginning in the third quarter of 2017 and running through the first quarter of 2020.

The modified web-portal will represent several upgrades and enhancements. The customer will have instant access to an AMI consumption chart on their *MyAccount* Summary page. This first creates instant access to the AMI consumption data without the customer having to find an icon that takes them to another web-page for the data as is the current method. Secondly, this significantly reduces the latency our customers have with the current web-portal. Tips, tools and insights using the granular data along with weather data and customer inputs and preferences will allow for a personalized experience that is meaningful to the customer to motivate them to take action to save energy or just be an informed energy consumer.

This program is available to customers with an AMI meter. Benefits of this tool have been estimated in the AMI Washington Business Case filed with the Washington Utilities and Transportation Commission, Docket Nos. UE-160228 & UG-160229 (consolidated).

Avista's Vision for the Changing Utility

Within its current role as an electric and natural gas utility, Avista recognizes the quickening pace of the continually changing environment for the utility and its stakeholders. The residential, commercial, and industrial customers, the regulatory policymakers, the investor community, and the analytical and technology development partners are all engaged participants in this dynamic utility ecosystem.

Information about the dramatically changing utility landscape and the associated opportunities is no further away than current headlines. For investor owned utilities (IOU), activities associated with New York's Reforming the Energy Vision (REV) and California's Distribution Resources Plans (DRP) are pointing to new service and business opportunities within the nascent domain behind the customers' meters. The economic, environmental, and social influences currently impacting coal and nuclear generation resources represent the concerted shift towards renewable energy resources that inherently place more expectations on the distribution network. Ongoing concerns about cyber and physical security, sustainability, and economic relevance are driving new considerations for customer focus, energy policies, and technology opportunities, driving Avista and other utilities to reevaluate traditional energy business models to maintain their critical role in the energy and infrastructure economies.

Today, Avista recognizes consumer expectations are being shaped by products and services outside of the energy space. With the advancement of technology, an outgrowth of new industries from Uber to Airbnb are reshaping local economies toward shared economies. Social networking, the advent of the Internet of Things (IoT), and omnipresent connectivity are facilitating new ways to align consumer values with like-minded product and services. The ubiquitous smart phone as a personal digital platform has enabled the consumer to participate in these shared markets in near real-time with alerts, notifications, and interactive experiences. The utility brand must compete for the positive mobile experience relating to its services as it leverages the engagement that mobile technology offers. Clearly, the electric utility industry cannot stay insulated from these external market forces, but rather must recognize the opportunities and respond to the challenges as they help to shape the future energy marketplace.

The prudent roadmap towards the future grid will make incremental investments in technology and infrastructure that brings consumer value today but builds the organizational and infrastructure capabilities required for tomorrow. The smart grid and grid modernization projects implemented at Avista are achieving these objectives by deploying projects that are improving reliability and energy efficiency but also constructing distribution and communication infrastructure that is providing a substantial foundation for the evolving services platform.

Several concurrent transitions are working to reshape the social and technology landscape, and the present-day utility must demonstrate an awareness and agility in its response that historically has not been expected or required. The traditional passive approach of providing commoditized energy services is being replaced by a more proactive model necessary to accommodate rapid shifts in consumer interests and expectations. After decades of utility grids operating only to provide one-way power flows from generators to meters, the rampant introduction of new generation and storage technologies at the edge of the grid require the management of two-way power flows that accommodate the inherent levels of intermittency, effectively creating an energy cloud (Lawrence & Woods, 2015), as depicted below in Figure 9. Passive equipment in service throughout the grid is being supplanted by autonomous, intelligent infrastructure that is required to achieve the requisite responsiveness and service levels expected by the consumer and generator alike. For the utility of today, these influences are dramatic, especially considering the historical risk discernment that has focused on reliability, dependability, and standardization.

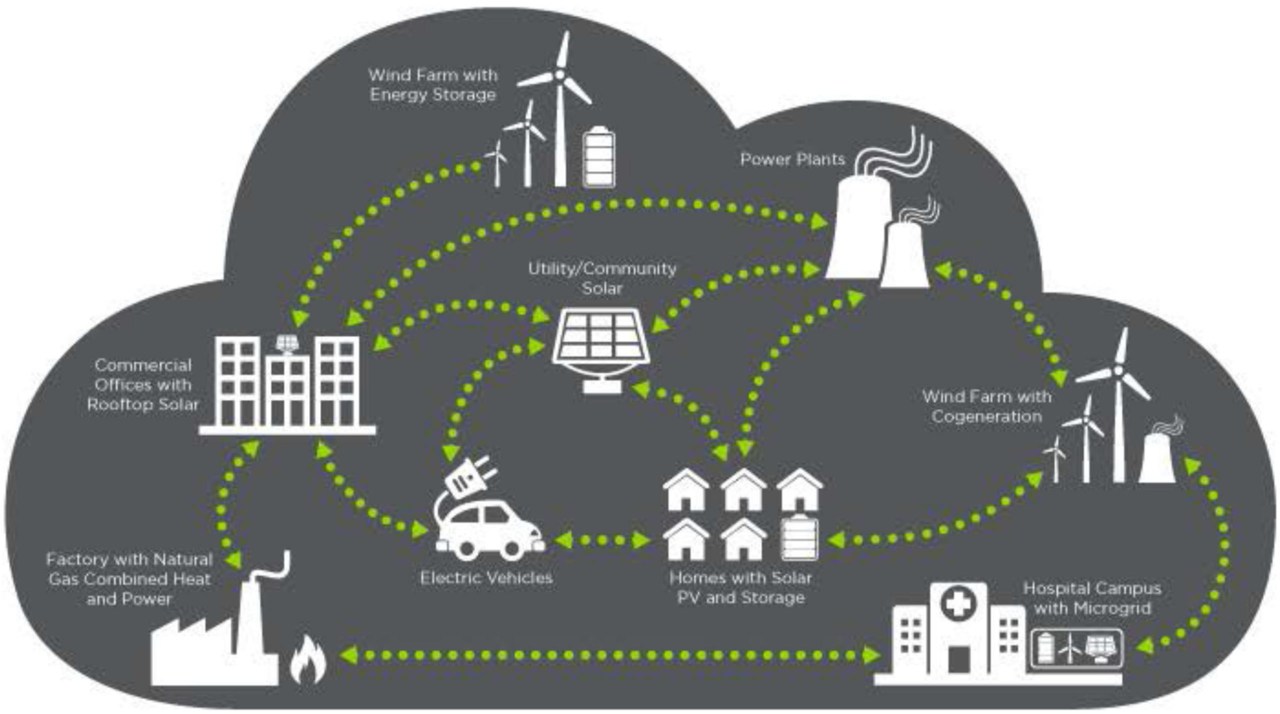


Figure 9: The Emerging Energy Cloud (Source: Navigant Consulting) (Gauntlett, 2016)

For a utility such as Avista, planning for a future that emphasizes increased uncertainty requires a significant intellectual and corporate commitment in an attempt to understand how each potential outcome will impact the breadth of its business and operation, affecting customer services and relationships, asset planning and management, revenue streams, and regulatory interaction. For instance, in 2015 alone, at least 46 states enacted policies relating to distributed energy (PA Knowledge Limited, 2016), essentially forcing the utilities to establish significant planning exercises that can accommodate the technology influences and regulatory shifts. These prudent steps are essential, not to necessarily predict the future, but rather to have strategies and foundations today on which to build the utility of tomorrow.

As chronicled throughout this report, Avista has compiled numerous examples of research programs, equipment tests, pilot programs, technology deployments, and integrated evaluations specifically within the smart grid domain in an intentional effort to develop an active awareness and gain sufficient understanding regarding the next steps in the path forward. The principal focus has continued to center on delivering reliable energy services in consideration with the choices that matter most to our customers. Figure 10 presents a relative progression of technologies and capabilities that have contributed to Avista's corporate knowledge associated with the modernized grid and other technological developments impacting the utility arena. Avista's project portfolio has focused on projects that support improved system reliability and energy efficiency but also provide an opportunity to evolve the service platform for the future benefit of our customers.

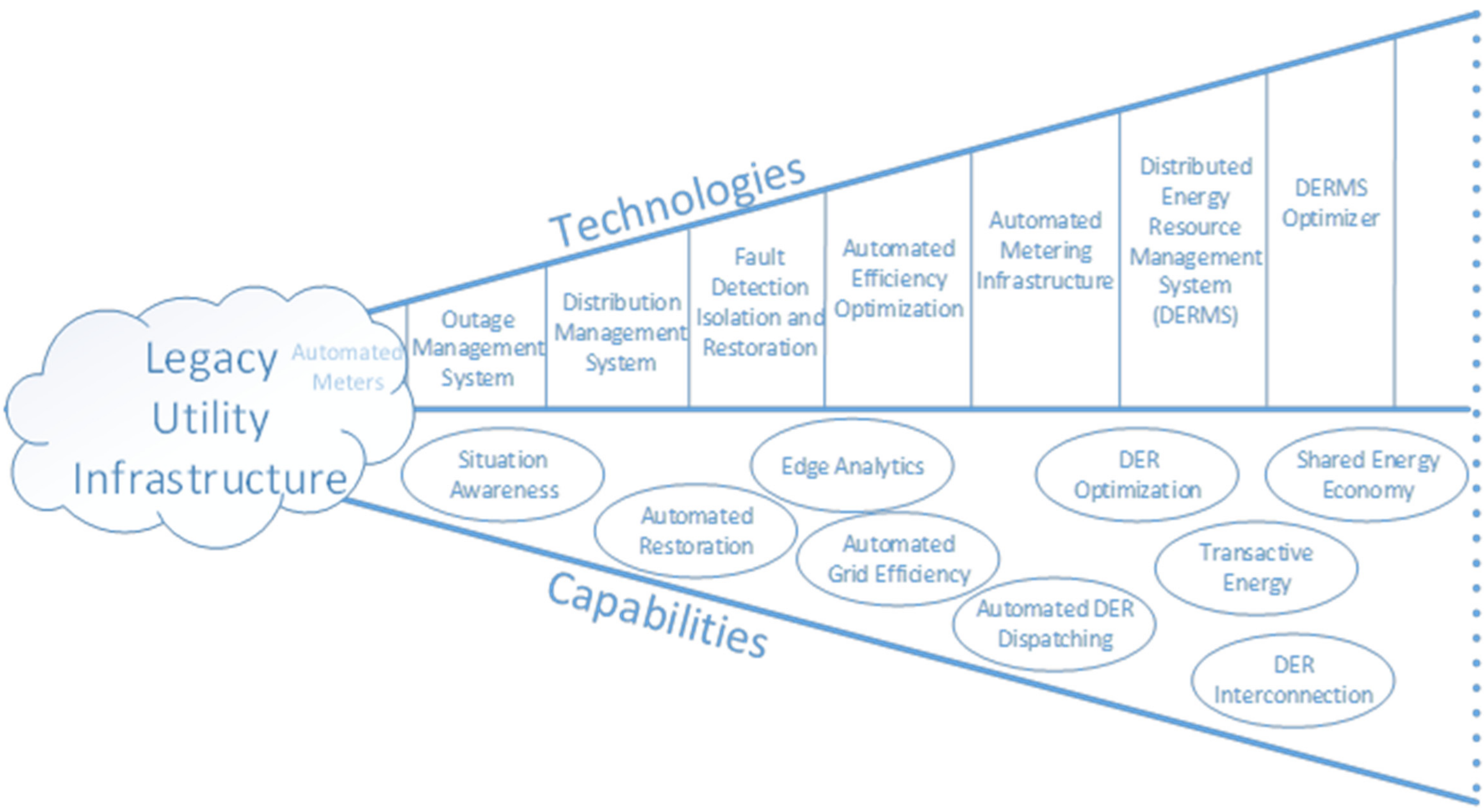


Figure 10: Grid Technologies and Capabilities

Distributed Energy Resources

Distributed Energy Resources (DER) pose some of the most significant challenges and opportunities for the future utility grid. These DER assets include wind and solar generation, energy storage, advanced batteries such as in electric vehicles, fuel cells, dedicated microgrids, fueled generators, and even demand response. Although the adoption of DERs in Avista's service territory is lagging behind other national markets, attaining the ability to manage and control various DERs remains important. As DER penetration increases, new storage technologies, such as developed in the Turner Energy Storage project, become increasingly critical, along with the communication and control systems that support grid reliability.

According to Navigant Research, distributed generation will grow from 20,000MW to nearly 35,000MW between 2016 and 2024. During this same time period, electric vehicle charging load will grow from just 2MW to nearly 15MW, demonstrating the significance of the bidirectional energy flow that will impact the operation of the distribution grid (Gauntlett, 2016).

A significant opportunity for a utility with managed DER is to defer or avoid costly infrastructure investments as virtual power plants can be assembled through the aggregation of multiple generation and storage assets. This approach would provide incremental deployment of energy resources in contrast to the current method of bulk resources that can overshoot the reserve power plan margin.

Regulatory Advocacy

As a regulated utility, Avista recognizes the critical relationship it shares with the regulatory bodies in its service territories. As has been demonstrated, Avista seeks to foster an entrepreneurial and innovative culture that coexists with the regulatory compact. Some aspect of risk is required in such endeavors, but the planning and testing associated with the various projects is intended to achieve project support from the regulatory commissions. The opportunity to proceed beyond the status quo is critical for utilities, as the alternative is to become irrelevant to the needs and expectations of its customers and other stakeholders.

The utility has a responsibility to help define and promote a preferred future state for its customers, demonstrating the benefits and value that new technology and innovation can provide.

Within the regulatory framework there are still major considerations regarding data and information privacy. The data that is collected, analyzed, and stored is becoming increasingly crucial to business operations, but the controls for data access and retention are critical. In addition, the resources simply to store and manage the data that is being collected are costly, increasing the expectation that the stored data produces significant value to the utility and its customers.

Technology and Innovation

Over the past three years, Avista has sponsored internal working groups to study, envision, and guide future technology projects. Identified as Grid Edge I and Grid Edge II, these cross-functional teams leveraged dedicated resources for intensive studies, interviews, and analysis of specific topics related to distribution technologies and applications.

The Grid Edge I team evaluated several applications and technologies including micro DC grids, combined heat and power, electrification of buses and trolleys, standby generation, utility-scale solar, and data collection devices on utility poles.

Grid Edge II developed DER scenario analysis that considered customer economic opportunities with potential program adoption rates and the resulting impact for Avista, primarily around the solar photovoltaic as resource from residential and commercial applications. The recommendations pointed to the need for near-term incentives to achieve economic viability for customers until the system costs decreased sufficiently, likely in the 2024 timeframe. Net metering would not create significant cross subsidies in the near-term, but high adoption rates could create a significant impact on Avista's system. Regarding energy storage associated with these same applications, significant cost reductions would be required for economic viability under existing rate design.

Several current projects were implemented based on these findings and recommendations. One project was the Community Solar program where 650 customers participate in a 423kW solar generation facility. Related to this project was the development of an online solar estimator that allows customers to receive a customized characterization of their rooftop for a potential solar installation.

Also, the Electric Vehicle Supply Equipment project, noted earlier in this report, is currently deploying Level 2 electric vehicle chargers in homes, businesses, and public locations throughout Avista's Washington service territory.

Micro-Transactive Grid

In August 2016, Avista received a $3.5 million grant from the Washington State Department of Commerce Clean Energy Fund II to develop a Micro-Transactive Grid (MTG) pilot that demonstrates a Shared Energy Economy model and its benefits for Washington energy customers. Avista will contribute an additional $3.5 million for the pilot project. Avista developed the MTG model to test and validate methods where energy assets, including distributed energy resources like solar and storage, may be managed in a shared system and leveraged for both customer and utility benefits. These assets would also be coordinated in conjunction with traditional large-scale utility generation assets.

Partnering with UniEnergy Technologies, McKinstry, Schweitzer Engineering Laboratories, Pacific Northwest National Laboratories, the U.S. Department of Energy, Washington State University, and Itron, the demonstration will attempt to validate grid resiliency and system efficiency opportunities where mutual benefits can be identified. This is a follow-on from the Clean Energy Fund I grant in 2014 where Avista gained experience integrating intermittent renewable energy resources into the electric grid through the Turner Energy Storage project. The intention is to identify solutions and methods that result in an electric grid with greater reliability, energy efficiency, resiliency, and flexibility.

In light of evolving consumers' expectations, the MTG or "grid within a grid" can become a platform to share in the investment and return of DER with a connected energy community. In addition to resiliency, the Microgrid would facilitate economic value creation and exchange while operating in parallel with the distribution system (grid-connected). In essence, the MTG facilitates the sharing of DERs through a controls platform which supervises, operates and optimizes utilization of DERs to improve building efficiency, renewable integration, DER utilization, grid coordination and transactive energy.

The MTG will benefit from the transactive signal system that was developed as part of the SGDP. For large volumes of transactions it was determined that human intervention would not be practical for all but the largest resources. Avista is interested in delivering economies of scale (number of assets) as well as economies of scope (number of uses) to maximize value from all distributed energy resources regardless of size. The transactive signal system is required, in modified and enhanced form to make the MTG project feasible. This signaling provides the foundation for automated dispatch of distributed energy resources for enhancing grid efficiency and power quality by deploying and then delivering value from distributed energy resources, regardless of ownership, to the mutual benefit of customers, the resource owner, and the utility. As distributed energy resources proliferate, Avista will be positioned to promote and manage them effectively orchestrate the shared energy economy and identify new business models and services that can be provided by electric utilities.

In the planning for the MTG pilot, it was shown that the number and aggregate size of assets dictates the degree of reliability enhancement that can be delivered in the case of an outage. Smaller assets can be effective to manage power quality, indirectly enhancing reliability and resiliency. Also identified during the planning phase was the need for a new tariff structure for the participants to reflect the cost of service and the value associated with the DER-based transactions.

Intended to be a three-year pilot, the demonstration will be deployed and operated within the University District in downtown Spokane. With its cluster of higher education and health care sites, the University District has been the focus of revitalization efforts targeting economic development and attracting new economy, workers, and businesses. The District already has a base system of smart circuits, and there is an opportunity to build on smart grid experience gained from the SGDP in Pullman to position the University District as a smart city proving ground.

Tangentially, the City of Spokane was recently selected among the first 10 cities in America to participate in a smart city program sponsored by Envision America. As part of the selection, Spokane joins nine other cities in a yearlong technical support program that began in January 2016. Spokane's pilot project under Envision America is smart and connected street lights that will be deployed in the University District. As a participating group member, Avista will be actively involved with this project.

Shared Energy Economy

The Shared Energy Economy for the utility industry is a recently developed concept that considers the opportunity to enable an exchange of value between existing assets, regardless of the actual ownership of those assets. These relational activities will help to increase utilization of assets and positively influence system economics. This is accomplished by the monetization of trust and a communicable exchange between participants. Much the same as with Uber and Airbnb provide services to their consumers, the utility marketplace has the opportunity to engage with consumers and producers to facilitate the exchange of energy for money, leveraging the existing utility infrastructure while compensating the entities that are necessary to complete the transaction. These services could also help to impede any load defection as energy consumers may seek alternative solutions not provided by the utility.

One lesson learned from observing other shared economy models is the requirement for a common platform to facilitate the interchange between the participant community and the transactions. In the shared energy economy, the principal participants will be interested in managing consumption and generation, possibly at the same time. This complexity points to significant challenges for a regulated utility like Avista. In such an evolving industry, no prediction is sufficient to sufficiently describe how the shared energy economy is going to be structured in the future. As such, Avista continues to seek both Federal and state funding opportunities to continue its efforts with grid modernization initiatives. Through these funded projects, Avista has partnered with leading researchers from state universities, national labs, and private industries to incorporate thought leadership with these project initiatives.

Conclusion

The onward progression into the changing utility landscape, including the modernized grid and its linked technologies, will require continued participation and mutual support from engaged stakeholders to achieve the benefits and advancements the future will most certainly provide. Certain obligations remain invariable, such as customer expectations being met, regulatory policy being respected, and the financial requirements of the utility being achieved, all while safe, reliable, and affordable energy is prevalent. The perpetual advancement of products, capabilities, and technologies will certainly pose many challenges, but the prudent risks taken should serve to overcome the obstacles encountered, resulting in a utility well positioned for the 21st century and beyond.

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Acronym and Abbreviation List

AMI	Advanced Metering Infrastructure
ARRA	American Recovery and Reinvestment Act (of 2009)
BDP	Backhaul Distribution Point
CAIDI	Customer Average Interruption Duration Index
CBC	Capacitor Bank Control
CPN	Customer Premise Network
CVR	Conservation Voltage Reduction
CVRf	Conservation Voltage Reduction factor
DER	Distributed Energy Resources
DMS	Distribution Management System
DOE	(U.S.) Department of Energy
DREE	Distribution Reliability and Energy Efficiency
DRP	Distribution Resources Plans
EVSE	Electric Vehicle Supply Equipment
FAN	Field Area Network
FCI	Fault Circuit Indicators
FDIR	Fault Detection, Isolation, and Restoration
GIS	Geographic Information System
HVP	High Voltage Protection
IoT	Internet of Things
IOU	Investor Owned Utility
IRP	Integrated Resource Plan
IVVC	Integrated Volt/VAr Control
MPLS	Multi-Protocol Label Switching
MTG	Micro-Transactive Grid
NAN	Neighborhood Area Network
O&M	Operation and Maintenance
OMS	Outage Management System
PNWSGD	Pacific Northwest Smart Grid Demonstration
REV	Reforming the Energy Vision
RF	Radio Frequency
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SGDP	Smart Grid Demonstration Project
SGIG	Smart Grid Investment Grant
SGWT	Smart Grid Workforce Training
SSL	Secure Socket Layer
TES	Turner Energy Storage
VC	Voltage Control
Volt/VAr	Volt/Volt-Ampere reactive
VPN	Virtual Private Network
WAN	Wide Area Network

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